Strategy for code implementation of 6 + 2 wood-frame podium buildings

Date: June 5, 2017

By:

Marilyn Lanni – Technorm Inc.
Christian Dagenais, P.Eng., Ph.D. – FPInnovations

Report prepared for:

Natural Resources Canada
Canadian Forest Service

Ressources Naturelles Canada
Service Canadien des Forêts
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PROJECT NO 301011233 – Strategy for code implementation of 6 + 2 wood-frame podium buildings

ACKNOWLEDGEMENTS

This project was financially supported by the Canadian Forest Service under the Contribution Agreement existing between the Government of Canada and FPInnovations.

REVIEWERS

Chun Ni, P.Eng., Ph.D.
Lindsay Ranger, P.Eng., M.A.Sc.
Advanced Building Systems

PROJECT LEADER

Christian Dagenais, P.Eng., Ph.D.
Senior Scientist
Serviceability & Fire Performance Group
Advanced Building Systems
Telephone: 418-659-2647
christian.dagenais@fpinnovations.ca

Steven Kuan, Ph.D., P.Eng., Manager
Advanced Building Systems

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Disclosure for Commercial Application: If you require assistance to implement these research findings, please contact FPInnovations at info@fpinnovations.ca.
EXECUTIVE SUMMARY

Sustainable, safe, durable, cost-effective and efficient; wood is used across Canada in occupancy classes such as business, residential, commercial and assembly. In the United States, many mixed-use buildings have been designed as “podium” buildings; a wood structure bearing on a podium of noncombustible construction. The International Building Code includes provisions that allow wood buildings, often housing residential or business occupancies, to be constructed over a podium of noncombustible construction accommodating mercantile or assembly occupancies.

The concept of a horizontal fire separation, acting to a certain degree as a “horizontal firewall”, was introduced in the International Building Code in the mid-2000s, allowing the podium to be considered a separate and distinct building from the wood structure that sits overtop. Since podium structures are becoming increasingly “à la mode” in the construction industry, integrating the horizontal fire separation concept into the National Building Code of Canada would allow the industry to benefit from the advantages of wood construction in mixed-use buildings.

At the request of FPInnovations, this technical report has been prepared as a guideline for the implementation of design provisions for wood podium buildings into the National Building Code of Canada. Various strategies, special considerations, and possible risks for fire safety in this type of building are explored.
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1. OBJECTIVES

Additional opportunities can be created for wood-frame construction (residential or office) by placing 6-storey wood-frame above a 2-storey concrete/steel podium occupied by office, retail, restaurants, etc. In Canada, this format (6+2 wood-frame podium) increases the market opportunity by 42% for wood-frame from 6.6 million sq. ft. (5-6 storey class) to 9.3 million sq. ft. (combined opportunities for both 5-6 and 7-8 storey class). However, 6+2 wood-frame podium buildings are beyond what is currently permitted in the prescriptive provisions of the National Building Code of Canada and would require an alternative solution, or otherwise a code change to be made. Nonetheless, where a market exists (e.g. urban areas ready to transition from low-rise to mid-rise), early adopters can benefit by following the “alternative solutions” compliance path.

The objective of the current project is to conduct a study to evaluate the technical and process risks based on accepted fire performance-based criteria for 6+2 podium buildings.

The report has been conducted by a fire engineering firm, Technorm Inc., per FPInnovations staff request and guidance. The complete report is presented in Appendix A.

2. TECHNICAL TEAM

Christian Dagenais, P.Eng, Ph.D.  Senior Scientist, Serviceability & Fire Performance
Chun Ni, P.Eng., Ph.D.  Principal scientist, Structural Performance
FPInnovations

Marc-André Langevin, Eng., M.Eng., M.Sc.A.  President, Technorm Inc.
Marilyn Lanni  Technical consultant, Technorm Inc.

3. BENEFITS TO FPINNOVATIONS MEMBERS

This report studied the technical and process fire risks for 6+2 wood-frame podium buildings, which is not allowed by the current prescriptive provisions of the National Building Code of Canada. This information will support potential code implementation of such building systems in Canada, therefore further expanding the use of wood in Canadian residential and commercial construction.
Appendix A

Report prepared for FPI by Technorm inc.
Technical report
Strategy for Code Implementation of “6 + 2” Wood Buildings

O/Ref.: 160001-063

PRESENTED TO
Mr. Christian Dagenais, Eng., Ph.D.
FPInnovations
Y/Ref.: PSA16-11-752

BY
Marc-André Langevin, Eng., M.Eng., M.Sc.A.

DATE OF PUBLICATION
March 31, 2017
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1. EXECUTIVE SUMMARY

Sustainable, safe, durable, cost-effective and efficient; wood is used across Canada in occupancy classes such as business, residential, commercial and assembly. In the United States, many mixed-use buildings have been designed as “podium” buildings; a wood structure bearing on a non-combustible podium. The International Building Code includes provisions that allow wood buildings, often housing residential or business occupancies, to be constructed over a non-combustible podium accommodating mercantile or assembly occupancies.

The concept of a horizontal fire separation, acting to a certain degree as a “horizontal firewall”, was introduced in the International Building Code in the mid-2000s, allowing the podium to be considered a separate and distinct building from the wood structure that sits overtop. Since podium structures are becoming increasingly “à la mode” in the construction industry, integrating the horizontal fire separation concept into the Canadian Code would allow the industry to benefit from the advantages of wood construction in mixed-use buildings.

This technical report has been prepared as a guideline for the implementation of provisions for wood podium buildings into the National Building Code of Canada. Various strategies and the possible risks and special considerations for fire safety in this type of building will be explored.
2. INTRODUCTION

A growing trend in the real estate and construction industries is the mixed-use podium building. During the past ten years, the demand for this type of structure has significantly increased. Podium buildings are generally designed as a one- or two-storey reinforced concrete base, known as the “podium”, supporting one or more mid-rise wood structures constructed above.

The National Building Code of Canada (NBCC) does not currently have any provisions that would facilitate the construction of a podium building. Although the NBCC allows a parking garage to be considered a separate building from the structure above it under certain conditions, the garage is required to be located entirely underground. Although it is currently possible to design a small, one-storey podium structure above grade supporting a 5-storey residential or business superstructure with the NBCC, the area of this type of building is always limited by Code prescriptions set forth in its Division B.

This report serves as a continuation of the Guideline on Building Code Approaches for Podium Structures¹, published by FPInnovations, in November 2015.

2.1 Purpose of report

The present guideline provides an overview of possible strategies to implement design provisions in the NBCC that would allow a 6-storey combustible construction to be constructed above a 2-storey podium of non-combustible construction. In the following report, we will refer to this building concept as a “6+2 podium building”.

Several design aspects require careful consideration in this analysis, notably fire safety risks to occupants and fire fighters, special requirements for high buildings, structural integrity and building envelope durability.

It should be noted that the latest edition of the US building code (IBC 2015) allows a podium structure to support a wooden superstructure of up to 85 feet in height (depending on the type of construction). Such allowance would be viewed as an alternative solution in Canada (see Subsection 5.5 of this report).

¹ “Guideline on Building Code Approaches for Podium Structure”, Geoff W. Triggs, FPInnovations, November 2015
2.2 Objectives

The objectives of this study are the following:

- To provide background information on general fire safety requirements found in the NBCC;
- To determine the fire safety issues and risks associated with a “6+2” podium building, consisting of either mass timber or light wood-frame construction over a concrete base;
- To present a succinct evaluation for the inclusion of a horizontal fire separation having a fire-resistance rating of 3 hours in the NBCC, similarly to the provision currently incorporated in the IBC.
### 3. ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHJ</td>
<td>authority having jurisdiction</td>
</tr>
<tr>
<td>CLT</td>
<td>cross-laminated timber</td>
</tr>
<tr>
<td>FRR</td>
<td>fire-resistance rating</td>
</tr>
<tr>
<td>FRTW</td>
<td>fire retardant treated wood</td>
</tr>
<tr>
<td>IBC</td>
<td>International Building Code (USA)</td>
</tr>
<tr>
<td>LSL</td>
<td>laminated strand lumber</td>
</tr>
<tr>
<td>LVL</td>
<td>laminated veneer lumber</td>
</tr>
<tr>
<td>NBCC</td>
<td>National Building Code of Canada</td>
</tr>
<tr>
<td>NRCC</td>
<td>National Research Council of Canada</td>
</tr>
<tr>
<td>OSL</td>
<td>oriented-strand lumber</td>
</tr>
<tr>
<td>PSL</td>
<td>parallel strand lumber</td>
</tr>
<tr>
<td>ULC</td>
<td>Underwriters’ Laboratories of Canada</td>
</tr>
</tbody>
</table>
4. DEFINITIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative solutions</td>
<td>An alternative method of compliance to the objectives, functional statements and intent of the NBCC, which demonstrates the same (or a higher) level of safety and protection prescribed by the acceptable solutions of the NBCC.</td>
</tr>
<tr>
<td>Closure</td>
<td>A device or assembly for closing an opening through a fire separation or an exterior wall, such as a door, a shutter, wire glass or glass block, and includes all components such as hardware, closing devices, frames and anchors.</td>
</tr>
<tr>
<td>Combustible construction</td>
<td>Type of construction that does not meet the requirements for consideration as non-combustible construction. It historically relates to wood-frame construction; heavy timber and mass timber construction are also deemed combustible construction.</td>
</tr>
<tr>
<td>Fire block</td>
<td>A material, component or system that restricts the spread of fire within a concealed space, or from a concealed space to an adjacent space.</td>
</tr>
<tr>
<td>Fire-resistance</td>
<td>Ability of a material, product or assembly to withstand fire or provide protection from fire, for a specified period of time.²</td>
</tr>
<tr>
<td>Fire-resistance rating</td>
<td>Time (in hours or minutes) that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire, under specific conditions of test performance criteria (ULC S101 in Canada).</td>
</tr>
</tbody>
</table>

² ASTM E 176-15 Standard Terminology of Fire Standards
<table>
<thead>
<tr>
<th><strong>Fire separation</strong></th>
<th>A vertical or horizontal construction assembly that acts as a barrier against the spread of fire.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire stop</strong></td>
<td>A system or assembly consisting of a material, component and means of support used to fill gaps between fire separations or between fire separations and other assemblies, or used around items that wholly or partially penetrate a fire separation.</td>
</tr>
<tr>
<td><strong>Firewall</strong></td>
<td>A type of fire separation of non-combustible construction that subdivides a building or separates adjoining buildings to resist the spread of fire, has a fire-resistance rating (usually 2 or 4-hour), and has the structural stability to remain intact under fire conditions for the required fire-rated time.</td>
</tr>
<tr>
<td><strong>Flame-spread rating</strong></td>
<td>An index or classification indicating the extent of spread-of-flame on the surface of a material or an assembly of materials as determined in a standard fire test (ULC S102 in Canada).</td>
</tr>
<tr>
<td><strong>Flashover</strong></td>
<td>Sudden transition from a localised fire to combustion of all exposed sources of fuel within a compartment or enclosure.</td>
</tr>
<tr>
<td><strong>Heavy timber construction</strong></td>
<td>Type of combustible construction in which a degree of fire safety is obtained by the sizes of wood structural members, the thickness and composition of wood floors and roofs, and by the avoidance of concealed spaces under floors and roofs and deemed compliant to Div. B - art. 3.1.4.6 of the NBCC.</td>
</tr>
<tr>
<td><strong>High building</strong></td>
<td>A multi-storey structure having a comparatively large number of storeys and equipped with elevators. The National Building Code of Canada defines a high-rise building differently than the International Building Code does.</td>
</tr>
<tr>
<td><strong>Interconnected floor space</strong></td>
<td>Superimposed floor areas or parts of floors areas in which floor assemblies that are required to be fire separations are penetrated by openings that are not provided with closures.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Mass timber construction</strong></td>
<td>Type of combustible construction where a certain degree of fire safety is ensured by the use of structural elements, floors and roofs of large dimensions and by the absence of construction voids within floors, walls and roofs. A structural post and beam system makes up this type of construction, which typically consists of large panelized solid wood products such as CLT (cross-laminated timber), NLT (nail-laminated timber) and glulam (glue-laminated timber). All structural elements of mass timber construction must have a fire resistance rating superior to that which is required by virtue of Div. B, Sentence 3.1.4.6. 1) of the NBCC.</td>
</tr>
<tr>
<td><strong>Non-combustible construction</strong></td>
<td>Type of construction in which a degree of fire safety is achieved by the use of non-combustible materials for structural members and other building assemblies.</td>
</tr>
<tr>
<td><strong>Podium structure</strong></td>
<td>Horizontal platform used to raise a secondary structure above grade. In the North American context, a podium building is usually a large bottom reinforced concrete construction housing non-residential occupancies and supporting one or more wood-frame residential or business structure(s) constructed overtop.</td>
</tr>
<tr>
<td>Stack effect</td>
<td>The tendency for air to rise within a heated building when the temperature is cooler on its exterior. If the stack effect in a building is great enough, it may overcome the pressures determined during the design analyses and allow smoke to enter areas outside the zone of origin.</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Type I construction (IBC)</td>
<td>Non-combustible construction where Type IA has 3-hour FRR primary structure frame and walls, and 2-hour FRR floors, whereas Type IB has 2-hour FRR primary structural frame, walls and floors.</td>
</tr>
<tr>
<td>Type II construction (IBC)</td>
<td>Non-combustible construction where Type IIA has a 1-hour FRR primary structural frame, walls and floors, whereas Type IIB is unrated throughout.</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Type III construction (IBC)</td>
<td>Type of construction in which the exterior walls are of non-combustible materials and the interior building elements are of any material permitted in the IBC. Type IIIA requires 1-hour FRR for the primary structural frame, interior walls and floors, whereas Type IIB is unrated throughout with the exception of the exterior walls that need to be 2-hours FRR.</td>
</tr>
<tr>
<td>Type IV construction (IBC)</td>
<td>Heavy timber construction (which includes CLT) with exterior walls made of non-combustible materials, 2-hour FRTW walls or protected CLT. The interior structure is made of solid, glue-laminated, or CLT wood components without concealed spaces. While the IBC does not assign FRR to Type IV construction, it is allowed in roof construction of all occupancies where a FRR no greater than 1-hour is required.</td>
</tr>
<tr>
<td>Type V construction (IBC)</td>
<td>Type of construction in which the structural elements, exterior walls and interior walls are of any material permitted in the IBC. It typically refers to wood-frame construction (walls, floor, and roof) where primary structural frame, walls and floors are 1-hour FRR (Type VA) or unrated (Type VB).</td>
</tr>
<tr>
<td>Wood-frame construction</td>
<td>Type of construction using repetitive structural elements of small dimensions such as dimensional lumber, structural engineered wood products (e.g. I-joists, trusses) and structural sheathing (plywood or OSB).</td>
</tr>
</tbody>
</table>
5. BACKGROUND INFORMATION

5.1 Code provisions for podium buildings
In North America, a “podium” or “pedestal” building is comprised of a non-combustible podium base of one or more storeys, with one or more buildings erected over the base. The structure(s) above the podium can be of either combustible or non-combustible construction. The current report focuses on combustible (wooden) superstructures and the possible integration of this concept in the National Building Code of Canada.

Figure 1. Typical podium building during construction; wooden superstructure bearing on a concrete podium, with an underground parking garage

The prescriptive requirements of podium buildings found in Division B of the NBCC are scarce. The current Canadian Code does not include provisions for the design of a horizontal fire separation. This concept, currently offered in the IBC 2015, facilitates the design of a podium building, and separates the podium from the structure above it.

5.1.1 Canadian Code (NBCC 2015)
The model Canadian building code does not have the flexibility of its North American counterpart in offering a provision for a 3-hour horizontal fire separation (see Subsection 5.1.2. of this report).
The closest Canadian concept to this horizontal fire separation is a basement used primarily as a storage (parking) garage, permitted to be considered as a separate building from the superstructure above. This upper structure is divided from the basement by a non-combustible fire separation having a FRR of at least 2 hours, and must be situated entirely below grade (NBCC 2015, Division B, Art. 3.2.1.2.).

With this Code provision, the superstructure(s) can be designed independently of the basement (see figure 2). The overall building is still considered as one building for other dispositions of the Code (e.g. alarm system, spatial separation, etc.).

![Diagram](image)

Figure 2. Basement podium structure complying to Div. B, Art. 3.2.1.2 of the NBCC 2015

The design of a podium building with a combustible superstructure is still possible in Canada however certain limitations are inevitable with the current version of the NBCC:

- The podium base would be smaller compared to similar buildings designed using the most recent IBC (2015 edition);
- The podium’s maximum area would be limited to the maximum area permitted for the combustible superstructure: 1,500 m\(^2\) for a residential occupancy, and 3,000 m\(^2\) for a business occupancy (based on requirements of the NBCC 2015, Division B, Articles 3.2.2.50 and 3.2.2.58 respectively);
- The maximum overall height of the podium building would be 6 storeys (a “5+1” building having a one-storey base and five upper storeys). The maximum height permitted between grade and the uppermost floor level is 18 m. If this maximum height...
is exceeded, additional Code requirements for high buildings must be applied to the design.

The currently permitted “5+1” wood podium building could be occupied by multiple uses such as assembly occupancies (bars, restaurants), commercial (shops) and businesses (banks) as per Division B, Article 3.2.2.7 “Superimposed Major Occupancies” (see figure 3).

![Figure 3. 6-Storey residential or business “5+1” wood podium building complying to the NBCC](image)

In order to obtain a larger podium area, a firewall having a FRR of 2 hours or 4 hours (depending on the occupancies within the podium) would be required. The firewall would allow the maximum permitted area to be doubled (see figure 4).

![Figure 4. 6-storey podium mixed-use building with vertical firewall subdivision to underside of podium only, complying to the NBCC 2015](image)
5.1.2 USA code (IBC 2015)

The provisions of Section 510.2 of the IBC allow a horizontal assembly having a 3-hour FRR to divide the bottom non-combustible Type IA podium from any structure above the podium (Type IIIA, IV or VA). Similarly to the concept used for fire walls, this horizontal fire separation creates separate and distinct buildings (see figure 5). One or more upper structures could be erected independently over the podium, as per their applicable requirements (e.g. occupancy, height and area provisions specified by the IBC).

**Figure 5.** Example of a podium structure concept as per the IBC 2015

The area of the podium section is permitted to be unlimited in most occupancy classifications. The podium must be sprinklered throughout and cannot be occupied by a Group H (high hazard) occupancy, as per the IBC’s classification.

Furthermore, height limits have been set forth in Section 504.3 of the IBC. The maximum height for Type IIIA, IV and VA is between 70 feet (18m) and 85 feet (26 m), for residential and business occupancies respectively (both protected by a sprinkler system conforming to NFPA 13 “Standard for the Installation of Sprinkler Systems”).

It is important to note that the IBC defines a high-rise building as follows:

“A building with an occupied floor located more than 75 feet (22,860 mm) above the lowest level of fire department vehicle access.”
Hence, a podium structure that is built with Type VA construction would never be considered a high-rise building, because its height is limited by Code prescriptions to 70 feet (18 m) for all occupancies. Comparatively, the NBCC’s current requirements for a 6-storey residential wood building limit the building height to a maximum of 18 m (60 ft), measured between grade and the floor level of the top storey.

A podium structure of 85 feet in height designed with either Type IIIA or Type IV construction for the superstructure must respect the additional requirements for high-rise buildings. The height limitations found in Section 504.4 of the IBC limit Type VA construction to 4 storeys, and Types IIIA and IV to 6 storeys above the Type IA podium base, as illustrated in figure 5.

5.2 Code provisions for fire safety

5.2.1 Type of construction

The NBCC recognizes two types of construction: combustible and non-combustible. A material is classified as non-combustible if it meets the criteria set forth in ULC S114 “Standard Method of Test for Determination of non-combustibility in building materials”. Typically, natural materials such as rocks, glass, minerals (iron), stones, plasters, clay, etc. are deemed non-combustible. In the construction industry, non-combustible construction generally consists of steel, masonry and/or concrete, whereas combustible construction is made up of wood.

Combustible construction consists of either a light wood-frame structure sheathed by gypsum boards (e.g. typical 38 x 140 mm wall studs with 38 x 184 mm wood joists or engineered joists), and is typically referred as “platform framing” (vs. balloon framing). Heavy timber and mass timber construction are considered combustible construction as well. The structural members of a heavy timber construction are exposed (unprotected by sheathing). Large structural elements (posts and beams) or mass timber panels such as CLT are used in heavy timber construction. When a combustible construction is permitted by the NBCC and it is not required to have a FRR of more than 45 minutes, heavy timber construction is permitted to be used. To meet the deemed level of performance of a heavy timber construction, the elements need to respect the minimum sizes specified in Division B, Article 3.1.4.7 of the NBCC. A mass timber structure could offer a FRR well beyond 2 hours, due to the size of its members, and thus be allowed in other applications.
In the scope of a Canadian 6+2 podium building, the base comparative is an 8-storey residential or business building. Articles 3.2.2.47 and 3.2.2.55., in both cases, require non-combustible construction providing a 2-hour FRR and complete protection by an automatic sprinkler system complying to NFPA 13 (see Table 1).

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Number of storeys</th>
<th>Height (in m)</th>
<th>Construction type</th>
<th>Fire-resistance rating</th>
<th>High building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>residential</td>
<td>6</td>
<td>18</td>
<td>Combustible permitted</td>
<td>1h for floors, mezzanines and structural members</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Unlimited</td>
<td>Non-combustible</td>
<td>2h floor assemblies 1h mezzanines</td>
<td>Yes</td>
</tr>
<tr>
<td>Group D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>business</td>
<td>6</td>
<td>18</td>
<td>Combustible permitted</td>
<td>1h floors, mezzanines and structural members.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Unlimited</td>
<td>Non-combustible</td>
<td>2h floor assemblies 1h mezzanines</td>
<td>No³</td>
</tr>
</tbody>
</table>

Table 1. NBCC 2015 provisions for 6- and 8- storey residential and business buildings

Subsection 5.2.3. of this report will further demonstrate how the FRR of an assembly does not entirely depend on the type or degree of combustibility of the materials used in the assembly.

5.2.2 Area and height limitations

Senez and Calder⁴ published a well-documented report regarding the historical background related to height and area limitations for each main occupancy class in the NBCC. The 1953 edition of the NBCC was partly based on a model prepared by B.L. Wood⁵. This model ascribed firefighting capabilities to building size and the corresponding fuel load (lb/ft²) of a FRR (see Subsection 5.2.3.). At that time, building height potentially represented a problem for

---

³ Subsection 3.2.6 of the NBCC provides additional requirements for high buildings. If the floor level of the uppermost storey of a Group D building is 18m high and the cumulative or total occupant load on or above any storey above grade, other than the first storey, divided by 1.8 times the width in metres of all exit stairs at the storey exceeds 300, the building is then considered a high building and must respect the requirements of Subsection 3.2.6.


⁵ « Fire protection Through Modern Building Codes », B.L. Wood, AISI, 1945
Firefighting. Fighting a fire in a 4-storey building was accomplished from the exterior of the building with a stream from a fire hose. The trajectory of the hose stream limited the height and area to that which fire fighters could manage at that time (approximately 100 feet ≈ 30 m). Consequently, our Code height provisions were established based on the capabilities of fire departments in the 1940’s, and those provisions have not changed much over time.

5.2.3 Fire-resistance

A research study conducted by S.H. Ingberg and the National Bureau of Standards-NBS (now called the National Institute of Standards and Technology-NIST) developed the empirical relationship between fuel load and the duration of exposure to fire, which became the theory behind the determination of fire-resistance ratings with respect to occupancy in a building.

The prescribed fire-resistance rating for floors, roofs and their supporting elements are based on Ingberg’s work. The study conducted by Ingberg made a correlation between the standard temperature curve to the complete burnout of a fuel load, and became the basis for the fire-resistance requirements stipulated in the 1953 edition of the NBCC.

<table>
<thead>
<tr>
<th>Fuel Load (lb/ft²)</th>
<th>Fire Severity (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>½</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>1½</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>40</td>
<td>4½</td>
</tr>
<tr>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>70</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2. Ingberg relationship between fuel load and fire severity

However, it is important to note that the FRR is not based on the type of material used in an assembly. Despite this fact, the Code distinguishes combustible and non-combustible materials. The historical reasons for this distinction may be the following:

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Steel and concrete are man-made materials with physical characteristics that are inert to high heat;

Combustible building components (e.g. structural elements) may add fuel to a fire, hence a potential fire would be dangerous to the building occupants and fire fighters;

Combustible surfaces may enable the spread of fire and thus reduce the time needed for the safe egress of building occupants;

Fire may spread via voids and concealed spaces, rendering it more difficult to be controlled by a fire department and decreasing the available safe egress time (ASET);

Steel or iron structures were not typically involved in important conflagrations that occurred in both in the US and Canada in the 1800s and early 1900s with many injured or dead occupants.

These historical reasons were eventually discarded by scientists or by means of other fire safety provisions (such as requirements for fire stops and fire blocks included in building codes).

Over the years, professionals involved in the fields of fire safety and fire protection have become aware that the structural behavior of large dimension wood products (i.e. heavy timber) surpasses that of bare steel during a fire (see figure 6).
5.3 Code Provisions for Structural Integrity

Part 4 (Division B) of the NBCC contains mostly performance-based provisions for the structural design of a building. However, some prescriptive provisions can be found, such as the height limitations of seismic force resisting systems (SFRS).

The Code requires the designer to apply gravitational and lateral loads as per the specified requirements and allows the designer to choose the type of structural system desired, according to national CSA standards on concrete, steel and wood design.

The design of a “6+2” podium structure may present certain challenges. The superstructure, consisting of wood, would be flexible and ductile. However, the design must account for the unavoidable difficulties of differential shrinkage, shear wall and diaphragm considerations and structural or seismic irregularities.

*Figure 6. Wood and steel resistance with temperature*8

8 « Superior Fire resistance », American Institute of Timber Construction, 2003
Design provisions and additional sources of information can be found in Section 3.11 of the “Mid-Rise Wood-Frame Construction Handbook” published by FPInnovations\(^9\). The seismic design of a 6-storey wood-frame superstructure over a reinforced concrete podium would not be different than that of a superstructure consisting of light-weight cold-formed steel construction.

Given that structural design of buildings is mostly performance-based, Code provisions for structural design are not viewed as possible restrictions to the conception of a 6+2 podium structure, and will not be further addressed in this report.

### 5.4 Code Provisions for Building Envelope Design

Part 5 (Division B) of the NBCC is similar to its structural counterpart; it contains mostly performance-based provisions and some prescriptive requirements with respect to environmental separation in building design.

There are no variations between the design of a building envelope for a combustible building and a non-combustible building. Both types of construction must withstand the exterior elements and provide an effective barrier to separate the interior conditioned environment from the exterior of the building.

Given that building envelope design of buildings is mostly performance-based, Code provisions for building envelope design are not viewed as possible restrictions to the conceptions of a 6+2 podium structure, and will not be further addressed in this report.

### 5.5 Alternative Solutions (NBCC)

In Canada, the 6+2 podium building is presently only possible when using alternative solution compliance requirements (NBCC 2015, Division A, Clause 1.2.1.1. (1)(b)).

If a building design respects all the requirements of the applicable acceptable solutions, it is deemed to have respected the objectives, functional statements and intents attributed to those provisions.

Most Code requirements are attributed objectives, functional statements and intent statements. When a design differs from the acceptable solutions of the Code, it is considered an alternative solution and must be approved by the AHJ in order to be in compliance with the

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Code. An alternative solution must respect the objectives, functional statements and intents of the Code attributed to the requirements that it differs from, to the same level or to a higher level than the acceptable solutions prescribed. The following diagram illustrates the approaches available to achieving compliance to the NBCC:

![Diagram of routes to achieving building code compliance with the NBCC](image)

**Figure 7.** Diagram of routes to achieving building code compliance with the NBCC

Presently, wood construction is limited to buildings having a maximum height of 6 storeys, under specific conditions stipulated by the NBCC.

The province of Quebec has published a guide for a “pre-approved” alternative solution for the design of 12-storey mass timber (residential) buildings that could be built on a single podium (one mass timber superstructure sitting over one podium only).

As previously stated, the notion of a non-combustible horizontal fire separation (e.g. a firewall), as described in subsection 510.2 of the IBC 2015, currently exists in the NBCC to some extent. As such, in order to allow the design of a “6+2” combustible building, some modifications to the NBCC would be required such as the introduction of a new article (3.2.1.3)

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entitled, for example, “Construction over podium considered as a separate building”. This new article would introduce the notion of a 3-hour horizontal fire separation between the two storey podium and the wooden superstructure(s).

The following table lists the principal objectives and functional statements attributed to Code prescriptions that would require a closer look if provisions for a 6+2 combustible building were implemented into the NBCC:

### Objectives

<table>
<thead>
<tr>
<th>OS1</th>
<th><strong>Fire Safety</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>An objective of this Code is to limit the probability that, as a result of the</td>
</tr>
<tr>
<td></td>
<td>design or construction of the building, a person in or adjacent to the building</td>
</tr>
<tr>
<td></td>
<td>will be exposed to an unacceptable risk of injury due to fire. The risks of</td>
</tr>
<tr>
<td></td>
<td>injury due to fire addressed in this Code are those caused by:</td>
</tr>
<tr>
<td>OS1.1</td>
<td>fire or explosion occurring</td>
</tr>
<tr>
<td>OS1.2</td>
<td>fire or explosion impacting areas beyond its point of origin</td>
</tr>
<tr>
<td>OS1.3</td>
<td>collapse of physical elements due to a fire or explosion</td>
</tr>
<tr>
<td>OS1.4</td>
<td>fire safety systems failing to function as expected</td>
</tr>
<tr>
<td>OS1.5</td>
<td>persons being delayed in or impeded from moving to a safe place during a fire</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OP1</th>
<th><strong>Fire Protection of the Building</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>An objective of this Code is to limit the probability that, as a result of its</td>
</tr>
<tr>
<td></td>
<td>design or construction, the building will be exposed to an unacceptable risk of</td>
</tr>
<tr>
<td></td>
<td>damage due to fire. The risks of damage due to fire addressed in this Code are</td>
</tr>
<tr>
<td></td>
<td>those caused by:</td>
</tr>
<tr>
<td>OP1.1</td>
<td>fire or explosion occurring</td>
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<tr>
<td>OP1.2</td>
<td>fire or explosion impacting areas beyond its point of origin</td>
</tr>
<tr>
<td>OP1.3</td>
<td>collapse of physical elements due to a fire or explosion</td>
</tr>
<tr>
<td>OP1.4</td>
<td>fire safety systems failing to function as expected</td>
</tr>
</tbody>
</table>

### Functional Statements

| F02 | To limit the severity and effects of fire or explosions.                      |
| F03 | To retard the effects of fire on areas beyond its point of origin.            |
| F04 | To retard failure or collapse due to the effects of fire.                    |

Table 3. NBCC 2015 Objectives and functional statements

As previously stated, a provision currently exists in the NBCC allowing an underground parking garage to be considered a separate building (see figure 2).

Intent statements provided by the NRCC explain the purpose of a specific provision or portion of provision found in Division B of the NBCC. Additionally, intent statements present the consequences of non-compliance with a requirement.
The NRCC attributes the following intent to Article 3.2.1.2. of the NBCC:

- To allow a basement storage garage to be considered as a separate building from the portion above and to exempt openings in certain fire rated separations which would otherwise require fire-rated closures, if certain measures are taken. These measures are to:
  - limit the probability of the spread of fire from the garage to the upper portions of the building during the time required to achieve occupant safety and for emergency responders to perform their duties, which could lead to harm to persons in the upper portions of the building, including emergency responders; and
  - limit the probability of the spread of fire from the garage to the upper portions of the building, which could lead to damage to the building.
6. IDENTIFICATION OF POSSIBLE RISKS AND PROPOSED SOLUTIONS

Changing the current NBCC to include provisions for a “6+2” podium building would involve the evaluation of many risks. Fire safety requirements, structural integrity and building envelope design would require careful analysis before the implementation of prescriptions in the NBCC for this type of building.

6.1 Fire safety

The Effectiveness of Sprinkler Systems

The presence of a sprinkler system greatly increases the level of fire safety of the building. The NFPA 13 “Standard for the Installation of Automatic Sprinkler Systems” provides the minimum requirements for the design and installation of sprinkler systems, and was written with the assumption that a sprinkler system is designed to protect against a single fire originating within the building. The maximum area of a building permitted by the NBCC is allowed to be doubled when a sprinkler system is present, due to the reduced risk of fire spread and, potentially, subsequent building collapse. A sprinkler system would not entirely suppress a fire however it would aid in controlling the growth and spread of a fire. According to a NFPA report, when sprinklers operated during a fire (e.g. sprinklers operated 91% of reported fires), they were effective at controlling the fire 96% of the time\textsuperscript{11}, therefore having an overall performance of 87%.

Considering that sprinklers significantly reduce the probability of a fire reaching flashover, the requirement for an automatic sprinkler system conforming to NFPA 13 would increase the safety in any building, including a podium building, and would dramatically decrease the risk of fire and smoke spread. Consequently, occupant safety would be increased.

Type of Construction

The most recent edition of the NBCC allows a sprinklered Group C (residential) building, up to 6 storeys in height, to be of combustible construction. Due to the dangerous effects of fire and smoke, the NBCC imposes a height limitation on these types of buildings.

Combustible construction includes two main types of wood construction:

- light wood-frame construction; and
- heavy timber (and mass timber) construction.

Light wood-frame uses standard dimensional lumber (nominal 2x4, 2x6, 2x8, 2x10, etc.) and engineered wood (such as I-joists and trusses) to form walls and floors ultimately supported by a concrete foundation.

Figure 8. Light wood-frame structure partially covered by plywood sheathing
Figure 9. Light wood-frame engineered joists partially covered by plywood sheathing

Light wood-frame construction is normally covered by gypsum board to conceal and protect insulation, wiring and piping within the framed assemblies. Gypsum board is generally used to achieve a FRR as specified by the Code.

The voids and concealed spaces in light wood-frame construction present an inherent risk to the building itself and to occupant safety. For instance, openings created in floors joists or wall studs to allow services to pass through as well as other construction voids within the structure are hazardous because they could induce the spread of fire and result in structural collapse. Concealed spaces that are not properly fire stopped would pose one of the biggest hazards to a light wood-frame superstructure above a podium base. Special attention should be given to concealed spaces and penetrations for services (pipes, ducts, etc.); any concealed space extending past a fire separation should be adequately fire stopped.

Heavy timber and mass timber construction include large dimension timber pieces and structural composite lumber, LVL, PSL, LSL, OSL, glulam and CLT. Hence, the fire-resistance rating in these types of construction is achieved by using large mass structural members, which could be left exposed (uncovered) in most cases.
Due to their size, the members provide a certain degree of fire-resistance. Very few, if any, concealed spaces are present in heavy timber construction thus greatly reducing the risk of non-visible fire spread.

Where combustible construction is permitted by the NBCC and a FRR of not more than 45 minutes is required, the construction could be heavy timber. The FRR of a heavy timber construction could be increased up to 2 hours or more by increasing the cross-sectional area of a member or by protecting members with Type "X" gypsum board. If this were an acceptable solution of the NBCC, a new definition for “mass timber construction” should be introduced in the Code.

Due to the decreased risk of concealed spaces and the inherent level of fire-resistance in a heavy timber structure, this type of construction may be a safer option for the superstructure of a podium building.

Annex B of CSA O86-14 assigns a one-dimensional charring rate of 0.65 mm per minute to wood members of large cross-sections (i.e. greater than those used in traditional wood-frame construction). As such, one can easily calculate the required minimum initial cross-section of a
member to ensure that the reduced cross-section (i.e. after charring) can still resist the effects of the applied loads. The larger the initial cross-sectional area of a member, the longer the member will maintain its structural integrity in a fire.

**Integrity of Fire Separations**

The qualifications and competency of contactors and trades involved in the realization of a building project are major factors to be considered. Presently, there is no industry standard or “best practices” for passive fire protection building methods such as the installation of fire blocking, fire stopping, fire separations and the creation of fire compartments in a building.

The fire-resistance ratings of certain assemblies specified by the Code (i.e. floors, mezzanines and structural elements required to be constructed as fire separations) are dependent on the integrity of their installation, rather than on the materials that form those assemblies. In other words, if a required fire separation, fire stop or fire blocking is not adequately installed, its integrity may become compromised, regardless of the FRR of the material itself. Gypsum board, used in light wood-frame construction to create fire separations in a building, is susceptible to improper installation, which would affect the integrity of an assembly and cause fire or smoke to spread.

![Figure 11. Example of a fire stop evaluated for CLT assemblies](image-url)
Figure 12. Examples of technical penetrations protected by fire-resistant assemblies (firestop systems)

As shown in figure 12 above, the detailing and installation of elements penetrating a fire separation or an assembly for which a degree of fire-resistance rating is required should be sealed by an adequate fire stop and tested as per ULC S115 “Fire Tests of Fire stop Systems”.

The delivery of a building that is entirely compliant with the Code has always been a challenge in the industry. With adequate installation, passive fire protection methods have proven to be effective, however those methods should be carefully reviewed and a standard for best practices should be developed in order to mitigate practical risks during the construction phase. Mandatory regular field reviews and job site inspections should also be enforced by all AHJs to elevate the quality of a construction project.
Considerations for High Buildings

A high building requires fire fighter staging operations and special measures to protect occupant safety during a fire. The time required for the complete evacuation of a high building could potentially exceed general safety limits. Subsection 3.2.6 of the NBCC provides requirements that maintain occupant safety during a fire and includes provisions for the efficient access to the building by fire fighters.

In a high building, stack effect is a condition that requires significant consideration. The building itself acts as a “chimney” when the temperature outside of the building envelope is much lower than the temperature of the spaces within the building envelope; the exterior air enters at the lower floors of the building and exits through the upper floors. The warm interior air flows through any gaps situated at the top of the building, and the cold exterior air tends to penetrate into the building at lower floor levels. A neutral pressure plain is formed at the mid-height point of the building (see figure 13).

In the event of a fire, smoke and fire effluents generally migrate upwards. Elevator and other vertical service shafts could be severely affected. Exit stairwells could also become contaminated with smoke, jeopardizing occupant safety or delaying occupant egress and rendering firefighting efforts ineffective.
In order to mitigate the risks that stack effect creates, careful consideration is necessary to ensure that a building is sealed as much as possible against air leakage. The NBCC includes provisions to limit the movement of smoke in a high building and requires that exit stairways serving storeys above grade are separate from those serving storeys below grade.

During a fire, occupant safety is threatened mostly by the migration of smoke and other fire effluents. The implementation of provisions for a high rise podium building should include the mechanical pressurisation of exit stairwells because this type of smoke-control system would maintain a minimum pressure differential to prevent smoke migration from floor areas and reduce stack effect.

### 6.2 Structural Integrity

The provisions for seismic protection, guidelines for quality processes and considerations for higher lateral loads are all factors that can affect the structural integrity of a podium building. However, these factors are also applicable to any other type of construction whether concrete, masonry, steel or wood.
In a typical seismic design, it is recommended to conduct a “two-stage analysis procedure”, as detailed in the 2010 edition of ASCE-7, presuming that specific conditions are met (refer to Clause 12.2.3.2 of ASCE-7). Additional information can be found in Section 3.11 of the “Mid-Rise Wood-Frame Construction Handbook” published by FPInnovations.

6.3 Building Envelope Integrity

While building envelope design is mostly performance-based in the NBCC, caution should be made for wood construction as wood may be more vulnerable to harsh weather conditions during the construction period.

If exposed to a source of moisture (e.g. rain or snow), the moisture content of elements of the building envelope could increase, when compared to their initial value and thus render the building envelope prone to damage or deterioration from the shrinkage of the wood or from the moisture content itself. The differential movement from the drying and shrinkage of the wood structure is a considerable risk in taller light wood-frame and heavy timber construction. It is therefore essential to account for the potential movement of a wood structure due to the building envelope components that are likely to be affected.

A guide published by the AHJ in the province of Quebec for the construction of 12-storey mass timber buildings requires exterior façades to be sheathed in non-combustible materials or an exterior wall assembly that complies with the performance requirements set forth in Article 3.1.5.5 of Division B of the NBCC. This stipulation would prevent the spread of fire from the exterior of the building. Exterior sheathing is an important component to be taken into account when considering building envelope integrity and overall safety against the spread of fire.
7. ANALYSIS

7.1 Fire Risks

As presented in Section 5.5 of this report, the NBCC contains objectives that address the safety of occupants and fire fighters in the event of a fire in a building. Objectives OS1.1 to OS1.5, OP1.1 to OP1.4 and OP3.1 can be summarized in the following table:

<table>
<thead>
<tr>
<th>Fire Risk</th>
<th>Objective(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire spread beyond point of origin</td>
<td>OS1.2, OP1.2</td>
</tr>
<tr>
<td>Fire spread to adjacent buildings</td>
<td>OP1.3</td>
</tr>
<tr>
<td>Fire detection/recognition for occupants compromised</td>
<td>OS1.4, OS1.5, OP1.4</td>
</tr>
<tr>
<td>Ignition of first item</td>
<td>OS1.1, OP1.1</td>
</tr>
<tr>
<td>Evacuation for occupants compromised</td>
<td>OS1.4, OS1.5, OP1.4</td>
</tr>
<tr>
<td>Premature structural collapse</td>
<td>OS1.3, OP1.3</td>
</tr>
<tr>
<td>Ineffective firefighting operations</td>
<td>OS1.2, OS1.3, OP1.2, Op1.3, OP3.1</td>
</tr>
<tr>
<td>Ineffective sprinkler system</td>
<td>OS1.4, OP1.4</td>
</tr>
</tbody>
</table>

Table 4. Fire risks and code objectives.

**Fire Spread Beyond Point of Origin (OS1.2, OP1.2)**

The 2-hour fire separation required by Article 3.2.1.2. of Division B is related to objectives OS1.2 and OP1.2, hence reducing the risk of fire spread beyond the compartment/floor of origin. The implementation of provisions for podium buildings in the Code would inevitably require a fire separation between the podium and the superstructure. A 3-hour FRR horizontal assembly, as provided in the IBC, would be an advisable requirement for this type of structure. The risk of fire spread from the upper storey of the podium to the wood superstructure would be decreased due to the horizontal fire separation staying in place for a longer period of time. Moreover, the sprinkler system required in the podium floor areas would control the fire at its incipient stage, therefore limiting the heat release rate and wetting of the area of fire origin.

Code provisions for vertical fire separations in a “6+2” podium building would remain the same, hence reducing the risk of fire spread. This same logic could be applied to minimize fire spread on wall and ceiling finishes.
Provisions in the NBCC for a non-combustible construction will prevail in both the podium and the wood-frame superstructure. Consequently, the risk of fire spread in an 8-storey non-combustible construction would be equal to that of a “6+2” podium building with a wood-frame superstructure. Considering the low potential for a heavy timber or mass timber structure to be ignited and for a fire to spread, the 6-storey superstructure could, in theory, be permitted to have exposed interior finishes (e.g. the wood members themselves), if a sprinkler system conforming to NFPA 13 is present.

In a non-combustible construction, wood finish materials of less than 25 mm in depth having an FSR of less than 150 are permitted to be on 100% of the walls and 10% of the ceilings (Division B, Sentences 3.1.5.12. (2) and (3)). In the case of heavy timber and mass timber construction, the walls could be left exposed since they would not present a substantial risk in a sprinklered building.

Furthermore, a non-combustible construction that has a ceiling finish of less than 25 mm thick and an FSR of less than 25 must be protected as per the NBCC (Division B, Sentences 3.1.5.12. (2) and (3)). According to certain proprietary data from a Canadian manufacturer, mass timber (panel) elements exhibit a FSR of less than 50. A modification of Sentence 3.1.5.12. (3) could be proposed in order to allow 50% of the ceiling to be exposed when the FSR is less than 75, based on future research.

Moreover, an even safer mass timber construction incorporates the encapsulation of its components. Tests that were performed at NRCC in 2014\textsuperscript{12} showed that a fire in an encapsulated CLT construction could withstand flashover and resist a complete burnout of the compartment contents. In fact, this study showed that a wood-frame structure protected with gypsum boards performed as well as the non-combustible construction benchmark in a fire, represented by a light-gage steel stud system (protected with gypsum board), and that the wood itself was not a contributing factor in the involvement of the fire until post-flashover.

As previously mentioned, fire spread though concealed spaces and structural voids is a major problem for the integrity of the structure and for the safety of building occupants and fire fighters. In theory, the risks caused by concealed spaces are non-existent in a heavy timber and mass timber construction, unless non-loadbearing walls or dropped ceilings are present. A

\textsuperscript{12} « Fire safety summary – Fire research conducted for the project on mid-rise wood construction », J.Z. Su & G.D. Lougheed, NRCC, Dec 31 (2014)
wood-frame construction would contain many concealed spaces that must be protected by fire blocks or automatic sprinklers. In a “6+2” podium building, the concealed spaces could be eliminated by the installation of non-combustible insulation or by the protection of these voids with automatic sprinklers. This subject will be further addressed later in this report.

A fire could potentially spread through exterior windows and other openings in the building envelope. For this reason, combustible cladding should be prohibited in a podium building, unless it is compliant to ULC 134 “Standard Method of Fire Test of Exterior Wall Assemblies” and thus has the same level of risk than a non-combustible construction.

Fire and smoke could also spread within an interconnected floor space (sometimes referred to as “atria”). The NBCC requires that a floor terminates at a vertical fire separation having a FRR not less than that required for the floor assembly (Division B., Subsection 3.2.8.). Some exceptions are permitted, for instance, an opening of less than 10 m$^2$ in the floor assembly to accommodate a small escalator, or between the first storey of a building and the storey next above or below it under certain conditions. The NBCC recognizes that fire spread in a sprinklered building does not represent a severe hazard and requires that a building containing an interconnected floor space be sprinklered throughout, regardless of the type of construction (Division B, Article 3.2.8.3). As such, this will not change in a “6+2” podium building, but the current NBCC exception between the first storey and the storey next above or below it should perhaps be permitted only for the podium base of the building.

If an interconnected floor space in a building does not fall within the exceptions to special protection requirements of the NBCC, several fire and smoke protection provisions must be respected as per Division B, Articles 3.2.8.3. to 3.2.8.8. Since the publication of the 2015 edition of the NBCC, protection requirements for interconnected floor spaces are applicable whether the building is combustible or non-combustible. It can therefore be contended that the risk caused by interconnected floor spaces are the same whether the construction is combustible or non-combustible, if all the protective measures and requirements of Articles 3.2.8.3. to 3.2.8.8. are respected.

The NBCC still limits the fuel load to 16 g of combustible contents, excluding interior finish materials, for every cubic meter of the interconnected floor space when the distance between the ceiling and the floor is more than 8 m (Division B, Article 3.2.8.8). The NBCC is however
obsolete with respect to this requirement considering that, since the mid-1980s, tests have shown that a sprinkler system may be effective even when the distance between the fire and the ceiling is 12 m or more\textsuperscript{13,14}. Also, considering that it is sometimes not possible to limit the fire load to such a low level, the code should address the potential for smoke propagation by referencing NFPA 92 “\textit{Standard for Smoke Control Systems}” for the control of potential smoke in the atria or communicating spaces such as the IBC-2015 does at articles 404.4 and 909.8.

Finally, it should be further investigated whether exposed heavy timber and mass timber surfaces could be left exposed in all interconnected cases (e.g. 2 to 6 storeys interconnected floor spaces), knowing that for the extreme case (6 storeys and a possible height of 24 m), the sprinklers may not be effective. Harmsworth and Chen have proposed that interconnected floors spaces in a building of heavy timber construction be limited to a maximum height of 12 m (4 storeys)\textsuperscript{15}.

\textbf{Fire Spread to Adjacent Buildings (OP3.1)}

The possible implementation of a 3-hour fire separation to facilitate the design of a “6+2” podium building would not diminish the benefits of the requirements provided in Division B, Subsection 3.2.3. “\textit{Spatial Separation and Exposure Protection}” of the NBCC, which are mainly relative to occupancy, distance to property lines or between buildings, and the presence of a sprinkler system. After flashover, a probable stage of a fire in an unsprinklered building, radiative heat would be at its maximum level. In a sprinklered building, only 5% of fires reach flashover. Nonetheless, the exterior cladding of a “6+2” podium building should be either non-combustible or in compliance with ULC S134 “\textit{Standard Method of Fire Test of Exterior Wall Assemblies}”. This additional safety measure decreases the risk of an external flame spread.

\textsuperscript{13}“Sprinkler protection of non-storage occupancies with high ceiling clearance”, Kung et als, Fire Safety Journal, Nov 2012

\textsuperscript{14}“FIRE PROTECTION FOR NON-STORAGE OCCUPANCIES WITH HIGH CEILING CLEARANCES”, Nam et als, PROCEEDINGS OF THE SEVENTH INTERNATIONAL SYMPOSIUM, pp. 493-504, 2002

\textsuperscript{15}“Study of 8 storey Heavy Timber Buildings of Group D Occupancy”, A. Harmsworth & K.M. Chen, GHL Consultants Ltd, April 123, 2012
Ineffective Fire Detection (OS1.4, OS1.5, OP1.4)

A “6+2” podium building would require a NFPA 13 sprinkler system on every floor and a fire alarm system conforming to ULC S524 “Standard for the Installation of Fire Alarm Systems”.

The risk that building occupants perceive the fire at a later stage than for a “typical” 6-storey building is irrelevant.

Ignition of the first item (OS1.1, OP1.1)

Igniting the first item is mostly based on the occupancy classification or on operations during the service life of a building. To minimize the risk of ignition, the National Fire Code of Canada contains provisions that the owner, operator or tenant must minimally respect in order to reduce the risk of fire. The NBCC also provides restrictions for the use of flammable liquids, although the Code requirements themselves can mitigate consequences of a fire by requiring the use of sprinklers, compartmentation, fire-resistance, service room provisions, etc.

A common source of heat that can ignite a wood-frame structure is faulty electrical wiring or other electrical components embedded in the concealed spaces (structural cavities). The NBCC specifies that the electrical system must comply with CSA C22.1, “Canadian Electrical Code, Part I” to mitigate potential hazards. To reduce the potential of fire spread, a provision requiring that all concealed spaces be filled with non-combustible insulation could be implemented in the NBCC. Testing and further research could be beneficial to determine whether this cavity filling is adequate.

As for the other sources of ignition (kitchen fire, smoking articles, arson, etc.), there are no more risks in a “6+2” podium building that is protected with a sprinkler system than in a standard 8 storey non-combustible (sprinklered) construction.

Consequently, the risk of ignition does not significantly increase in a “6+2” podium building.

Occupant Evacuation compromised (OS1.4, OS1.5, OP1.4)

Evacuation provisions and fire-resistance of exit stairs set in the NBCC are predominantly based on occupancy and sprinkler protection for egress distance, type of construction for finish materials and main building characteristics (e.g. number of storeys, type of construction, sprinklers, etc.). The egress time to attain a public way is slightly greater in a podium building than that of a standard 6-storey building because occupants have two more storeys to walk
down, and possibly a podium of a larger area than the upper wood-frame structure. For an adult, the additional time of egress to walk down the distance in the stairway represents less than 15 seconds (with a mean speed of 0.74 m/sec)\(^{16}\). Considering the occupants are already within a “zone of refuge” in the exit staircase (1-hour FRR), this 15 seconds is negligible.

In order to avoid a large number of occupants in the staircases which could delay the evacuation of a building in a fire situation, the podium exit staircases must be distinct from the wood superstructure. Further analysis is required to determine whether the interior finish of exit stairs and elevator shafts should consist of non-combustible materials due to fire safety concerns.

For a “6+2” podium building, the travel distance within a floor area to an exit would be unaffected and would not compromise the means of egress of building occupants.

**Premature Structural Collapse (OS1.3, OP1.3)**

The design of a “6+2” podium structure would imply that the superstructure is erected overtop of a 3-hour non-combustible (reinforced concrete) horizontal fire separation that isolates occupancies having a larger fuel load or risk (e.g. commercial shops or restaurants) from the occupancies in the structure above.

The six storeys (1-hour FRR) above the podium are not any more susceptible to failure than a wood building supported by a typical foundation.

As discussed in section 5.2.3. of this report, the FRR is not dependent on the type of construction; the assembly must resist the standard time-curve temperature whether it consists of wood, steel or concrete materials. As a result, a standard 6-storey wood building has the same level of risk as a 6-storey superstructure over a non-combustible podium.

As previously stated, the continuity and integrity of fire separations and the protection of their supporting structures (beams and columns) as well as the protection of concealed spaces are dependent on well-designed details and adequate workmanship on site. The latter is defined as “process risk”\(^{17}\). The NBCC already contains requirements for fire stops/blocks, continuity

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and FRR requirements. However, the careful installation and maintenance of these components is critical to avoid a premature collapse of a wood-frame structure.

A standard 6-storey wood frame structure has the same level of process risk as the superstructure of a “6+2” podium building. During a fire situation in a podium structure, the building would be evacuated. Pursuant to this, the fire department would fight the fire from the interior of the building, possibly at upper storeys; ergo in order to limit the probability of premature structural collapse, any structural voids consisting of combustible materials should be protected by sprinklers or filled with non-combustible insulation.

**Ineffective Firefighting Operations**

Access to a podium building would be required by the fire department in order to perform firefighting operations from the interior. This was already the case with a 6-storey wood-frame building designed as per Division B, Articles 3.2.2.50 (residential) and 3.2.2.58 (business). The NBCC recognized in Division B, Art. 3.2.5.1. (with the presence of sprinklers) that firefighting would be performed from inside the building and not outside, by eliminating fire access openings and having the building facing only one street. Both types of construction require standpipes and, most importantly, a sprinkler system for fire control at the early stages of a fire. The efficiency and reliability of sprinkler systems make both building types equally safe for firefighting operations.

The fire department would have to fight a fire over a 1,500 m$^2$ or 3,000 m$^2$ floor area (6-storey superstructure with residential or business occupancies respectively), whereas a 6-storey sprinklered building of non-combustible construction would be 6,000 m$^2$ and 7,200 m$^2$ respectively.

The important differences in both designs are that the fire fighters have to walk up two more storeys, when necessary, and a “6+2” building is more susceptible to stack effect, which promotes upward smoke propagation especially during colder temperatures. Ascending two more storeys should not pose a problem for well-trained fire department personnel. Furthermore, in order to reduce stack effect and the risk of upward smoke propagation, additional provisions could be implemented in the NBCC such as:

- Pressurisation of elevators and exit staircases; or
• Pressurised vestibules protecting the elevator or the exit staircases at the podium level; or
• Podium elevator shafts and staircases distinct from superstructure elevator shafts and staircases; and
• Vertical technical shafts separated between the podium and superstructure(s).

The other problematic for fire fighters conducting an effective intervention was discussed earlier; fire spreading within structural voids in a wood-frame superstructure. This can be avoided by:
• Structural voids filled with non-combustible insulation; or
• Structural voids protected by sprinklers.

Finally, if several superstructures sit on a large podium, programming of the fire alarm system should be performed very carefully in order to avoid sending the fire department to the wrong “tower” and thus prolonging the response time and hindering the intervention.

**Ineffective Sprinkler System**

The inherent risk of sprinklers being unable to control a fire or failing to operate exists as much in an 8-storey non-combustible building than it does in a “6+2” podium building. Both buildings would be designed according to NFPA 13 requirements and would be inspected as per the National Fire Code and NFPA 25, “Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems”. As a result, the risk of a sprinkler malfunction would not increase in a podium building design.

### 7.2 Structural Risks

Given that structural design is mostly performance-based, a podium building with a 6-storey wooden superstructure does not present a greater risk than if its superstructure consisted of another type of construction.

### 7.3 Building envelope Risks

Given that building envelope design is mostly performance-based, a podium building with a 6-storey wooden superstructure does not present a greater risk than if its superstructure consisted of another type of construction.
8. CONCLUSION

This report has been prepared at the request of FPInnovations to provide a broad verification of the possible strategies to implement a provision in the NBCC that would facilitate the design of a two-storey non-combustible podium over which would sit a 6-storey wood-frame superstructure, housing business or residential units. This concept is currently permitted in the IBC and requires a 3-hour horizontal fire separation between the podium and the superstructure.

As elaborated in this report, the NBCC could incorporate a similar provision for a horizontal fire separation, in order to allow the design of a “6+2” podium building. Similar to Division B, Article 3.2.1.2 that presents the “underground podium” provision (2-hour fire separation), a 3-hour fire separation over the second floor of the podium could be drafted with certain additional provisions.

The succinct comparison between the risk of fire in an 8-storey non-combustible (residential or business) building and a “6+2” podium building was made; the risks that a podium building presents are not significantly greater than its comparative. Sprinkler systems have greatly mitigated the risks in all buildings that are protected throughout. The inadequate assembly of a fire separation or fire blocking increases the likelihood of fire spreading into concealed spaces. This could potentially reduce the FRR of an assembly or structural component and become a challenge in firefighting operations. A high standard of workmanship is required during the installation of components that act as barriers against the spread of fire or smoke.

In order to reduce the process risk related to fire spreading into concealed spaces, protecting these voids with sprinklers or with non-combustible insulation would further enhance the safety of the building.
Furthermore, in a podium building, the means of egress of the podium itself should be separated from those of the superstructure, unless other protective measures are implemented. The overall height of the building potentially calls for exit stairwells and elevator shafts to be pressurised in order to minimize possible smoke spread.

Marc-André Langevin, Eng., M.Eng., M.A.Sc.
President
MAL/ML/