INTRODUCTION

The *National Building Code of Canada (NBCC)*[1] defines fire safety under Objective OS1: "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 a building will be exposed to an unacceptable risk of injury due to fire."

In simpler terms, fire safety is the reduction of the potential for harm to life as a result of fire in buildings. Although the potential for being killed or injured in a fire cannot be completely eliminated, fire safety in a building can be achieved through proven building design features intended to minimize the risk of harm to people from fire to the greatest extent possible.

Designing a building to ensure minimal risk or to meet a prescribed level of safety from fire is more complex than just the simple consideration of what building materials will be used in construction of the building, since all building materials are affected by fire. Many factors must be considered including the use of the building, the number of occupants, how easily they can exit the building in case of a fire and how a fire can be contained.

The NBCC only regulates those elements which are part of the building construction. The building contents found in any building are typically not regulated by the NBCC, but in some cases they are regulated by the *National Fire Code of Canada (NFCC)*[2].

The classification of buildings or parts of buildings according to their intended use accounts for:

- the quantity and type of combustible contents likely to be present (potential fire load);
- the number of persons likely to be exposed to the threat of fire;
- the area of the building; and,
- the height of the building.

This classification is the starting point in determining which fire safety requirements apply to a particular building.

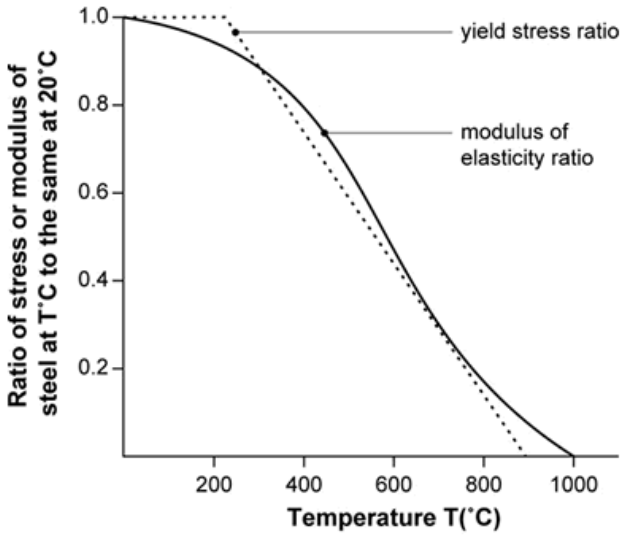
Classification dictates:

- the type of building construction,
- the level of fire protection, and
- the degree of structural protection against fire spread between parts of a building that are used for different purposes.

Even materials that do not sustain fire do not guarantee the safety of a structure. Steel, for instance, quickly loses its strength when heated and its yield point decreases significantly as it absorbs heat, endangering the stability of the structure (Figure 1). An unprotected, conventional cold-formed steel joist floor system will fail in less than 10 minutes under standard laboratory fire exposure test methods, while an unprotected, conventional wood joist floor system can last up to 15 minutes.

Even reinforced concrete is not immune to fire. Though concrete structures have rarely collapsed, concrete will spall under elevated temperatures, exposing the steel reinforcement and weakening structural members.

Figure 1: Steel loses strength at elevated temperatures



Source: *Fire Engineering Design Guide*, University of Canterbury, New Zealand, 1994

Figure 1. Steel loses strength at elevated temperatures.

As a result, it is generally recognized that there is really no such thing as a fire-proof building.

Fires can occur in any type of structure. The severity of a fire, however, is contingent on the ability of a construction to:

- confine the fire,
- limit a fire's effects on the supporting structure, and
- control the spread of smoke and gases.

To varying degrees, any type of construction can be designed as a system – that is, a combination of construction assemblies – to limit the effects of fire. This allows occupants sufficient time to escape the building and for firefighters to safely carry out their duties.

Occupant safety also depends on other parameters such as detection, exit paths, and the use of automatic fire suppression systems such as sprinklers. These concepts form the basis of the NBCC requirements.

Structural Systems in Wood

Structural systems in wood can be divided into two main categories: lightweight wood frame construction, and mass timber construction.

These two types of construction have important differences that relate to:

- the size of the wood members,
- the methods of assembly, and
- the degree to which they must be combined with other materials to achieve fire-safe conditions.

The type of construction currently permitted by the NBCC depends on building size (height and area) and use (occupancy classification).

Though the structure of a modern wood-frame building may be made entirely of wood, protective finishes such as gypsum board can be applied to the framing to provide structural fire resistance where required.

Wood-frame assemblies can economically and easily be made to resist the effects of a fire for up to two hours through the use of appropriate materials and construction methods. Experience has proven this construction system to be reliable and safe. Various configurations of wood-frame floor and wall assemblies have been tested and based on the test results, have been assigned varying degrees of fire resistance from 45 minutes to two hours.

Mass Timber Construction

Large dimension wood sections have an inherent resistance to fire. Wood burns slowly at approximately 0.6 mm/minute. The char created on the wood surface as it burns helps protect and insulate the unburnt wood that remains below the charred layer. The unburnt portion of a thick member retains at least 85 to 90 percent of its strength.

Hence, a wood member with a large cross-section can burn for a significant amount of time before its size is

reduced to the point where it can no longer carry its load.

The most familiar form of mass timber construction is "heavy timber construction."

Heavy Timber Construction

Heavy timber construction is defined in the NBCC as: "a type of combustible construction in which a degree of fire safety is attained by placing limitations on the sizes of wood structural members and on thickness and composition of wood floors and roofs and by the avoidance of concealed spaces under floors and roofs."

Both solid-sawn and glue-laminated members qualify under this definition provided they have the minimum sizes given in Table 1. Of course, they must be designed to carry the expected loads in conformance with CSA Standard O86, *Engineering design in wood*, and actual dimensions must conform to CSA Standard 0141, Softwood Lumber.

To satisfy heavy timber requirements wood elements must be arranged in solid masses with essentially smooth, flat surfaces to avoid thin sections and sharp projections. This is to reduce to a minimum the surfaces which can be exposed to fire.

For the same reason, when roof arches, trusses, beams or girders are made from several pieces, the connection elements must be a minimum of 64 mm thick and be protected by sprinklers. Where not protected by sprinklers, they must be built so that they constitute a solid mass or have the voids blocked off on the underside by a continuous wood cover plate at least 38 mm thick. The NBCC also includes specific requirements related to floor and roof assemblies in heavy timber construction.

The NBCC recognizes the inherent fire resistance of heavy timber construction, and allows the unprotected wood members, including floor and roof decks, that meet the minimum size requirements to be used both where a 45-minute fire-resistance rating is required and in many noncombustible buildings.

Other forms of mass timber construction are being developed, including cross-laminated timber (CLT). More information about such systems will become available over time.

More detailed information about fire safety can be found in CWC's *Fire Safety Design in Buildings.*[3]

Other Related References

1. Fitzgerald, Robert W., Fundamentals of Fire Safe Building Design, Fire Protection Handbook, National Fire Protection Association, Quincy, MA, 1997.
2. Watts, J.M. (Jr); Systems Approach to Fire-Safe Building Design, Fire Protection Handbook, National Fire Protection Association, Quincy, MA, 2008.
3. Rowe, W.D.; Assessing the Risk of Fire Systemically ASTM STP 762, Fire Risk Assessment, American Society for Testing and Materials, West Conshohocken, PA, 1982.

Table 1. Minimum dimensions of wood elements of heavy timber construction in NBCC.

Supported Assembly	Structural Element	Solid Sawn (width x depth) mm x mm	Glue-laminated (width x depth) mm x mm	Round (diameter) mm
Roofs only	Columns	140 x 191	130 x 190	180
	Arches supported on the top of walls or abutments	89 x 140	80 x 152	-
	Beams, girders and trusses	89 x 140	80 x 152	-

	Arches supported at or near the floor line	140 x 140	130 x 152	-
Floors, floors plus roofs	Columns	191 x 191	175 x 190	200
	Beams, girders, trusses and arches	140 x 241 or 191 x 191	130 x 228 or 175 x 190	-
Source: National Building Code of Canada, 2010				

[1] National Building Code of Canada, National Research Council, Ottawa, ON, 2010.
[2] National Fire Code of Canada, National Research Council of Canada, Ottawa, ON, 2010.
[3] Available at www.cwc.ca as a free PDF for download.