Fire Safety Defined

The National Building Code of Canada[1] (NBCC) defines fire safety as "*an objective to reduce the probability that a person in or adjacent to a building will be exposed to an unacceptable fire hazard as a result of the design and construction of the building.*"[2]

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 minimise 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. [3,4,5,6]. 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 are regulated by the National Fire Code of Canada[7]. The classification of buildings or parts of buildings according to their intended use accounts for:

- the quantity and type of combustible materials 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
- the height of the building

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

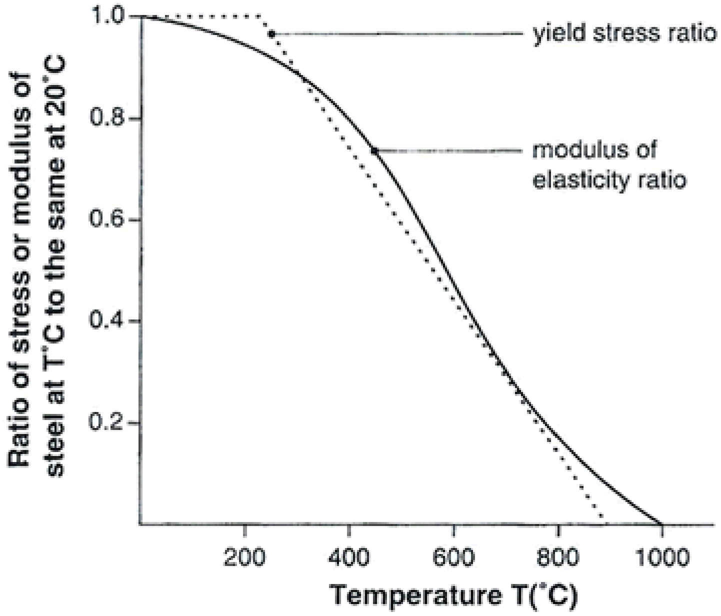
Classification dictates:

- the type of building construction
- the level of fire protection
- 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 (Graph 1). An unprotected, conventional steel joist system will fail in less than 10 minutes under standard laboratory fire exposure test methods, while a 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.

Graph 1: Steel loses strength at elevated temperatures



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

It is generally recognized then, that there is really no such thing as a fireproof 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 its effects on the supporting structure
- 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 reach the seat of the fire.

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

Structural Systems in Wood

Structural systems in wood can be divided into wood-frame and heavy timber construction. The fire resistance and minimum sizes of structural components in heavy timber construction is discussed under the section on *Heavy Timber Construction*.

These two types of construction have important differences. They relate to:

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

The type of construction permitted, wood-frame, heavy timber of non-combustible depends on building size and use. Buildings are typically classified according to occupancy, building height and area.


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

Wood-frame assemblies can economically 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.

The following section on *Fire Resistance Ratings* provides specific information and construction details on wood frame wall assemblies that are assigned various fire resistance ratings. Additional information is listed in the NBCC.

Fire Resistance Ratings

In the National Building Code of Canada "Fire-resistance rating" is defined in part as: "the time in hours or fraction thereof that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria..."

Horizontal Assemblies

Horizontal assemblies such as floors, ceilings and roofs are tested for fire exposure from the underside only. This is because a fire in the compartment below presents the most severe threat. For this reason, the fire-resistance rating is required from the underside of the assembly only.

The fire-resistance rating of the tested assembly will indicate, as part of the listing limitations, the restraint conditions of the test. When selecting a fire-resistance rating, it is important to ensure that the restraint conditions of the test are the same as the construction in the field. Wood frame assemblies are normally tested with no end restraint to correspond with normal construction practice.

Vertical Assemblies

Partitions or interior walls required to have a fire-resistance rating must be rated equally from each side since a fire could develop on either side of the fire separation. They are normally designed symmetrically. If they are not symmetrical, the fire-resistance rating of the assembly is determined based on testing from the weakest side.

For a loadbearing wall, the test requires the maximum load permitted by design standards be superimposed on the assembly. Most wood-stud wall assemblies are tested and listed as loadbearing. This allows them to be used in both loadbearing and non-loadbearing applications. Most steel-stud wall assemblies are tested and listed as non-loadbearing because they are used primarily in non-loadbearing applications in noncombustible buildings.

Loadbearing steel-stud wall assemblies typically use studs of a heavier gauge steel than non-loadbearing studs to be able to support the load. The heavier gauge stud reacts differently when exposed to fire and withstands the tendency for studs to twist and distort when exposed to heat. Loadbearing and non-loadbearing steel stud wall listings are not interchangeable because the properties of the studs in these assemblies are not the same. Listings for loadbearing wood stud walls can be used for non-loadbearing cases since the same studs are used in both applications.

Loading during the test is critical as it affects the capacity of the wall assembly to remain in place and serve its purpose in preventing fire spread. The strength loss in studs resulting from elevated temperatures or actual burning of structural elements causes deflection. This deflection affects the capacity of the protective wall membranes (gypsum wallboard) to remain in place and contain the fire.

The fire-resistance rating of loadbearing wall assemblies is typically lower than that of a similarly designed non-loadbearing assembly.

Exterior walls only require rating for fire exposure from within a building. This is because fire exposure from the exterior of a building is not likely to be as severe as that from a fire in an interior room or compartment. Because this rating is required from the inside only, exterior wall assemblies do not have to be symmetrical.

Fire Performance of Lightweight Construction

The **National Fire Protection Research Foundation** has published a report ,**ENGINEERED LIGHTWEIGHT CONSTRUCTION LITERATURE REVIEW & TECHNICAL ANALYSIS**, resulting from a study on the fire performance of various types of lightweight construction. The following is a brief description of the report. For availability of the report see http://www.nfpa.org/Research/foundation/summaries/summaries.asp

ENGINEERED LIGHTWEIGHT CONSTRUCTION LITERATURE REVIEW & TECHNICAL ANALYSIS
by Kirk Grundahl, P.E.

The Literature Review and Technical Analysis -- the first phase of the Engineered Lightweight Construction Fire Research Project -- comprehensively surveys the literature on engineered lightweight construction (trusses, bar joists, prefabricated wood I-joists, light-gauge steel joists, etc.), and analyzes the issues of potential sudden collapse when subjected to fire conditions. There has been widespread concern among the fire service, manufacturing, fire sprinkler and insurance communities regarding the fire performance of construction that relies more for strength on engineering design than on mass. The concern is for firefighter and occupant safety, roof or floor collapse, and fire suppression system adequacy. Many feel that there is inadequate documentation for some current practices, and misapplication of codes. The Technical Analysis measures progress toward answering these questions. It also identifies gaps in knowledge, thus providing a starting point for further research.

Some web sites of wood product manufacturers that contain more information on fire ratings are:

American Wood Council

Truss Joist, A Weyerhaeuser Business

Willamette

Wood Truss Council of America

Standard Fire Test Methods

The test and acceptance criteria the *NBCC* refers to are contained in a standard fire test method, CAN/ULC-S101, *Standard Method of Fire Endurance Tests of Building Construction and Materials*, published by Underwriters' Laboratories of Canada.

Alternative Fire Test Methods

The *NBCC* permits the authority having jurisdiction to accept results of fire tests performed according to other standards. Since test methods have changed little over the years, results based on earlier or more recent editions of the CAN/ULC-S101 standard are comparable.

The primary US fire-resistance standard, ASTM E119, is very similar to the CAN/ULC-S101 standard.

Both use the same time-temperature curve and the same performance criteria. Fire-resistance ratings developed in accordance with ASTM E119 are usually acceptable by Canadian officials. Whether an authority having jurisdiction accepts the results of tests based on these standards depends primarily on the official's familiarity with them.

Availability of Test Results

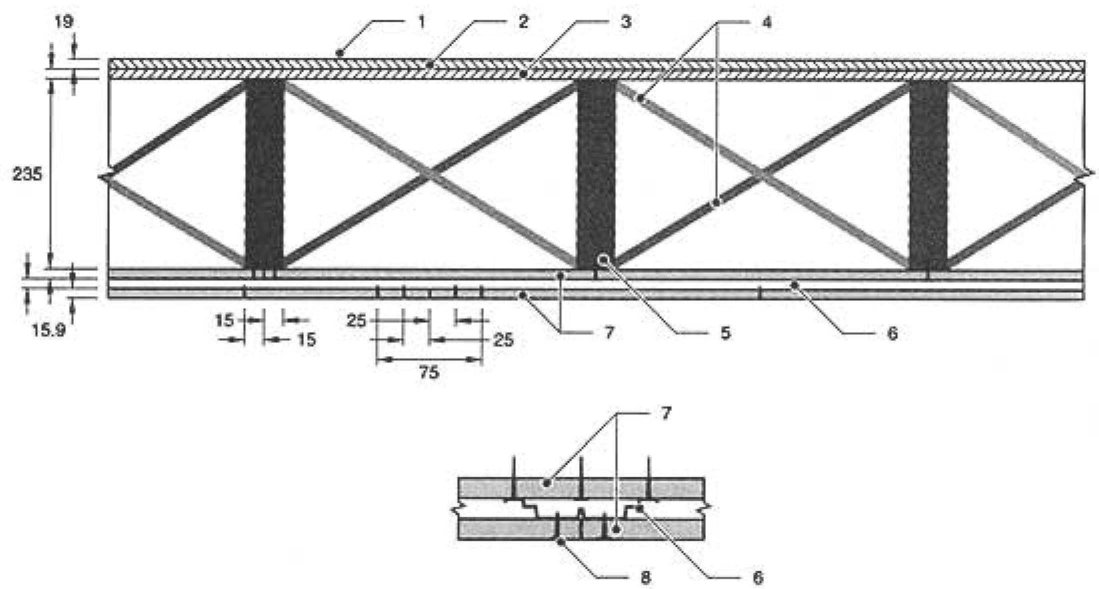
A multitude of fire-resistance tests have been conducted over the last 70 years by North American laboratories. Results are available through:

- Underwriters' Laboratories of Canada
- Intertek Testing Services ETL SEMKO
- Underwriters' Laboratories Incorporated
- Factory Mutual Research Corporation

In addition, manufacturers of construction products publish results of fire-resistance tests on assemblies incorporating their proprietary products (for example, Gypsum Association's *Fire Resistance Design Manual*).

Testing laboratories and manufacturers also publish information on proprietary listings of assemblies which describe all materials used and assembly methods. Figures 3 & 4 reproduce information published by ULC.

Figure 3: Listed wood joist floor assembly



End joint detail

Design No. M503 Unrestrained Assembly Rating: 2h

Combustible Construction

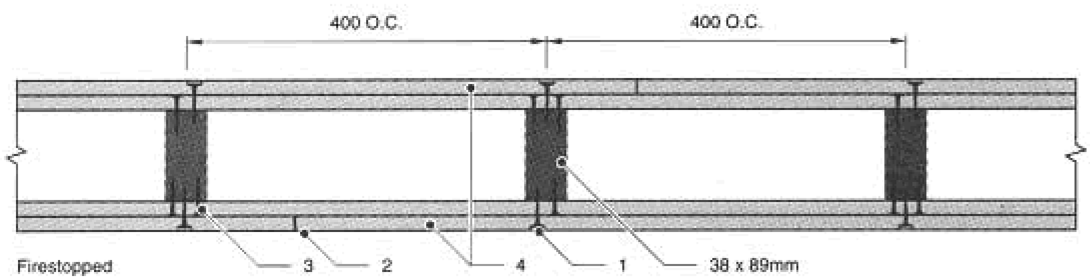
(Finish Rating - 75 minutes)

1. Finish Flooring: 19 x 89mm T & G flooring laid perpendicular to joists or 15.5mm select sheathing grade T & G phenolic bonded Douglas Fir plywood with face grain perpendicular to joists and joints staggered.
2. Building Paper (optional): Commercial sheathing material, 0.25mm thick.
3. Sub-flooring: 19 x 140mm T & G boards laid diagonally to joists or 12.5mm unsanded sheathing grade phenolic bonded Douglas Fir plywood with face grain perpendicular to joists

and joints staggered.
4. Bridging: 19 x 64mm
5. Wood Joists: 38 x 235mm spaced 400mm O.C., firestopped.
6. Furring Channel: Resilient, formed of 0.5mm electrogalvanized steel as shown, spaced 600mm O.C. perpendicular to joists. Channels overlapped at splice 38mm and fastened to each joist with 63mm common nails. Minimum clearance of channels to walls, 20mm. Additional pieces 1500mm long placed immediately adjacent to channels at end of joists of second layers; ends to extend 150mm beyond each side of end joint.
7. Gypsum Wallboard: (Guide No. 40U18.23). 15.9mm thick, 1200mm wide. First layer of wallboard installed with long dimension perpendicular to joists and end joints of boards located at the joists. Nailed to joists with uncoated 63mm box nails spaced 180mm O.C. All nails located 15mm minimum distance from the edges and ends of the board. Second layer of wallboard secured to furring channels by 25mm long wallboard screws. Second layer installed with long dimension perpendicular to the furring channels and centre line of boards located under a joist and so placed that the edge joint of this layer is not in alignment with the end joint of the first layer. Secured to furring channels with wallboard screws 300mm O.C. with additional screws 75mm from side joints. End joints of wallboard fastened at additional furring channels as shown in end-joint detail. All screws located 25mm minimum distance from edges of boards.
   ATLANTIC GYPSUM, a division of the Lundrigans-Comstock Limited
   DOMTAR INC.
   GEORGIA PACIFIC CORPORATION
   WESTROC INDUSTRIES LIMITED
8. Wallboard screws:Type S Phillips self-drilling and self-tapping 25mm long.
9. Joint System (not shown): Paper tape embedded in cementitious compound over joints and exposed nail heads covered with compound, with edges of compound feathered out.

Reproduced by permission of Underwriters' Laboratories of Canada.

Figure 4: Listed wood stud wall assembly



Design No. U301 Assembly Rating: 2h

Bearing Wall - Combustible Construction

(Finish Rating - 66 minutes)

1. Nailheads: Exposed or covered with joint finisher.
2. Joints: Exposed or covered with tape and joint finisher.
3. Nails: 51mmm, cement-coated flathead.
4. Gypsum Wallboard: (Guide No. 40U18.23), 15.9mm thick applied in two layers.
   Base layer placed vertically with joints butted over studs and nailed to studs 150mm O.C. Face layer applied horizontally with joint finisher cement and nailed 300mm O.C. temporarily to base layer until cement sets. All joints in face layers staggered with joints in base layers and with joints on opposite sides.
   Canadian Gypsum Company, Limited, A division of CGC Inc.
   Domtar Inc.

Reproduced by permission of Underwriters' Laboratories of Canada.

The NBCC contains fire and sound resistance tables describing various wall and floor assemblies of generic building materials and assigns specific fire resistance ratings to the assemblies. The fire-resistance ratings listed have been determined on the basis of tests conducted in accordance with the ULC-S101 standard which is shown in Table 4 - Fire and Sound Resistance of Walls - 2.3M PDF (Excerpt from Table A-9.10.3.1.A 1995 National Building Code of Canada). Just prior to the publishing of the 1995 NBCC, the results of a major research project at the National Research Council of Canada were used to add over one hundred different wall assemblies being assigned fire-resistance and sound transmission ratings. These results are published in the NBCC Table A-9.10.3.1.A. Not all assemblies described were actually tested. The fire-resistance ratings for some assembles were extrapolated from fire tests done on similar wall assemblies. Similar updated fire and sound information on wood joist and wood I-joist floor assemblies will be added shortly to the same NBCC table.

The listings are useful because they offer off-the-shelf solutions to designers. They can, however, restrict innovation because designers use assemblies which have already been tested rather than pay to have new assemblies evaluated. Listed assemblies must be used with the same materials and installation methods as those tested.

Alternative Methods for Determining Fire Resistance

The previous section on fire-resistance ratings deals with the determination of fire-resistance ratings from standard tests. Alternative methods for determining fire-resistance ratings are permitted as well.

The alternative methods of determining fire-resistance ratings are contained in the NBCC Appendix D, *Fire-Performance Ratings*. These alternative calculation methods can replace expensive proprietary fire tests. In some cases, these allow less stringent installation and design requirements such as alternate fastener details for gypsum wallboard and the allowance of openings in ceiling membranes for ventilation systems.

Section D-2 in *NBCC* Appendix D includes methods of assigning fire-resistance ratings to:

- wood-framed walls, floors and roofs
- glue-laminated timber beams and columns

Component Additive Method

The most practical alternative calculation method, includes procedures for calculating the fire-resistance rating of light wood-frame wall, floor and roof assemblies based on generic descriptions of materials. This component additive method (CAM) can be used when it is clear that the fire-resistance rating of an assembly depends strictly on the specification and arrangement of materials for which nationally recognized standards exist.

The assemblies must conform to all requirements in *NBCC* Appendix D for the rating to be valid.

Calculating Fire Resistance of Glulam Timbers

NBCC Appendix D also includes empirical equations for calculating the fire-resistance rating of glue-laminated (glulam) timber beams and columns. These equations were developed from theoretical predictions and validated by test results.

Large wood members have an inherent fire resistance because:

- the slow burning rate of large timbers, approximately 0.6mm/minute under standard fire test conditions
- the insulating effects of the char layer which protects the unburned portion on the wood

These factors result in unprotected members that can stay in place for a considerable time when exposed to fire. The NBCC recognizes this characteristic and allows unprotected wood members including floor and roof decks, which meet the minimum sizes for heavy timber to be used both where a 45 minute fire-resistance rating is required and in many noncombustible buildings.

Provisions for calculating the fire-resistance rating of glulam beams and columns are based on data from tests on timber beams and columns. This calculation method determines a fire-resistance rating for beams and columns based on exposure to fire from three or four sides. Using this approach, the fire-resistance rating (FRR) in minutes of glulam beams and columns is

$$FRR = 0.1fB\left[4-2\frac{B}{D}\right]$$

for beams exposed to fire on 4 sides,

$$FRR = 0.1fB\left[4-\frac{B}{D}\right]$$

for beams exposed to fire on 3 sides,

$$FRR = 0.1fB\left[3-\frac{B}{D}\right]$$

for columns exposed to fire on 4 sides,

$$FRR = 0.1fB\left[3-\frac{B}{2D}\right]$$

for columns exposed to fire on 3 sides,

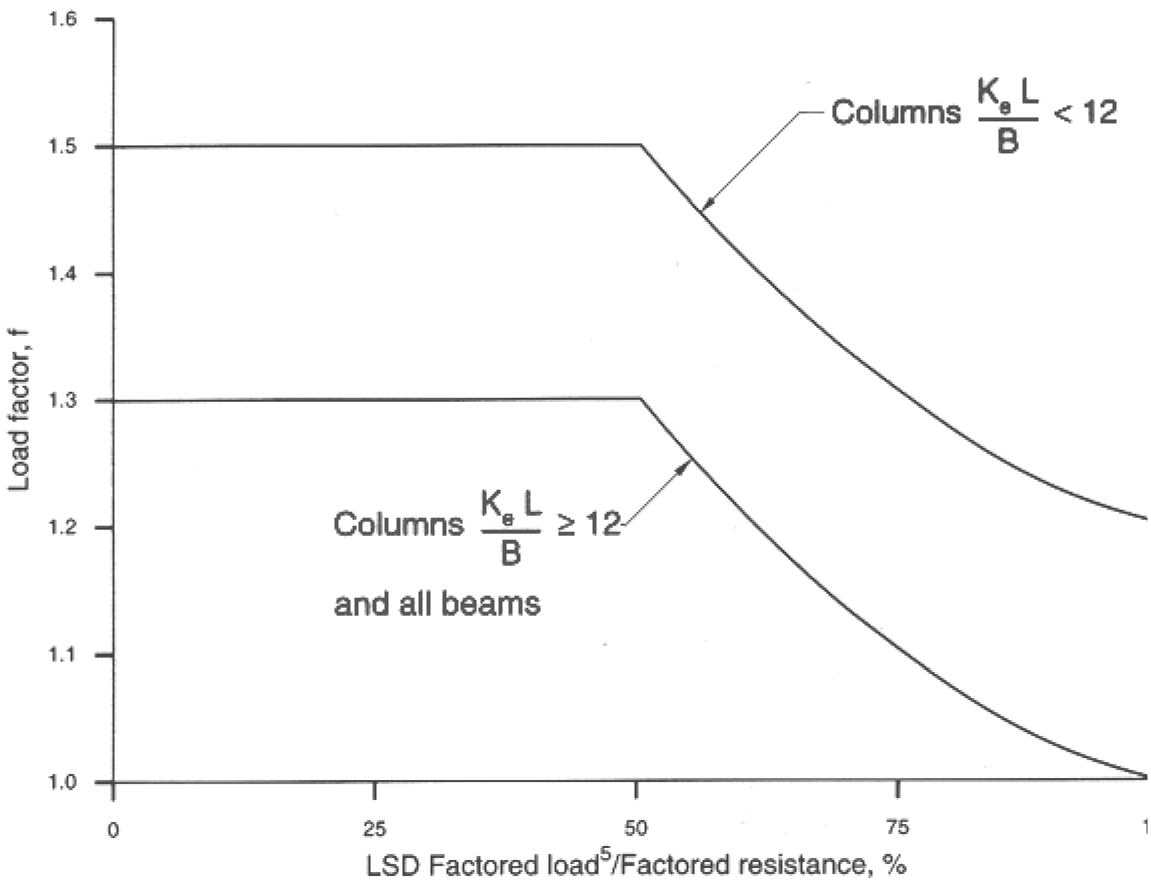
Where

f = the load factor shown in Figure 1 to compensate for partial loading

B = the full dimension of the smaller side of the beam or column in mm before exposure to fire as shown in Figure 2

D = the full dimension of the larger side of the beam or column in mm before exposure to fire as shown in Figure 2

Figure 1: Load factor for glulam fire-resistance calculations (NBCC, 1995)

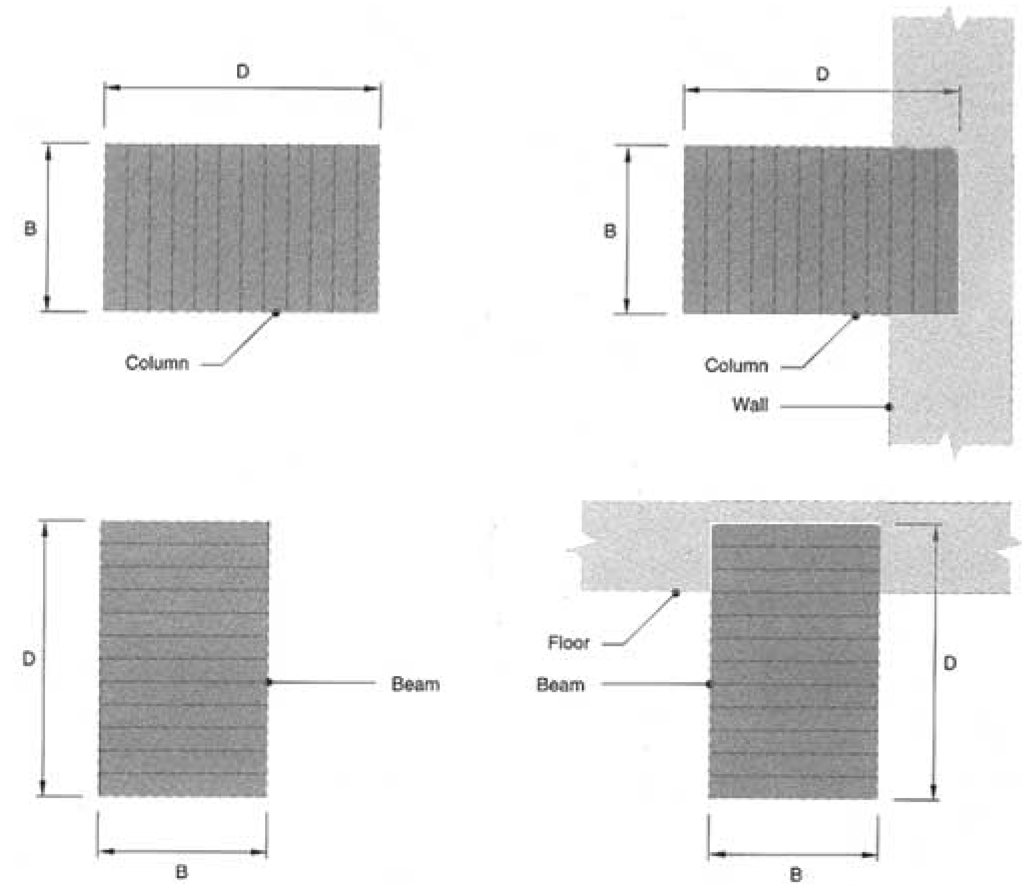


Notes:

1. K_e = Effective length factor
2. L = Unsupported length of a column in mm
3. B = Smaller side of a beam or column in mm (before fire exposure)
4. LSD = Limit States Design
5. In the case of beams, use factored bending moment in place of factored load.

The formula for columns or beams which may be exposed on three sides applies only when the unexposed face is the smaller side of a column; no experimental data exists to verify the formula when a larger side is unexposed. If a column is recessed into a wall or a beam into a floor, as shown below, the full dimensions of the structural member are used in the formula for exposure to fire on three sides.

Figure 2: Glulam exposure cases (NBCC *Appendix D*, 1995)



Comparisons of the calculated fire-resistance ratings with experimental results show the calculated values are very often conservative.

A designer may determine the factored resistance for a beam or column by referring to CSA Standard CAN/CSA-O86.1-M94 *Engineering Design in Wood* or the 1995 Canadian Wood Council's *Wood Design Manual*.

An example of fire-resistance calculation of glulam beam is shown below.

Example

Determine the fire-resistance rating of a glulam beam exposed on three sides having dimensions of 175 x 380mm and with a factored bending moment equal to 80 percent of its bending moment resistance.

B = 175mm D = 380mm

From Figure 1, f=1.075 for a beam designed to carry a factored load producing 80 percent of factored bending moment resistance.

$$t = 0.1fB\left[4 - \frac{B}{D}\right]$$

$$t = 0.1 \times 1.075 \times 175 \times \left[4 - \frac{175}{380}\right]$$

Total fire-resistance rating = 66.6 minutes

This beam could be used to support a one hour fire-resistance rated wood frame floor assembly.

Further information on the calculation of fire resistance of heavy timber members is available in the American Wood Council's publication Calculating the Fire Resistance of Exposed Wood Members. Note that this document is not currently referenced in the NBCC.

Heavy Timber Construction

Large dimension wood sections have an inherent resistance to fire. Wood burns slowly at approximately .6mm/minute. The char created on the wood surface as it burns helps protect and insulate unburnt wood below the charred layer. The unburnt portion of a thick member retains 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 assigned loads.

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 the table below. Of course, they must be designed to carry the expected loads and actual dimensions must conform to *CSA Standard 0141, Softwood Lumber*.

Table 1: Minimum dimensions of wood elements in heavy timber construction

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*, 1995

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 64mm 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 38mm thick.

Interior Finishes

General

Any material that forms part of the building interior and is directly exposed is considered to be an interior finish. This includes interior claddings, flooring, carpeting, doors, trim, windows, and lighting elements.

If no cladding is installed on the interior side of an exterior wall of a building, then the interior surfaces of the wall assembly are considered to be the interior finish, for example, unfinished post and beam construction. Similarly, if no ceiling is installed beneath a floor or roof assembly, the unfinished exposed deck and structural members are considered to be the interior ceiling finish.

The flame-spread rating and smoke developed classification of a material can be determined from the information contained in Appendix D of the *NBCC*.

Information is only provided for generic materials for which extensive fire test data is available (Table 2). For instance, lumber, regardless of species, and Douglas fir, poplar, and spruce plywood, of a thickness not less than those listed, are assigned a flame-spread rating of 150.

In general, for wood products up to 25mm thick, flame-spread rating decreases with increasing thickness. Values given in the Appendix D of the *NBCC* are conservative because they are intended to cover a wide range of materials. Specific species and thicknesses may have values much lower than those listed in Appendix D.

Specific ratings by species are given in Table 2 below. Information on proprietary and fire-retardant materials is available from ULC listings or from manufacturers. The values listed in Table 2 apply to finished lumber, however, there has been no significant difference in flame-spread rating noted in rough sawn lumber.

Table 1: Typical flame-spread ratings and smoke developed classifications of wood products

Product Lumber, 19mm thickness		Flame-Spread Ratings	Smoke Developed Classification
Cedar	Western Red	73	98
	Pacific Coast Yellow	78	90
Fir	Amabilis (Pacific Silver)	69	58
Hemlock	Western	60-75	
Maple	(flooring)	104	
Oak	Red or White	100	100
Pine	Eastern White	85	122
	Lodgepole	93	210
	Ponderosa	105-230	
	Red	142	229
	Southern Yellow	130-195	
	Western White	75	
Poplar		170-185	
Spruce	White	65	
	Sitka	74	74
	Western	100	
Shakes	Western Red Cedar	69	
Shingles	Western Red Cedar	49	

The American Wood Council has additional information on Design for Code Acceptance of Flame Spread Performance of Wood Products in the U.S.

Paint and Wall Coverings

Normally, the surface finish and the material to which it is applied both contribute to the overall flame-spread performance. Most surface coatings such as paint and wallpaper are usually less than 1mm thick and will not contribute significantly to the overall rating.

This is why the *NBCC* assigns the same flame-spread and smoke developed rating to common materials such as plywood, lumber and gypsum wallboard whether they are unfinished or covered with paint, varnish or cellulosic wallpaper as shown in Table 2 below.

Table 2: Assigned flame-spread ratings and smoke developed classifications

Materials	Applicable Standard	Minimum Thickness mm	Unfinished[3]		Paint or Varnish not More than 1.3mm Thick, Cellulosic Wallpaper not more than 1 Layer[5,6]	
			FSR	SDC	FSR	SDC
Hardwood or softwood flooring [3]	-	-	300	300		
Gypsum wallboard	CSA A82.27-M[4]	9.5	25	50	25	50
Lumber	None	16	150	300	150	300
Douglas Fir plywood[1]	CSA O121	11	150	100	150	300
Poplar plywood[1]	CSA O153	11	150	100	150	300
Plywood with Spruce face veneer[1]	CSA O151	11	150	100	150	300
Douglas Fir plywood[1]	CSA O121	6	150	100	150	100
Fiberboard low density	CSA A247	11	> 150	100	150	100
Hardboard, Type 1	CGSB-11.3	9	150	> 300	[2]	[2]
Hardboard, Standard	CGSB-11.3	6	150	300	150	300
Particleboard	CAN3-O188.1	12.7	150	> 300	[2]	[2]
Waferboard	CAN3-O437	–	[2]	[2]	[2]	[2]

Notes:

1. The flame-spread ratings and smoke developed classifications shown are for those plywoods without a cellulose resin overlay.
2. Insufficient test information available.
3. Wood flooring unfinished or finished with a spar or urethane varnish coating.
4. Gypsum Wallboard complying with the following ASTM standards is also acceptable - ASTM C36, ASTM C442, ASTM

C588, ASTM C630 & ASTM C931.

5. Flame-spread ratings and smoke developed classifications for paints and varnish are not applicable to shellac and lacquer.
6. Flame-spread ratings and smoke developed classifications for paints apply only to alkyd and latex paints.

Source: Appendix D, Section D-3, 1995 *NBCC*

There are also special fire-retardant paints and coatings that can substantially reduce the flame-spread rating of an interior surface. These coatings are particularly useful when rehabilitating an older building to reduce the flame-spread rating of finish materials to acceptable levels, especially for those areas requiring a flame-spread rating no greater than 25.

In general, the *NBCC* sets the maximum flame-spread rating for interior wall and ceiling finishes at 150, which can be met by most wood products.

For example, 6mm Douglas Fir plywood may be unfinished, painted, varnished or covered with conventional cellulosic wallpaper. This has been found to be acceptable on the basis of actual fire experience.

This means that in all areas where a flame-spread rating of 150 is permitted, the majority of wood products may be used as interior finishes without special requirements for fire-retardant treatments or coatings.

Flooring

In a room fire, the flooring is usually the last item to be ignited, since the coolest layer of air is near the floor.

For this reason, the *NBCC*, like most other codes, does not regulate the flame-spread rating of flooring, with the exception of certain essential areas in high buildings:

- exits
- corridors not within suites
- elevator cars
- service spaces

Traditional flooring materials such as hardwood flooring and carpets can be used almost everywhere in buildings of any type of construction.

Fire-Retardant Treated Wood

General

Fire-Retardant Treated Wood (FRTW) is wood which has been impregnated with fire-retardant chemicals in solution under high pressure in accordance with CSA standard O80, Wood Preservation. The treatment reduces surface burning characteristics, such as flame spread, rate of fuel contribution and smoke contribution.

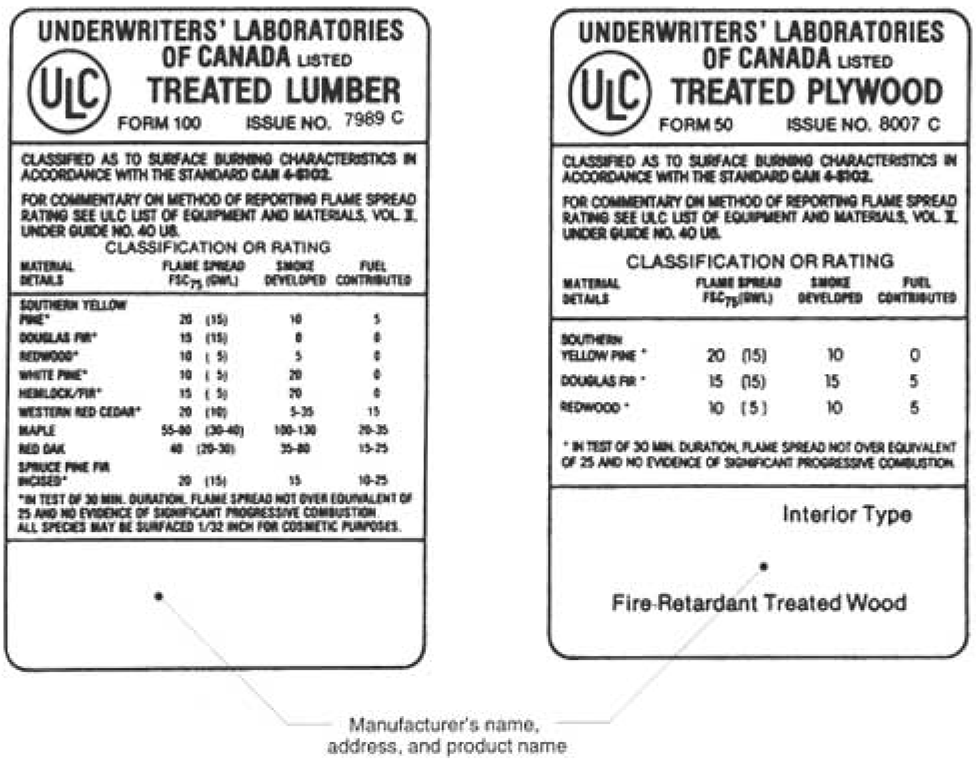
To dispel any myths that may still exist, the fire-retardant treatment does not make the wood noncombustible. This idea stems from certain earlier versions of building codes which equated a 25 surface flame-spread rating to noncombustibility.

FRTW contains different chemicals than products known as preservative treated wood. However, the same manufacturing process is used to apply the chemicals. The products are not interchangeable. FRTW products are harder to ignite than untreated wood products.

The use of fire-retardant treatment does not prevent ignition or charring. The rate of burn through treated wood is approximately the same as that for untreated wood.

Flame-Spread Rating

FRTW specified in the *NBCC* must have a flame-spread rating of not more than 25. It therefore qualifies as an interior finish for any application since the most restrictive flame-spread rating is 25. FRTW must be identified by a label (as shown below) from an independent testing laboratory which indicates that the necessary tests were made and production controls maintained.



For many wood species, and particularly plywood and lumber in sizes common to frame construction, treatment results in chemical retentions high enough to obtain a flame-spread rating of 25 or less. It should be noted that the chemicals will not usually penetrate the entire wood member, refusal will usually occur when the chemicals have penetrated approximately 13mm from the outer surface.

The actual flame-spread rating of treated lumber or plywood depends on the fire-retardant chemicals used and the amount of chemicals retained in the wood.

Commonly used chemicals are proprietary mixtures which are free of halogens, sulphates, ammonium phosphate and formaldehyde. These provide superior performance characteristics over previous formulations and lower corrosivity to metal fasteners. These water-soluble chemicals are effective in

reducing flame spread, and through careful proportioning succeed in reducing smoke development and afterglow.

Exterior Use

When FRTW products are used in areas where the material is exposed to weather or high humidity, it must be treated with special non-leaching chemicals similar to those used for fire-retardant treated cedar shakes and shingles.

An accelerated weathering test (ASTM D2898) exposes FRTW to regular wetting and drying cycles to represent actual long-term outdoor conditions. FRTW must still achieve a flame-spread rating of 25 after undergoing this accelerated weathering in order to qualify for exterior use.

These requirements apply to exterior grade fire-retardant treated plywood siding over wood studs in exterior walls of noncombustible buildings and FRTW decorative cladding on exterior marquee fascias of noncombustible buildings.

Fire-Retardant Coatings

Listed fire-retardant coatings applied to wood also reduce the flame-spread rating to less than 75 or 25. These coated products can be used for interior finish in noncombustible buildings except where the flame-spread rating limits apply not only to exposed surfaces but also to surfaces that may be exposed by cutting through the product in any direction. FRTW products are excluded from these requirements while products protected by fire-retardant coatings are not. This recognizes the permanency of the fire-retardant treatments.

The image shown here is a photo of the attic of a church. Trusses in the attic spaces were fire-stopped and coated with a fire-retardant paint. This avoided the cost of sprinklering the concealed spaces.

Fire-Retardant Treated Wood Roof Systems

In certain unsprinklered one-storey buildings, the *NBCC* permits the use of a roof deck construction system, using FRTW, that meets the flame-spread performance standard originally developed for noncombustible roof assemblies.

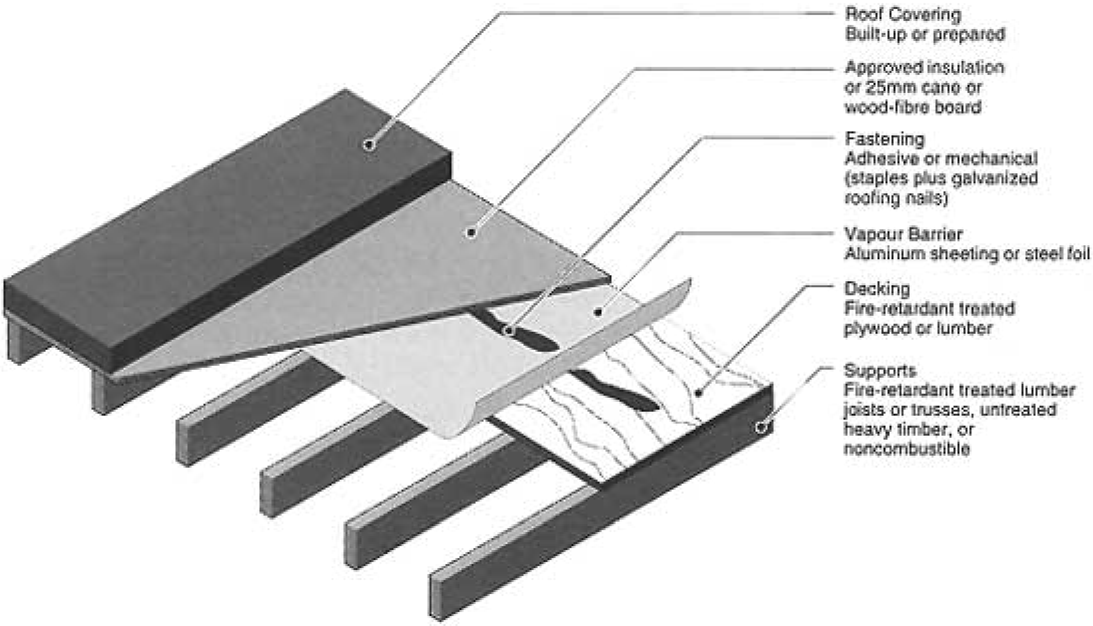
The required fire-resistance rating of the roof assembly can be waived if the deck is constructed of FRTW and the assembly passes the requirements of CAN/ULC S126.

A roof deck system of FRTW may be supported by:

- metal and reinforced concrete beams or joists
- heavy timber supports
- FRTW joists or trusses

When supporting an FRTW roof system, unless the wood members are heavy timber, which has an inherent capacity to withstand fire exposure, they must be fire-retardant treated. Experience shows that both lumber and plywood decking must have a minimum actual thickness of 19mm and both should be tongue and groove. Plywood decking, if not tongue and groove, must also have unsupported joints solidly backed with FRTW or plywood.

The figure below shows that the construction of roof assemblies using FRTW is similar to that of other types of roof assemblies, using a metallic vapor barrier membrane between the decking and the insulation. Usually 0.05mm aluminum sheeting is attached with an approved adhesive, although steel foil is also acceptable. Galvanized roof nails may be used to fasten the insulation to the vapor barrier which is then stapled to the deck.



FRTW or noncombustible ceilings may be attached to the underside of the system, with the resulting concealed spaces appropriately fire stopped.

FRTW roof assemblies are permitted as an alternative to roof assemblies of noncombustible construction or ordinary wood-frame roof assemblies having a fire-resistance rating of 45 minutes. When used, however, the *NBCC* requires that, except for mercantile or light industrial occupancies, the area of the building be half that which would be permitted if either of the other two types of roof assembly were used.

As noted earlier, fire-retardant coated wood is not the same as FRTW and therefore is not permitted to be used under this requirement unless the system passes the extended 30-minute tunnel test (CAN/ULC-S126).

Roof Coverings

Roof coverings have often been contributing factors in conflagrations. Most roof coverings, even today, are combustible by the very nature of the materials used for making them waterproof.

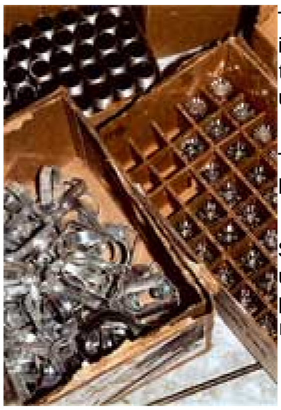
The objective of the *NBCC* is therefore to require that the risks associated with a roof covering be minimized for the type of building, its location and use.

The *NBCC* permits roof coverings that meet a Class C rating to be used for any building regulated by Part 3 of the Code, including any noncombustible building, regardless of height or area.

This C rating can be met easily using FRTW shakes or shingles, asphalt shingles, or roll roofing.

Small assembly occupancy buildings not more than two storeys in building height and less than 1000 m^2 in building area do not require a classification for the roof covering. In these traditional cases, untreated wood shingles are acceptable if they are underlaid with a noncombustible material to reduce the potential for burn through with a burning brand.

Sprinkler Alternatives



The provision of automatic sprinklers in a building or floor area will in many instances relax the *NBCC* fire-protection requirements. The underlying principle is that a sprinkler system provides a level of fire safety at least equal to that of an unsprinklered building with passive fire protection requirements in place.

The use of sprinklers results in an increase in the size of buildings permitted to be constructed of wood.

Sprinkler installation costs can be weighed against savings resulting from their use, either in the form of reduced construction costs or reduced insurance premiums for the building. An automatic sprinkler system properly installed and maintained ensures a high level of fire safety for occupants at all times.

Automatic sprinklers have a direct impact on fire protection requirements in several areas:

- The area or height of a building can be increased without increasing the level of fire resistance or changing construction type to that otherwise required for the larger sized building
- A heavy timber roof assembly can be used in all sprinklered buildings up to two storeys in building height without a limit on building area
- The fire-resistance rating for roof assemblies is waived for all sprinklered buildings.

This last item expands opportunities for the use of exposed unrated wood-frame roof assemblies especially in non-residential applications (warehouses, schools, retail stores). In this case, if glulam or solid sawn timber elements or solid wood roof decks are used, the heavy timber minimum sizing requirements would not apply.

Minimum size specifications for heavy timber components would still apply when a heavy timber roof assembly is used in a sprinklered noncombustible building of two storeys or less. However, no fire-resistance rating would be required for the roof assembly.

By waiving the fire-resistance ratings for roofs, the roof's loadbearing support elements such as columns or walls are also exempt from ratings.

Wood in Noncombustible Buildings

The *NBCC* requires that some buildings be of noncombustible construction.

Noncombustible construction is defined as: a "type of construction in which a degree of fire safety is attained by the use of noncombustible materials for structural members of other building assemblies."

Noncombustible construction is, however, something of a misnomer: it does not exclude the use of combustible materials but rather, it limits their use. Some combustible materials can be used since it is neither economical nor practical to construct a building entirely out of noncombustible materials.

Wood is probably the most prevalent combustible material used in noncombustible buildings.

It may be used as furring strips or fascia and canopies, cant strips, roof curbs, firestopping, roof sheathing and coverings, millwork, cabinets, counters, window sash, doors, flooring, studs and even as wall finishes.

Its use in certain types of buildings such as tall buildings is slightly more limited in areas such as exits, corridors and lobbies, but even there, fire-retardant treatments can be used to meet *NBCC* requirements.

In sprinklered noncombustible buildings not more than 2 storeys in height, entire roof assemblies and the roof supports can be heavy timber construction. Fire loss experience has shown, even in unsprinklered buildings, that heavy timber construction is superior to noncombustible roof assemblies not having any fire-resistance rating.

In other noncombustible buildings, heavy timber construction, including the floor assemblies, is permitted without the building being sprinklered.

Table 2: Permitted uses of heavy timber construction in or as an alternative to noncombustible buildings

Occupancy[2]	Height	Sprinklered[1]	Permitted Uses
Group A, Div 1	1 Storey	Yes	Roof, floors and supports
Group A, Div 3	2 Storeys	No	Roof and its supports
Group A, Div 3	2 Storeys	Yes	Roof, floors and supports, arches supporting floors
Group A, Div 4	Not regulated	No	Roof and its supports
Group F, Div 1	3 Storeys	Yes	Roof, floors and supports
Group F, Div 3	1 Storey	Yes	Roof, floors and supports

Note:
1. Article 3.2.2.16 permits roof assemblies and the supports to be heavy timber construction in any sprinklered noncombustible building not more than two stories in height.
2. Occupancy definitions are contained in the NBCC.

Examples of permitted heavy timber construction uses in or, as an alternative to, noncombustible buildings are shown in Table 2.

Brief description of other uses of wood permitted in noncombustible buildings can be found in Chapter 2 of Fire Safety Design in Buildings

Wood Furring

Wood is particularly useful as a nailing base for different types of cladding and interior finishes. Wood furring strips can be used to attach interior finishes such as gypsum wallboard, provided:

- The strips are fastened to noncombustible backing or recessed into it
- The concealed space created by the wood elements is not more than 50mm thick
- The concealed space created by the wood elements is firestopped

Experience has shown that a lack of oxygen in these shallow concealed spaces prevents rapid development of fire.

Wood nailer strips can also be used on parapets, provided the facings and any roof membrane covering the facings are protected by sheet metal. This is permitted because it is considered that a nailing base such as plywood or oriented strandboard (OSB) does not constitute an undue fire hazard.

Roofing Materials

In the installation of roofing, wood cant strips, roof curbs, nailing strips are permitted in noncombustible construction. Roof sheathing and sheathing supports of wood are also permitted provided:

- They are installed above a concrete deck
- The concealed space does not extend more than 1m above the deck
- The concealed roof space is compartmented by firestops
- Openings through the concrete deck are located in noncombustible shafts
- Parapets are provided at the deck perimeter extending at least 150mm above the sheathing.

The noncombustible parapets and shafts are required to prevent roof materials igniting from flames projecting from openings in the building face or roof deck.

In buildings that must be of noncombustible construction the roof coverings must have a fire classification of Class A, B or C. In such cases the use of fire-retardant treated wood shakes and shingles on sloped roofs is allowed.

Window Sashes and Frames

Wood sashes and frames are permitted in noncombustible buildings provided each window is separated from adjacent windows by noncombustible construction and meets a limit on the aggregate area of openings in the outside face of a fire compartment.

Glass typically fails early during a fire, allowing flames to project from the opening and thereby creating serious potential for the vertical spread of fire. The requirement for noncombustible construction between windows is intended to limit fire spread along combustible frames closely set into the outside face of the building.

Wood Cladding Systems

The NBCC contains the rules on the use of combustible claddings and supporting assemblies on certain types of noncombustible buildings. Specifically, the use of wall assemblies containing both combustibles cladding elements and non-load-bearing wood framing members is allowed (See Figure 1 and Figure 2 below).

Insert of a picture here

These wall assemblies can be used as in-fill or panel type walls between structural elements, or be attached directly to a load-bearing noncombustible structural system. This applies in unsprinklered buildings up to three storeys and sprinklered buildings of any height.

The wall assembly must satisfy the criteria of a test that determines its degree of flammability and the interior surfaces of the wall assembly must be protected by a thermal barrier (for example, 12.7mm gypsum wallboard) to limit the impact of an interior fire on the wall assembly.

These requirements stem from fire research that indicated that certain wall assemblies containing combustible elements do not promote fire spread beyond a limited distance.

The ULC test standard, CAN/ULC-S134, *Standard Method of Fire Test of Exterior Wall Assemblies* is referenced in the NBCC. Each assembly must be tested in accordance with this standard to confirm compliance with fire spread and heat flux limitations specified in the code.

Figure 1: Wood frame exterior wall in noncombustible construction

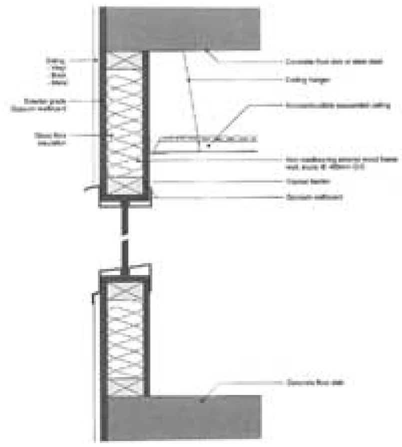


Figure 2: Wood stud framing in exterior wall of noncombustible building

Wood Fascias and Canopies

Fire - retardant treated wood (FRTW) decorative cladding is permitted on first floor canopy fascias. In this case, the wood must undergo accelerated weathering before testing to establish the flame-spread rating. An FSR of 25 or less is required.

Millwork

Wood millwork such as interior trim, doors and door frames, show windows and frames, aprons and backing, handrails, shelves, cabinets and counters are also permitted in noncombustible construction.

Because these elements contribute minimally to the overall fire hazard it is not necessary to restrict their use.

Wood Flooring Elements and Stages

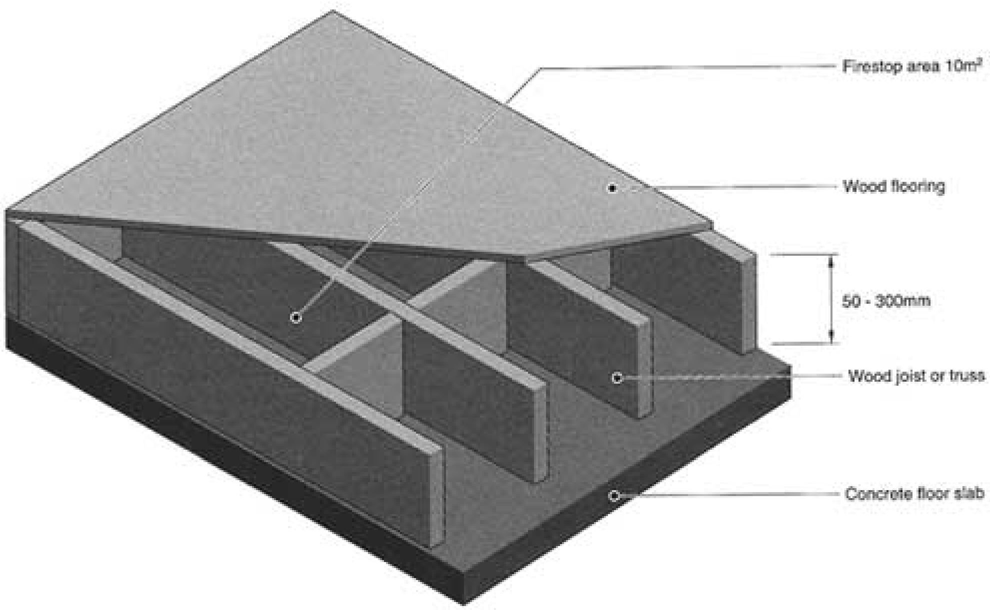
Combustible sub-flooring and finished flooring, such as wood strip or parquet is allowed in any non-combustible building, including high rises. Finished wood flooring is not a major concern. During a fire, the air layer close to the floor remains relatively cool in comparison with the hot air rising to the ceiling.

Wood supports for combustible flooring are also permitted provided:

- they are at least 50mm but no more than 300mm high
- they are applied directly onto or are recessed into a noncombustible floor slab
- the concealed spaces are firestopped (as in Figure 3 below)

This allows the use of wood joists or wood trusses, the latter providing more flexibility for running building services within the space.

Stages are normally fairly large and considerably higher than 300 mm which creates a large concealed space. Because of this, wood stage flooring must be supported by noncombustible structural members.



Wood Partitions

Wood framing has many applications in partitions in both low rise and high rise buildings required being of non-combustible construction. The framing can be located in most types of partitions, with or without a fire-resistance rating.

Wood framing and sheathing is permitted in partitions, or alternatively, solid lumber partitions at least 38mm thick (seldom used) are permitted, provided:

- the partitions are not used in a care or detention occupancy
- the area of the fire compartment, if not sprinklered, is limited to 600m^2 (unlimited in a floor area that is sprinklered)

- the partitions are not required by the Code to be fire separations.

Alternatively, wood framing is permitted in partitions throughout floor areas, and can be used in most fire separations with no limits on compartment size or a need for sprinkler protection provided:

- the buildings is not more than three storeys in height
- the partitions are not used in a care or detention occupancy
- the partitions are not installed as enclosures for exits or vertical service spaces

Similarly, as a final option, wood framing is permitted in buildings with no restriction on building height provided:

- the building is sprinklered
- the partitions are not used in a care or detention occupancy
- the partitions are not installed as enclosures for exits or vertical service spaces.
- the partitions are not used as fire separations to enclose a mezzanine.

These allowances in the code are based on the performance of fire rated wood stud partitions compared to steel stud partitions. This research showed similar performance for wood or steel stud assemblies.

Also, the increase in the amount of combustible framing material permitted is not large compared to what is permitted as contents. In many cases, the framing is protected and only burns later in a fire once all combustible contents have been consumed, by which time the threat to life safety is not high.

The exclusion of the framing in care and detention occupancies and in applications around critical spaces such as shafts and exits are applied to keep the level of risk as low as practical in these applications.

Stairs and Storage Lockers

Stairs within a dwelling unit can be made of wood, as can storage lockers in residential buildings. These are permitted, as their use is not expected to present a significant fire hazard.

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 64mm 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 38mm thick.

Wood Finishes

The use of interior finishes is mostly regulated by restrictions on their flame-spread rating. However, where finishes are used as protection for foamed plastic insulation, they are required to act as a thermal barrier.

Wood finishes not exceeding 25mm in thickness and having a flame spread rating (FSR) of 150 or less may be used extensively in noncombustible buildings, not considered a high building. They may be used on walls both within and outside suites.

Some restrictions do apply in certain areas of a building. The area permitted to have a FSR of 150 or less is limited as follows:

- in exits - only 10% of total wall area
- in certain lobbies - only 25% of total wall area
- in vertical spaces - only 10% of total wall area

The use of wood finishes on the ceilings in non-combustible buildings is much more restricted, but not totally excluded. In such cases, the flame-spread rating must be 25 or less. In certain cases, ordinary wood finished can also be used on 10% of the ceiling area of any one-fire compartment, as well as on the ceilings of exits, lobbies and corridors.

Fire retardant treated wood (FRTW) must be used to meet the most restrictive limit of FSR 25. Consequently, it is permitted extensively throughout noncombustible buildings. The only restriction is that it cannot exceed 25mm in thickness when used as a finish, except as wood battens on a ceiling, in which case no maximum thickness applies.

The FSR 75 flame limit for interior wall finishes in certain corridors does not exclude all wood products. Western red cedar, amabilis fir, western hemlock, western white pine and white or sitka spruce all have flame-spread ratings at or lower than 75.

Corridors requiring FSR 75 include:

- public corridors in any occupancy
- corridors used by the public in assembly or care or detention occupancies.
- corridors serving classrooms
- corridors serving sleeping rooms in care and detention occupancies

If these corridors are located in a sprinklered building, wood finishes having FSR 150 or less may be used to cover the entire wall surface.

In high rise buildings regulated by *NBCC* Subsection 3.2.6., wood finishes are permitted within suites or floor areas much as for other buildings of non combustible construction. However, certain additional restrictions apply for:

- exit stairways
- corridors not within suites
- vestibules to exit stairs.
- certain lobbies
- elevators cars
- service spaces and service rooms

Links

American Society for Testing and Materials

National Fire Protection Association

National Research Council of Canada

Society of Fire Protection Engineers

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