For many years, wood-frame construction has been providing Canadians with high-quality, affordable housing. This goes from town houses to multi-storey apartment buildings, and from single-family bungalows to large luxury houses.

The secret of this success lies with many factors, and speed of erection is definitely one of them, not to mention the fact that occupants can move into the building almost as soon as it is completed. In addition, wood-frame construction uses a renewable resource; and its design flexibility allows for efficient building concepts in terms of energy conservation as well as safety and reliability under extreme conditions such as earthquakes.

North American fire-loss statistics reveal that death and injury in building fires are usually caused by smoke inhalation, and occur long before structural failure. With large numbers of residential fires resulting from the cooking of meals or the ignition of furnishings by cigarettes, it is clear that people are just as safe in a wood-frame house as they would be in a house built of stone, bricks, steel or any other material.

Research and experience confirm that fire safety in a house or apartment has little to do with the combustibility of the structural materials used in its construction. In fact, the occupants’ safety is far more dependent on their own awareness of fire hazards (open flames, etc.), the contents of their homes, and the fire protection measures designed into the building. The main objectives of fire protection are a) to confine any fire to its area of origin and ensure that the structural integrity of the building is maintained during evacuation, and b) to ensure that measures are in place to allow for the safe exit of all occupants.

The intent of this brochure is to provide some background on fire safe construction concepts, as well as examples of wood-based light-frame building systems designed to maximize fire safety.
**Fire resistance in single-family construction**

For single-family houses, Canadian building codes contain measures to limit the risk of fires spreading from one house to another. These measures usually involve minimum permitted distances between houses, combined with restrictions on cladding combustibility and opening sizes (windows or doors) in critical walls. Regardless of the materials used in construction of the dwellings, electrical and heating systems must be installed and maintained according to approved procedures; and minimum permitted distances are prescribed between combustible materials and heat sources (cooking range to kitchen cabinets, wood stove to wall lining, etc.). However, Canadian codes do not require fire-rated floors or walls in single-family construction. It is assumed that people within an individual dwelling are generally aware of each other’s activities and will react in a mutually responsible manner to the occurrence of fire and smoke alarms within their dwelling. Regular grades of gypsum board used to sheath walls and ceilings offer meaningful measures of fire containment and protection of wood structural members while contributing time for occupants to safely evacuate the house; basements are frequently left without a ceiling. In countries where building codes may require fire-rated construction in single-family houses, the techniques described for multi-family construction would be equally applicable.

**Fire resistance in multi-family construction**

In Canada as in most countries, fire-resistance-rated building assemblies in multi-family dwellings are used to prevent, for a certain period of time, the spread of fire, smoke and heat from one unit to another (essentially through walls and floors), and to ensure that the structural integrity of the building is maintained. Fire-resistance-rated walls and floors are also required for exit corridors and stairways to ensure that people can safely leave the building in the event of a fire.

**Fire-resistance rated gypsum board**

The fire-resistance of wood-frame assemblies (walls or floors) depends almost entirely on the gypsum board (also called wallboard or plasterboard) used to shield structural wood members from the effects of heat. When exposed to fire, the gypsum absorbs large amounts of heat as its water content is released.

There are different kinds of gypsum board on the market, but the construction of fire-rated wood-frame assemblies requires specially manufactured fire-rated panels. These panels contain, among other constituents, glass fibres that improve their dimensional stability and nail-head pull-through resistance, allowing them to remain in place for longer periods of time when exposed to fire. Specific construction practices and design details are used to maximize the length of time that the gypsum board remains in place.
Fire-resistance ratings provide a measure of the time that an assembly will withstand the passage of flame and smoke, and the transmission of heat when exposed to fire under specified fire conditions, including structural loads if applicable. They are generally based on tests conducted in conformance with one of two standards: International Standards Organisation (ISO); ISO 834 Fire Resistance Tests – Elements of Building Construction, or American Standard Testing Method (ASTM); ASTM E-119 Standard Test Methods for Fire Tests of Building Construction and Materials. Fortunately, the fire exposures prescribed in the two standards are essentially identical. Therefore, fire-resistance ratings determined in one country are often accepted by building officials in others.

Fastening gypsum board to walls or ceilings

Attaching gypsum board to walls or ceilings using resilient metal channels reduces sound transmission as well as the stresses on gypsum caused by movement in the joists or studs during a fire. Keeping wallboard fasteners 38 to 50 mm from the edge of the panel allows much more shrinkage to occur before the panel pulls away from the fasteners. The fasteners holding the gypsum board in place on a wall or ceiling should be spaced no further than 200 mm apart along each resilient metal channel, stud or joist. The screws used to attach gypsum board to resilient metal channels should be long enough to penetrate 10 mm through the channel. The screws used to attach resilient metal channels to the wall studs or ceiling joists, or to attach gypsum board directly to the studs or joists should penetrate 32 mm into the wood members. If nails are used, these should penetrate at least 45 mm into the wood members. Screws used to fasten gypsum board to resilient channels should never come into contact with structural members.

For ceilings consisting of a single layer of gypsum board, this design detail requires two resilient channels to be placed back-to-back at joints between the butt ends of adjacent gypsum panels (See Figure at top of next page). For ceilings consisting of two layers of gypsum board, there is no need to keep the fasteners back from the butt-end edges of the base layer, but they should be kept 38 to 50 mm from the butt-end edges of each panel in the face layer. The easiest way to do this is to fasten the butt-ends of the face layer of gypsum board to the base layer using Type G wallboard screws (thicker shank, coarser thread). When ceilings consist of two layers of gypsum board, joints between adjacent panels of gypsum board in the face layer should be centred on the panels in the base layer.

1 The screws used to attach the gypsum board to resilient channels must be located away from the studs, as any direct contact with structural members would create a path for sound transmission.
2 Additional information on gypsum installation for fire resistance and sound control is available from the Canada Mortgage and Housing Corporation (CMHC), Ottawa, Canada, and the Gypsum Association, Washington, D.C., USA.
Use of insulation in floors or walls separating different dwellings

Placing glass-fibre or rock-fibre insulation between the joists of wood-frame floor assemblies reduces sound transmission. It also restricts heat transfer from the ceiling into the joist cavities and, for a time, shields the sides of the joists and subfloor from the effects of the fire. However, the additional heat retained in the gypsum board reduces the time it will remain in place. Once the gypsum board falls from the ceiling, the insulation is exposed directly to the fire. Glass-fibre insulation melts after a few minutes. Rock-fibre insulation does not melt and only shrinks slightly; bats of rock-fibre insulation

3 The screws used to attach the gypsum board to resilient channels must be located away from the joists, as any direct contact with structural members would create a path for sound transmission.
supported between the joists by the resilient channels will therefore shield the joists and subfloor from fire for a significant period of time after the ceiling falls away.

Insulating materials are installed in close contact with the sides of the studs or joists, as gaps would allow hot fire gases to penetrate into the cavity and attack the sides of the wood members.

Fire-rated wall construction

In multi-family construction, load-bearing walls (supporting upper floors) and party walls (separating two dwelling units, or public corridors and exits from the rest of the building) are designed to provide specific fire-resistance ratings as per applicable building codes.

Fire-rated gypsum board is available in two thicknesses: 12.7 mm and 15.9 mm. The thicker panels present a somewhat better thermal barrier and allow significantly greater fire resistance. On the other hand, the stud spacing (400 mm or 600 mm on-centre) does not significantly change the fire resistance of a wall assembly.

Horizontal installation of gypsum board (i.e. with the long direction perpendicular to the studs) results in unbacked horizontal joints. Since the joints between gypsum board panels are weak points in fire-resistance rated walls, the panels should be installed vertically so joints may be centred on studs. There are two exceptions: 1) if wall cavities are filled with rock-fibre insulation, and 2) if the wall includes a double layer of gypsum board (with the joints in the face layer offset from those in the base layer); then, the gypsum board may be applied in either direction.

Some countries’ building codes require horizontal blocking at 400 or 600 mm spacing between the studs. These components provide additional opportunities to fasten the gypsum panels to the wall when resilient channels are not used, thereby increasing the fire resistance of the assembly. They also serve to increase the fire resistance of taller walls, where the mode of failure is likely to be due to wall buckling.

In the construction of shear walls, plywood or oriented-strandboard (OSB) panels nailed to the studs and covered with gypsum board add 5 to 10 minutes to the overall fire resistance of the assembly, depending on which side of the wall they are placed (ambient or fire-exposed side). There are no significant differences between the fire-resistance ratings of wall assemblies constructed with plywood or OSB shear panels.

Firewalls are fire separations of non-combustible construction. They have fire-resistance ratings as prescribed in building codes, and structural properties such that they will remain intact under fire conditions for the required fire-rated time. Firewalls are commonly used to divide row-housing blocks into smaller groups and resist the spread of fire from one group to another. They are also used to divide a large building into smaller units where standard fire protection measures are applicable.

Fire-rated floor construction

Fire-rated floors, used in most types of multi-storey, multi-family buildings, are constructed with joists, a ceiling and a subfloor.

In ceiling applications, there is little advantage in using 15.9-mm gypsum board panels as their greater weight causes them to fall off during fires at about the same time as the thinner panels, so that the fire resistance of the floor assembly is not substantially increased.

When the gypsum board ceiling is attached with resilient metal channels, the use of blocking or bridging between the joists will not enhance the fire resistance of a floor assembly. If, on the other hand, the ceiling is attached directly to the bottom of the joists, the use of blocking or bridging between the joists along the centreline of a floor assembly will reduce twisting of the joists during a fire, thereby helping the gypsum board to remain in place and protect the assembly.

When a gypsum board ceiling is attached directly to the bottom of the joists, the fire resistance of that floor assembly may be significantly reduced if the spacing between the joists is increased (from 400 to 600 mm, for example) because of the corresponding increase in distances between the rows of fasteners. However, if the gypsum board is attached to the joists through resilient metal channels spaced at 400 mm on-centre, increasing the joist spacing may actually increase the fire resistance rating of the assembly because the structural loads are reduced and wider joist spacing requires a thicker subfloor.
Subfloors usually consist of 1220 mm x 2440 mm panels, either tongued-and-grooved plywood or OSB. The long directions of the panels are oriented perpendicular to the joists. The 1220-mm butt ends of the panels are centred on joists. Floor assemblies with joists spaced 400 mm on-centre are constructed with 15.9-mm thick panels; those with joists spaced 600 mm on-centre use 19.0-mm panels. There are no significant differences between the fire resistance rating of floor assemblies constructed with plywood or OSB.

For a given floor span, the fire resistance of a floor assembly constructed with I-Joists will generally be three to five minutes less than that of a similar assembly constructed with solid wood joists (which is insignificant in most situations). This can be attributed to the thinner profile of the structural members, particularly the webs. Overall, there is no significant difference in the fire resistance of I-Joists manufactured with laminated-veneer-lumber (LVL) or solid lumber flanges; nor is there any significant difference in the fire resistance of I-Joists manufactured with plywood or OSB webs. Finally, there is no significant difference in the fire performances of I-Joists of identical profile fabricated by different manufacturers.

Fire resistance ratings for floor assemblies constructed with parallel-chord wood trusses (glued or connected with metal or gusset plates) differ very little from those for floors constructed with solid wood joists. While failure of wood trusses in fires usually results from the teeth of the gusset plates pulling out of charred wood in the bottom chord, the metal teeth do not accelerate char formation in the underlying lumber.

Finally, there is no scientific evidence to support the anecdotal claims that floors constructed with wood I-Joists or metal-plate-connected wood trusses fail catastrophically and without warning during fires.
Sound transmission

Wood-frame construction is particularly efficient in row houses and small apartment buildings where high levels of sound insulation are desired between adjoining dwelling units.

In Canada, airborne-sound-transmission measurements are made in accordance with ASTM E 90 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions. Sound-transmission class (STC) is determined in accordance with ASTM E 413 Standard Classification for Rating Sound Insulation. Transmission of impact sound through floors is measured in accordance with ASTM E 492 Standard Test Method for Laboratory Measurement of Impact Sound Transmission through Floor-ceiling Assemblies Using the Tapping Machine. Impact-insulation class (IIC) is calculated according to ASTM E 989 Standard Classification for Determination of Impact Insulation Class.

The National Building Code of Canada currently specifies STC 50 for partywalls in multifamily dwellings. However, individual sensitivities to noise differ, in terms of both volume and frequency ranges. Researchers at the National Research Council Canada suggest that music or sounds from a television set could be transmitted through a wall with STC 45, but that only a bit of the base beating might be heard if the STC of the wall was 50. Following a number of homeowner acoustic-comfort surveys, Canada Mortgage and Housing Corporation identified the following sound-insulation objectives for multifamily buildings: STC >55 for inter-unit walls and floors, impact insulation class (IIC) >55 for inter-unit “hard” floors and IIC >65 for inter-unit carpeted floors.

The reduction of sound transmission between dwelling units relies on three factors: 1) decoupling the two sides of walls or floors from each other; 2) increasing the assembly’s overall mass; and 3) filling the joist or stud cavities with sound-absorbing insulation. Resilient metal channels used to attach gypsum board to wood-frame assemblies, double layers of gypsum in ceilings and walls, and insulation in the wall or floor cavities simultaneously enhance fire resistance and minimize sound transmission. Furthermore, wood-frame construction does not present the impact-noise transmission problems commonly noted with concrete construction.

Acoustic chambers at the National Research Council of Canada
Examples of fire-rated assemblies

The following are examples of sound-transmission-class (STC), impact insulation class (IIC) and fire-resistance ratings assigned to specific wood-frame walls and floor designs approved by the National Building Code of Canada (NBCC). Many other designs exist to achieve similar ratings.

Wall Descriptions

- 38 mm by 89 mm studs spaced 400 mm o.c.
  - 89 mm thick insulation between the studs
  - one layer of 12.7 mm non-fire-rated gypsum board on each side

- 38 mm by 89 mm studs spaced 400 mm o.c.
  - 89 mm thick insulation between the studs
  - one layer of 15.9 mm fire-rated gypsum board on each side

- 38 mm by 89 mm studs spaced 400 mm o.c.
  - 89 mm thick insulation between the studs
  - two layers of 15.9 mm fire-rated gypsum board on each side

- one layer of 15.9 mm fire-rated gypsum board
  - 38 mm by 89 mm studs spaced 400 mm o.c.
  - 89 mm thick insulation between the studs
  - resilient channels on one side spaced 400-mm o.c.
  - two layers of 15.9 mm fire-rated gypsum board on resilient channels

- 38 mm by 89 mm studs spaced 400 mm o.c.
  - 89 mm thick insulation between the studs
  - resilient channels on one side spaced 400-mm o.c.
  - two layers of 15.9 mm fire-rated gypsum board on each side

- two rows 38 mm by 89 mm studs, each spaced 400 mm o.c.
  on separate 38 mm by 89 mm plates set 25 mm apart
  - 89 mm thick insulation between the studs on each side
  - one layer of 15.9 mm fire-rated gypsum board on each side

- two rows 38 mm by 89 mm studs, each spaced 400 mm o.c.
  on separate 38 mm by 89 mm plates set 25 mm apart
  - 89 mm thick insulation between the studs on each side
  - two layers of 15.9 mm fire-rated gypsum board on each side

4 Fire-resistance ratings are assigned according to the requirements of the National Building Code of Canada. They are usually described in 15- or 30-minute increments (e.g., 45 min, 1 h, 1.5 h). Under 45 minutes, rating ranges may be less than 15 minutes.
**Floor Descriptions**

- one layer of 15 mm tongued and grooved plywood or OSB subfloor on joists
- 38 mm by 241 mm joists spaced 400 mm o.c.

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- one layer of 15 mm tongued and grooved plywood or OSB subfloor on joists
- 38 mm by 241 mm joists spaced 400 mm o.c., or
  - 241-mm deep I-Joists, or 300 mm deep wood floor trusses
- 89 mm thick insulation between the joists
- one layer of 15.9 mm fire-rated gypsum board on ceiling

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<th>Fire Resistance Rating (FRR)</th>
<th>Sound Transmission Class (STC)</th>
<th>Impact Insulation Class (IIC)</th>
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<tr>
<td>30 - 45 min</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>1 h</td>
<td>37</td>
<td>33</td>
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5 Impact Insulation Classes (IIC) are for floor assemblies without any finish floor.
6 Minimum dimensions for I-Joist components are 38 mm by 38 mm LVL or lumber flanges and 9.5 mm OSB or plywood web.
7 Minimum lumber dimensions for truss components are 38 mm by 64 mm.
**Floor Descriptions**

- one layer of 15 mm tongued and grooved plywood or OSB subfloor on joists
- 38 mm by 241 mm joists spaced 400 mm o.c., or 241-mm deep I-Joists, or 300 mm deep wood floor trusses
- 89 mm thick insulation between the joists
- resilient channels below joists, spaced 400-mm o.c.
- one layer of 15.9 mm fire-rated gypsum board below resilient channels

<table>
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<tr>
<th>Fire Resistance Rating (FRR)</th>
<th>Sound Transmission Class (STC)</th>
<th>Impact Insulation Class (IIC)</th>
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<tbody>
<tr>
<td>35 - 45 min</td>
<td>48</td>
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<tr>
<th>Fire Resistance Rating (FRR)</th>
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</thead>
<tbody>
<tr>
<td>1 h</td>
<td>54</td>
<td>47</td>
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</table>

- one layer of 15 mm tongued and grooved plywood or OSB subfloor on joists
- 38 mm by 241 mm joists spaced 400 mm o.c., or 241-mm deep I-Joists, or 300 mm deep wood floor trusses
- 89 mm thick insulation between the joists
- resilient channels below joists, spaced 400-mm o.c.
- two layers of 15.9 mm fire-rated gypsum board below resilient channels
Floor Descriptions

- two layers of 15 mm tongued and grooved plywood or OSB subfloor on joists
- 38 mm by 241 mm joists spaced 400 mm o.c., or
  241-mm deep I-Joists, or 300 mm deep wood floor trusses
- 89 mm thick insulation between the joists
- resilient channels below joists, spaced 400-mm o.c.
- two layers of 15.9 mm fire-rated gypsum board below resilient channels

- 38 mm concrete topping on subfloor
- one layer of 15 mm tongued and grooved plywood or OSB subfloor on joists
- 38 mm by 241 mm joists spaced 400 mm o.c., or
  241-mm deep I-Joists, or 300 mm deep wood floor trusses
- 89 mm thick insulation between the joists
- resilient channels below joists, spaced 400-mm o.c.
- two layers of 15.9 mm fire-rated gypsum board below resilient channels
In conclusion

The fire performance of wood-frame construction is based on many years of North American experience. It has been documented through extensive testing, including tests on full-size buildings.

Fire loss statistics and research demonstrate that people are just as safe from fire in a wood-frame house, whether single family or low-rise multi-family, as they would be in houses built with any other material. Whatever the material used, the fire protection measures laid out by modern building codes such as the National Building Code of Canada ensure adequate building integrity and safe evacuation for all occupants.

Wood-frame construction also provides a superior level of comfort with respect to sound transmission, and it can be designed to accommodate the broadest range of climatic, cultural, regulatory and economic conditions. Housing units exported from Canada are designed to meet clients’ performance requirements anywhere in the world.

For more information

Fire Safety Design in Buildings is a reference for applying the fire safety requirements of the National Building Code of Canada to building design. This publication is available from the Canadian Wood Council. Tel.: 1-800-463-5091. Website: www.cwc.ca