Canada Wood
Produits de bois canadien

Fire Resistance and Sound Transmission

in Wood-Frame Residential Buildings

INTERNATIONAL
Building series NO. 3

Introduction

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

The secret to 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. Wood's high strength-to-weight ratio facilitates the creation of structurally efficient buildings. In addition, wood-frame construction uses a renewable resource. 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.

PHOTO 1: Wood-frame construction produces high quality and affordable housing.

Fire is an ever-present danger for building occupants. 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 home (furniture, etc.), and the fire protection measures designed into the building.

Minimization of sound transmission in single- and multi-family residential buildings is also an important factor to ensure occupant comfort, and is closely related to fire-resistant construction.

The intent of this brochure is to demonstrate how wood-frame buildings meet code requirements by providing examples of wood-based light-frame building systems designed to maximize fire safety and minimize sound transmission.

Fire Safety Defined

Fire safety can be defined 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." (National Building Code of Canada)

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 the types of building materials that will be used in the construction of the building.

Many factors must be considered including the use of the building, the number of occupants, how easily they can exit from the building in case of a fire and how a fire can be contained.

PHOTO 2: Several factors, beyond the construction materials themselves, contribute to the fire safety of buildings.

Wood Compared to Steel and Concrete

The fire safety of a building is far more complicated than whether the materials used to construct it are combustible or noncombustible – the characteristics of the entire system must be taken into account.

Although wood is a combustible material, when it burns, a layer of char is created which helps to protect the wood and maintain the strength and structural integrity of the wood inside. This is the reason why a heavy timber system can be left exposed and still achieve a fire-resistance rating of up to 90 minutes. Wood-frame walls, floors and roofs using conventional wood framing, wood trusses and wood I-joists can be designed to provide fire resistance ratings up to 2 hours.

Fire testing of loadbearing and non-loadbearing wood-stud and sheet-metal-stud wall assemblies protected with gypsum board (also know as wallboard, plasterboard or drywall) shows that fire-rated wood-stud wall assemblies prevent fire spread through the wall for as long as, if not longer than, identical walls built with sheet-metal studs.

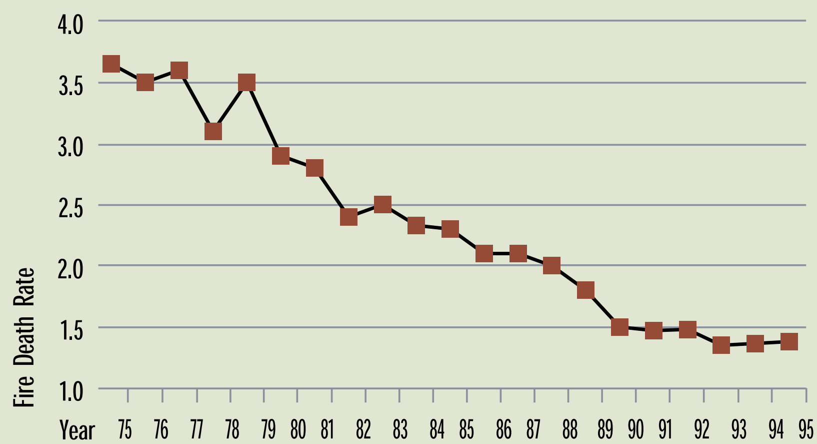
Steel is a noncombustible material but quickly loses its strength when exposed to the high temperatures of a fire. Like wood-frame assemblies, steel must also be protected from direct exposure to fire, often by gypsum board, to prolong the time before collapse occurs in a fire.

Concrete is also a noncombustible material, but newer residential insulated concrete form (ICF) systems use flammable foam on the exterior of the concrete as the insulation and the form. This foam generates toxic gases and intense heat in a fire. These newer ICF systems also need gypsum board or some other form of protection to retard the spread of fire when used between dwelling units in multi-family residential buildings. Also, ICFs must be shielded by a thermal barrier to protect all combustible foam insulation materials.

Fire Loss Statistics

In Canada, over 90% of homes are built with wood. Statistics show that fire deaths in Canada have been dropping for the last two decades (see Figure 1). This is mainly due to increased use of smoke detectors, improvements in electrical and heating systems, changes in lifestyle habits of the inhabitants (non-smoking / reduced alcohol consumption / dining out), and public awareness (education programs). Statistics also indicate that contents and furnishings are the items first ignited and representative of the most deadly fires (see Tables 1 and 2).

FIGURE 1: Annual Fire Death Rate per 100,000 Residents



Source: Fire Losses in Canada, Annual Report 1995, Association of Canadian Fire Marshals and Fire Commissioners, Ottawa

TABLE 1: Annual Fire Loss Record for Single-family Dwellings – Items First Ignited

Item First Ignited (list not complete)	Deaths per 100 Fires	Injuries per 100 Fires
Upholstered Furniture	5.11	9.24
Mattress or Bedding	1.94	7.48
Multiple Forms	1.94	4.47
Gas or liquid	1.47	8.61
Floor covering	1.32	3.88
Structural Members	0.75	1.78

Source: Examining Fires in Selected Residential Properties, National Fire Protection Association 1998

TABLE 2: Annual Fire Loss Record for Apartment Buildings 1-4 Storeys – Items First Ignited

Item First Ignited (list not complete)	Deaths per 100 Fires	Injuries per 100 Fires
Upholstered Furniture	4.16	15.75
Mattress or Bedding	2.16	12.21
Multiple Forms	1.91	10.00
Interior Wall Covering	1.65	6.53
Gas or liquid	1.56	10.94
Structural Members	1.38	4.94

Source: Examining Fires in Selected Residential Properties, National Fire Protection Association 1998

Building Code Requirements

A builder or designer considering fire safety in a residential building must consider an intricate balance of measures, many of them contained in the building and fire codes, to achieve minimal risk to the occupants of the residence.

The safety measures specified in building codes for the design of buildings vary with the size of the building and also by how the building is used. For example, indoor stadiums that will accommodate thousands of people require sophisticated fire safety systems including smoke control systems and sprinkler systems to ensure that the large number of occupants can be evacuated. High-rise apartment buildings have similar requirements for sprinklers and other smoke control measures. On the other hand, smaller buildings such as single-family houses, which have fewer occupants who can readily evacuate, do not require the same complexity of design and safety systems.

The fire safety requirements for single-family houses in Canadian and American model building codes are the same regardless of the type of construction used. These requirements focus on ensuring that the occupants can evacuate if there is a fire, because research has shown that it is the contents of the building that pose the greatest fire risk. Building codes do not require any prescribed level of structural fire resistance for floors and walls in houses. Typically, houses are finished with regular gypsum board that inherently provides some minimum protection from fire for the structural assemblies. Even without a prescribed minimum fire resistance for floors and walls in single-family homes, structural fires or structural collapse do not play a major role in the deaths and injuries that occur.

In several countries, building codes allow multi-family residential buildings up to three stories in height using any construction material. Safety measures include requiring the floors and walls separating apartments to have a required fire resistance rating. As the buildings get larger, building codes require additional safety measures such as sprinkler systems and higher fire resistance ratings on the load bearing structure. This reflects the increased risk of having more occupants and more floors for them to descend for evacuation. For example in Canada, the National Building Code of Canada (NBCC) mandates that four-storey residential buildings be sprinklered and that the structure have a one-hour fire resistance rating regardless of whether the structure is wood, steel or concrete.

High-rise apartment buildings pose a higher risk because of the time involved for alerting and evacuating the occupants. Even though the NBCC mandates that the loadbearing structural systems be noncombustible, strict requirements including sprinklers or other forms of smoke control measures along with much higher fire resistance requirements must also be met.

Research studies examining major causes of fatalities in residential buildings conclude that only 0.2% of the deaths were attributable to fires where a floor or wall collapsed. These studies also show that combustible contents are the first materials to be ignited in residential fires and that smoke and heat generated by these burning contents cause about 90% of deaths. (National Fire Protection Association)

Minimizing Fire Risk

In order to achieve the basic objective of life-safety, a combination of measures can be applied to:

- Prevent fires,
- Detect fires,
- Allow time for people to exit,
- Minimize the spread of fires, and
- Facilitate extinguishment of fires.

Most of the fires safety requirements contained in building codes can typically be categorized under two fundamental principals for minimizing risk :

- Prevention of fire ignition, and
- Management of fire impact.

Prevention of Fire Ignition

Obviously, preventing fires from starting in the first place is an important safety goal. Although fire prevention can never be completely assured, the chances of preventing a fire are increased by ensuring that:

- The design and construction of a building complies with the building codes, and
- The operation of a building complies with the regulations in the fire codes.

These codes apply to all residential buildings, regardless of the type of materials used to construct the building.

Certain code-required features are intended to minimize the risk of fire ignition. For example, electrical systems must be installed according to the referenced national electrical codes so that fire ignition from electrical sources is minimized.

The main factors for ensuring that a fire does not start are related to the operation of a building. The fire regulations establish the fire safety requirements during the use of a facilty.

An example of a fire code prevention measure is the requirement for the separation of combustible materials (such as refuse) from furnaces and other heat-generating devices.

Management of Fire Impact

Preventing fire ignition is the first line of defense in fire safety. The second line of defense, if ignition does occur, is to manage the fires impact and minimize the risk. The two main methods for managing the impact of a fire are:

- Manage the people exposed, and
- Manage the fire itself.

Managing the people exposed means getting the occupants out of the building and away from the hazard before they are injured. Most injuries or deaths are caused by toxic fumes from the smoke, so it is important that people are alerted to the fire quickly and can escape the fire hazard by exiting the building.

Building codes require building facilities or systems that are intended to limit the exposure of people to fire by facilitating their escape. Fire safety measures in this category include:

- Detectors and/or fire alarm systems to warn people and cause them to evacuate,
- Window and door openings to allow people to escape or provide for fire fighters to evacuate people, and
- Exits such as corridors and stairs to allow people to evacuate safely.

Managing the fire involves providing measures intended to limit the spread and severity of the fire. In smaller buildings, this can be as simple as ensuring that there is a fire extinguisher available. In larger buildings, such as multi-storey apartment buildings, managing the fire becomes more complex and more critical. In a multi-family residential building, the built-in fire safety features related to managing the fire include such things as:

- Fire-resistant walls and floors built to contain fire to a single dwelling unit,

- Fire-resistant walls and floors built to ensure that structural members continue to function under fire attack long enough for the people to escape or be evacuated,

- Limits on the flammability of wall, ceiling and floor finishes to reduce the potential for fire growth in a room, and

- Sprinkler systems installed to control or extinguish fires.

These measures will allow the occupants more time to become aware of the fire and escape the hazard.

All the foregoing measures related to both managing the people exposed and managing the fire itself are used in buildings to minimize the risk, regardless of the type of construction materials in the building.

PHOTO 3: Numerous types of light wood-frame building systems are available to maximize fire safety and minimize sound transmission.

Fire-Rated Construction

The fire resistance of wood-frame assemblies (walls or floors) depends almost entirely on the gypsum board 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. Fire-rated gypsum board is available in at least two thicknesses. The thicker panels present a somewhat better thermal barrier and allow greater fire resistance.

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.

Placing glass-fibre or rock-fibre insulation between the joists of wood-frame floor assemblies or between the studs of wood-frame wall assemblies restricts heat transfer from the wall or ceiling surface into the assembly cavities. 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 the sides of the wood members.

In the construction of shear walls, structural wood panels (such as plywood) 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).

FIGURE 2: Wood-Stud Wall Assembly After 1-Hour Test

The fire resistance rating of a structural assembly is determined by subjecting the assembly to a standard fire. The assembly, if designed to be loadbearing, must support the full design load for the duration of the fire test without allowing any flames to pass through.

Fire Resistance Ratings

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 (see Figure 2).

Fire resistance ratings are usually described in 15- or 30-minute increments (e.g., 45 min, 1h, 1.5h). Under 45 minutes, rating ranges may be less than 15 minutes.

They are generally based on tests conducted in conformance with one of two standards:

- International Organization for Standardization (ISO): ISO 834 Fire Resistance Tests – Elements of Building Construction, or
- American Society for Testing and Materials (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 considered by building officials in others.

Firewalls

Firewalls are fire separations of noncombustible construction. They have fire resistance ratings 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.

PHOTO 4: Wood construction assembly being tested in the fire chamber at the National Research Council of Canada.

Sound Transmission

PHOTO 5: Acoustic chambers at the National Research Council of Canada.

Wood-frame construction is particularly efficient in residential dwellings where sound insulation is required. Attaching gypsum board to walls and ceilings using resilient metal channels significantly reduces sound transmission (see Figures 3 and 4). In addition, placing glass-fibre or rock-fibre insulation within wood-frame floor and wall assemblies also reduces sound transmission. Wood-frame construction does not present the impact-noise transmission problems commonly noted with concrete construction.

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 ISO method takes airborne-sound transmission measurements in accordance with ISO 140-3 Acoustics – Measurement of sound insulation in buildings and of building elements (Part 3: Laboratory measurements of airborne sound insulation of building elements).

A weighted sound reduction index (R_W) is determined in accordance with ISO 717-1 Acoustics – Rating of sound insulation in buildings and of building elements (Part 1: Airborne sound insulation).

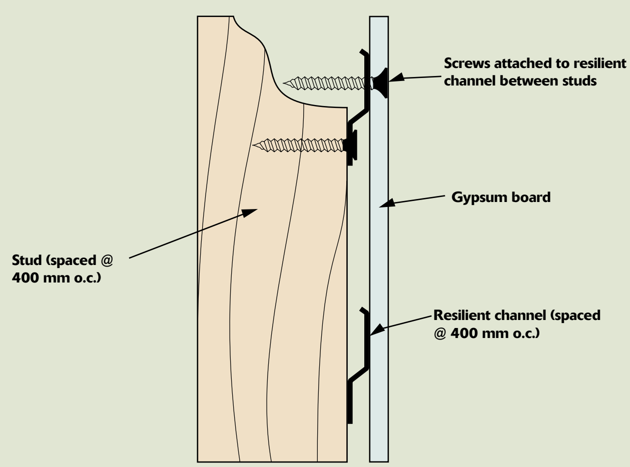
Impact sound through floors is measured in accordance with ISO 140-6 Acoustics – Measurement of sound insulation in buildings and of building elements (Part 6: Laboratory measurement of impact sound insulation of floors). A weighted sound reduction index is determined in accordance with ISO 717-2 Acoustics – Rating of sound insulation in buildings and of building elements (Part 2: Impact sound insulation).

The STC rating and the weighted sound reduction index, R_W, have been found to correlate well.

FIGURE 3: Gypsum Board Installation on Walls

Resilient Channels to Reduce Sound Transmission

Attaching gypsum board to walls or ceilings using resilient metal channels reduces sound transmission.



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.

The National Building Code of Canada currently specifies STC 50 for "party walls" in multi-family dwellings. However, individual sensitivities to noise differ, in terms of both volume and frequency ranges.

Researchers at the National Research Council of 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.

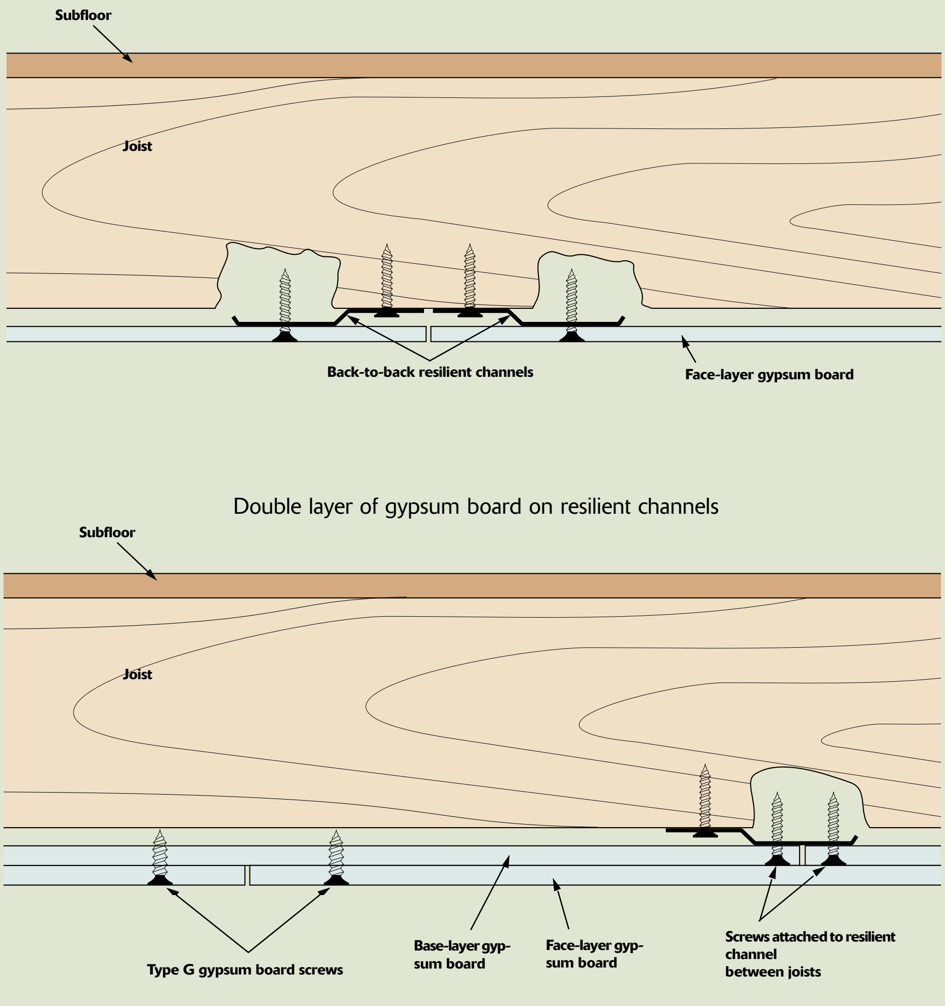
Following a number of home-owner acoustic-comfort surveys, Canada Mortgage and Housing Corporation identified the following sound-insulation objectives for multi-family buildings: STC > 55 for inter-unit walls and floors, IIC > 55 for inter-unit "hard" floors and IIC > 65 for inter-unit carpeted floors.

FIGURE 4: Gypsum Board Installation on Ceilings

Resilient Channels to Reduce Sound Transmission

Single layer of gypsum board on resilient channels

Double layer of gypsum board on resilient channels

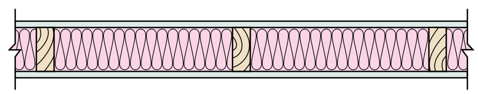
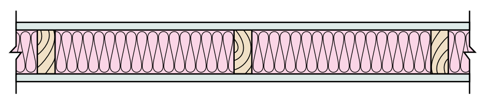
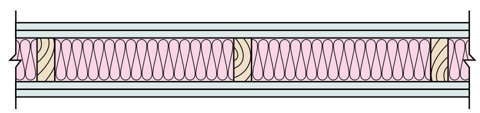
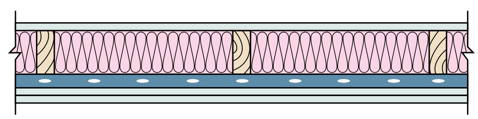
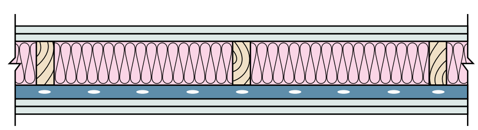
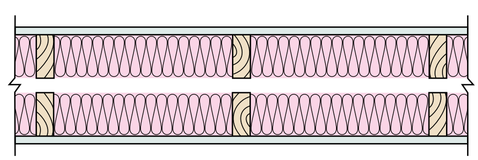
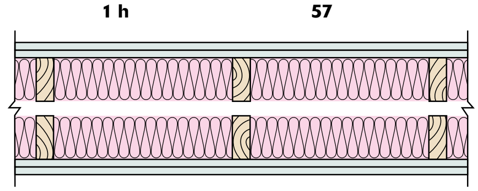


The screws used to attach the gypsum board to resilient channels must be located away from the joists, as any direct contact with structural members would create a path for sound transmission.

Examples of Assemblies

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

Wall Descriptions

Wall Description		Fire Resistance Rating (FRR)	Sound Transmission Class (STC)
- 38 x 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		30 min	32
- 38 x 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		1 h	36
- 38 x 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		1.5 h	38
- one layer of 15.9 mm fire-rated gypsum board - 38 x 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		1 h	51
- 38 x 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		1.5 h	55
- two rows of 38 x 89 mm studs, each spaced 400 mm o.c. on separate 38 x 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		1 h	57
- two rows of 38 x 89 mm studs, each spaced 400 mm o.c. on separate 38 x 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		1.5 h	66

Floor Descriptions

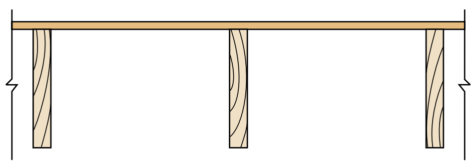
Fire resistance ratings for floor assemblies constructed with wood I-joists and parallel-chord wood trusses (glued or connected with metal or gusset plates) differ very little from those for floors constructed with solid wood joists.

While failure of wood trusses in fires usually results from the teeth of the gusset plate pulling out of charred wood in the bottom chord, the metal teeth do not accelerate char formation in the underlying lumber.

In the following floor descriptions, 38 x 241 mm joists can be substituted for 241 mm-deep I-joists or 300 mm-deep floor trusses. (Minimum dimensions for I-joist components are 38 x 38 mm LVL or lumber flanges and 9.5 mm structural wood panel web. Minimum lumber dimensions for truss components are 38 X 64 mm). Impact Insulation Classes (IIC) are for floor assemblies without any finish floor.

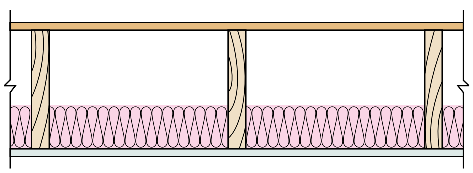
Fire Resistance Rating (FRR)	Sound Transmission Class (STC)	Impact Insulation Class (IIC))

- one layer of 15 mm tongued and grooved structural wood panel subfloor on joists
- 38 x 241 mm joists spaced 400 mm o.c.



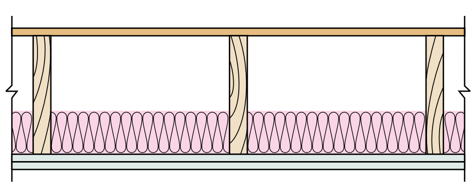
12-15 min **no sound ratings**

- one layer of 15 mm tongued and grooved structural wood panel subfloor on joists
- 38 x 241 mm joists spaced 400 mm o.c.
- 89-mm-thick insulation between the joists
- one layer of 15.9 mm fire-rated gypsum board on ceiling



30-45 min	**34**	**30**

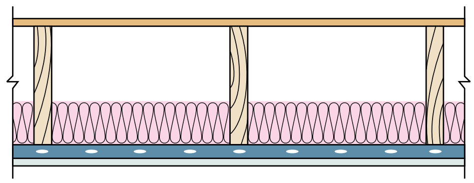
- one layer of 15 mm tongued and grooved structural wood panel subfloor on joists
- 38 x 241 mm joists spaced 400 mm o.c.
- 89-mm-thick insulation between the joists
- two layers of 15.9 mm fire-rated gypsum board on ceiling

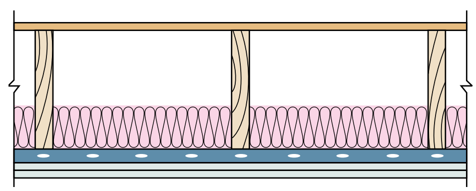


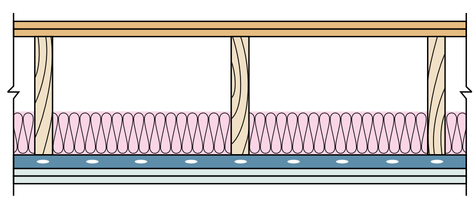
1 h	**37**	**33**

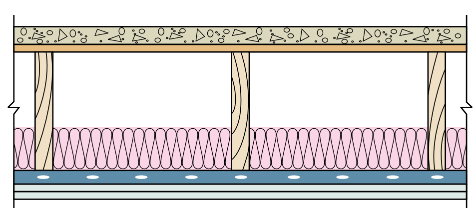
Floor Descriptions

	Fire Resistance Rating (FRR)	Sound Transmission Class (STC)	Impact Insulation Class (IIC)
- one layer of 15 mm tongued and grooved structural wood panel subfloor on joists - 38 x 241 mm joists spaced 400 mm o.c. - 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 on ceiling below resilient channels	30-45 min	48	40
- one layer of 15 mm tongued and grooved structural wood panel subfloor on joists - 38 x 241 mm joists spaced 400 mm o.c. - 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 on ceiling below resilient channels	1 h	54	47
- two layers of 15 mm tongued and grooved structural wood panel subfloor on joists - 38 x 241 mm joists spaced 400 mm o.c. - 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 on ceiling below resilient channels	1 h	57	50
- 38 mm concrete topping on subfloor - one layer of 15 mm tongued and grooved structural wood panel subfloor on joists - 38 x 241 mm joists spaced 400 mm o.c. - 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 on ceiling below resilient channels	1 h	69	44









Conclusion

As demonstrated by research, fire safety is determined to a much higher degree by the contents that homeowners bring into their residences and by their personal living habits than by the structural composition of the residence itself.

PHOTO 6: Wood-frame construction meets building code requirements for safe housing.

Fire safety is a complex science that is not simply explained by only using such terms as "fire-safe", "fire-proof" and "noncombustible". No building can be completely "fire-proof" because it is the contents and the occupants that create the greatest risk.

How a building performs is not a factor of the materials used, but of how the building is designed and constructed. It is wrong to claim that sheet-metal-frame construction provides better fire safety than wood-frame construction. Building codes require that all building systems perform to the same level of safety, regardless of material used. Wood-frame construction meets, and in many cases exceeds, these requirements to provide safe housing.

The fire performance of wood-frame construction is based on many years of Canadian 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.

As demonstrated, wood-frame construction also provides a superior level of comfort with respect to the minimization of sound transmission, and it can be designed to accommodate the broadest range of climatic, cultural, regulatory and economic conditions.

Canadian wood-frame construction technology is being adopted in both emerging and developed economies throughout the world that want to achieve the same level of comfort and security that Canadians have enjoyed for decades.

References

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