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Fire Resistance of Floor Assemblies in Multi-Family Dwellings

by M.A. Sultan

This Update discusses how various factors affect the fire resistance of floors in multi-family dwellings. The information is based on results from a major industry/government research project carried out by the National Research Council's Institute for Research in Construction (IRC).*

Researchers at IRC set out to determine how the sound transmission class (STC) and fire-resistance ratings (FRR) of insulated and non-insulated floor assemblies protected by gypsum board would be affected by the more stringent acoustic requirements of the National Building Code of Canada (NBC) 1995. The STC between dwelling units was increased from 45 in the NBC 1990 to 50 in the NBC 1995.

These new requirements necessitate changes in traditional construction, some of which may alter the fire-resistance ratings of floor assemblies. These changes for acoustic reasons, and other changes in the materials themselves, have created doubt about the veracity of existing fire-resistance data for common floor assemblies.

Whole floor systems, not just materials, were tested to get a complete picture of how various parameters affect both acoustic and fire-resistance performance. It is known, for example, that the achievement of high acoustic performance may have negative implications for fire-resistance performance, or vice versa. This Update presents the results of the fire study; a later Update will discuss the results of the acoustics study.

The gypsum board ceiling finish of the floor assemblies was exposed to heat in a propane-fired horizontal furnace. The tests were carried out in accordance with CAN/ULC-S101-M89 "Standard Methods of Fire Endurance Tests of Building Construction and Materials," which is similar to ASTM E119 "Standard Test Method for Fire Tests of Building Construction and Materials."

Impact on the Industry

As a result of this project, a table with STC ratings for more than 600 floor assemblies and fire-resistance ratings for more than 150 floor assemblies was drafted and proposed for inclusion in the National Building Code of Canada.

Effect of Various Factors on Fire Resistance

The influence of the various parameters on the fire-resistance of load-bearing floor assemblies are as follows:

Gypsum Board Screw Spacing from Board Edges

The location of screws used to fasten gypsum board edges to resilient channels can have an influence on the fire-resistance performance of floor assemblies. Current construction practice places screws 10–12 mm from the board edges. Test results showed that by placing the screws further away from the edges (at 38 mm from the edge), the fire resistance increased by 50%. This is explained as follows: the gypsum board core dries faster in the vicinity of the screw heads than in the field of the board because of rapid heat transfer from the steel screws to the gypsum core around them. Also, the gypsum board core has more water in the field of the board than at the edges owing to the drying process that takes place during manufacturing.

The tests demonstrated that the board shrank faster at the edges than in the field

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of the board. The combined effects of shrinkage of the board and heat transfer through the screws contribute to the edges of the board peeling away from the channels, thus exposing them and the joists to furnace heat. This, in turn, accelerated the burning of the joists and subfloor, and caused the assembly with screws at 10 mm from the edges to fail earlier than the assembly with screws at 38 mm from the edges.

For floor assemblies with one layer of gypsum board ceiling finish, moving the screws away from the board edges requires the use of either double rows of regular-size resilient channels or channels with a wider flange.

For assemblies with two layers of gypsum board (base layer and face layer), the fire-resistance of the face layer is more critical for overall performance than that of the base layer. The base layer can be fastened to the resilient channels with screws at 10 mm from the board edges. The face layer can be fastened to the base layer and resilient channels in three different ways using:

1) Type G screws (commonly used to attach two layers of gypsum board to each other) at 38 mm from the edges of the board, in which case, double rows of regular-size resilient channels are not required;
2) Regular screws at 38 mm from the edges with double resilient channels;
3) Regular screws at 38 mm from the edges with resilient channels with a wider flange.

Type of Insulation

Insulation such as glass, rock and cellulose fibre is commonly installed in the floor assembly cavity to reduce sound transmission; however, this may have either a negative or a positive effect on fire resistance. This effect depends on the type of insulation and heat exposure time. Insulation in the floor cavity reduces the heat transmission from the gypsum board to the floor cavity, which causes the board to dry and crack faster than in an assembly with no insulation.

Three types of insulation were used: glass fibre batts (90 mm thick), rock fibre batts (90 mm thick) and wet-sprayed cellulose fibre (59 mm to 122 mm thick). The effect of insulation on the fire resistance of floor assemblies is discussed below.

Floor assemblies with solid wood joists

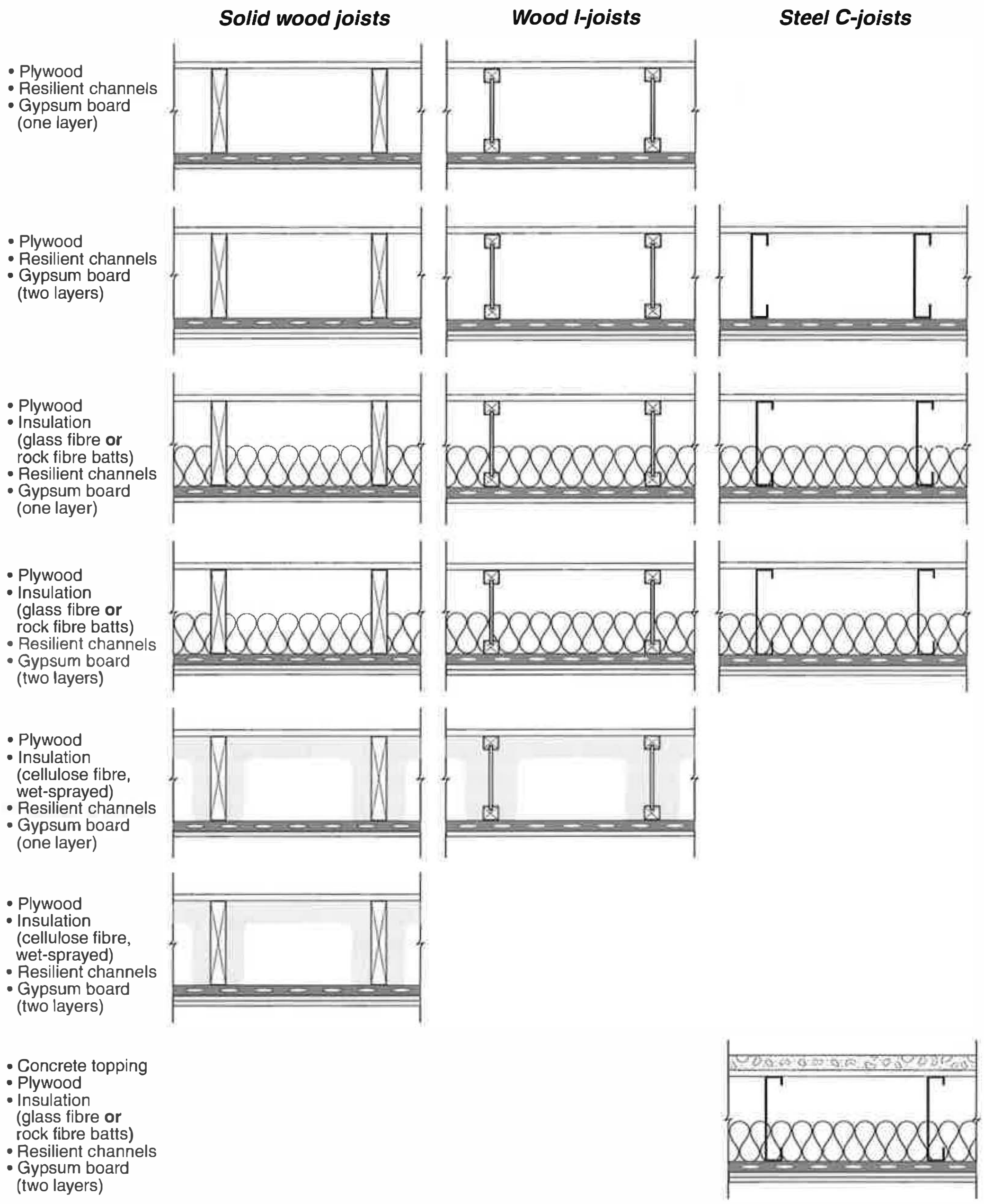
Assemblies with a single layer of gypsum board. The test results showed that in the assembly with glass fibre batts installed above resilient channels, the insulation melted 2 to 3 minutes after the gypsum board fell off and, subsequently, the joist sides and subfloor were exposed to furnace heat. The glass fibre was unable to compensate for the earlier failure of the gypsum board and, thus, reduced the fire resistance by 20% compared to an assembly with no insulation. In the assemblies with rock fibre batts installed above resilient channels and cellulose fibre sprayed wet on the joist sides and underside of the subfloor, the insulation remained in place longer and, thus, increased the fire resistance by 33% and 31%, respectively. It should be pointed out that assemblies with solid wood joists, one layer of gypsum board ceiling finish and either rock or cellulose fibre insulation installed in the cavity provided a 45-minute FRR.

Assemblies with a double layer of gypsum board. The results showed that, compared to a non-insulated assembly, the insulation reduced the fire resistance by 16% with glass fibre, by 10% with rock fibre and by 7.5% with cellulose fibre. Here, with two layers of gypsum board, the heating exposure time was much longer than in an insulated assembly with a single layer of gypsum board. Thus, the three insulations were more deteriorated when the board eventually fell off as a result of this longer heat exposure. The deteriorated glass, rock and cellulose fibre insulations were unable to compensate for the earlier failure of the gypsum board and, thus, all insulations had a negative effect on fire resistance. However, assemblies with solid wood joists, a double layer of gypsum board ceiling finish and glass, rock or cellulose fibre insulation installed in the cavity provided a one-hour FRR.

Floor assemblies with wood I-joists

Assemblies with a single layer of gypsum board. Insulation increased the fire resistance by 10% in the assembly with rock fibre batts installed above resilient channels and by 24% in the assembly with cellulose fibre, wet-sprayed on the joist sides and on the underside of the subfloor, compared to an assembly with no insulation. With wood I-joists, as with solid wood joists, the rock and cellulose fibre provided a positive effect on fire resistance. Like the assemblies with solid wood joists, those with wood I-joists, one layer of gypsum board ceiling finish and either rock or cellulose fibre insulation installed in the cavity provided a 45-minute FRR.

Assemblies with a double layer of gypsum board. Insulation reduced the fire resistance by 7% in the assembly with glass fibre and increased the fire resistance by 7% in the assembly with rock fibre compared to an assembly with no insulation. The glass fibre



had a negative effect on fire resistance (as was the case with the solid wood joist assembly mentioned above). The rock fibre, however, had a positive effect on fire resistance, contrary to its effect in the assembly with solid wood joists, where it had a negative effect. This difference is due to the difference in failure mechanisms: the solid wood joist assembly failed as a result of flame penetration through the subfloor while the wood I-joist assembly failed structurally as the joists, attacked by fire, were unable to carry the load. Nevertheless, assemblies with wood I-joists, a double layer of gypsum board ceiling finish and glass, rock or cellulose fibre insulation were able to provide a one-hour FRR.

Floor assemblies with steel C-joists

Assemblies with a double layer of gypsum board. The installation of glass fibre batts in the floor cavity above resilient channels reduced the fire resistance by 8% compared to an assembly with no insulation. This negative effect is due to the reduction in the heat transfer from the unexposed face of the exposed gypsum board to the cavity, which caused the board to fail earlier.

Number of Gypsum Board Layers

Using two layers of gypsum board ceiling finish instead of one provides extra fire-resistance protection to the assembly and, consequently, improves the FRR. A second layer increased the fire resistance by 78% for solid wood joists and 71% for wood I-joists compared to an assembly with a single layer of gypsum board.

Joist Spacing

Widening the spacing between joists, from 400 mm o.c. to 600 mm o.c., for floor assemblies with gypsum board ceiling finish

* **The partners for this industry/government research project included:** Boise Cascade Corporation, Canada Mortgage and Housing Corporation, Canadian Home Builders' Association, Canadian Portland Cement Association, Canadian Sheet Steel Building Institute, Canadian Wood Council, Cellulose Insulation Manufacturers Association of Canada, Forintek Canada Corporation, Gypsum Association, Gypsum Manufacturers of Canada, Louisiana-Pacific Corporation, Nascor Inc., Ontario New Home Warranty Program, Ontario Ministry of Housing, Owens Corning Canada, Willamette Industries, Roxul Inc. and Trus Joist MacMillan.

attached directly to the joists may not be desirable as it reduces the number of fasteners holding the gypsum board to the joists, thus reducing the fire resistance. However, if resilient channels at 400 mm o.c. are used between the ceiling finish and joists, widening the joist spacing from 400 mm o.c. to 600 mm o.c. can improve the fire resistance.

Floor assemblies with solid wood joists

This type of joist was not investigated in the joist-spacing study, but will be in future.

Floor assemblies with wood I-joists

For wood I-joist floor assemblies with a double-layer gypsum board ceiling finish, resilient channels at 400 mm o.c. and glass fibre insulation, widening the joist spacing from 400 mm o.c. to 600 mm o.c. increased the fire resistance by 16%. The wider joist spacing provided better fire resistance owing to the increase in convective cooling inside the larger floor cavity created by the joists; this reduced slightly the heat build-up in the gypsum board core and the insulation compared to the assemblies with the smaller cavity.

Floor assemblies with steel C-joists

For steel C-joist floor assemblies with a double-layer gypsum board ceiling finish and glass fibre insulation, widening the joist spacing from 400 mm o.c. to 600 mm o.c. increased the fire resistance by only 2%. The effect of steel joist spacing on fire resistance is insignificant in this type of assembly as the cooling effect due to widening the joist spacing is small compared to the heat-gain effect in the cavity as a result of heat transfer through the joists.

Resilient Channel Spacing

Widening the spacing between resilient channels from 400 mm o.c. to 600 mm o.c. for floor assemblies with gypsum board ceiling finish attached directly to the channels might not be desirable. The wider resilient channel spacing provided less fire resistance owing to the smaller number of fasteners for the gypsum board. The more screws holding up the gypsum board, the better the chance for it to remain in place and protect the frame and, thus, the better the fire resistance.

As an example, when the resilient channel spacing was widened from 400 mm o.c. to 600 mm o.c. for an assembly with wood I-joists, the fire resistance decreased by 12%.

Type of Subfloor

Two types of subfloor (OSB and plywood) were considered in this study. The researchers concluded that the type of subfloor (OSB or plywood) did not affect the fire resistance of the floor assembly.

Concrete Topping

To reduce sound transmission, a concrete layer is often added on top of a lightweight floor assembly. The topping increases the thermal resistance of the assembly and, thus, reduces the heat transfer across it. As a result, the gypsum board will dry and crack faster and fall off earlier than in an assembly with no concrete topping. Test results showed that adding a concrete topping to a floor assembly reduced the fire resistance by 12%.

Summary of Findings

- Placing the gypsum board screws further away from board edges (at 38 mm from the edge) increases the fire resistance.
- For assemblies with a single layer of gypsum board, either rock fibre batts or cellulose fibre sprayed wet in the floor cavity increases the fire resistance.
- An additional layer of gypsum board increases the fire resistance significantly.
- Widening the spacing between joists for direct application of gypsum board should be avoided.
- With resilient channels at 400 mm o.c., widening the joist spacing increases the fire resistance of a wood-frame assembly.
- Widening the spacing of the resilient channels should be avoided.
- Floor assemblies with OSB or plywood subfloors provided similar fire resistance.
- A concrete topping reduces the fire resistance of an assembly.

Reference

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