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Construction Technology Update No. 16

Sound Isolation and Fire Resistance of Assemblies with Fire Stops

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This Update examines various fire-stopping techniques that meet the intent of the National Building Code of Canada (NBC) with respect to fire resistance and that do not adversely affect the sound isolation of the wall assembly. The information is derived from the results of an industry-sponsored consortium project led by the National Research Council's Institute for Research in Construction (IRC).[1]

The National Building Code of Canada (NBC) 1995 requires that wood-frame construction have a fire stop (a material that is placed across the concealed air space in a wall) at each floor/ceiling level to block the passage of flame and smoke in partition walls containing combustible materials. However, in multi-family construction, certain types of material and methods of installation may introduce physical connections between the dwellings, and while these connections may be desirable for fire and structural reasons, they can be detrimental to acoustical privacy.

A recently completed multi-disciplinary project undertaken by IRC focused on ways to provide the necessary fire resistance without compromising the sound isolation in walls between dwelling units. The results of the project are summarized in this Update.[2,3]

Evaluating the Fire Resistance of Fire-Stop Materials

The fire-resistance portion of the study was conducted in parallel with the acoustics portion to ensure that acoustically effective fire-stop methods or materials would also satisfy the intent of the NBC with respect to fire resistance.

The NBC clearly specifies when and where fire stops are required, and for how long they must resist the passage of flames. However, a suitable standardized test method for evaluating the various fire-stopping techniques did not exist at the inception of this project. Although the NBC makes reference to CAN/ULC-S101-M89, "Standard Methods of Fire Endurance Tests of Building Construction and Materials," this standard is primarily intended to be applied in the testing of individual wall or floor assemblies rather than intersecting assemblies. This made it difficult for the consortium steering committee to determine how the standard could be applied to evaluate fire-stop materials at the wall/floor joint. For this reason, before methods to reduce fire spread through wall/floor joints could be investigated, the intent of the NBC, as stipulated in Sentence 3.1.11.7.(1), had to be interpreted and a test method that satisfied this intent had to be defined.

Test Method and Failure Criterion

The steering committee, in consultation with IRC codes advisors, agreed to test the assemblies by exposing the bottom of the floor/ceiling joint to a fire that replicated the CAN/ULC-S101-M89 temperature/time relationship, using IRC's propane-fired

construction

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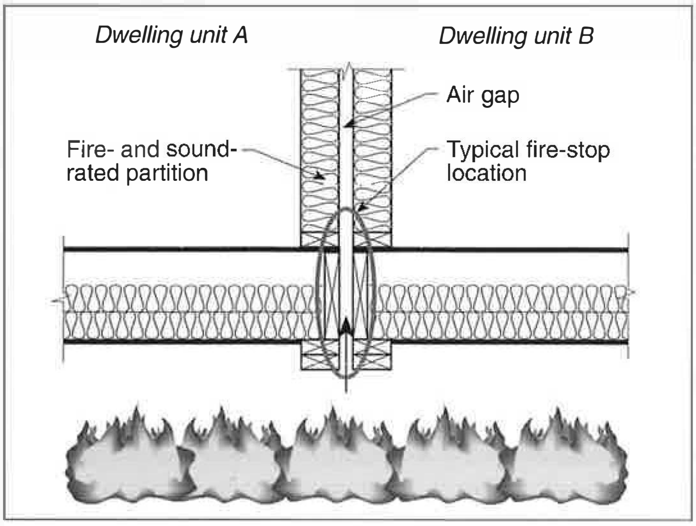


Figure 1. *Section through one of the wall assemblles Installed in the horizontal furnace. Note: The double head plates of what would have been the load-bearing wall below were included in the test and are shown in the figure.*

horizontal furnace. (See Figure 1 showing a section through a wall and floor/ceiling assembly.) The propagation of the flame up into the wall cavity was monitored.

The NBC requires (in Article 3.1.11.7) that materials used to separate concealed spaces, such as wall cavities, remain in place and prevent the passage of flames for not less than 15 minutes when subjected to the standard fire exposure of CAN/ULC-S101-M89. Thus, a fire-stop approach was considered by the consortium steering committee to have met the intent of the NBC if, after 15 minutes, the fire had not spread into the wall cavity above the floor level. If, at 15 minutes, flames were visible or the hot gases reached a temperature of 550°C, indicating the presence of flame, the fire-stop approach was considered to have failed.

Fire-Resistance Test Results

The assemblies tested can be grouped into two categories:

- systems ***with*** an explicit fire stop, and
- systems ***without*** an explicit fire stop.

Systems with explicit fire-stop materials

Of the four materials tested as fire stops, two were listed in the NBC and two were not (see Table 1). Those materials listed were oriented strand board (OSB), 13 mm, or thicker, and sheet steel, 0.38 mm, or thicker. They were installed under the sole plates of the partition wall.

Those materials not listed were semi-rigid mineral fibre boards, including both glass fibre boards and rock fibre boards. These boards,

Table 1. *Fire-stop options examined in the study*

Fire-stop material ranked by acoustical effectiveness	**Group***	**Typical installation**	**Location of flame at 15 minutes as measured in the fire-resistance study**
No explicit fire stop** • 13-mm gap, wood stud • 25-mm gap, wood stud • 25-mm gap, steel stud • 38-mm gap, wood stud	0	Fill the wall cavity so that the depth of the air gap is 25 mm or less	 Below floor level 300 mm above floor level Below floor level 1200 mm above floor level
Semi-rigid mineral fibre board • 48-kg/m³ glass fibre • 80-kg/m³ rock fibre	1	25 mm thick, placed vertically between joist headers	 Below floor level Below floor level
Gypsum board	2	25 mm thick, placed vertically between joist headers	**Not measured in the fire study**
Sheet steel	2	0.38 mm thick, without profile, installed under the wall plates	Below floor level
OSB	3	Continuous subfloor under partition wall	Below floor level

* See "Effect of Fire Stops on Sound Isolation between Dwellings," p.4, for description of groups.

** The NBC does not require an explicit fire stop if the width of the concealed space (air gap) is 25 mm or less. In this project, the individual double-stud assemblies were filled with insulation so that the two rows of studs were separated by gaps of various widths to determine the effect of these gaps on the propagation of flame in the cavity.

which are 25 mm thick, are oriented vertically and placed between the joist headers (for a load-bearing wall) or between the trimmer joists (for a non-load-bearing wall).

Table 1 shows that all the explicit fire-stop materials, including the semi-rigid boards (with actual densities of 46.4 kg/m^3 in the case of glass fibre, and 80.9 kg/m^3 in the case of rock fibre), prevented the passage of flames above the subfloor level for at least 15 minutes, thereby satisfying the intent of the NBC as interpreted by the consortium steering committee.

These results verified that the use of 13-mm OSB (and, indirectly, plywood, which has the same fire-resistance rating as OSB) and 0.38-mm sheet steel as fire-stop materials is consistent with the intent of the NBC (Article 3.1.11.7). A recommendation will be made to the appropriate codes standing committees that mineral fibre boards (both glass and rock fibre products) with a density of 46 kg/m^3 or greater also be listed in the NBC as acceptable fire-stop materials.

Systems without an explicit fire stop

The NBC does not require explicit fire stops at the wall/floor joint provided that the width of the air gap in the wall is 25 mm or less (see Articles 3.1.11.2 and 9.10.15.2). Thus, if insulation is placed in the cavity

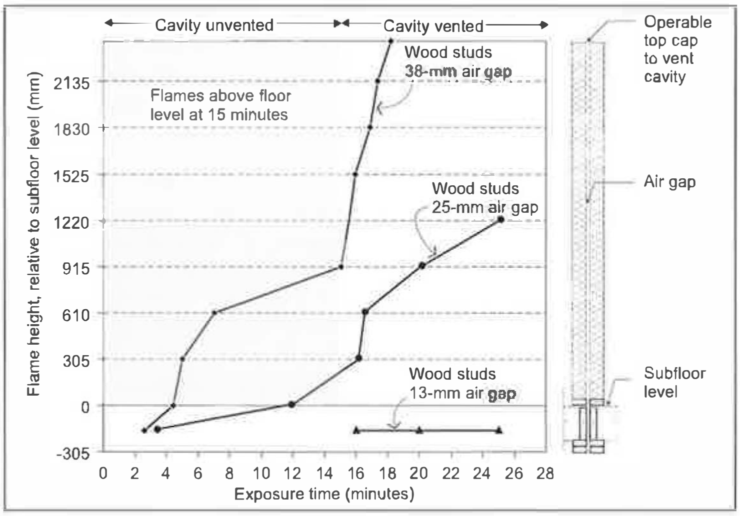


Figure 2. Location of the flames in the air gap as a function of time (assuming that the temperature in the wall cavity must be 550°C or higher to support flames). Data begins when the flames reached the first set of thermocouples, which were 168 mm below the subfloor level. Data for the steel-stud wall is not shown as the flames did not reach the first set of thermocouples at any point in the test.

such that the width of the air gap is 25 mm or less, an explicit fire stop is not required. (Acoustically, this was shown to be the preferred method of satisfying the intent of the NBC with respect to a fire stop).

The effect of air-gap width on flame spread inside the wall was systematically investigated in four different types of walls — three wood-frame walls and one steel-frame wall. The air gaps in the wood-frame constructions were 13 mm, 25 mm and 38 mm. The steel-stud assembly with a gap of 25 mm was included for purposes of comparing combustible with non-combustible framing. In all the walls, steel-wire mesh was attached to each stud on the air-gap side to ensure that the insulation remained in place and that the gap remained clear throughout the height and width of the wall. In addition, each assembly had an operable top cap that could be opened to simulate a vented cavity. Figure 2 shows a section through one of the walls with an operable cap. During the first 15 minutes, the cap was closed, simulating a closed or non-vented cavity. At 15 minutes, the caps were opened for an additional 15 minutes, simulating a vented cavity.

The temperature of the gases in the wall cavity, and indirectly, the location of the flames, was determined by thermocouples placed throughout the wall cavity. Figure 2 shows the position of the flames as a function of time for three of the four assemblies (assuming that a flame exists when the temperature of the hot gases is 550°C or greater).

13-mm air gap width with wood studs. Flames were contained in the space between the joist headers and did not reach the subfloor level within 15 minutes. Opening the cap at 15 minutes did not have an appreciable effect on the height of the flames; they remained below the subfloor level.

25-mm air gap width with wood studs. Flames reached the subfloor level in 12 minutes. At 16 minutes, the flames had propagated 300 mm above the subfloor level, and at 17 minutes (two minutes after the cap was opened) the flames had propagated 610 mm above this level.

This NBC-permitted assembly did not meet the performance criterion set by the steering committee. However, the flames remained at the same level and the situation did not threaten to rapidly involve the whole wall in the fire.

25-mm air gap width with steel studs. For this condition, the joist headers were covered with sheet steel to simulate a steel-frame floor. Flames did not reach the subfloor level even after 30 minutes.

38-mm air gap width with wood studs. Flames reached the subfloor level in only 4 minutes, and at 17 minutes, two minutes after the cap was opened, flames reached a height of 1830 mm above the subfloor level.

The project results indicate that the vertical propagation of flames in a concealed cavity with wood framing is highly dependent on the width of the air gap between the studs and the degree to which the cavity is vented at the top. With non-combustible framing, the flames did not reach the subfloor level and were not affected by cavity venting.

The results of this project will be made available to the NBC standing committees so that they can consider the code implications of the findings.

Effect of Fire Stops on Sound Isolation between Dwellings

In all buildings, there is a direct sound transmission path through the elements that are intended to separate one space from another. In addition, there are indirect transmission paths, or flanking paths, as shown in Figure 3. The degree of acoustical privacy between dwellings is determined not only by direct sound transmission through the separating wall or

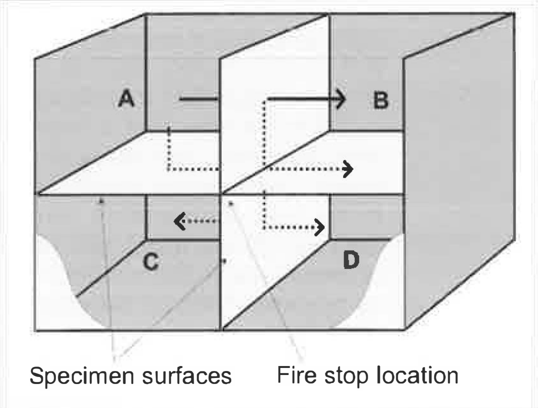
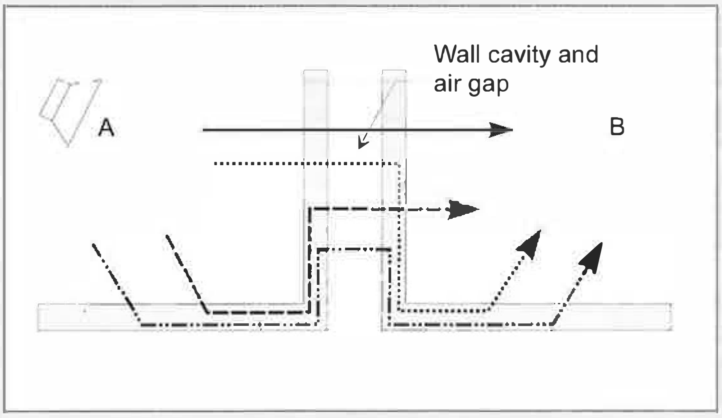


***Figure 3.** Sketch of the IRC flanking transmission test facility showing the direct transmission path from Dwelling A to Dwelling B and some of the possible flanking paths*

floor but also by the indirect flanking paths shown above. In this Update we refer to the measured sound isolation, where there is both a direct path and a series of flanking paths, as being the *apparent sound isolation*. "Apparent" refers to the degree of sound privacy experienced by occupants.

Rigid fire stops at the wall/floor intersection introduce a structural connection that creates four additional flanking paths, one of which completely bypasses the separating element as shown in Figure 4. The acoustics portion of the project examined the effect of fire-stop materials or techniques applied at the wall/floor joint on the sound isolation between the rooms "A" and "B," which were separated by the upper wall.

Flanking Transmission



This term refers to the transmission of sound energy from one room to another by any path other than the direct path through the separating wall or floor.

The simple representation of a wall/floor assembly at the left shows that flanking paths are introduced when the wall is connected to another building element (e.g., a floor). In this case, the floor introduces three flanking paths as indicated by the broken lines.

The phenomenon of flanking transmission partially explains why walls and floors tested in buildings usually exhibit significantly worse sound isolation than the identical ones measured in the laboratory.

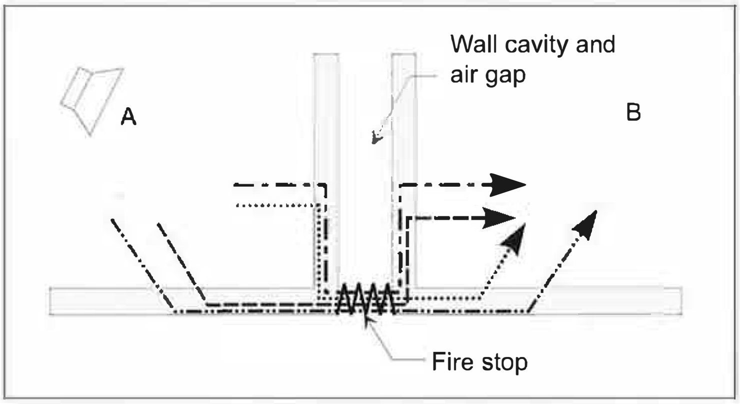


Figure 4. Simplified cross-section through rooms A and B showing the four flanking paths introduced when a structural fire stop is installed at the wall/floor joint

The specimen used for the systematic testing of the fire stops was typical of wood-frame construction that has double wood-stud partition walls with a 25-mm gap between the two sets of framing. The floor/ceiling assemblies were also of wood-frame construction with a 25-mm gap between the joist headers.

The effect of various fire-stop materials on sound isolation was determined by comparing the measured sound isolation both with and without the fire stop installed. This approach permitted any change in the measured sound isolation to be attributed to flanking paths involving the fire stop. It also allowed each fire-stop material to be 1) ranked in terms of its acoustical effectiveness and 2) assigned an apparent sound-isolation range, indicating the reduction in sound isolation as a result of the fire stop. (Discussion of the assignment of a sound-isolation range is beyond the scope of this Update. See reference 2 for more information.)

Group 0 Fire Stops — No Flanking Transmission

Adding insulation to the cavity between the two sets of studs so that the air gap is 25 mm or less does not introduce any flanking paths. In fact, this approach will actually help to improve the sound isolation of the wall (assuming that the wall had less cavity insulation before the application of the fire-stop method) because, in the absence of a physical connection at the wall/floor joint, all sound energy must pass through the wall cavity and the additional insulation. (See box, "Flanking Transmission"). Strictly speaking, this approach does not constitute a fire stop, but it meets the prescriptive requirements for fire separations in the NBC, Clauses 3.1.11.2.(2)(d) and 9.10.15.2.(2)(a). Acoustically, this is by far the most effective method of satisfying the intent of the NBC with respect to a fire stop.

Group 1 Fire Stops — Negligible Flanking Transmission

This group of fire stops bridges the wall/floor junction with relatively soft materials, which compress in response to vibration, thus transferring negligible vibration energy to the other side of the joint. Low-density (48–80 kg/m^3) semi-rigid mineral fibre boards were found to be acoustically neutral since no significant structural (rigid) connection was introduced. Although these materials are not listed in the NBC, they were tested in the fire-resistance portion of this project and found to be acoustically superior to the conventional, listed fire-stop materials (i.e., OSB, plywood and sheet steel).

Group 2 and Group 3 Fire Stops — Significant Flanking Transmission

For constructions with fire stops from Group 2 or Group 3, the most significant flanking path did not involve the partition wall. The path the sound took was from the "source" room subfloor to the "receive" room subfloor, via the fire stop under the partition wall. A detailed analysis of individual flanking paths showed that with a Group 3 fire stop, the apparent sound isolation may never be better than STC 48, regardless of the wall construction. This finding indicates that fire stops formed from continuous surfaces that go under the partition wall (Group 3 fire stops) should be avoided whenever possible.

> An STC 67 wall was degraded by 19 STC because the transmission path through the continuous subfloor (plywood or OSB) fire stop provides much less resistance than the direct path through the wall.

The study also showed that the effect of Group 3 fire stops on the apparent sound isolation was a function of the floor construction — in particular, the orientation of the joists with respect to the partition wall. Significantly lower sound isolation was found when the partition wall was non-load-bearing; i.e., when the joists were parallel to the wall. This finding is expected to hold true for Group 2 fire stops as well.

When a Group 3 fire stop was installed, there was no appreciable difference in the sound isolation performance of plywood and OSB of the same nominal thickness.

In all cases considered, the fire stop did not affect the sound isolation between vertically separated dwellings (i.e., between rooms A and C, and rooms B and D as shown in Figure 3).

Retrofit Techniques as Mitigation Measures

Treatments to the floor were shown to be very effective in controlling the floor-to-floor flanking paths introduced by Group 3 fire stops. When the finished floor surface was not structurally connected to the subfloor (i.e., an engineered floating floor) in both the source and receive rooms, the apparent sound isolation increased from STC 52 to STC 67, the nominal laboratory value of the partition wall. An alternative, but less effective, approach was to add a 16-mm OSB overlay to the subfloor in each room (with the separating wall already in place). This resulted in variable improvement, which was highly dependent on the construction of the wall.

Summary and Recommendations

The project demonstrated that:

- The method of fire stopping must be chosen to reflect the required or desired level of sound isolation between dwellings.
- The importance of using a systems approach when building wall/floor assemblies that must be both fire- and sound-rated, was demonstrated.
- Fire-stop materials and methods that introduce rigid structural connections between the two rows of studs in the cavity wall should be avoided, whenever possible, especially in the form of continuous surfaces such as the subfloor.
- Adding more cavity insulation to a double-stud wall so that the width of the air gap is 25 mm or less is by far the most effective method of satisfying the intent of the NBC from an acoustics point of view.
- Semi-rigid fibre board materials (rock fibre or glass fibre with a density of between 47 and 81 kg/m^3) were found to be acoustically neutral and also satisfied the intent of the NBC (as interpreted by the consortium steering committee).

The vertical flame spread in the wall cavity was highly dependent on:

- the type of framing members (wood or steel)
- the width of the air gap
- the degree of cavity venting.

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2. Nightingale, T.R.T. and Halliwell, R.E.H., Flanking transmission at joints in multifamily dwellings. Phase I: Effects of Fire Stops at Floor/Wall Joints, Institute for Research in Construction, National Research Council, Internal Report 754, December 1997.

3. Sultan, M.A., Seguin, Y.P., and Leroux, P., Fire Performance of Fire Stops in Multi-Family Dwellings, (in preparation), Institute for Research in Construction, National Research Council, 1998.

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