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Fire Resistance and Sound Insulation of Load-Bearing Steel-Stud Wall Assemblies

by V.K.R. Kodur, T.R.T. Nightingale, M.A. Sultan and L. Saint-Martin

This Update discusses the importance of various factors in achieving the required fire resistance and sound control for load-bearing steel-stud wall assemblies with gypsum board faces.[1]

In recent years, steel-stud framing has found wide application in residential construction, including townhouses and multi-unit low-rise buildings. In this type of building, the party walls and the walls between units and corridors are frequently load-bearing and required to have both a fire-resistance rating of 45 minutes (one hour in some cases) and a sound transmission class, or STC, rating of 50 in accordance with the National Building Code of Canada (NBC).

A previous study, completed by IRC in 1994[2], provided the basis for updating the fire-resistance and sound-insulation ratings in Appendix A of the 1995 edition of the NBC, Table A-9.10.3.1. [1], which contains deemed-to-comply assemblies for Part 9 type buildings, utilizing generic materials and components. However, the scope of that project did not include load-bearing steel-stud walls and, consequently, Table A-9.10.3.1 currently contains no information on this type of assembly. To fill that gap, IRC and nine industry partners initiated a major collaborative research project to develop fire-resistance and sound-insulation ratings for load-bearing steel-stud wall assemblies and other types of assemblies that were not part of the earlier study.

Experimental Set-Up

To get a meaningful picture of how various parameters affect fire and acoustic performance, tests were carried out on full-scale assemblies, not just materials. For this project, 14 wall assemblies were exposed to a standard fire test [2] and a total of 41 different assemblies were tested in the acoustics laboratory [3]. Type X gypsum board was used on both sides in all assemblies and, except for assemblies with a shear membrane, all specimens included steel cross-bracing for applications where lateral load resistance is required. Figure 1 shows cross-sections and construction details for the basic wall configurations tested.

In the fire testing, wall assemblies 3048 mm high by 3658 mm wide were exposed to heat in a propane-fired vertical furnace. Because these were load-bearing walls, a load was applied to the assembly during testing using hydraulic jacks. The fire resistance of each assembly was determined by the time it took to fail when exposed to fire in accordance with standard procedures stipulated in CAN/ULC S101-M89. In this study, all 14 assemblies failed structurally as a result of local or overall buckling under the applied load.

Tests for sound insulation were performed in accordance with methods described in ASTM E90 and E413. Wall assemblies 2451 mm high by 3670 mm wide were set in a vibration-isolated frame (to make sure the only significant sound transmission path was through the assembly) between a "source" room and a "receiving" room. The transmission loss of airborne sound directly through the assembly was measured

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over a range of frequencies, and the STC, a single composite attenuation rating, was calculated.

Factors Influencing Fire Resistance and Sound Insulation

Single Row versus Double Row of Studs

The fire test results suggest that wall assemblies with a double row of steel studs have better fire resistance than those with a single row. This can be attributed in part to the fact that the double-row assembly has a larger cavity, allowing for greater heat dissipation. Assemblies with a double row of studs and two layers of gypsum board on each side, both with and without absorptive material in the cavity, achieved ratings of one hour or more while assemblies with only one layer did not achieve the required 45-minute rating.

When there are two rows of studs on separate tracks (Wall Construction 4), there is no direct structural connection from one side of the assembly to the other. This results in a significant improvement (compared to single-row construction) in sound attenuation because vibrational energy cannot be transmitted directly through the framing. To fully benefit from this type of construction, it is best to increase the number of layers of gypsum board on each side and add absorptive material to the cavity (see *Number of Gypsum Board Layers* and *Cavity Insulation* below).

Number of Gypsum Board Layers

In every configuration shown in Figure 1, assemblies with single layers of gypsum board were substantially less effective in terms of providing fire resistance than assemblies with two layers on each side. In the fire tests, these single-layer assemblies, both with and without absorptive material in the cavity, failed to meet the minimum NBC requirement of 45 minutes.

All assemblies shown in Figure 1 with two layers of gypsum board on both sides were suitable for applications requiring a 45-minute fire-resistance rating. The greater fire resistance of the two-layer assemblies is due in part to the staggering of joints. Although a joint constitutes the weakest part of the face layer, the base layer underneath still offers protection after the face layer has opened. It is therefore important to specify staggered joints to fully benefit from the double layer.

Doubling the number of layers of gypsum board means doubling the mass, and since the greater the mass the better the sound attenuation, this can improve the sound performance of an assembly. However, in the case of single-row walls with no other sound-control elements (such as resilient channels and absorptive material), this translates into an improvement over single-layer applications of only about four points. Also, it is important to note that in the case of single-row load-bearing assemblies without sound-control elements, neither single- nor double-layer assemblies meet the NBC requirement for sound insulation (STC 50 or greater).

Shear Panel Replacing Gypsum Board

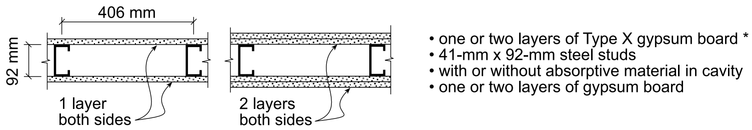
In one experiment, steel cross-bracing was omitted and the base layer of gypsum board on one side of a single-row construction was replaced with OSB shear panels (Wall Construction 3). In the fire test, the side of the wall with the shear panels was exposed to the fire. Once cracks began to form in the face layer of the gypsum board, the OSB layer burned rapidly, exposing the framing. This resulted in a significant reduction in fire resistance when compared to an assembly with two layers of gypsum board on each side.

In general, replacing one layer of gypsum board with a lighter wood-based material resulted in a slight degradation of the acoustical performance. This can be attributed to the lower mass of OSB (with a nominal thickness of 10 to 13 mm) compared to that of Type X gypsum board.

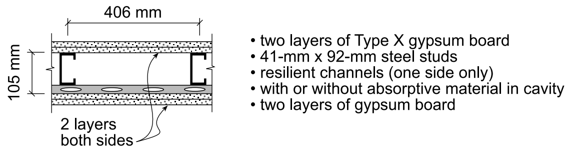
Absorptive Material in Cavity

The type of absorptive material (regular batt or loose-fill insulation) placed in the stud cavity has an influence on the fire resistance of both single-row and double-row steel-stud wall assemblies. With a single row of studs and double layers of Type X gypsum board on both sides, assemblies filled with rock and cellulose fibre insulation lasted over an hour while those filled with glass fibre lasted slightly less than an hour. This is because rock and cellulose fibre insulations remain in place slightly longer, thus protecting the framing, while glass fibre melts when exposed to fire after the gypsum board has fallen off.

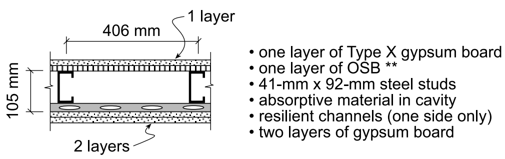
Regardless of the type of absorptive material used, however, wall assemblies with filled cavities were not as fire resistant as those with empty cavities. The primary reason for this is that the absorptive material keeps the gypsum board facing the fire hotter, causing it to crack and fail more quickly than when the cavity is empty, thus



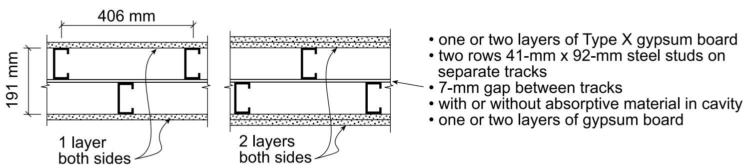
Wall Construction 1. *Single row of steel studs*



Wall Construction 2. *Single row of steel studs with resilient channels*



Wall Construction 3. *Single row of steel studs with resilient channels and shear membrane*



Wall Construction 4. *Double row of steel studs*

* All tests were carried out using Type X gypsum board, which must meet minimum fire-resistance requirements in accordance with standard CAN/CSA-A82.27-M91.
** All constructions except Wall Construction 3 had steel cross-bracing.

Figure 1. *Basic Wall Configurations Tested*

hastening the structural failure of the steel studs, which lose their ability to sustain the applied test load when directly exposed to the furnace.

While maximum fire resistance can be obtained in a wall assembly with no absorptive material, this is not compatible with achieving acceptable levels of acoustical performance. With respect to sound insulation, the placing of absorptive material in the cavity is highly desirable in controlling both direct sound transmission and potential leaks. The tests showed that the differences between various types of fibrous absorptive materials are not significant and that all types perform well in dissipating sound energy.

Effect of Resilient Channels

Resilient channels have only one purpose: to provide a discontinuity to reduce the amount of structurally transmitted sound energy through the wall framing. They usually consist of a long strip of thin steel with a stepped configuration, where one flange is attached to the stud and the other to the gypsum board. In the tests, resilient channels were attached horizontally to the fire-exposed side at 406 mm on centre perpendicular to the steel studs.

Generally, wall assemblies with resilient channels have a lower fire resistance than those without. In the testing, Wall Construction 2 with rock fibre insulation achieved a one-hour fire-resistance rating with no resilient channels while the same assembly with resilient channels obtained a 45-minute rating. This reduced fire resistance could be attributed in part to the fact that the edges of the gypsum board perpendicular to the resilient channels are unsupported, resulting in a gap between the gypsum board and the studs. This gap between the two materials is a continuous space that allows hot gases and heat to spread more quickly into the wall cavity once the gypsum board has failed.

For sound performance, resilient channels are most effective when applied to single-row walls with absorptive material in the cavity. Tests show that they can increase the STC in a wall assembly with a single row of steel studs by up to 10 points, depending on the number of gypsum board layers and the spacing of both the framing and resilient channels. For walls, spacing resilient channels at 610 mm rather than 406 mm provides a slightly improved acoustical performance (because there are fewer attachment points)—typically about 2 to 3 STC points—without affecting the fire resistance.

Summary of Findings

The study showed that the two main factors affecting the fire resistance of load-bearing steel-stud wall assemblies are the number of layers of gypsum board and the presence and type of absorptive material.[3] Doubling the number of layers of gypsum board significantly increases fire resistance and sound insulation, both with and without absorptive material; staggering the joints of the two (base and face) layers helps achieve even greater fire resistance.

Adding absorptive material (regular batt or loose-fill insulation) to the cavity to improve sound insulation causes a reduction in fire resistance; however, all assemblies tested with double layers of gypsum board on both sides would be suitable for applications where a minimum 45-minute rating is required, regardless of which of the three types of insulation is used. To maximize acoustical performance, the type of absorptive material chosen is not overly important, but it should completely fill the cavity. Adding

Table 1. Effects of the various assembly parameters studied

Parameter	Effect on Fire Resistance Rating (FRR)	Effect on Sound Transmission Class (STC)
Using two rows of studs rather than one	↑	↑
Doubling the number of layers of gypsum board	↑	↑
Replacing layer of gypsum board with shear panel	↓	↓
Adding absorptive material to the cavity	↓	↑
Adding resilient channels	↓	↑

↑ Increased performance

↓ Decreased performance

absorptive material is most effective where a structural discontinuity is present; for example, in double-row stud assemblies on separate tracks or in single-row stud assemblies with resilient channels. In both cases, completely filling the cavity can result in an increase of 8 to 10 STC points compared to an empty cavity.

For a single-row wall assembly, isolating the gypsum board on one side using resilient channels is key to achieving good sound insulation. Unfortunately, resilient channels can decrease the fire resistance, especially when there is only a single layer of gypsum board mounted on the resilient channels. Adding another layer of gypsum board to the side of the assembly with resilient channels will improve both fire resistance and sound insulation.

In fact, many of the requirements for good fire resistance are not compatible with those for sound insulation, and vice versa. Consequently, proper consideration of the various performance trade-offs (see Table 1) is needed when selecting a wall that must satisfy both fire-resistance and sound-insulation rating requirements.

Impact on the Industry

The data obtained from this research project are being used to generate new tables of FRR and STC ratings for inclusion in the NBC.

A more detailed discussion of the factors affecting sound insulation can be found in reference [3] along with the measured STC ratings. For more detailed information about the factors affecting fire resistance, specifically the table of results, see reference [2].

Footnotes

1. The information in this CTU is based on results from an extensive industry-supported research project carried out by the National Research Council's Institute for Research in Construction (IRC). The project was supported by a consortium that included: Canadian Home Builders Association, Canadian Steel Construction Council, Canadian Sheet Steel Building Institute, Canadian Wood Council, Cellulose Insulation Manufacturers Association of Canada, Forintek Canada Corporation, Gypsum Manufacturers of Canada, Owens Corning Canada Inc. and Roxul Inc.
2. The 1994 study was supported by a consortium that included Canada Mortgage and Housing Corporation, Canadian Sheet Steel Building Institute, Cellulose Insulation Manufacturers Association of Canada, Forintek Canada Corporation, Gypsum Manufacturers of Canada, National Research Council Canada (Institute for Research in Construction), Owens-Corning Fiberglas Canada Inc. and Roxul Inc.
3. It should be noted that the fire resistance of wall assemblies presented here is dependent on a number of other factors such as fastener spacing, quality of gypsum board (manufacturer), load level, etc. Detailed information on these factors are given in the IRC Internal Reports.

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