Results of Fire Resistance Tests on Full-Scale Insulated and Non-Insulated Gypsum Board Protected Wall Assemblies

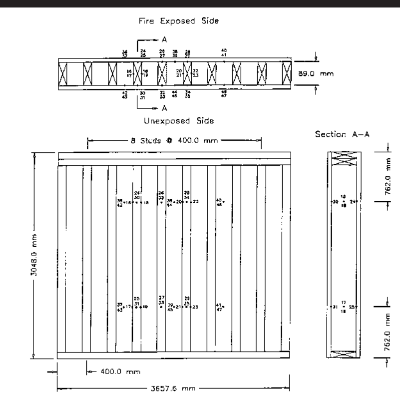
Introduction

When the CSA standard for "Gypsum Board Building Materials and Products," CAN/CSA-A82.27, was revised in 1991, the mass per unit area requirement for gypsum board products was removed. About the same time, changes to the 1990 edition of the National Building Code of Canada increased the required sound transmission ratings between dwellings. Concerns regarding the effect of these changes on the fire resistance of insulated and non-insulated gypsum board protected wall assemblies prompted this joint research project by Canada Mortgage and Housing Corporation (CMHC), the Institute for Research in Construction at the National Research Council, and seven industry partners (Canadian Home Builders Association, Canadian Sheet Steel Building Institute, Cellulose Insulation Manufacturers Association of Canada, Fiberglas Canada Inc., Forintek Canada Inc., Gypsum Manufacturers of Canada and Roxul Inc.).

Research Program

Twenty-two full-scale assemblies, 3,048 mm high by 3,658 mm wide, were tested in a propane-fired vertical furnace. To simulate loads on a load-bearing assembly, a loading system consisting of two steel frames was located at the top and bottom of the wall assembly, and eight hydraulic jacks were used to provide a vertical load to the top of the wall assembly. During the test, the wall assembly was exposed to heating on the exposed side in such a way that the average temperature in the furnace followed, as closely as possible, the CAN/ULC-S101-M89 standard temperature-time curve. Thermocouples

Figure 1: Thermocouple Location in Full Scale Test F-01B



were used to monitor the temperature of the assembly. Depending on the assembly, between 24 and 77 thermocouples were placed throughout the assembly. Figure 1 shows thermocouple locations for one of the test assemblies. Nineteen thermocouples were placed on the unexposed surface of the gypsum board. Nine of the thermocouples were placed under insulated pads. Furnace and wall assembly temperatures were recorded at one-minute intervals. An assembly was considered to have failed if:

(i) a single-point thermocouple temperature reading on the unexposed face rose above 180 °C;
(ii) the average temperature of the nine thermocouples under the insulated pads on the exposed face rose 140 °C above the ambient temperature (approximately 22 °C); or
(iii) there was passage of flame or gases hot enough to ignite cotton waste.

Cette publication est aussi disponible en français sous le titre : *Résultats d'essais de résistance au feu menés sur des murs à grande échelle, isolés et non isolés, protégés par des plaques de plâtre*

Similar tests were performed on 48 small-scale assemblies. The results of the small-scale tests are summarized in CMHC's R&D Highlight 96-212.

Test Assemblies

Five different gypsum boards were included in the testing:

(i) Type X gypsum, 12.7 mm thick;
(ii) Type X gypsum, 15.9 mm thick;
(iii) regular gypsum, 12.7 mm thick (7.82 kg/m^2);
(iv) low-density regular gypsum, glass fibre in the gypsum core, 12.7 mm thick (7.35 kg/m^2); and
(v) low-density regular gypsum, no glass fibre in the gypsum core, 12.7 mm thick (7.27 kg/m^2).

The gypsum board was mounted on 90-mm steel studs at 600-mm spacing or 89-mm wood studs at 400-mm spacing (one test used 600-mm spacing). Either one or two layers of gypsum were mounted on both sides of the studs. In seven of the assemblies, resilient channels were used and a load was applied to 13 of the assemblies. Three insulation types were used: glass fibre insulation (R 12 and R13); mineral fibre insulation (R13); and cellulose fibre insulation (4.57 kg/m^2 and 5.25 kg/m^2).

Table 1 summarizes the assemblies tested and, for each assembly, the time to failure and the mode of failure.

Results

To aid in reporting, the chosen reporting convention lists the layers of gypsum board on the exposed side and then on the unexposed side. For example, a 1 x 2 assembly indicates that there was one layer on the exposed side and two layers on the unexposed side.

Effects of Insulation Type

In 1 x 2 non-load-bearing steel stud assemblies, neither glass fibre insulation nor wet-sprayed cellulose fibre insulation had an effect on fire resistance ratings, while the installation of 90-mm thick mineral fibre insulation provided a 54 per cent increase in fire resistance rating over the uninsulated assembly. However, the tests showed that, to maximize the benefit of the mineral fibre insulation, it is important to install the insulation tightly between the studs. The temperature failure criterion was reached at 60 minutes with loose-fitting insulation versus 100 minutes for tight-fitting insulation.

Where resilient channels were used on the exposed side in load-bearing wood stud assemblies, the failure was predominantly due to the pilot ignition of the unprotected wood stud edges in the space created by the thickness of the resilient channels on the exposed side. The eventual reduction of the wood cross-section resulted in structural failure of the assemblies. As a result, in general, the insulation type had little effect on the fire resistance rating when resilient channels were used on the exposed side.

Table 1:
Description of Assemblies Tested and Fire Test Results

Assembly Number	Stud Type	Stud Size (mm)	Stud Rows	Stud Spacing (mm)	Gypsum Board Layers (Exp/Unexp.)	Gypsum Board Thickness (mm)	Gypsum Board Type	Insulation Type	Insulation Thickness (mm)	Resilient Channel	Load	Fire Rating (min)	Mode Of Failure
F-01	Wood	89	1	400	1x1	12.7	RL	***	***	***	Yes	33	S/F
F-01B	Wood	89	1	400	1x1	12.7	RL*	***	***	***	Yes	26	S/F
F-02	Wood	89	1	400	2x2	12.7	RL	***	***	***	Yes	53	S/F
F-02B	Wood	89	1	400	2x2	12.7	RL*	***	***	***	Yes	49	S/F
F-03	Steel	90	1	600	2x2	12.7	RL	***	***	***	No	63	Temp.
F-04	Wood	89	1	600	2x2	12.7	RL	***	***	***	No	65	Temp.
F-05	Steel	90	1	600	2x2	12.7	RH	***	***	***	No	69	Temp.
F-06	Steel	90	1	600	1x1	15.9	X	***	***	***	No	52	Temp.
F-07	Steel	90	1	600	1x2	12.7	X	***	***	***	No	65	Temp.
F-08	Wood	89	1	400	1x2	12.7	X	GFI	89	E	Yes	51	S/F
F-09	Steel	90	1	600	1x2	12.7	X	GFI	90	***	No	65	Temp.
F-10	Steel	90	1	600	1x2	12.7	X	MFI*	90	***	No	60	Temp.
F-10B	Steel	90	1	600	1x2	12.7	X	MFI**	90	***	No	100	Temp.
F-11	Steel	90	1	600	1x2	12.7	X	CFI*	90	***	No	62	Temp.
F-12	Wood	89	1	400	1x2	12.7	X	MFI	89	E	Yes	52	S/F
F-13	Wood	89	1	400	1x2	12.7	X	CFI	89	U	Yes	56	S/F
F-14	Wood	89	1	400	1x2	15.9	X	GFI	89	E	Yes	52	S/F
F-14B	Wood	89	1	400	1x2	15.9	X	GFI	89	E	Yes	51	S/F
F-15	Wood	89	2*	400	1x2	12.7	X	GFI*	89	***	Yes	51	S/F
F-16	Wood	89	2**	400	1x1	15.9	X	GFI*	89	***	Yes	59	S/F
F-17	Wood	89	1	400	1x2	12.7	X	MFI	89	U	Yes	58	S/F
F-18	Wood	89	1	400	2x2	12.7	X	GFI*	89	E	Yes	79	S/F

Notes to Table

X Type X gypsum
MFI Mineral fibre insulation
RL Low-density regular gypsum board
MFI* MFI, 584-mm wide batts
RL* RL, no glass fibre in gypsum core
MFI** MFI, 615-mm wide batts
RH Regular gypsum board
CFI Cellulosic fibre insulation (blown dry)
GFI Glass fibre insulation (R12)
CFI* CFI (wet sprayed)
GFI* Glass fibre insulation (R13)
E Exposed side
U Unexposed side

In 1 x 2 load-bearing wood stud wall assemblies with resilient channels installed on the unexposed side, the assembly with mineral fibre insulation provided a slightly better fire resistance rating than the assembly with dry-blown cellulose fibre insulation.

Effect of Resilient Channels

It was found that the location of the resilient channels plays an important role in the fire resistance rating. In a load-bearing 1 x 2 wood stud assembly with mineral fibre insulation, the assembly with resilient channels installed on the unexposed side provided 11 per cent better fire resistance rating than the assembly with resilient channels installed on the exposed side.

In load-bearing wood stud walls with resilient channels on the exposed side, it was found that gypsum board thickness does not make a difference to the fire resistance rating. The gypsum board joints were the dominant factor in the failure of load-bearing wall assemblies with resilient channels on the fire-exposed side. Thus, a second layer of gypsum on the fire-exposed side, with staggered joints, provided a 55 per cent increase in fire resistance rating compared to an assembly with a single layer on the exposed side.

Effects of Single Plate vs. Double Plate in Staggered Stud Assemblies

The fire resistance of a load-bearing 1 x 2 staggered wood stud assembly with a single plate was compared with that of a load-bearing 1 x 1 assembly with separate plates. There was a 16 per cent improvement of the fire resistance rating of the assembly with separate plates as opposed to the assembly with a single plate (51 minimum vs. 59 minimum).

Effects of Glass Fibre in Regular Lightweight Gypsum Board Core

The presence of glass fibre in the gypsum core of a 1 x 1 assembly using lightweight regular gypsum board provided a 27 per cent increase in fire resistance over a similar board without fibreglass in the core. In a 2 x 2 wall, however, the improvement was much smaller.

Effects of Mass per Unit Area of Regular Gypsum

In a 2 x 2 non-load-bearing steel stud assembly, heavier gypsum board (7.82 kg/m^2) provided 10 per cent better fire resistance performance than lightweight (7.35 kg/m^2) gypsum board.

Effects of Stud Type

In 2 x 2 non-load-bearing walls, the assembly with wood studs demonstrated a slightly better fire resistance performance than an assembly with steel studs but, taking into account the systematic error of the test method, the difference was insignificant.

Correlation of Small-Scale and Full-Scale Tests

The 22 full-scale tests reported in this R&D Highlight were correlated with the 49 small-scale tests reported in Highlight 96-212. The fire resistance ratings obtained using small-scale tests correlated well with results obtained with full-scale tests. For non-load-bearing wall assemblies, the full-scale fire resistance rating equalled 0.7 times the small-scale fire resistance rating. For load-bearing wall assemblies, the full-scale fire resistance rating equalled 0.6 times the small-scale fire resistance rating.

Implication for the Housing Industry

The study revealed that the mass per unit area of the gypsum board did have an effect on the fire resistance performance of the assemblies. As the requirement for mass per unit area has been removed from the CAN/CSA-A82.27 Standard, "Gypsum Board Building Materials and Products," designers may have to specify more than just the thickness of gypsum board for fire-rated assemblies.

Of particular concern, a non-load-bearing steel stud assembly with 15.9-mm thick Type X gypsum board on both sides was found to provide a 52-minute fire resistance rating, thus failing to provide the one-hour fire resistance rating specified by CAN/CSA-A82.27-M91.

The use of mineral fibre insulation can significantly improve the fire resistance rating of non-load-bearing 1 x 2 steel stud walls. However, when resilient channels were used on the exposed side of wood stud walls, the insulation type had little effect on the fire rating resistance.

The use of resilient channels is likely to become more prevalent in light of the more stringent National Building Code requirements for sound transmission ratings between dwellings. It was found that, due to the mode of failure, the location of resilient channels (exposed vs. unexposed side) played an important role in the fire resistance rating of load-bearing walls. Designers may have to redesign walls to ensure that adequate sound transmission class and fire rating resistance can be achieved. Where resilient channels were located on the exposed side of wood stud walls, two layers of gypsum with staggered joints greatly improved the fire resistance rating.

For non-load-bearing and load-bearing walls, a correlation was found between the small-scale tests and the full-scale tests. Thus, designers will have a conservative means of determining the fire resistance rating of a full-scale wall assembly through less expensive small-scale testing.

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Research Consultant: *National Research Council Canada, National Fire Laboratory*

Research Report: *Results of Fire Resistance Tests on Full-Scale Insulated and Non-Insulated Gypsum Board Protected Wall Assemblies, 1996.*

A full report on this research project is available from the Canadian Housing Information Centre at the address below.

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