

Fire Protection

CANADIAN STEEL CONSTRUCTION COUNCIL

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Practical Fire Protection in Cold Formed Steel Framed Buildings

Introduction

Fire Protection Bulletin No. 22, issued January 1996, outlines the requirements for fire-resistance ratings and fire protection as contained in the 1995 National Building Code of Canada (NBCC). Emphasis in that Bulletin is given to Part 3 - Fire Protection, Occupant Safety and Accessibility - of the NBCC, and most buildings using hot rolled steel framing systems would have to comply with this Part.

Buildings using cold formed steel framing systems - whether custom designed or pre-engineered - would also have to comply with Part 3. Smaller buildings could also be designed under Part 9 of the NBCC - Housing and Small Buildings (see NBCC Subsections 2.1.2. and 2.1.3. for applicability). Both Part 3 and Part 9 of the NBCC contain essentially the same requirements for fire protection, occupant safety and accessibility. Part 9 however includes extensive prescriptive requirements that enable buildings to be designed without the benefit of the services of either an architect or engineer.

Fire Protection Bulletin No. 22 describes how to establish the necessity for fire protection. This Fire Protection Bulletin provides some solutions to common fire protection requirements in the NBCC that the designer of a cold formed steel framed or pre-engineered building might encounter. While these details are primarily applicable to cold formed steel construction, many are equally applicable to buildings incorporating hot rolled structural members.

Applicability

Fire-resistance ratings in the NBCC are normally applied to floor assemblies, roof assemblies, supporting elements (such as columns), and walls (interior and exterior).

Most buildings using cold formed steel framing systems will rarely require fire-resistance ratings exceeding 1 h for their construction. Therefore, except where appropriate, fire-resistance ratings of more than 1 h are not covered in this Bulletin.

NBCC Sprinkler Requirements

The 1995 NBCC has placed significantly increased emphasis on supervised and monitored sprinkler systems as a primary means of fire safety. While this has not as yet resulted in any major relaxations in passive fire-resistance requirements, there are benefits for fully sprinklered buildings. These benefits include:

- 1 Waiving of fire-resistance ratings to roof assemblies in buildings otherwise required to have them;
- 2 Increased *Area* (doubled in most instances) for a given type of construction (such as combustible or non-combustible, rated or non-rated);



Algoma Steel Inc. • Dofasco Inc. • Sidbec-Dosco Inc. • Stelco Inc.
Canadian Fasteners Institute • Canadian Institute of Steel Construction • Canadian Sheet Steel Building Institute
Canadian Steel Service Centre Institute • Corrugated Steel Pipe Institute • Canadian Welding Bureau (Associate Member)

- 3 No restrictions or requirements on number of streets faced; and
- 4 Greatly reduced Limiting Distance requirements relating to exterior wall construction.

With these advantages in mind, and considering the relative inexpensiveness of modern sprinkler systems (usually around \$12/m² and invariably under \$15/m² of floor area for an ordinary hazard system - 1996 prices typical in most parts of Canada), it is almost always economically advantageous to sprinkler Part 3 buildings. This Bulletin therefore assumes that all cold formed steel framed or pre-engineered buildings designed under Part 3 and requiring fire protection will be sprinklered: fire protection requirements relating solely to non-sprinklered buildings (such as fire-resistance ratings to roof assemblies) are not covered.

(See also NBCC Sentence A-3.2.5.13.(6) for an explanation of some assumptions inherent in using sprinklers in lieu of fire-resistance ratings to roof assemblies.)

Fire Protection Design Methods

There are two primary methods of designing fire protection to an assembly in order to achieve a fire resistance rating. These are:

- 1 Application of an Underwriters Laboratories of Canada (ULC), Underwriters Laboratories Inc. (ULI) or Inchcape Testing Services-Warnock Hersey Listed Design;

- 2 Application of generic materials and assemblies as listed in NBCC Appendix D - Fire-Performance Ratings.

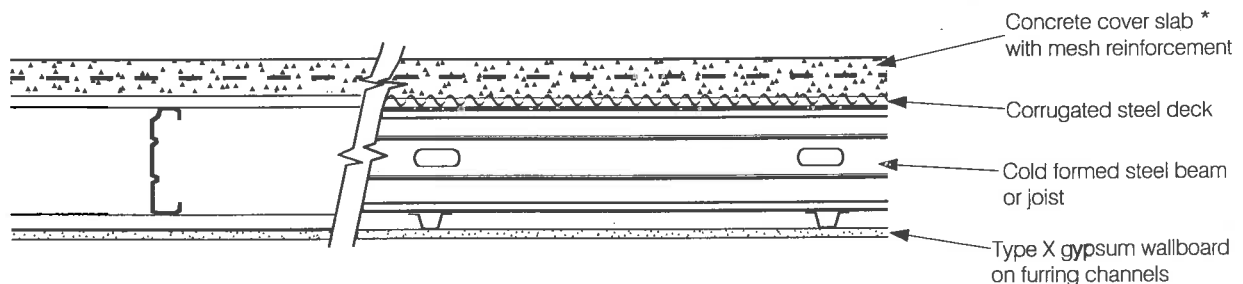
Wherever possible in the design solutions that follow, both a Listed Design and an assembly from Appendix D will be given. However, it should be noted that fire rated assemblies in Appendix D are generally much more conservative than equivalent Listed Designs, with commensurate cost penalties. Appendix D is most useful where there is no suitable Listed Design for a particular fire protection problem.

There are no Listed Designs utilising proprietary direct-applied (sprayed-on fibrous or cementitious) coatings to cold formed steel structural members. And while Appendix D of the NBCC still lists metal lath and plaster as a component in generic fire rated assemblies, this is both very expensive and extremely rare in the 1990s, as well as being generally inappropriate for cold formed steel framed or pre-engineered buildings. Consequently all the design solutions in this Bulletin involve the use of gypsum wallboard as the primary fire protection medium.

The diagrams that follow are schematic representations only of either Listed Designs or construction assemblies described in NBCC Appendix D. However, notwithstanding what is depicted in this Bulletin, all construction details of the selected assembly, either shown or described in the published Listed Design or Appendix D, must be followed **exactly**.

Floor Assemblies

Floor assemblies may consist of framing systems that utilise hot rolled beams, open web steel joists, cold formed joists, or a combination of all three. The floor construction may consist of steel deck with a concrete cover slab (such as is typified below), or a wood subfloor with a finish applied (NBCC Sentence D-2.3.5.(3), Table D-2.3.5.). Any beams or joists completely contained within the assembly are considered to be protected by the assembly (NBCC Article D-2.3.13.).



* Slab to be minimum thickness as specified in selected Listed Design, or else 50 mm (NBCC Table D-2.3.5.).

Floor Assemblies (Cont'd)

The diagram on Page 2 is representative of floor framing using cold formed steel joists with a corrugated steel deck and concrete topping. ULI Design No. G534 is typical of this construction, and is rated for 1 h. For a 2 h rating, a 25 mm layer of insulation must be added above the gypsum wallboard, such as is shown in ULI Design No. G533.

Appendix D:

Using NBCC Appendix D for floor assemblies is often significantly less economical than using a Listed Design, and sometimes may not even be usable at all.

It is not possible for instance to use Appendix D to design a 1 h rated cold formed steel framed floor assembly similar to that shown on the previous page (with just one layer of gypsum wallboard) by using the Component Additive Method - i.e. adding the individual time contributions assigned to various components (Article D-2.3.3.).

For example, Table D.2.3.4.A. assigns a time of 40 min for one layer of 15.9 mm Type X wallboard as its contribution to the total assembly. To this can be added the contribution for the light steel frame of 10 min (Table 2.3.4.C.), for a total of only 50 min.

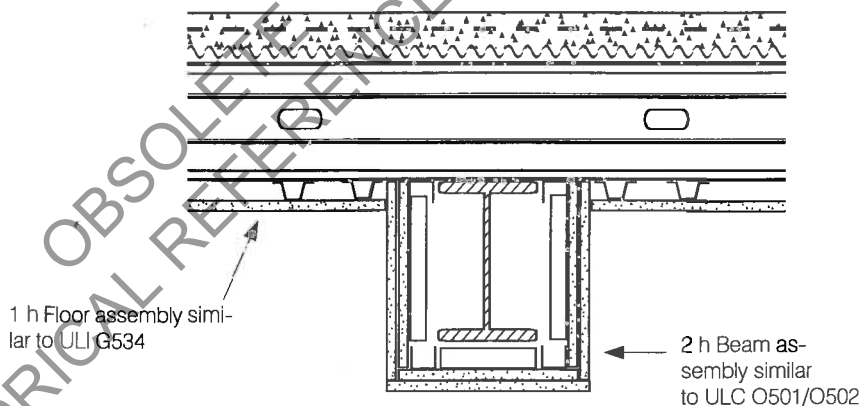
When using the Component Additive Method, where the time assigned to the wallboard is not a stand-alone time but merely its individual contribution to the total assembly rating, double layers of gypsum wallboard are not permitted, except as listed in Table D-2.3.4.A. (Sentence D-2.3.3.(3)).

To achieve a fire-resistance rating for such a floor assembly by using Appendix D, it is therefore necessary to resort to Table D-2.3.12., where the ceiling membranes listed have a full fire-resistance rating in their own right (i.e. they do not have to be part of an assembly). Here, two layers of 15.9 mm Type X wallboard are assigned 60 min, while two layers

of 12.7 mm Type X wallboard are assigned 45 min. The ceiling membrane cannot be penetrated (NBCC 2.3.12.), while the contribution of the steel frame is ignored. (See also Assemblies M1 and M2 in NBCC Table A-9.10.3.1.B.)

Projecting Beams:

If a beam that is part of the structure projects below the ceiling membrane, a combination of two Listed Designs may need to be used, as shown below. The 2 h rating for the beam would not be required in a 1 h rated structure - it's just that there are no 1 h rated beam Listed Designs using gypsum wallboard. Appendix D contains no beam protection details using gypsum wallboard.

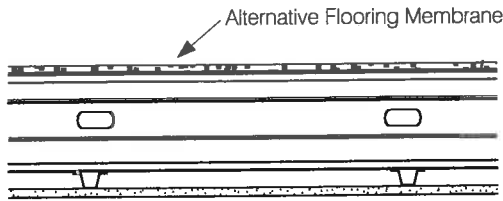


In this example, the construction typified by ULI G534 has been combined with a Beam Design, such as ULC O501 or O502. Alternatively, the same result can be achieved by using ULI L524. In each of these cases, the actual construction details vary between the Designs, and the designer must select the most appropriate.

Alternative Floor Construction:

The floor assemblies depicted so far have shown a corrugated steel deck with a concrete cover slab over. NBCC Table D-2.3.5. lists the permissible combinations of flooring membranes where cold

Floor Assemblies (Cont'd)



formed steel members are used. There are also various floor systems listed in a number of the ULI Listed Designs using cold-formed members, such as L527.

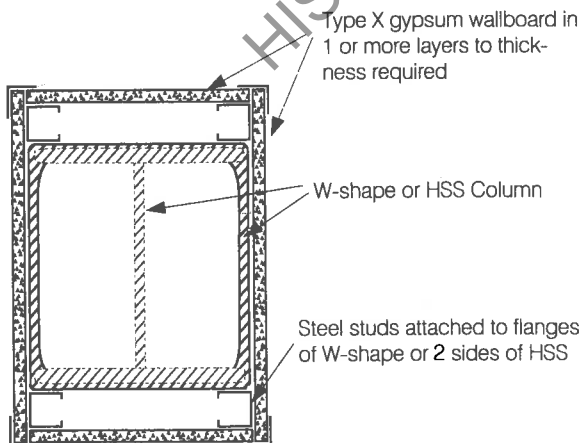
The most common alternative flooring membrane consists of tongued-and-grooved plywood, usually no less than 16 mm thick, to which a floor finish is applied. Some finishes require an additional plywood subfloor in order to achieve the full assembly fire-resistance rating. A number of Listed Designs include a wide variety of proprietary floor systems.

In all cases, the subfloor must be secured to the steel structural members either by specified fasteners, specified adhesive or a combination of the two.

Columns

Where hot rolled columns are used, either wide-flange section (W) or hollow structural section (HSS), they can be protected using both Listed Designs and NBCC Appendix D. Note that, while Appendix D specifically calls for Type X wallboard, all Listed Designs merely describe the wallboard that was actually tested. However, almost without exception, the tested wallboard in those Designs meets the specifications for, and in fact is, a Type X wallboard.

The following diagram illustrates typical assembly details for fire protection employing one layer of Type X gypsum wallboard. Additional layers (up to four, and usually with corner reinforcements beyond two) can be added where permitted.



Most Listed Designs for 1 h rated W-shape columns utilise no more than two layers of wallboard against the column's flanges (parallel to the web), and one or two layers attached to the steel studs at each end parallel to the flanges. Often, the inner layer is attached directly to the flanges, inside of the studs. Corner beads are required at each corner.

Typical of this construction are ULI Designs Nos. X524 and X528. For example, X528 lists a variety of W-shape and HSS sizes, with varying thicknesses of wallboard according to the column size. In this Design, for a 1 h fire-resistance rating, both a W150 x 22 column (which is the smallest W-shape produced in Canada) and an HSS 102 x 102 x 4.8 column require a total thickness of 25.4 mm of Type X wallboard on all four sides.

Larger sized columns in this Design require less thickness for the same 1 h rating - a W250 x 73 column requires 12.7 mm, while an HSS 203 x 203 x 6.4 column requires 15.9 mm, both thicknesses being achievable with one layer.

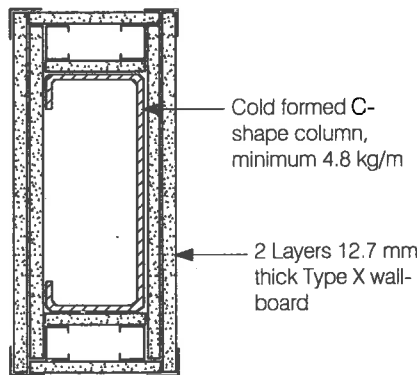
ULI X524 takes a slightly different approach. The minimum column size is defined by the column's M/D Ratio (see next page), which in this case is $M/D = 16$. This Design also includes integration with 'C' or 'Z' girts that are part of an adjacent wall assembly.

In all column designs using gypsum wallboard, no horizontal joints are allowed, and the wallboard must be attached with the specified fasten-

Columns (Con't)

ers. Some Designs require tie wire and/or additional steel corner reinforcements for multiple layers beyond two.

There are also 1 h (and 2 h) rated ULI Listed Designs using cold formed C-shape steel columns. One such Design is ULI X530, similar to the following diagram:



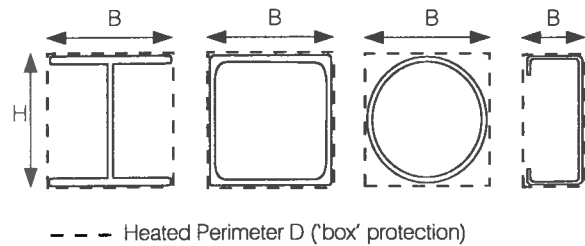
As an alternative to Listed Designs, NBCC Appendix D contains Table D-2.6.1.F. listing the required thickness of Type X gypsum wallboard according to the M/D Ratio of a column. As column fire tests are calculated only on temperature (i.e. failure is determined solely by the temperature of the steel, without any applied load), this Table can be applied to steel columns of any shape or section, including cold formed shapes.

The M/D Ratio of a column is determined as shown below, where M = the column's Mass (in kg/m), and D = the column's Heated Perimeter (in m). The heated perimeter is equivalent to the inside (non-exposed) face of the fire protection medium - in this case the inside face of the wallboard.

Notwithstanding this definition, NBCC Appendix D (Sentence D-2.6.4.(2).) defines the calculation of D, for columns using 'box'-shaped fire protection, as follows:

$$D = 2(B + H)$$

(See Diagram above.)



When using Table D-2.6.1.F. of Appendix D, for 1 h ratings, the following values are applicable in the context of this Bulletin. Note that it is possible to increase either the wallboard thickness or the M/D Ratio, or both, in order to meet these values.

Minimum Thickness of Type X Wallboard, mm	Minimum M/D Ratio
12.7	75
15.9	55
25.4	35

There are no values for columns with an M/D Ratio of less than 35, this being the minimum for which data is available on the Heated Perimeter concept. For columns with an M/D Ratio of less than 35, use a Listed Design.

As a comparison with Listed Designs, the M/D Ratio of the W150 x 22 column in ULI X528, for which the required wallboard thickness is 25.4 mm, is 36, while the W250 x 73 column, for which the required thickness is 12.7 mm, has an M/D Ratio of 72.

The specified minimum size of cold formed C-shape in ULI X530, at 4.8 kg/m and with 'box' protection, has an M/D Ratio of under 10. This means that for very light steel columns, Table D-2.6.1.F. cannot be used.

Finally, the use of HSS columns permits the use of concrete filling as a means of fire protection. Fire Protection Bulletin No. 21, issued November 1994, explains the methodology in detail. Appendix D of the NBCC also includes the same procedure (Subsection D-2.6.6.), which means that there should be no problem in having it accepted by the authority having jurisdiction.

Loadbearing Walls

(Note: Although both Canadian and US dictionaries of architectural terminology specifically define a partition as being either loadbearing or non-loadbearing, the NBCC defines a partition as being only non-loadbearing (Article 1.1.3.2. - *partition*). The NBCC definition is used in this Bulletin.)

A loadbearing wall will require a fire-resistance rating if it is part of, or a supporting element in, the building's structural frame (and assuming that frame is rated as required by the NBCC). Walls subjected to only wind or earthquake loads are not loadbearing (NBCC Article 1.1.3.2. - *loadbearing*).

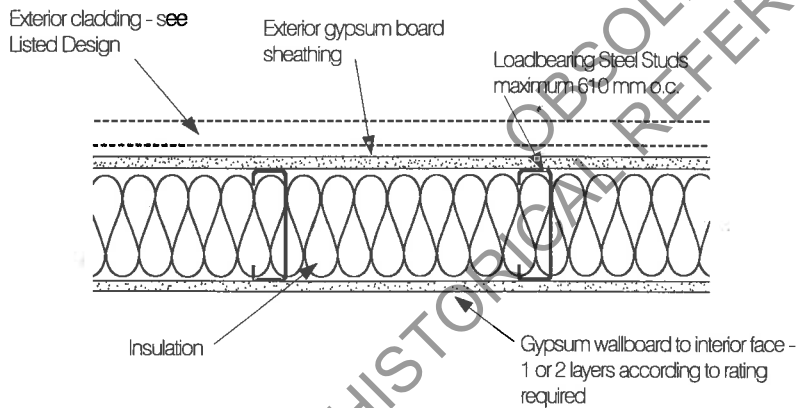
In addition, loadbearing exterior walls will need a fire-resistance rating if the NBCC's Limiting Distance provisions need to be satisfied, while interior walls, if they are fire separations, may also need a fire-resistance rating. Not all interior separations must be rated.

Exterior walls and interior walls are treated differently. The exterior wall needs to be rated only from fire exposure on the interior side. The interior wall must be rated from both sides.

If using the Component Additive Method in NBCC Appendix D to design a fire rated interior wall, no contribution can be attributed to the membrane on the unexposed face (NBCC D-2.3.5.(1)).

Exterior Loadbearing Walls:

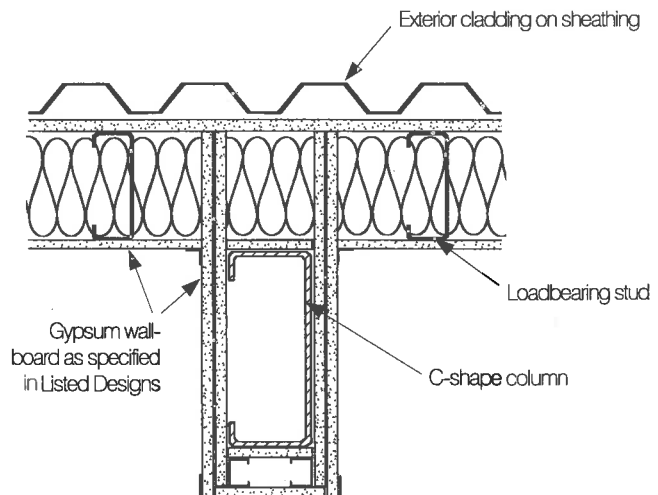
Generally, the most economical fire rated loadbearing exterior wall assemblies are Listed Designs, such as ULI U418 or U425 (there are no equivalent ULC or Warnock Hersey Listed Designs). The following diagram is representative of this type of construction. Note that such Designs often permit both glass fibre batts and mineral wool insulation, as well as a variety of exterior facings.



If the wall falls under the NBCC Limiting Distance requirements (Subsection 3.2.3.), then both the insulation and the exterior cladding must satisfy Article 3.2.3.7., Sentences (1) to (9) as appropriate. Many Designs also require some form of lateral support or bridging, by such means as horizontal steel straps or channels.

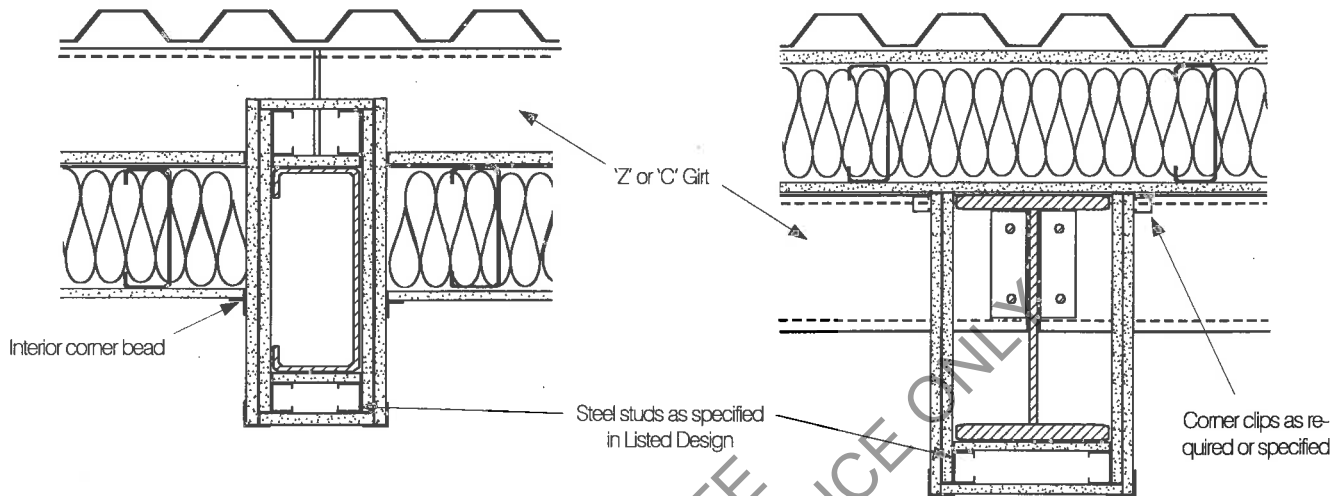
Wall and column Designs can be combined, as in the diagram opposite.

This detail is similar to that illustrated in Listed Design ULI U489, which is itself a combination of other ULI Listed Designs (X524 or X530 for the column components, U425 for the wall components).



Loadbearing Walls (Cont'd)

The following diagrams represent additional configurations of the loadbearing wall/column interface, incorporating C-shape and W-shape sections for the column. The exterior cladding in these examples is a profiled steel siding on 'Z' or 'C' girts. The girts may be positioned either inside or outside the loadbearing stud wall and/or column.



There are no fire rated loadbearing assemblies in the NBCC, in either Part 9 or Appendix D.

Interior Loadbearing Walls:

The most economical Canadian Listed Design for interior loadbearing walls is ULC W424. This Design consists of steel studs maximum 600 mm on centre, 38 mm wide channel section horizontal lateral bridging members maximum 1200 mm on centre passing through the stud cutouts and attached to each stud with brackets, and for a 1 h rating, one layer of 15.9 mm Type X wallboard each side. For a 1 h rating, there is no load restriction.

There are similar or equivalent ULI Designs, some requiring interior insulation to provide the required rating, but dispensing with the horizontal bridging (unless this is required for other structural reasons). Some of the ULI exterior wall Designs can also be used as an interior wall, such as ULI U425. In this case, the gypsum wallboard required for the interior side of an exterior wall is applied to both sides of the interior wall. All other details, including any wall/column interface, still apply.

Non-Loadbearing Walls and Partitions

Non-loadbearing exterior walls would require a fire-resistance rating if they are in close proximity to the property line or another building, and fall under the NBCC's Limiting Distance requirements. For more information on calculating any required fire-resistance in this situation, see Fire Protection Bulletins Nos. 20 and 24.

Non-loadbearing interior walls and partitions would require a fire-resistance rating when used to divide a building into fire separated suites. A typical example might be a large industrial building rented out to multiple tenants, each of which must be separated from its neighbour by a fire separation having a fire-resistance rating of, say, 45 min.

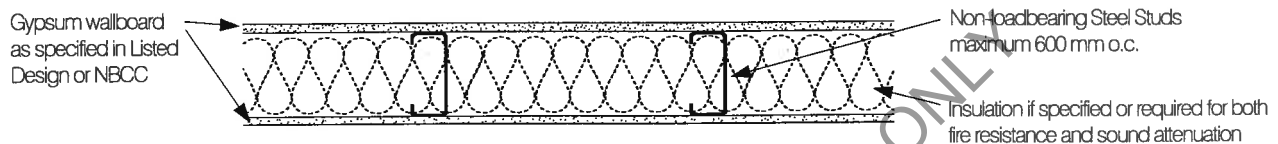
Non-Loadbearing Walls and Partitions (Cont'd)

Exterior non-loadbearing walls:

Any loadbearing fire rated wall, as shown on Pages 6 and 7, can also of course be used in a non-loadbearing situation. In addition, ULC Listed Design W605 is a generic insulated 1 h fire rated exterior wall assembly that was developed at the National Research Council - Institute for Research in Construction on behalf of the steel industry. Full details are described in Fire Protection Bulletin No. 20. No gypsum wallboard is required in this assembly.

Interior non-loadbearing walls and partitions:

There are many ULC and ULI Listed Designs for non-loadbearing interior walls and partitions. The most economical consist of steel studs and a single layer of gypsum wallboard both sides, as typified by the following diagram:



Designs typical of this construction, with a 1 h fire-resistance rating, are ULC W407 and ULC W415, both of which use 15.9 mm of wallboard each side and no insulation. There are other similar ULC Designs, such as W408, W409 or W412, that require batt insulation within the wall to achieve a 1 h rating, but require only 12.7 mm of wallboard each side. If insulation is required for sound attenuation, then these Designs are also suitable without economic penalty. Some of these insulated Designs permit 64 mm studs instead of the 92 mm studs required in non-insulated Designs.

In addition, NBCC Part 9, Table A-9.10.3.1.A - Fire and Sound Resistance of Walls - also lists similar generic assemblies. In this Table, a 45 min rating can be achieved, with no interior insulation, with Wall Numbers S1c, S4c and S4d, using one layer of

Type X 15.9 mm gypsum wallboard on each face. The addition of rockwool or slag insulation, to the densities as listed in Note (6) to Table A-9.10.3.1.A, will increase the rating to 1 h, as specified in Wall Numbers S1a, S1b, S4a or S4b.

Alternatively, for a 1 h rating, an additional layer of gypsum wallboard one side can be applied, as shown in Wall Numbers S2a to S2h. Table A-9.10.3.1. also lists numerous similar assemblies, where the same fire-resistance rating is achieved, but with different sound transmission class (STC) ratings. Selection therefore may depend on the required STC rating as much as the required fire-resistance rating.

The following diagram illustrates the integration of a wall with a column, both having a fire-resistance rating of 1 h.

