Lightweight Steel Framing

ARCHITECTURAL
DESIGN GUIDE

CANADIAN SHEET STEEL BUILDING INSTITUTE

PREFACE

This publication is intended as a guide for designers, specifiers and users of lightweight steel framing (LSF). LSF products are cold formed structural members used as studs, joists, rafters, purlins and girts and in assemblies such as steel roof trusses and panelized walls.

The Canadian Sheet Steel Building Institute would like to acknowledge the contribution of Mr. Tom Trestain, P. Eng., of T.W.J. Trestain Structural Engineering, for his work as a consultant retained for the preparation of this publication. Mr. Trestain is experienced in the design and erection of LSF products and is an active member on the CSA Technical Committee responsible for CSA S136, "North American Specification for the Design of Cold-Formed Steel Structural Members." In addition, Larkin Architect acted as both architectural and technical advisors, and their contribution has been gratefully received.

The material in this publication has been prepared for the general information of the reader. While the material is believed to be technically correct and in accordance with recognized good practice at the time of publication, it should not be used without first securing competent professional advice with respect to the suitability for any given application. Neither the Canadian Sheet Steel Building Institute, its members, T.W.J. Trestain Structural Engineering nor Larkin Architect warrant or assume liability for the suitability of the material for any general or particular use.

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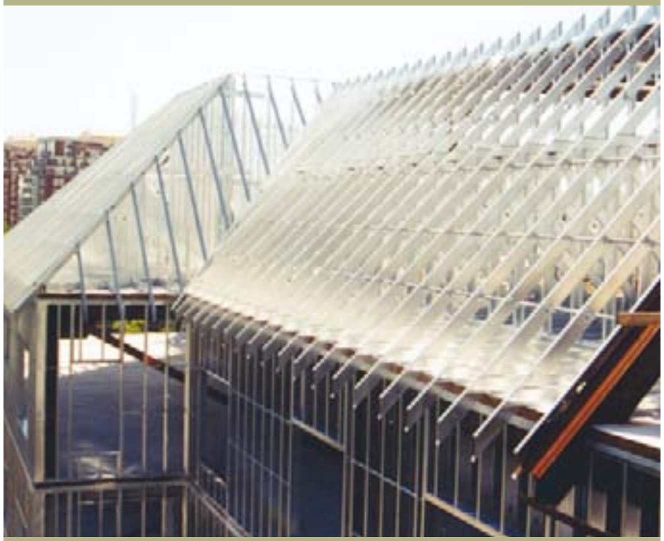

SCOPE AND PURPOSE OF GUIDE

This publication was written to assist practicing Architects with the selection, design and detailing of wall and floor systems incorporating lightweight steel framing (LSF) members for low rise commercial and medium and high rise residential applications. It is the logical complement to the "Lightweight Steel Framing Design Manual" published in 1991 by the CSSBI as a design guide for Structural Engineers.

A general description of lightweight steel framing products is presented along with a review of the advantages of this type of construction. Building science issues are discussed and the application of these principles is illustrated in a specific way for masonry veneer steel stud systems in low-rise commercial construction. A proposal for the allocation of design and construction responsibilities on a typical LSF project is also included. Lastly, a compendium of architecturally relevant technical information is provided:

- Available structural standards, guides and research
- Air leakage data for typical air barrier materials
- Fire ratings for floor and wall assemblies
- Sound transmission class ratings for floor and wall assemblies
- Heat loss data for wall assemblies
- Durability data
- Air leakage data for various air barrier

The Guide does not provide specific information on structural design issues for masonry veneer steel stud wall systems with the exception of the overview on design deflection limits and brick tie selection in Appendix E. Designers are referred to the references in Appendix G and in particular the CSA structural design standards for more information on this topic.

DESCRIPTION OF LIGHTWEIGHT STEEL FRAMING SYSTEMS

Wind Bearing Studs

Wind bearing studs are flexural members used in exterior wall systems. They are not designed to support axial loads other than self weight and weight of attached finishes.

These members provide structural back-up for a variety of exterior finishes including masonry veneer, metal cladding, stucco, synthetic veneers and exterior insulation and finish systems (EIFS). Interior finishes such as gypsum drywall can be attached directly to the studs.

Figure 1 illustrates a typical wind bearing stud application (excluding finishes). A number of features are illustrated in this figure including double jamb studs at typical window openings, steel bridging and a top track deflection detail. This deflection detail allows the floors to deflect without loading the studs axially and is shown enlarged in Figure 2. Several other deflection details are also used by the industry to achieve the same end.

Axial Loadbearing Studs with Joists and Rafters

Axial loadbearing studs, joists and rafters combine to create a complete structural system for a building. Such a system is illustrated in Figure 3, which includes typical platform construction details. For joists parallel, an alternative wall detail has been shown where the studs are not interrupted by the floor joist system as is typical in platform construction.

Figure 4 illustrates platform construction at an exterior floor to wall intersection. Figure 5a illustrates the same detail using balloon framing and Figure 5b shows balloon framing with a splice in the studs.

Platform type construction has been borrowed from the housing industry and has the advantage that each floor acts as a working "platform" for the construction of the next storey. Balloon framing, while less common, offers simplified structural details at floor to wall intersections.

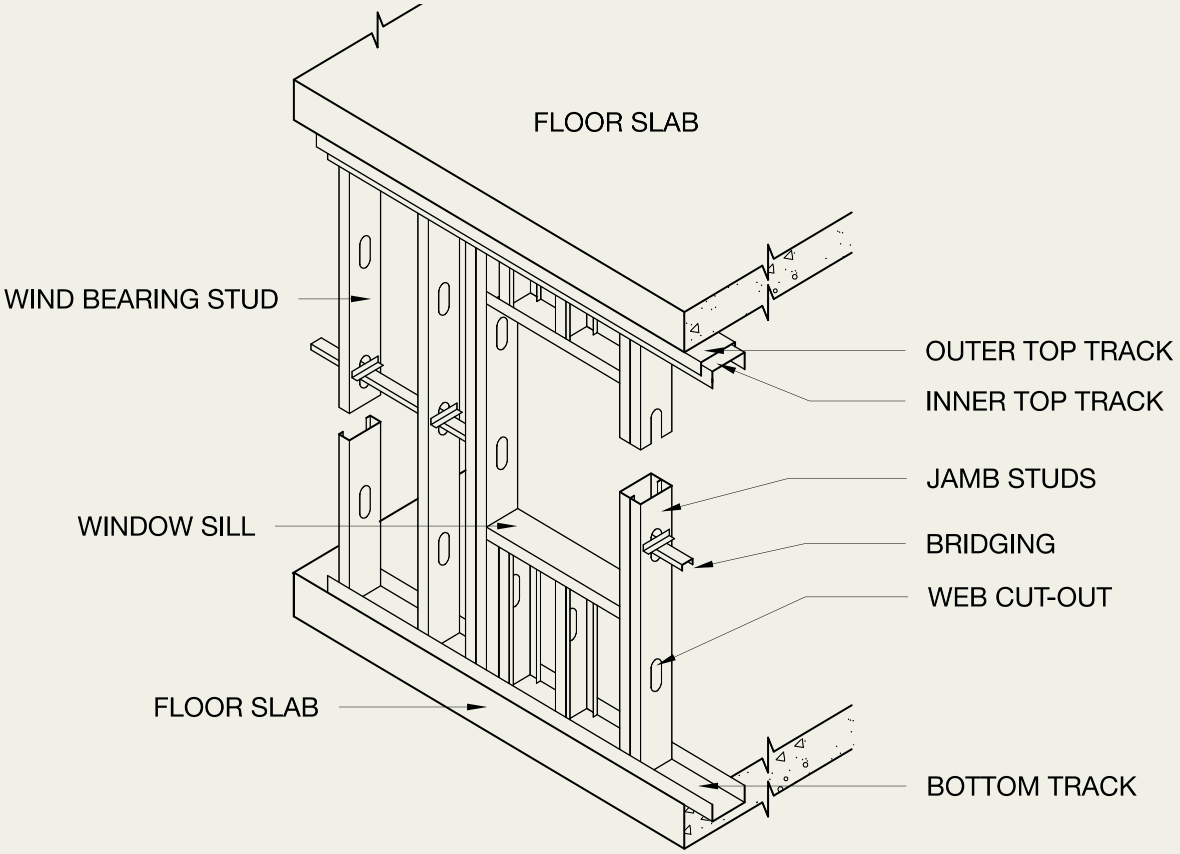

Figure 1: Typical wind bearing stud wall with window opening.

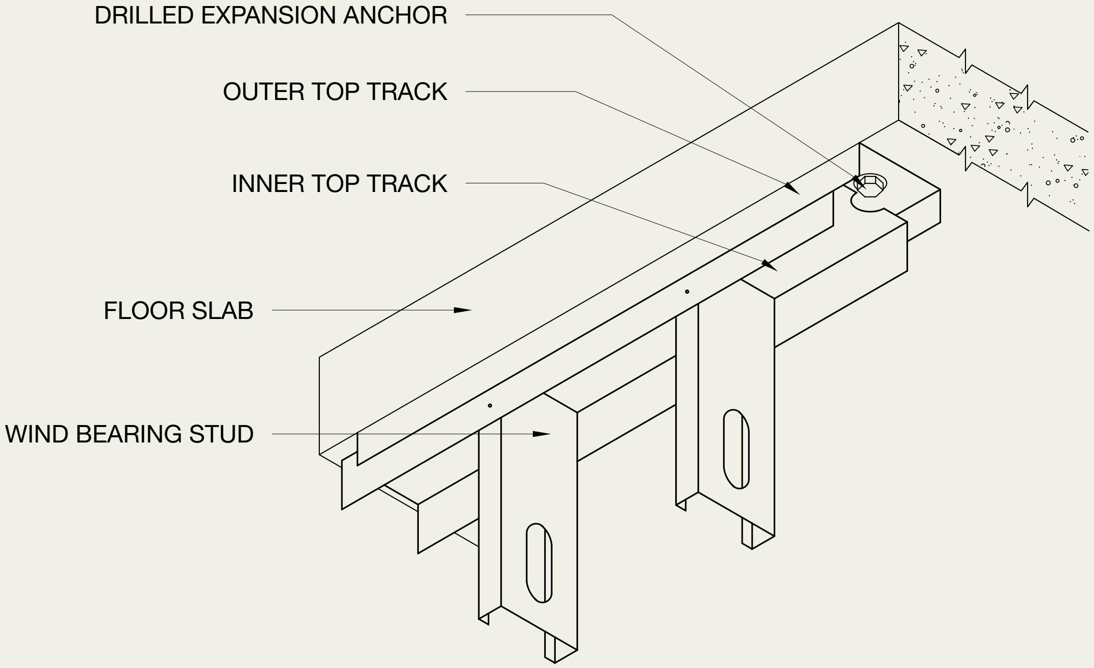

Figure 2: Typical top track deflection detail for wind bearing studs.

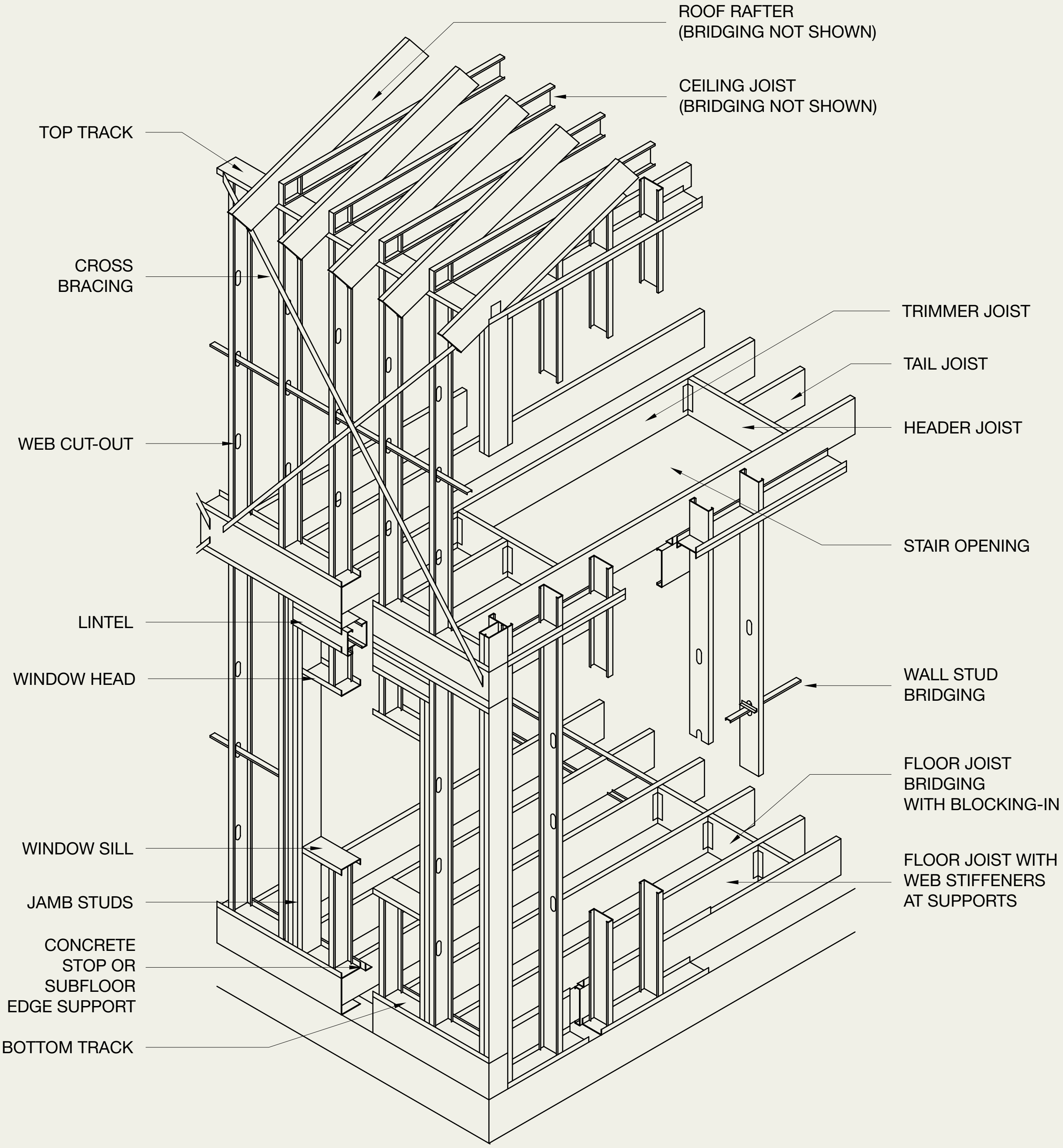

Figure 3: Typical platform construction.

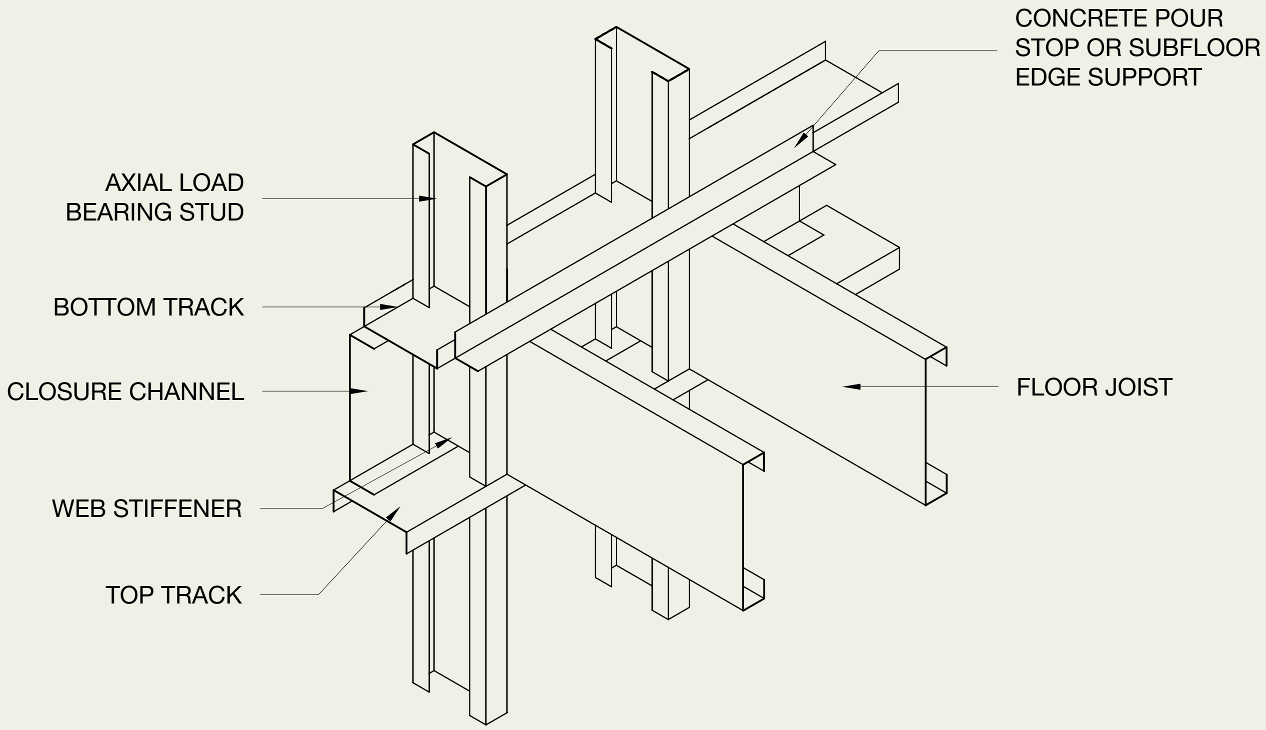

Figure 4: Typical platform framing detail.

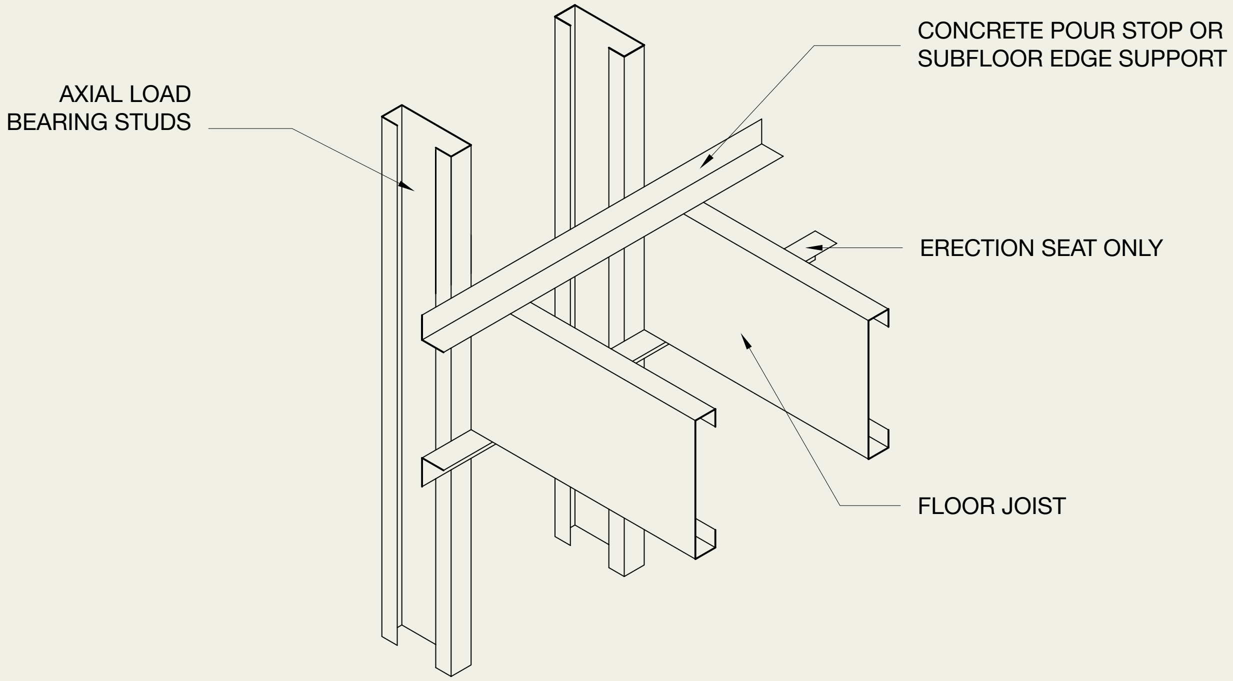

Figure 5a: Typical balloon framing detail.

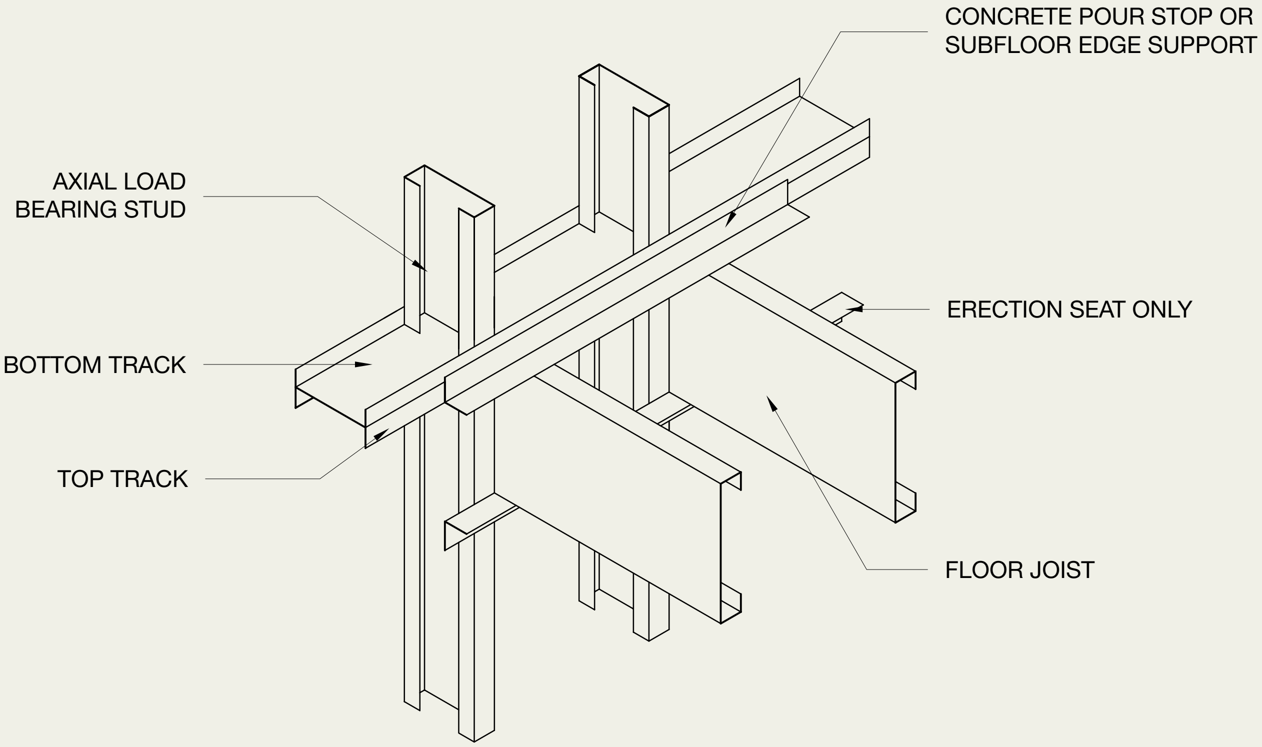

Figure 5b: Typical balloon framing detail at joint in studs.

ADVANTAGES OF LIGHTWEIGHT STEEL FRAMING SYSTEMS

Lightweight

- **Wind Bearing Studs**
  In curtain wall construction the weight of the wall affects the proportioning and cost of the spandrel beams, the columns, the footings and in earthquake zones the lateral load resisting members.

  Compare the weight of 150 mm steel stud and drywall versus 150 mm normal weight masonry back-up for a typical brick veneer wall.

  Stud = 0.29 kN/m^2
  Concrete block = 1.68 kN/m^2

Compare the weight of steel stud with exterior wall insulation and finish system versus 100 mm precast concrete.

Stud = 0.38 kN/m^2
Precast = 2.39 kN/m^2

In panelized construction, low weight assemblies cost less to transport and erect. In particular, significant savings in crane costs and installation can be realized.

- **Axial Loadbearing Studs with Joists and Rafters**
  Weight savings for a complete LSF building can be as dramatic as those outlined above for curtain walls. Lightweight translates into cost savings in a variety of ways.

  - Buildings not previously designed for an extra floor level may be candidates for expansion upwards.
  - Economical spread footings might be possible in marginal soil conditions as opposed to expensive deep foundations.
  - Low mass construction minimizes lateral bracing in seismic regions.
  - In panelized construction, low weight assemblies cost less to transport and erect.
  - In general, lightweight steel assemblies allow lighter more economical structural framing because less material is required to support the self-weight of the structure.

Low Cost

LSF construction has historically been less expensive than competing forms of construction. Specific cost comparisons are not provided here due to the variability in construction costs that occur in different geographic regions, and due to market demand.

Mass Produced

The basic building blocks of LSF are cold formed channels manufactured from zinc or 55% aluminum-zinc alloy coated sheet steel. The coated sheet steel is purchased by the manufacturer in the form of a coil, which is subsequently slit into various widths as required by the geometry of the final products. The slit coil of flat steel sheet is fed into one end of the roll forming mill and the cold formed channel member is cut to length as it emerges from the other end. (On some mills the sheet steel is cut to length before it enters the roll forming mill.)

Unlike structural steel shapes that are hot rolled into shape, manufacturing of lightweight steel framing is carried out at ambient temperature, hence the term cold formed. A single typical mill in one working shift can produce 20 km of straight, highly uniform, accurate product. Because the manufacturing process is fast, there is no need to carry manufactured product in stock. LSF can therefore be custom manufactured to fit specific job requirements including precise cut-off lengths and web cut-out locations.

Panelization of LSF, on or off site, extends the advantages of mass production (speed and quality control) to the fabrication of complete assemblies. Panels can also be delivered to the site with some types of finishes already installed.

Energy Efficient

Energy efficient buildings are well insulated and well sealed to retard air and moisture leakage.

Insulating an LSF building is relatively easy because the space between the studs (or roof rafters/joists) can be filled with batt insulation. Typically, rigid insulation is added on the outside face of stud walls to further enhance the overall R value and to control thermal bridging and the dew point location. Thermal performance data for some steel stud wall configurations is provided in Appendix B.

Reliable and Durable

LSF is a reliable product with no shrinking, warping, swelling, rotting, creep, nail-popping or termite problems. Durability of LSF products is assured with corrosion resistant metallic coatings in combination with well designed and built rain screens, air barriers and vapour retarders. See Appendix D for further information on metallic coatings and durability.

Non-combustible and Fire Resistant

- **Non-combustible Construction**
  LSF meets all the requirements for non-combustible construction required of certain building components by the provisions of the National Building Code of Canada and the various provincial building codes.

- **Fire-resistance Ratings**
  A fire-resistance rating is based on the time taken in a standard fire test for an assembly to fail the established criteria. The National Building Code of Canada requires buildings with certain occupancies and size to have some of the assemblies fire rated.

  Ratings for a variety of LSF assemblies are available and these are summarized in Appendix A. Generally these assemblies require the protection of gypsum drywall to achieve the necessary rating.

Resistant to the Transmission of Sound

The National Building Code of Canada requires that separations between dwelling units be designed for a sound transmission class (STC) rating of 50. For separations between a dwelling unit and an elevator shaft or a refuse chute, an STC rating of 55 is required. For increased occupant privacy, an STC rating from 55 to 60 may be specified.

The necessary STC ratings can be achieved with LSF by using combinations of resilient channels, layers of drywall, insulation, or staggered studs. Ratings for a variety of LSF assemblies are available in Appendix A.

Pre-punched for Services

LSF is manufactured with regularly spaced holes in the webs of studs, joists and rafters to serve as raceways for electrical and plumbing lines.

Electricians and plumbers do not have to drill or cut to install their work, minimizing construction time, cost and the possibility of inadvertent damage to the LSF members. Plastic grommets are available to fit the standard stud hole sizes.

Quickly and Easily Erected

Construction projects do not bring a return on the owner's investment until the building is finished and occupied. With LSF buildings the construction process can be accelerated.

Mass production at the manufacturing level assures a ready supply of product. Erection can proceed quickly even in temperatures below freezing allowing the interior trades to begin their work sooner. Contractors can choose either panelized or stick-built construction - whichever is the more expedient for the particular project.

Architecturally Attractive and Flexible

With LSF the Designer has extensive flexibility in the choice of finishes to achieve the desired aesthetics for the project. Some of the exterior wall finishes commonly combined with LSF are:

- Prefinished metal panels (single skin panels, combined panels, sandwich panels)
- Portland cement plaster (stucco) on metal lath
- EIFS
- Brick veneer
- Stone, ceramic tile, or concrete veneer
- Prefinished plywood

From large flat surfaces to small curved or angular projections and recesses, LSF framing can accommodate most building shapes and detail requirements.

Structurally Efficient

- **Strength**
  The high strength-to-weight ratio of LSF translates into significant construction savings.
  - Longer clear spans are possible.
  - Member spacing can be increased to minimize the number of pieces and the number of connections.
  - Axial loadbearing studs, joists and rafters can combine into a complete structural system up to six storeys high.
- **Serviceability**
  - LSF can support significant dead load without the problems of creep inherent in many other construction materials. For example, concrete floor slabs on LSF joists are a logical marriage of materials.
  - The characteristics of steel make it a suitable back-up for brittle masonry veneers.

  In walls built entirely of unreinforced masonry, flexural cracking represents ultimate structural failure and means the end of the useful life of the wall. In LSF construction, flexural cracking of the veneer represents a serviceability limit state rather than ultimate structure failure.

  The width of flexural cracks can be controlled through the selection of an appropriate deflection criterion for the LSF back-up member. Substantial additional load can be carried before the wall reaches ultimate structural failure. In addition, when the load is removed the flexural cracks tend to close and the wall returns to its unloaded configuration. Reinforced concrete and reinforced masonry design standards also recognize cracking and the need to control crack widths. This cracked design approach to masonry veneer steel stud is formally recognized in CSA S304.1, Masonry Design for Buildings (Limit States Design) where structural rules are provided for both the strength and serviceability limit states for the system. For further discussion, refer to Appendix E.
- **Adaptability**
  LSF integrates successfully with many different structural systems. Axial loadbearing studs supporting steel or wood trusses, open web steel joists, or precast slabs; floor joists bearing on masonry or concrete are common examples.
- **Knowledge**
  LSF is part of the family of cold formed steel products whose structural performance has been extensively researched over the past 50 years. The necessary tools for structural design are contained in CSA3-S136 North American Specification for the Design of Cold Formed Steel Structural Members, a referenced document in the National Building Code of Canada. A number of other helpful structural references are provided in the Bibliography (Appendix G).

LSF DESIGN AND CONSTRUCTION REVIEW – RESPONSIBILITIES OF THE PARTIES INVOLVED

On any construction project, there are many ways to distribute the responsibilities. What is proposed here has worked successfully on many projects.

It is assumed that the LSF Subtrade responsible for assembly and erection enters into a contract with the LSF Manufacturer or Distributor for the supply of materials and enters into a contract with the LSF Design Engineer for preparation of shop drawings.

Architect's Design and Construction Review Responsibilities Pertinent to LSF

- **Wind Bearing Studs**
  - Selects components to make up the wall assembly.
  - Resolves building science issues including performance of rain screens, air barriers, vapour retarders, flashings, interface between elements, insulation, finishes and appropriate fire and sound detailing.
  - In consultation with LSF Manufacturer, Manufacturer's product literature, project Structural Engineer and cladding supplier, determines maximum permissible member spacings; stud depths and minimum thicknesses; appropriate deflection limit under wind load; and appropriate detail to accommodate floor deflections.
  - Provides necessary contract drawings and specifications.
  - During construction, provides field review; reviews shop drawings, mill reports, samples of framing elements and calculations submitted by the Contractor's LSF Design Engineer; reviews site reports from the Independent Inspection Agency and LSF Design Engineer.
- **Axial Loadbearing Studs, Joists and Rafters**
  - Selects components to make up the wall, floor, roof and ceiling assemblies.

  - Resolves building science issues including performance of rain screens, air barriers, vapour retarders, flashings, interface between elements, insulation, finishes and appropriate fire and sound detailing.

  - Provides necessary architectural input to allow the Project Structural Engineer to determine member depths and minimum thicknesses, permissible member spacings, appropriate deflection limits.

  - Provides necessary architectural contract drawings.

  - Provides necessary architectural input to allow the Project Structural Engineer to prepare the contract specification.

  - Co-ordinates electrical, mechanical, structural and architectural drawings.

  - During construction, provides field review; reviews shop drawings, mill reports, samples of framing elements and calculations submitted by the Contractor's LSF Design Engineer; reviews site reports from the Independent Inspection Agency and LSF Design Engineer.

Project Structural Engineer's Design and Construction Review Responsibilities Pertinent to LSF

- **Wind Bearing Studs**

  - Provides alternative framing details for wall openings that exceed the structural capabilities of LSF.

  - Provides suitable structural details for the interface between the main structure and the LSF wall assembly.

  - Provides maximum expected floor deflection data to the LSF Design Engineer.

  - Does not provide field review or review of Contractor's submittals.

(Note: If additional input is required from the Project Structural Engineer, some re-negotiation of the usual fee structure between the Architect and the Project Structural Engineer may be required.)

- **Axial Loadbearing Studs, Joists and Rafters**

  - In consultation with Architect and LSF Manufacturer determines member depths and minimum thicknesses, permissible member spacings, appropriate deflection limits.

  - Provides structural contract drawings including information on design loads; location of axial loadbearing walls and wind bearing walls; layout of joists and rafters; location of lateral load carrying elements including cross-braced shear walls and horizontal shear diaphragms with applied loads, openings, typical details and foundation design.

  - In consultation with the Architect, provides the contract specification.

  - During construction, provides field review; reviews shop drawings, mill reports, samples of framing elements and calculations submitted by the Contractor's LSF Design Engineer; reviews site reports from the Independent Inspection Agency and LSF Design Engineer.

Manufacturer's Design and Construction Review Responsibilities Pertinent to LSF

- **Wind Bearing Studs**

  - Assists the Architect to determine maximum permissible member spacings, stud depths and minimum thicknesses, appropriate deflection limit under wind load and appropriate detail to accommodate floor deflections.

  - Does not provide shop drawings or construction review.

- **Axial Loadbearing Studs, Joists and Rafters**

  - Assists the Architect and Project Structural Engineer to determine member depths and minimum thicknesses, permissible member spacings, appropriate deflection limits.

  - Does not provide shop drawings or construction review.

LSF Subcontractor's Design and Construction Review Responsibilities Pertinent to LSF

The design and construction review responsibilities of the LSF Subcontractor are to be discharged by the LSF Design Engineer, a licensed Professional Engineer familiar with lightweight steel framing construction.

- **Wind Bearing Studs**

  - Derives wind loads for design.

  - Prepares necessary shop drawings bearing the professional stamp of the LSF Design Engineer.

  (Note: Shop drawings include all necessary shop details and erection diagrams; with member sizes, locations, thicknesses exclusive of coating, metallic coatings and mechanical properties; with connection details for attaching framing to itself and to the structure; with splice details where permitted; with dimensions, framing for window openings, requirements of related work and critical installation procedures; with temporary bracing required for erection purposes; and with design wind load shown.)

  - During construction provides field review.

- **Axial Loadbearing Studs, Joists and Rafters**

  - Derives wind load for design. Does not derive design gravity loads. (These are provided on the contract structural drawings.)

  - Prepares necessary shop drawings bearing the professional stamp of the LSF Design Engineer.

  (Note: Shop drawings include all necessary shop details and erection diagrams; with member sizes, locations, thicknesses exclusive of coating, metallic coatings and mechanical properties; with connection details for attaching framing to itself and to the foundation; with splice details where permitted; with dimensions, framing for openings, requirements of related work and critical installation procedures; and with temporary bracing required for erection purposes.)

  - During construction provides field review.

BUILDING SCIENCE OVERVIEW

The principal design requirements for an exterior wall were first outlined by Hutcheon in the 1963 Canadian Building Digest No. 48:

- Control heat flow
- Control air flow
- Control water vapour flow
- Control rain penetration
- Control light, solar and other radiation
- Control noise
- Control fire
- Provide strength and rigidity
- Be durable
- Be aesthetically pleasing
- Be economical

A number of authors have suggested additions to this list the most prominent of which is:

- Be buildable

To be buildable, a well designed system should take into account both the skills and limitations of the building trades, should use readily available building products and common construction procedures, should accommodate typical dimensional tolerances in building construction and should recognize construction sequencing issues.

The primary focus in this Guide will be on heat flow, air and water vapour flow and rain penetration.

Considerably more detailed discussions on building science and the building envelope are available in the literature. See the references in Appendix G.

Rain Penetration and its Control

In the 1963 Canadian Building Digest No. 40, G.K. Garden outlined the basic principles of rain penetration and its control. Much of the discussion that follows has been taken from that document supplemented by the results of more recent work.

As stated by Garden, rain penetration results from a combination of water on a wall, openings to permit its

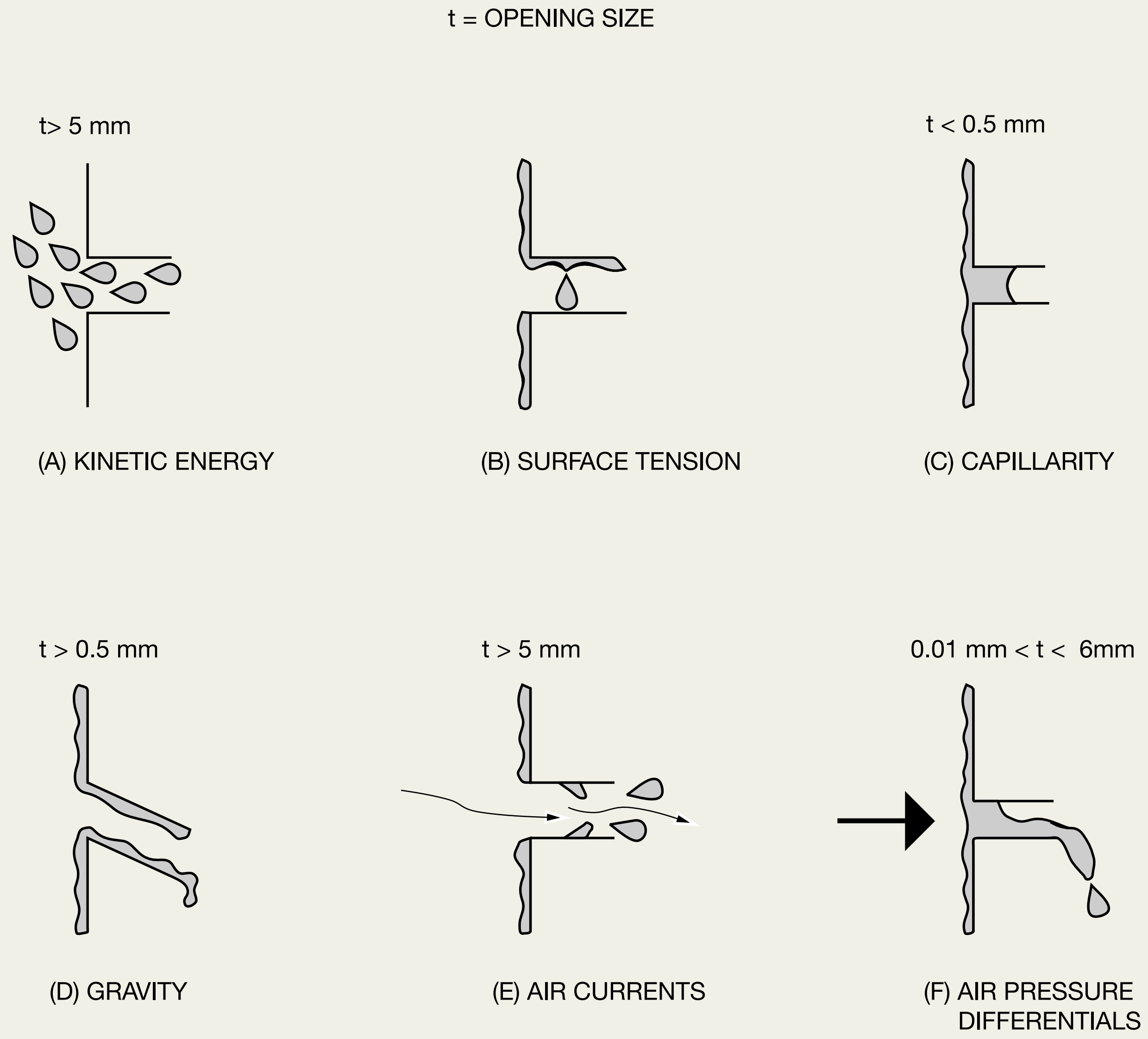

Figure 6: Driving forces on a pressure equalized rainscreen wall.

passage and forces to drive it or draw it inwards. He illustrated the basic mechanisms of rain penetration with sketches similar to those in Figure 6.

Penetration due to kinetic energy (Figure 6A) is simply wind blown rain entering a large opening such as an open window. It is relatively easy to design against such openings. Large openings such as fan exhausts can be protected with appropriate battens or baffles.

Drips are commonly provided at the underside of exterior slabs and sills to inhibit the flow of water into the building by surface tension (Figure 6B).

Rain penetration due to gravity alone (Figure 6D) can be very important if accidental openings that divert water inwards and downwards are present due to construction errors or due to post-construction deterioration. Exterior balcony slabs or window sills sloping into the building, cavity wall flashings sloping the wrong way or flashings lacking end dams are typical construction errors. Deteriorating seals at control joints with even small cracks (as small as 0.5 mm) may admit water by gravity flow. Cracking in the head joints of brick veneer is another problematic area. These types of leaks can be aggravated by the tendency for water flowing down the face of the building to concentrate in the joints.

Free water cannot be pumped through an opening as a result of capillary forces alone (Figure 6C). Capillary suction acts only to draw water into a space bound by wettable surfaces. The water it holds will have no tendency to exude unless acted on by an external force such as wind pressure (Figure 6F). Even in the presence of an external force, small capillaries hold water with such high suction that they do not contribute significantly to rain penetration. Large capillaries, however, have lower suction and higher volumes of water and the same external force can result in significant moisture penetration.

The following discussion focuses on rain penetration due to an air pressure differential across the wall system or some part of the wall system. These air pressure differentials are caused primarily by wind with lower order contributions from stack effects and mechanical pressurization. The discussion that follows will review two fundamental design methodologies for dealing with pressure driven rain penetration.

As noted earlier, rain penetration is the result of water on the wall, openings to permit its passage and forces to drive or draw it inwards. The face seal approach controls rain penetration by eliminating openings while the open rain screen approach eliminates the forces.

The Face Seal Approach

A face seal wall system is shown diagrammatically in Figure 7. The exterior face and the sealants at joints form the one and only barrier resisting wind and rain.

- **Advantages**
    - Water proofing efforts can be concentrated on one plane.
    - The overall wall thickness is kept to a minimum.
    - Cost is minimized.
- **Disadvantages**
    - Any openings due to imperfections in the exterior face or joint seals will result in water penetration into the wall assembly. This sensitivity to imperfections is a direct result of water and the air pressure differential occurring at the same plane.
    - Joint sealants are exposed to the deleterious effects of temperature extremes, expansion and contraction, weathering and ultraviolet radiation from the sun.

If imperfections do occur and moisture does accumulate in the wall, there may be little opportunity for drying. Some face seal systems are vapour as well as air impermeable. Vapour permeability to the outside is required for drying.

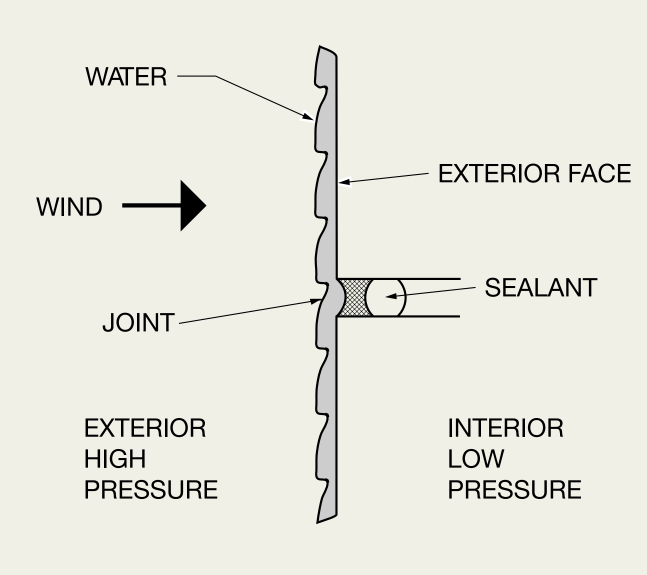

Figure 7: A face sealed wall.

The Pressure Equalized Rain Screen Approach

The pressure equalized rain screen wall system is shown diagrammatically in Figure 8.

A pressure equalized rain screen wall consists of an exterior rain screen, a cavity and an interior air barrier system. The exterior rain screen is vented to the outside such that changes in exterior air pressure are followed closely by changes in cavity air pressure. The air pressure between the cavity and the exterior is thus equalized and there should be little or no pressure drop to force rain through openings in the rain screen. The air pressure difference across the wall is carried instead by the interior air barrier assembly.

- **Advantages**
    - The exterior rain screen is not sensitive to imperfections. Any accidental openings (for example in sealants or mortar joints) are not likely to contribute to additional rain penetration since the pressure difference driving the water penetration is eliminated (or at least substantially reduced).
    - There is a second line of defence to water penetration. Water that passes through the exterior rain screen does not bridge the cavity but runs down the inside face of the rain screen to drain out.

  - The air barrier system is protected from the deleterious effects of water, ultraviolet radiation and temperature extremes.
  - Because the interior air barrier does not get wet, minor air leakage through it will not contribute to water penetration. (Leaky air barriers can, however, have other consequences. See Item on Air Leakage and its Control).
  - Air circulation in the cavity can assist drying.

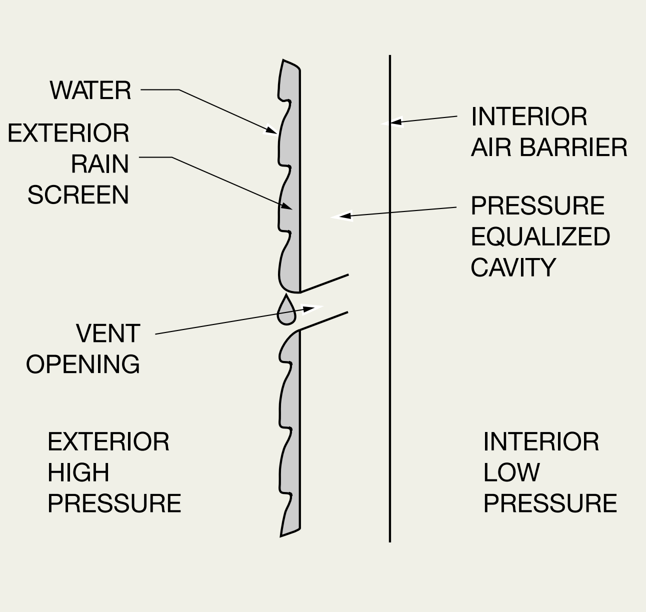

Figure 8: A pressure equalized rain screen wall.

- **Disadvantages**

  - The requirement for a cavity increases the overall thickness of the wall.
  - Rain screen walls may be more expensive than face seal walls.
  - True pressure equalization requires careful design and construction. See the discussion that follows.

In order to achieve pressure equalization, a number of design and construction details require attention:

- The vents and weepers(1) in the rain screen must have adequate area. The required vent size is a function of the volume of the cavity, the air barrier leakage rate and the flexibility of the air barrier assembly.
- The air barrier should have a low leakage rate. It is possible to have a pressure equalized wall in combination with an air barrier with a high leakage rate but this would require considerable air flow through the rain screen to supply the make-up air.

  While the pressure equalized principle would not be offended, water penetration through the rain screen could still occur via the mechanism illustrated in Figure (6E).
- Horizontal air flow in the cavity must be controlled. Horizontal air flow occurs because positive wind pressure on one wall is always accompanied by negative wind pressure on the adjacent side walls. See Figure 9a. This horizontal air flow substantially defeats other efforts to create a pressure equalized wall. Vertical baffles are required at least at the building corners. See Figure 9b.

Some building scientists have argued that a true open rain screen wall is not practical largely because pressure equalization is difficult to achieve. They have proposed another type of wall, designated the "drain" screen, which has similar construction details to the rain screen except that no particular effort is made to achieve pressure equalization. With this design approach, water will penetrate the exterior rain screen and efforts should be focused on insuring it does not bridge the cavity and can be drained out. Many current walls, although designed as pressure equalized rain screens, are probably closer to the drain screen principle.

Masonry veneer steel stud walls are better thought of as drain screen systems even when the best efforts are made to pressure equalize. Laboratory experiments indicate that in the absence of a pressure differential there is still significant water penetration through head joint cracks due to gravity flow (*Newman 1981*, and *Brown 1995*). For these types of walls, a near perfect pressure equalized rain screen may not be money well spent. Instead, efforts should be directed to achieve partial pressure equalization with good as-built details to remove moisture from the cavity. Moisture removal is dependent on:

- An adequate air space dimension.
- A minimum of mortar bridging.
- Flashings with proper connection to the back-up, adequate slope, adequate end dams and laps, adequate drip dimension, and made from waterproof, durable and robust materials that will withstand abuse during construction.
- Weepers that are free of obstruction (primarily mortar).

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(1) *Weepers or weepholes are openings placed in the mortar joints of the masonry veneer at the level of flashings (shelf angles, window heads and foundations) to permit the escape of moisture. Vents are openings placed in the mortar joints of the masonry veneer at the top of the cavity to permit air circulation within the air space in conjunction with the weepholes. See CSA Standard A371-94 for weephole and vent size and location.*

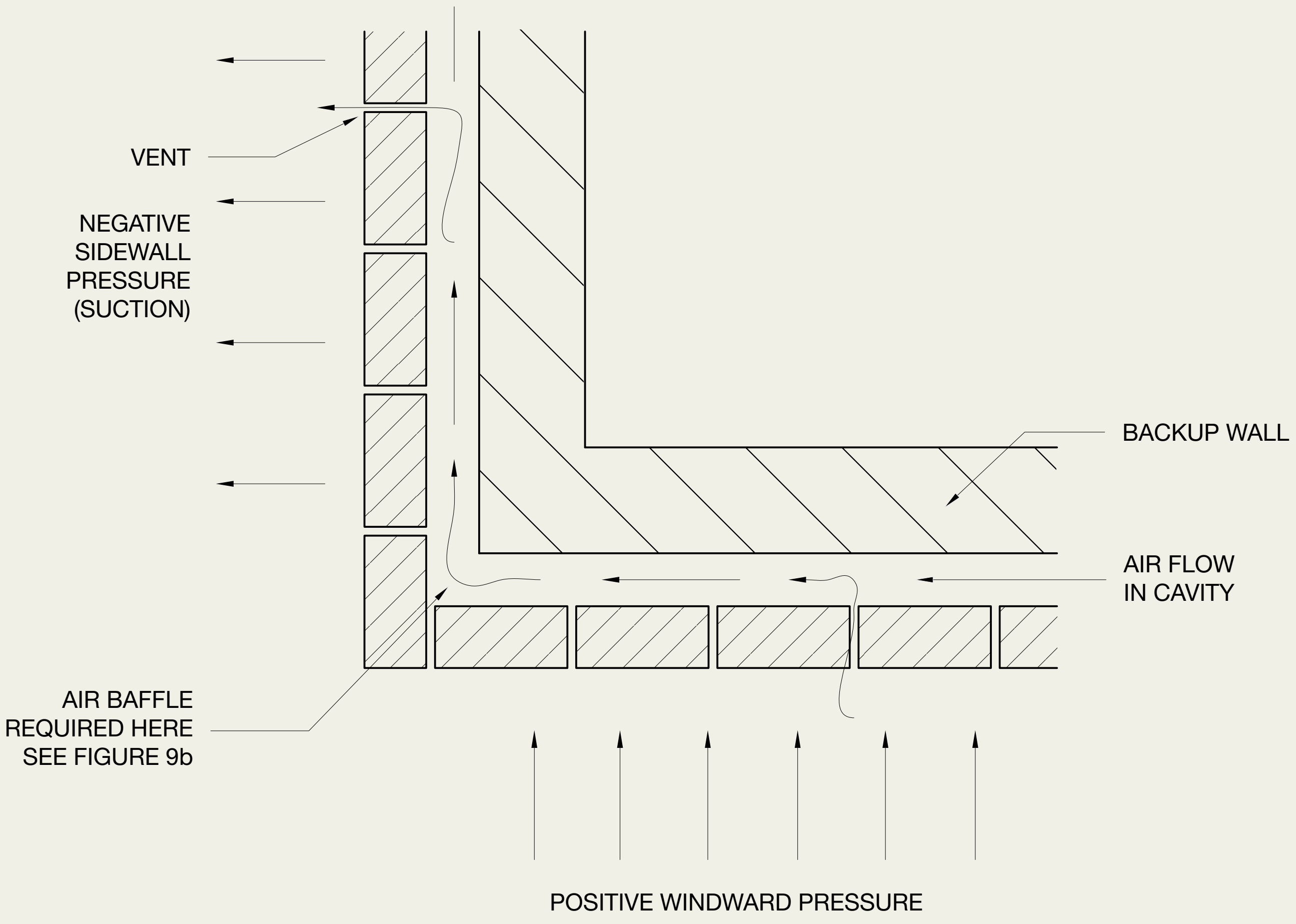


Figure 9a: Lack of pressure equalization due to cavity horizontal air flow (Drysdale and Suter, 1991)

Air Leakage and its Control

Air leakage is the uncontrolled movement of air through the building envelope and is driven by wind, stack effect or the pressures created by mechanical ventilating systems. Exfiltration in the winter season will increase heating and humidifying requirements, and infiltration in the summer season will increase the requirements for cooling and dehumidifying. Even when the volume of air may not be significant in terms of heating and air conditioning, the amount of moisture migrating and condensing into the wall system can cause a number of other deleterious effects including loss of R value; masonry efflorescence and spalling; ice build-up in cavities and under soffits; deteriorating gypsum drywall; mould; and corrosion.

These air leakage problems can be controlled with proper air/vapour barrier design and installation. Standard sheathings can perform as air barriers provided overall permeability is controlled, joints are sealed, continuity of the air barrier is maintained, and the sheathing and its connections have the structural capacity to resist the pressure differential across the air barrier. The sample details provided are based on the air barrier drywall approach.

Appendix C includes measured air flow rates through a number of common air barrier materials. These rates are required to confirm air barrier conformance with the NBCC/95.

The Interaction Between Air/Vapour Flow and Thermal Performance

Steel stud wall systems are frequently built with batt insulation in the stud space. A number of building science details require attention with this type of construction:

- **Exterior Insulation**
  In all but the mildest Canadian climates, it is essential to provide a minimum of 25 mm of rigid insulation

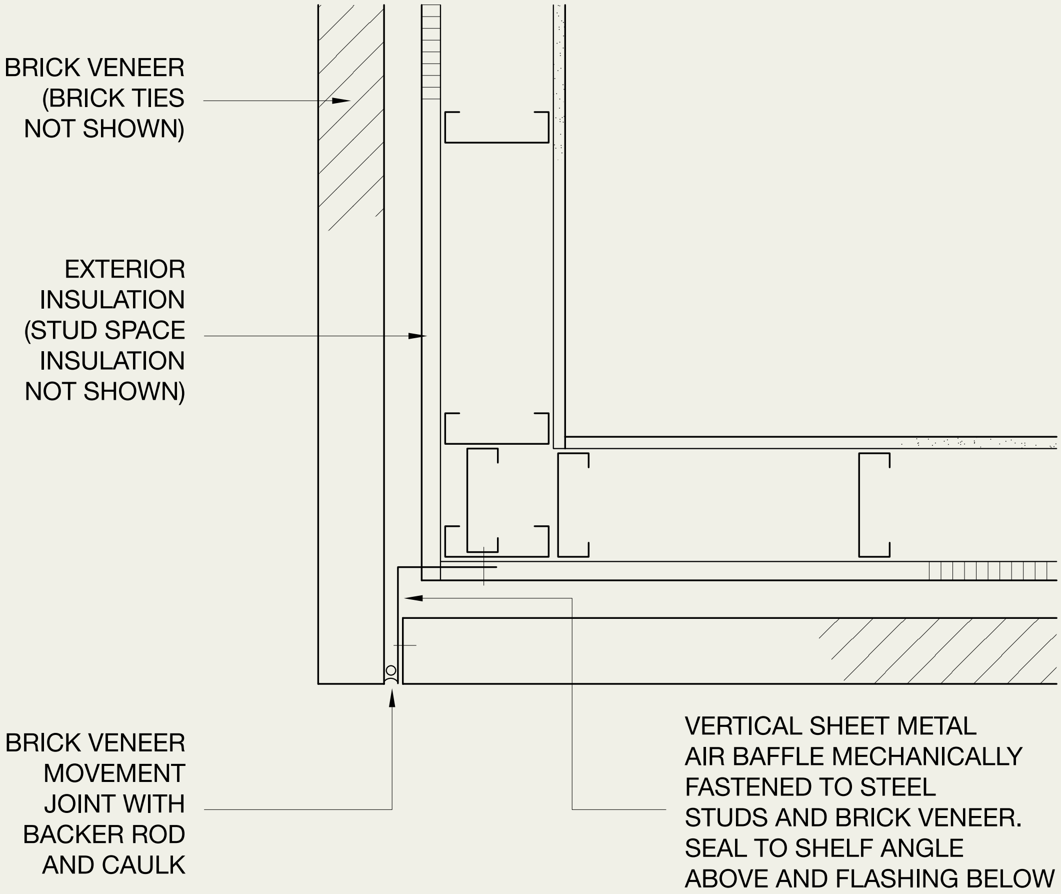


Figure 9b: Corner air baffle to reduce horizontal air flow cavity.

on the outside face of the studs in order to minimize thermal bridging and condensation. More may be required if it is preferred to keep the dew point in the exterior insulation away from the stud cavity and steel framing surfaces. Alternatively, all of the insulation can be moved to the outside face.

In a Canada Mortgage and Housing Corporation sponsored study (*Drysdale 1990*) steel stud walls with insulation in the stud space were studied in simulated winter conditions (-17 ˚C minimum) with 35 - 40% relative humidity on the warm side (21˚C) and a continuous pressure differential (75 Pa) across the wall. They included deliberate imperfections in the air barrier so that the vulnerability of the system to air leakage could be studied. Without exterior insulation, they found that both the studs and the inside face of the exterior sheathing were subject to moisture accumulation. With 25 mm of rigid polystyrene insulation, there was no moisture accumulation on either the studs or the inside face of the exterior sheathing. With 25 mm of rigid polystyrene insulation and with higher relative humidity (50 - 55%) on the warm side, condensation was observed on the inside face of the exterior sheathing. Refer to the research report for more detail.

Without exterior insulation, moisture accumulation and corrosion of the steel parts is a distinct possibility in many parts of Canada. In addition, the quantity of moisture accumulating on the exterior sheathing may be beyond the wetting capability of the sheathing and beyond the drying capability of the wall.

With exterior insulation (25 mm minimum), condensation on the steel parts can usually be ignored. In this case, the thermal bridging that occurs at stud locations is a virtue since they conduct heat to the cold side and keep themselves above the dew point temperature.

The potential for condensation between studs can be studied using the classical resistance formula to determine temperature at any point in the wall for comparison with the calculated dew point. The resistance formula can be presented as follows:

$$t_x = t_i - (R_x / R_t)(t_i - t_o)$$

Where,

t_x = the temperature at any point in the wall
R_x = resistance from the indoor air to any point in the wall at which the temperature is to be determined.
R_t = overall wall resistance from indoor air to outdoor air
t_i = indoor air temperature
t_o = outdoor air temperature

For brick veneer steel stud wall systems, the calculation of the overall wall resistance, R_t, usually excludes the cavity air space and the brick veneer because they are "short-circuited" thermally by circulating air through weepers and vents.

This formula must be used judiciously. If extreme interior humidities and outside temperatures are assumed, then excessively conservative designs may result. Occasional wetting in the stud space may also be acceptable provided adequate drying potential to the outside is available and the wall materials such as metallic coated sheet steel can tolerate moisture.

Additional guidance is also provided in NBCC/95 Part 9 Clause 9.25.1.2 (for information only - this clause does not apply to Part 3 - 4 type buildings). Background for this clause is provided in IRC Construction Technology Update #41.

- **Resistance to Moisture and Drying Potential**
  Where insulation is used in the stud space, the preferred location of the air/vapour barrier is on the warm side of the insulation. In the sample building details that follow, an interior drywall air barrier in combination with a poly vapour barrier is used to achieve this end.

  Also care is required to insure that the exterior sheathing and/or insulation do not become an accidental air or vapour barrier since this would inhibit the ability of the wall to dry to the outside. It is recommended that both air and vapour permeability to the outside be provided. The following is a quote from Drysdale and Suter (*Drysdale and Suter 1991*):

  "Tests, analysis and field review have all demonstrated that the mass of water which can be carried into a wall by air leakage through a very small hole is several magnitudes larger than the amount of water that is transmitted through a wall by diffusion. Therefore, when airborne moisture condenses, it is quite unlikely that this can be removed in sufficient volume by vapour transmission to the outside. In fact, drying is more likely to be accomplished by dry air moving through the wall under different weather conditions."

  In addition, the elements of the wall assembly should be resistant to occasional wetting.
  - Exterior sheathing should be moisture resistant. Conventional exterior gypsum based drywall requires the protection of a membrane sheathing.
  - Consideration should be given to a heavier coating on the studs and track of Z275 zinc or an AZM 150 coating of 55% aluminum-zinc alloy. (*CSSBI Specifications S5 and S6 show Z180 as the minimum galvanizing. For a marginal increase in cost, Z275 galvanizing will provide approximately 50% more corrosion life.*)
  - Corrosion resistant fasteners should be specified.
  - For masonry veneer steel stud construction, brick ties must meet the coating requirements specified in CSA A370. (See Appendix E)

SAMPLE BUILDING DETAILS

Introduction

The sample building details that follow show a brick veneer steel stud wall system as part of a single storey commercial building framed with hot rolled steel members. Design Example D1 shows the studs outside the face of the structure and Example D2 shows the studs as infill.

For both examples, batt insulation has been provided in the stud space supplemented by 25 mm of exterior rigid insulation. (*The wall is assumed not to require a fire-resistance rating.*) For this configuration of insulation, the dew point may fall within the stud space during cold periods. As a consequence the design and construction of this wall will require:

- Good quality air/vapour barriers on the warm side of the batt insulation.
- Moisture resistant materials.
- Drying capability for the wall system from the stud space to the outside.

The sample details show 25 mm of extruded polystyrene exterior insulation. This insulation serves a dual purpose – as exterior insulation and as a barrier to any rain that may breach the exterior brick veneer rain screen and the 50 mm air space. In order to achieve the desired drying capability to the outside, regular openings in the exterior insulation are required. Unless handled carefully, these openings may compromise the ability of the insulation to shed water and instead allow water to be transported into the insulated stud space.

As one possible solution, the details show the exterior insulation installed with ship lapped joints. The horizontal lap detail is oriented so that water would have to flow uphill to enter the stud space. If the insulation is supplied with butt joints, taping of the joints are required. (*Even with ship lapped joints taping may be desirable to insure that the joints do not fill with water via capillary suction and subsequently pump water into the stud space under an external pressure differential such as wind*). The bayonet style brick ties are installed from the inside by saw cutting the exterior insulation, stabbing the connector plate through and then fastening the connector to the studs with self-drilling self-tapping screws. The saw cuts are also possible entry locations for water and should be caulked from the outside.

At this point, the exterior insulation is a tight barrier that will not allow any moisture that might occur in the stud space to escape to the outside during drying periods. This problem is overcome by providing the necessary openings in the form of short saw cuts at each midpoint between the studs and spaced 600 mm o.c. vertically. These saw cuts are horizontal except at a 45˚ angle sloping down to the outside, approximately 50 mm long and cut using a keyhole saw with the teeth set to produce a substantial kerf.

The result is an insulating layer that repels water running down the outside face and allows sufficient air flow for drying. The openings also serve to reduce any wind load pressure differential that might occur accidentally across the exterior insulation.

For buildings with moderate to high humidity levels or colder outside winter temperatures, an alternative arrangement of insulation should be considered - either more exterior insulation or all of the insulation should be moved to the outside face of the studs.

Note that the sample building details do not cover a number of design issues for masonry veneer steel stud wall systems such as movement joints, lintels over wall openings, detail requirements at window and door interfaces and general structural requirements. Designers are referred to the references in Appendix G and in particular the CSA structural design standards.

Design Example D1 – Detail D1-1

Wind Bearing Steel Stud/Brick Veneer Wall System - Single Storey Commercial Building

This single storey commercial building is framed with hot rolled steel members. The steel stud wall system is installed outside the face of the structural steel with a parapet of sufficient height to hide the rooftop mechanical units. It has a conventional BUR roof on steel deck.

With the steel stud wall system outside the face of the structure:

Advantages

- The parapet can be framed with steel studs. No additional hot rolled steel is required.
- The hot-rolled structural steel cross bracing will not interfere with the steel studs.

Disadvantages

- The columns will intrude into the interior space.

Design Example D1 also shows the parapet portion of the wall attached to the roof structural steel such that they deflect together when the roof is loaded with snow. The deflection gap detail for the studs occurs in the wall below.

With the parapet attached to the roof structural steel:

Advantages

- There is no differential movement between the roof and the parapet which simplifies the flashing detailing and simplifies connecting the wall air barrier to the roof air barrier.

Disadvantages

- Studs are supplied in two pieces over the height of the wall and an inner and outer track deflection gap detail is required.

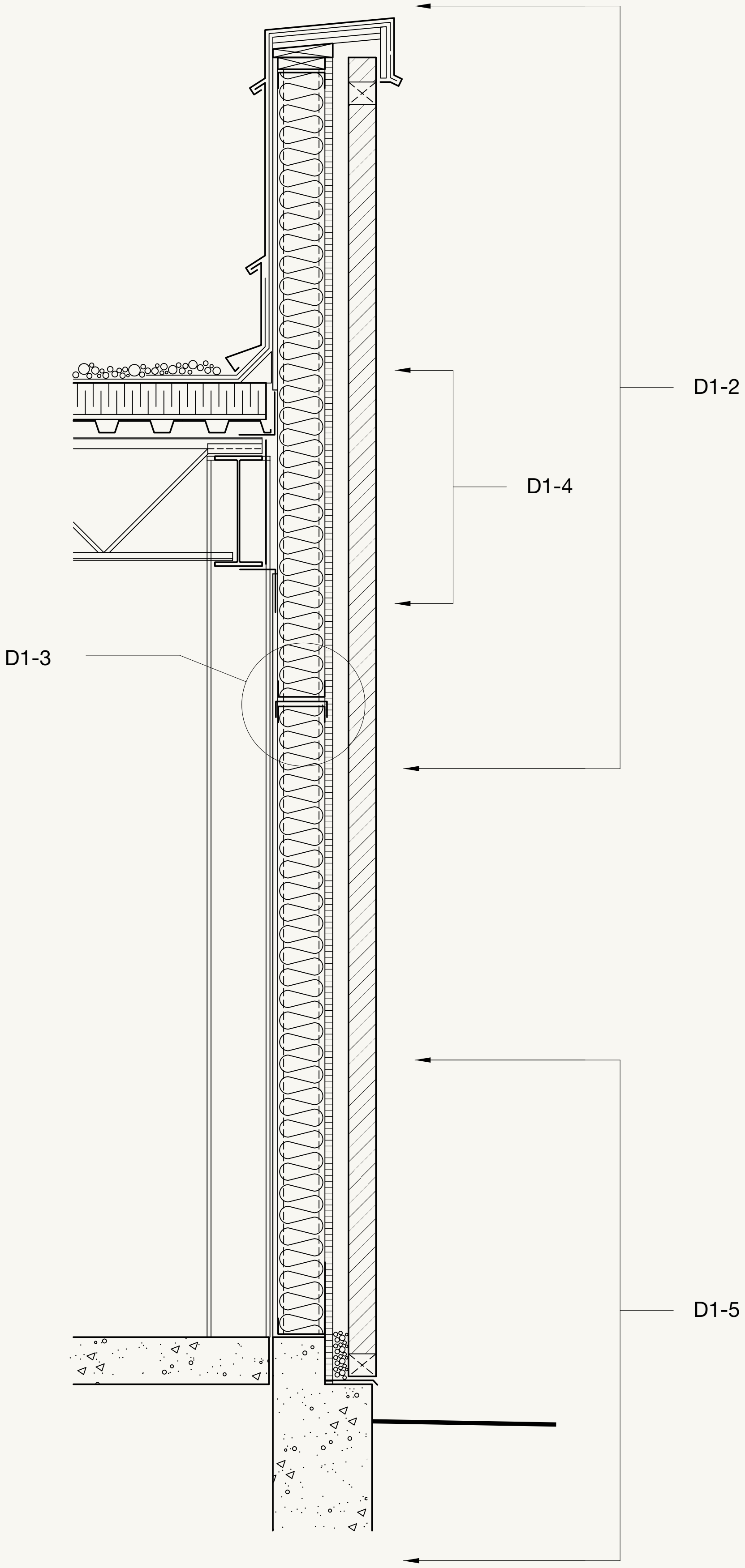
As an alternative, the studs could continue uninterrupted over the height of the wall with a slide clip connection to the steel roof beam. This approach would simplify the steel stud system but complicate flashings and air barriers.

For more detail on roofing and flashing details refer to the Canadian Roofing Contractors' Association "*Roofing Specifications Manual*" and the CMHC "*Best Practice Guide for Flashings*".

For more information on the performance of steel stud brick veneer walls, refer to the references listed in Appendix G. For project specification, see CSSBI S5.

Typical wall construction:	15.9 mm interior drywall Poly vapour retarder 152 mm steel studs at 400 o.c. 152 mm glass fibre insulation in the stud space 25 mm rigid exterior insulation (extruded polystyrene) 50 mm air space 90 mm brick veneer

Detail D1-1



Design Example D1 – Detail D1-2

1. CAP FLASHING - *Dimension "a" is required to accommodate differential vertical movement between the steel studs and the brick veneer. See also Detail D1-3. The cap flashing overlap on the brick, dimension "b", should be a minimum of 75 mm, with 100 mm to 150 mm preferred. Adjust the vent (8) location accordingly. A fascia board backing is required to support the flashing. Flashing attachment clips not shown - typical.*

2. METAL COUNTER FLASHING

3. FLASHING - *Continue flashing up and over the top of the parapet.*

4. FIBRE CANT STRIP

5. PRESSURE TREATED PLYWOOD

6. SEE DETAIL D1-4

7. 152 mm GLASS FIBRE BATT INSULATION - *Provide insulation in the stud space in combination with the rigid exterior insulation to attain the required R-value. See Appendix B for steel stud wall assemblies heat loss data. Refer to the Building Science Overview for further discussion.*

8. VENTS AT 800 mm o.c. - *At each vent location, leave out the mortar for the head joint and provide an insect screen/raindrop baffle. Vents are required to facilitate pressure equalization of the cavity and air movement for drying.*

9. 90 mm BRICK - *Provide filled, well tooled mortar joints in the brick veneer. Poor mortar joint workmanship can lead to significantly higher leakage rates through the brick veneer. The head joints require particular attention.*

10. 50 mm AIR SPACE - *It is recommended that a 50 mm minimum air space be provided. The 50 mm allows for some construction tolerance, minimizes mortar bridging and moisture migration and improves drainage and air circulation (drying) in the cavity.*

11. 25 mm RIGID EXTERIOR INSULATION (EXTRUDED POLYSTYRENE) - *Exterior insulation is essential for the thermal performance of steel stud. Refer to the Building Science Overview for further discussion. On these details, the insulation is also acting as the exterior sheathing to shed water. Provide ship lap joints and caulk the saw cuts at brick tie locations. To facilitate drying of the stud space insulation, provide 50 mm long saw cuts at each midpoint between the studs spaced 600 mm o.c. vertically. Saw cuts to be horizontal except sloping 45° to the outside. Refer to "Sample Building Details - Introduction" for further discussion.*

12 INNER AND OUTER TOP TRACK DEFLECTION DETAIL - *See Detail D1-3.*

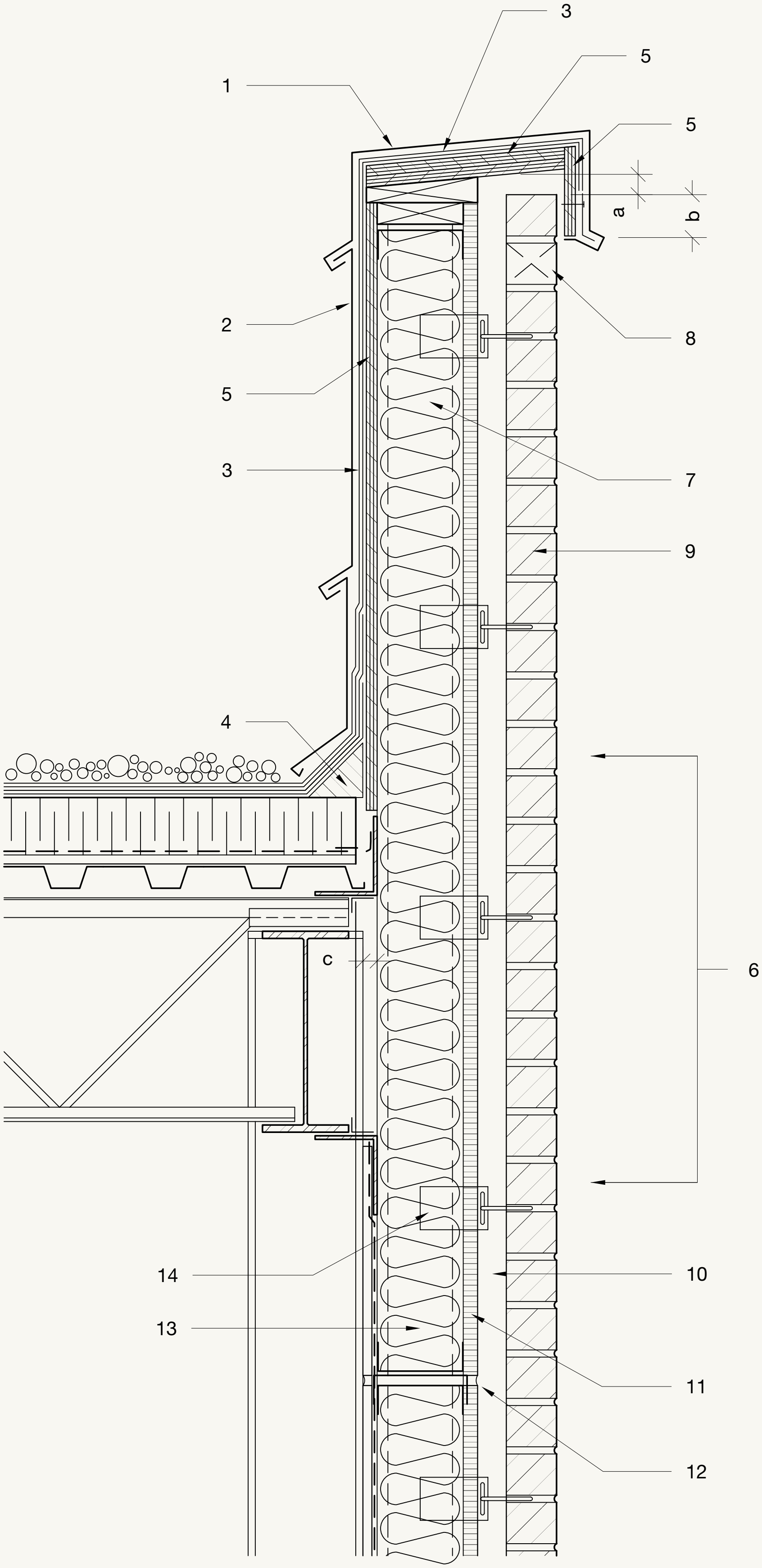
13. 152 mm STEEL STUDS AT 400 mm O.C. with minimum thickness of 1.22 mm - *The 1.22 mm minimum thickness is a recommendation from the research reported by Drysdale. Tests have shown that the structural performance of studs is significantly better in 1.22 mm material. (This is a minimum requirement only - thicker material may be required structurally).*

    The inside face of the studs is set at 20 mm (dimension "c") from the outside face of the structural steel columns. This gap allows the interior drywall air barrier to continue past the face of the columns uninterrupted.

    Studs and ties designed structurally to the requirements of CSA S304.1, CSA A370 and CSA S136 will have adequate stiffness to control flexural cracking (but not eliminate it).

14. BAYONET STYLE BRICK CONNECTOR AND V-WIRE - *See Detail D1-5*

Detail D1-2



Design Example D1 – Detail D1-3

1. OUTER TOP TRACK - *Thickness to be determined when shop drawings prepared. Suggested minimum thickness is 1.52 mm. (This is a minimum requirement only - thicker material may be required structurally).*

   The flexibility of this joint will have to be checked by the structural engineer responsible for the design of the steel stud wall system. These local deformations will add to the overall flexural deflection of the wall system.

2. INNER TOP TRACK - *1.22 mm minimum thickness. (This is a minimum requirement only - thicker material may be required structurally).*

3. CAULKED JOINT - *This joint accommodates the differential deflection between the stud wall above that is attached to the roof beam and the stud wall below that rests on the foundation. The expected roof beam deflection is shown as dimension "a". Dimension "b" (b > a) is selected to accommodate the expected roof beam deflection and the movement capability of the caulking material. If the roof deflections are beyond the expansion contraction capability of the caulk, the joint could be sealed with peel and stick air barrier membrane with an accordion fold to accommodate movement.*

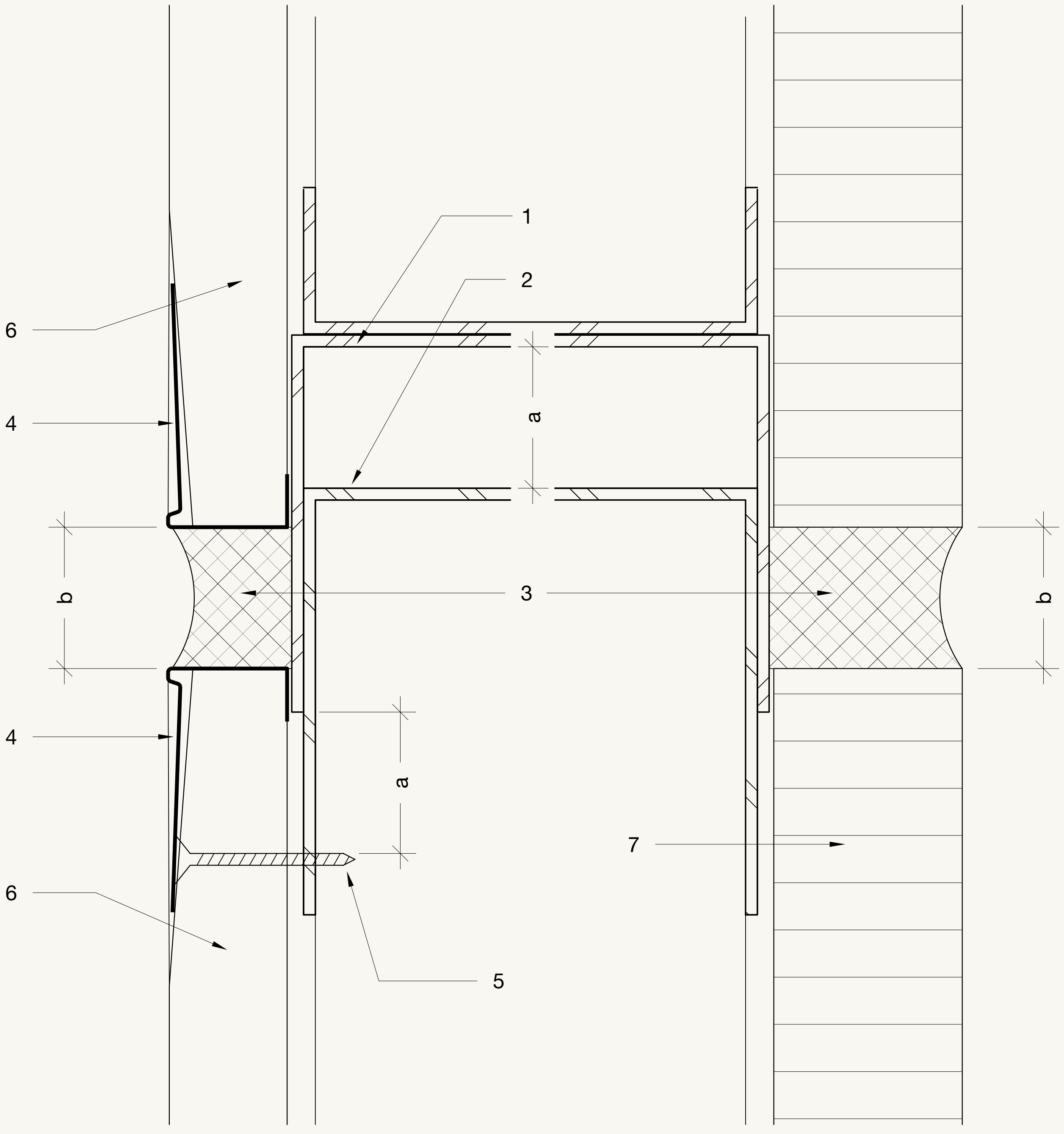
4. FILLABLE CHANNEL TRIM OR J-MOULD - *The caulked joint will be in tension or compression as the roof beam moves up and down with snow load applications. The edge of the drywall is reinforced to insure its integrity under these imposed stresses.*

5. DO NOT INSTALL DRYWALL SCREWS ABOVE THIS LEVEL - *See comments Item 3.*

6. DRYWALL AIR BARRIER - *See D1-5 Item 5.*

7. EXTERIOR INSULATION

Detail D1-3

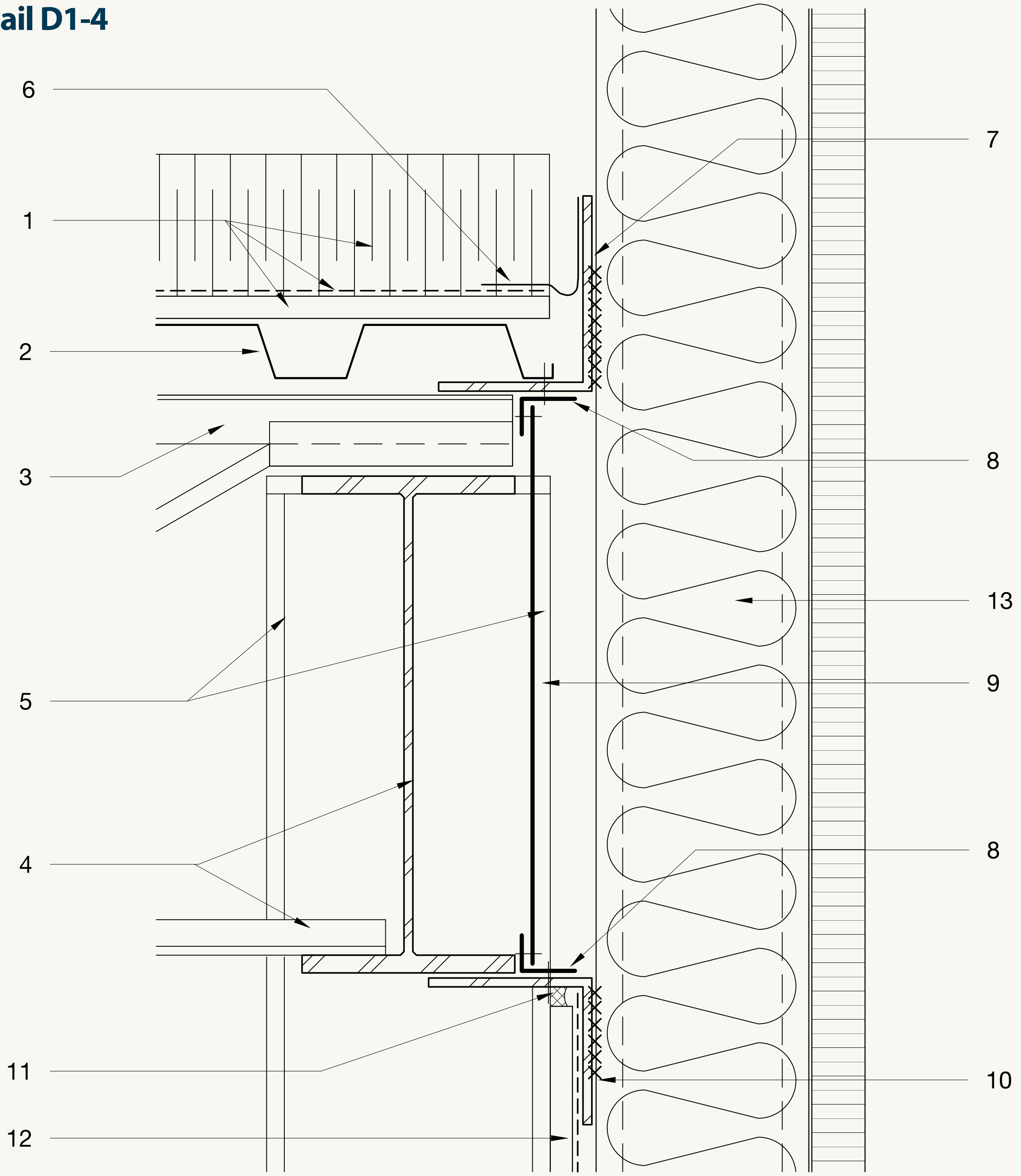


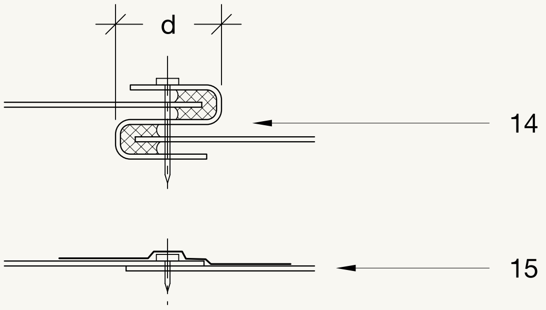
Design Example D1 – Detail D1-4

1. ROOF INSULATION, AIR/VAPOUR BARRIER AND SHEATHING
2. 38 mm STEEL ROOF DECK
3. OWSJ - *The joist parallel edge condition is similar with top of steel beam at underside of deck.*
4. STEEL BEAM - *Support bottom flange of steel beam with tie joists and/or bracing as required structurally.*
5. STEEL COLUMN BEYOND
6. PEEL AND STICK AIR BARRIER MEMBRANE - *The peel and stick membrane provides air barrier continuity between the roof air barrier and the continuous bent plate angle.*
7. STRUCTURAL BENT PLATE ANGLE WELDED TO TOP OF JOIST SHOE OR TOP OF BEAM WHERE JOISTS PARALLEL - *Provide intermediate support for angle between joist shoes as required structurally. Seal butt joints between angles with peel and stick air barrier membrane.*
8. CONTINUOUS 1.22 mm GALVANIZED ANGLE SET IN CAULK - *Fasten angle to bent plate angle with sheet metal screws at 300 mm o.c. Seal butt joints between angles with peel and stick air barrier membrane.*
9. CONTINUOUS 0.91 mm GALVANIZED SHEET METAL AIR BARRIER - *Fasten air barrier to continuous angles top and bottom at 200 mm o.c. maximum with sheet metal screws. Provide peel and stick air barrier membrane top and bottom (not shown) for air barrier continuity between the sheet metal and the continuous angles. Alternatively, set the sheet metal air barrier in caulk. See Items 14 and 15 for methods of making the lap connection in the sheet metal air barrier.*

   Note that the sheet metal air barrier will have to be built-out around columns. As an alternative detailing scheme, the hot-rolled steel roof beam could have been used as part of the air barrier system with special details required to transfer the air barrier from the top of the beam to the roof and to accommodate columns and splices in beams.
10. STRUCTURAL BENT PLATE ANGLE WELDED TO UNDERSIDE OF BEAM. - *Seal butt joints between angles with peel and stick air barrier membrane.*
11. LEAVE 13 mm GAP AT END OF DRYWALL. - *Caulk the joint to provide continuous seal between the drywall air barrier and the bent plate angle.*
12. DRYWALL AIR BARRIER WITH POLY VAPOUR RETARDER - *See D1-5 Item 5.*
13. STEEL STUDS - *Field weld to bent plate angles.(7 & 10)*
14. END LAP DETAIL FOR CONTINUOUS SHEET STEEL AIR BARRIER (ITEM 9) - *Provide 0.76 mm steel S-clip x 20 mm (dimension "d") with caulk filled joints. Embed sheet steel air barrier components in the caulk and fasten with sheet metal screws at 200 mm o.c.*
15. ALTERNATE END LAP DETAIL FOR CONTINUOUS SHEET STEEL AIR BARRIER (ITEM 9) - *Fasten lap at 150 mm o.c. with sheet metal screws. Seal with peel and stick air barrier membrane.*

Detail D1-4





Design Example D1 – Detail D1-5

1. 90 mm BRICK - *See D1-2 Item 9.*

2. 50 mm AIR SPACE - *See D1-2 Item 10.*

3. 25 mm RIGID EXTERIOR INSULATION (EXTRUDED POLYSTYRENE) - *See D1-2 Item 11.*

4. 152 mm GLASS FIBRE BATT INSULATION - *See D1-2 Item 7.*

5. 15.9 mm DRYWALL AIR BARRIER WITH POLY VAPOUR RETARDER - *Drywall air barriers perform well provided they and their fastenings to the steel studs have adequate structural resistance for the applied wind load on the wall system. Provide gasketed seals for all penetrations in the exterior wall. Using the interior drywall or exterior insulation as an air barrier has several advantages. The air barrier can be inspected and maintained over time. It is typically carefully installed since it forms the interior finish. It is not penetrated by brick ties. It is installed on the warm side of the wall free from the deleterious effects of temperature fluctuations and moisture. Its primary disadvantage is susceptibility to damage by building users.*

6. 152 mm STEEL STUDS AT 400 mm o.c. - *See D1-2 Item 13.*

7. STEEL STUD BRIDGING AT 1200 mm o.c. MAX. - *The structural design of the steel studs should be based on the unsheathed approach where steel bridging alone is used to brace the studs and no reliance is placed on the drywall or exterior insulation as a brace. Tests indicate that with the unsheathed design approach, a maximum bridging spacing of 1200 mm is preferred for brick veneer steel stud construction.*

8. BAYONET STYLE BRICK CONNECTOR AND WIRE PINTLE - *The superior structural performance of bayonet style ties has been demonstrated in tests. Bayonet style brick ties have several advantages. They provide a direct steel to steel connection between the brick and the steel studs. The connection to the steel stud uses sheet metal screws in shear in the warm, condensation and corrosion free part of the wall. They maintain their strength and stiffness for the full range of adjustment and they have a minimum horizontal area for the accumulation of mortar droppings. Provide corrosion resistance for both the connector and wire pintle to the requirements of CSA A370. (See Appendix E).*

9. BOTTOM TRACK 1.22 mm MINIMUM THICKNESS

10. LEAVE 13 mm GAP AT END OF DRYWALL - *Caulk to provide continuous air seal between the drywall and the bottom track.*

11. SLAB ON GRADE

12. ASPHALT IMPREGNATED JOINT FILLER

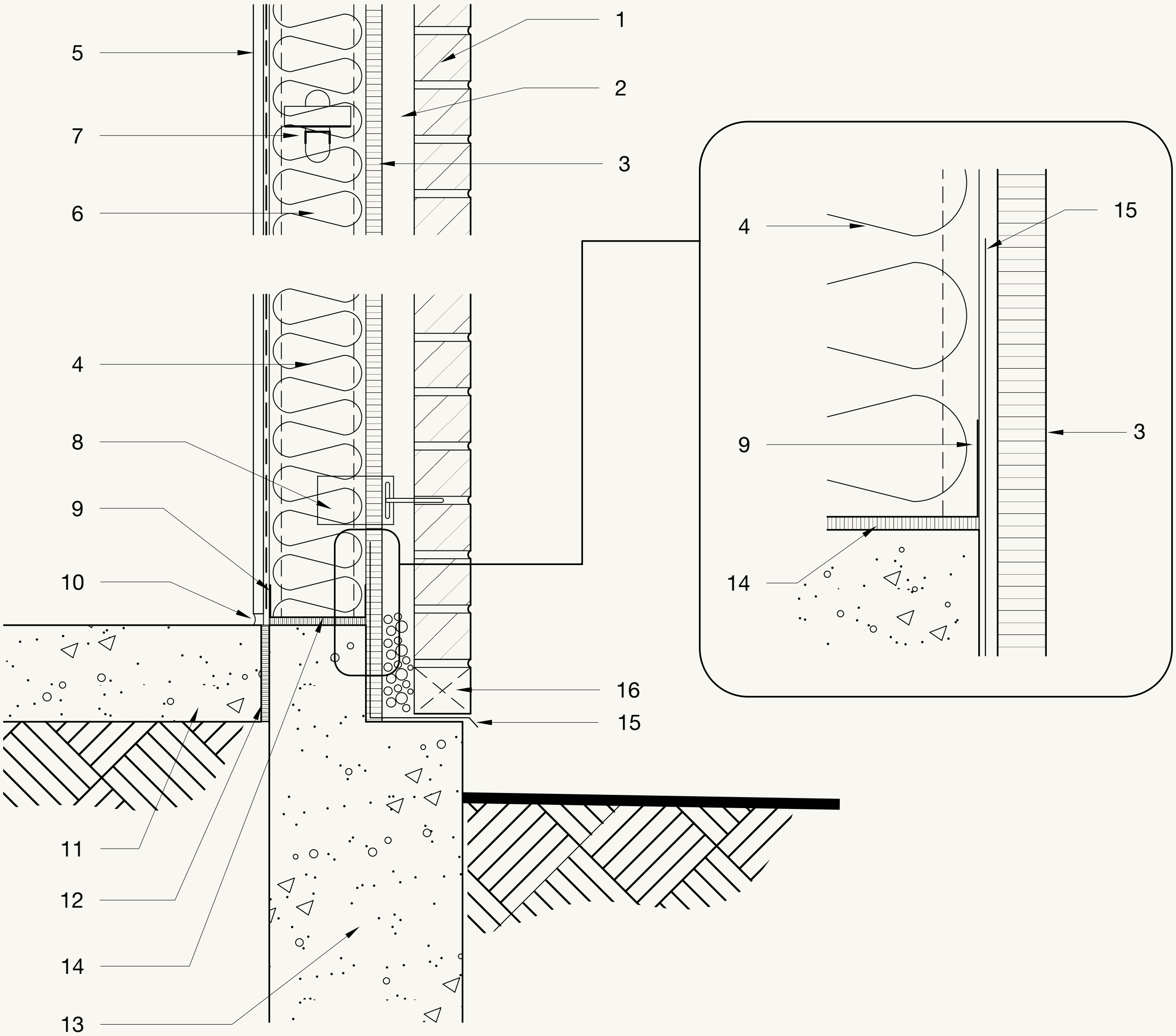
13. FOUNDATION WALL

14. CONTINUOUS COMPRESSIBLE GASKET MATERIAL UNDER BOTTOM TRACK - *Width of gasket to match width of track.*

15. FLASHING BEHIND RIGID INSULATION ANCHORED TO 0.91 mm SHEET STEEL BACK-UP - *Fasten sheet steel back-up to studs.*

16. WEEPERS - *See notes for vents D1-2 Item 8. To minimize plugged weepers due to mortar droppings during construction, coarse aggregate is shown which will help keep the drainage path open. Other methods are discussed by Drysdale & Suter, 1991.*

Detail D1-5



Design Example D2 – Detail D2-1

Wind Bearing Steel Stud/Brick Veneer Wall System - Single Storey Commercial Building

This single storey commercial building is framed with hot rolled steel members. The steel stud wall system is installed as infill with the outside face of the studs matching the outside face of the columns. The parapet is of sufficient height (1200 mm) to hide the rooftop mechanical units. It has a conventional BUR roof on steel deck.

With the steel stud wall system as infill:

Advantages

- The columns are incorporated into the depth of the wall system and do not intrude into the interior space (or only minimally). This provides more interior floor space.
- The parapet is attached to the roof structure and will deflect with the roof when loaded with snow. The lack of differential vertical movement between the roof and the parapet simplifies flashing details.

Disadvantages

- The parapet cannot be framed with steel studs alone. Supplementary hot rolled members are required.
- The hot rolled structural steel cross bracing will interfere with the steel studs.
- Continuity of air barriers is more difficult to achieve than with studs outside the face of the structure.

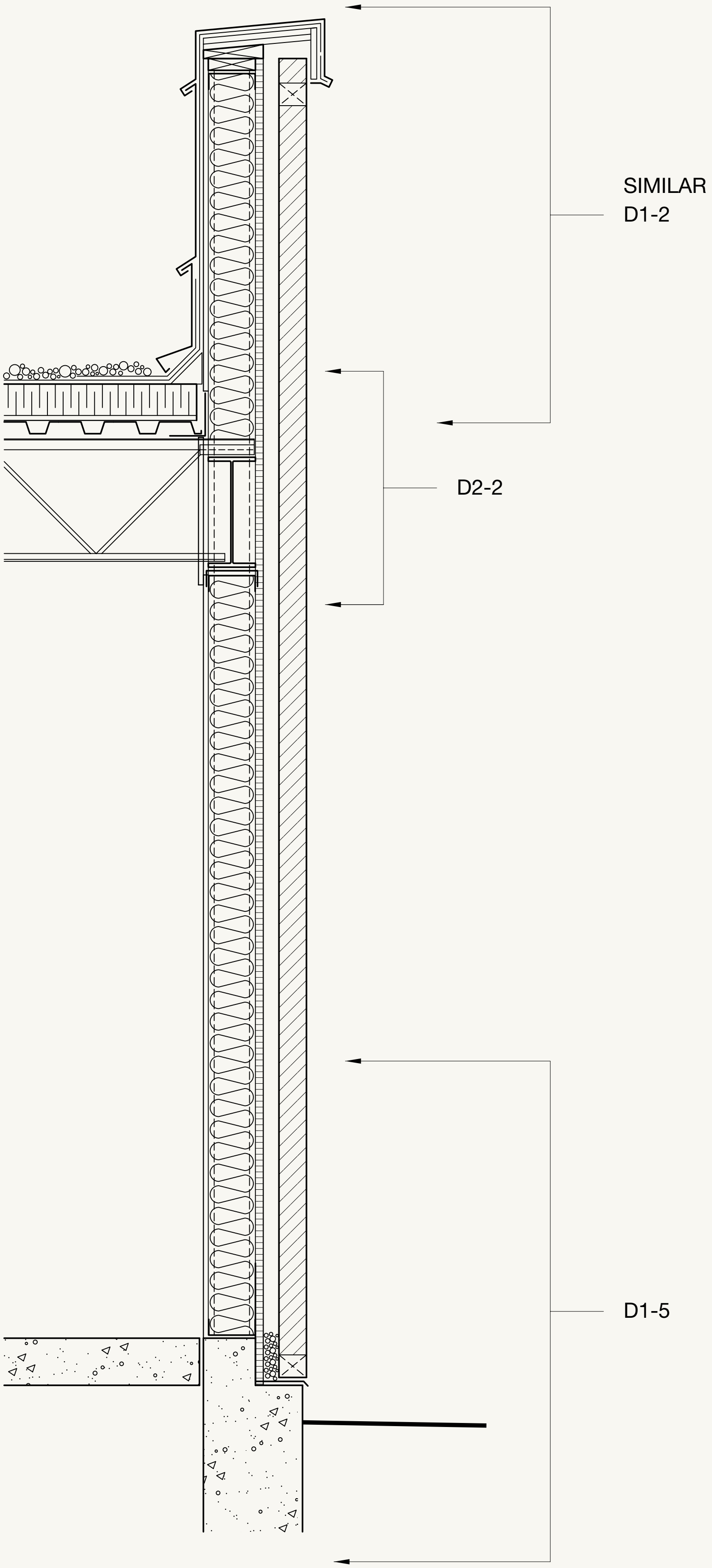
For more detail on roofing and flashing details refer to the Canadian Roofing Contractors' Association "*Roofing Specifications Manual*" and the CMHC Best "*Practice Guide for Flashings*".

For more information on the performance of steel stud brick veneer walls, refer to the references listed the Appendix G. For project specification, see CSSBI S5.

Typical wall construction:
15.9 mm interior drywall
Poly vapour retarder
152 mm steel studs at 400 o.c.
152 mm glass fibre insulation in the stud space
25 mm rigid exterior insulation
50 mm air space
90 mm brick veneer

Only limited detailing is shown for this design example. For details not shown, see Design Example D1.

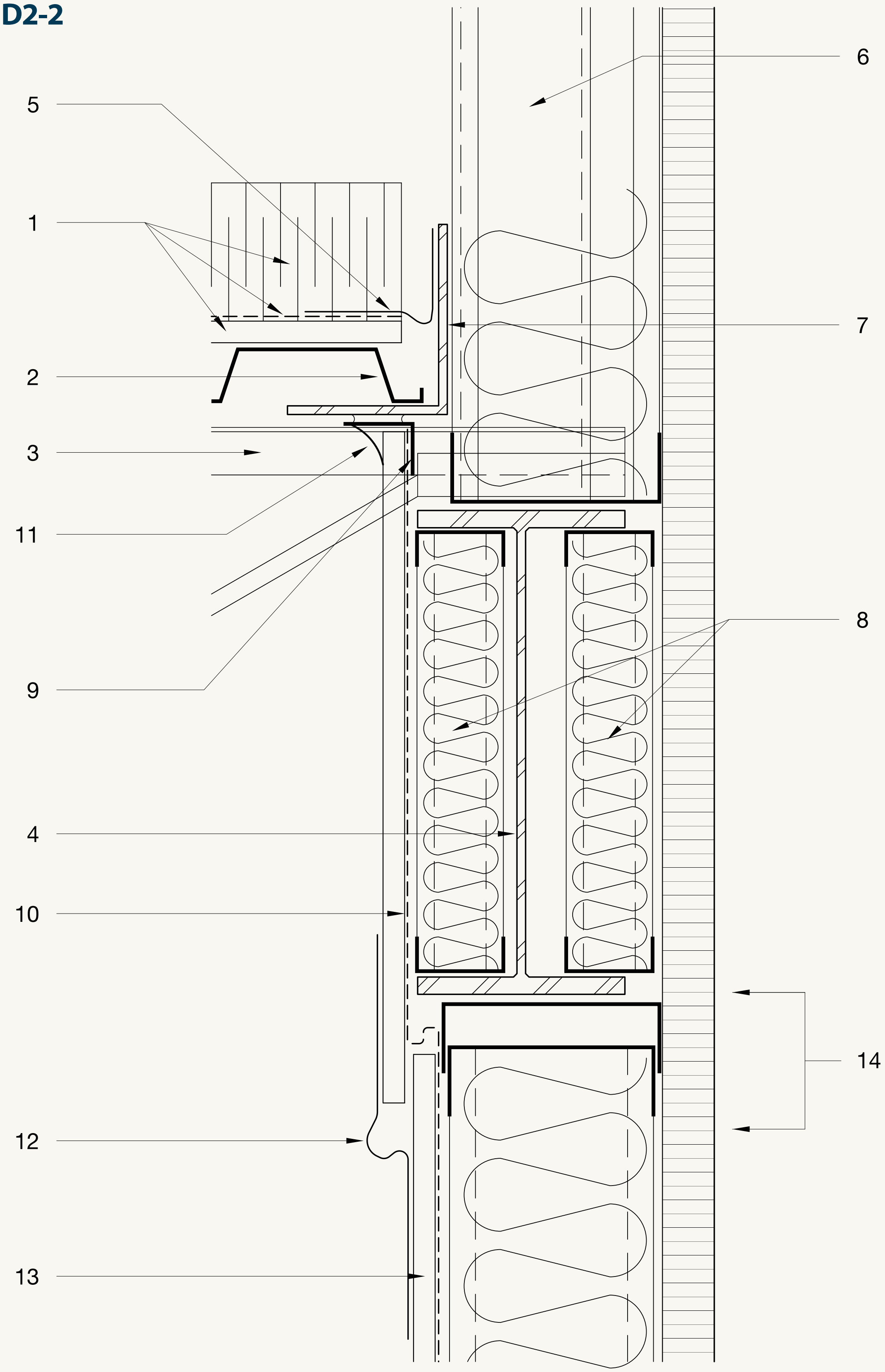
Detail D2-1



Design Example D2 – Detail D2-2

1. ROOF INSULATION, AIR/VAPOUR BARRIER AND SHEATHING
2. 38 mm STEEL ROOF DECK
3. OWSJ - *The joist parallel edge condition is similar with top of steel beam at underside of deck.*
4. STEEL BEAM - *Support bottom flange of steel beam with tie joists and/or bracing as required structurally – not shown.*
5. PEEL AND STICK AIR BARRIER MEMBRANE - *The peel and stick membrane provides air barrier continuity between the roof air barrier and the continuous bent plate angle.*
6. 100 mm MINIMUM HSS WELDED TO TOP FLANGE OF BEAM - *The hollow structural sections cantilever from the top flange of the beam to provide structural support to the parapet and are typically spaced to match the OWSJ spacing. Provide top track and 152 mm stud infill between the HSS.*
7. STRUCTURAL BENT PLATE ANGLE WELDED TO TOP OF JOIST SHOE OR TOP OF BEAM WHERE JOISTS PARALLEL - *Provide intermediate support for angle between joist shoes as required structurally. Seal butt joints between angles with peel and stick air barrier membrane.*
8. INFILL STUD AT 400 mm o.c. - *The infill stud walls provide support for the exterior insulation and the interior drywall air barrier.*
9. CONTINUOUS 1.22 mm GALVANIZED ANGLE SET IN CAULK - *Fasten angle to bent plate angle with sheet metal screws at 300 mm o.c. Seal butt joints between angles with peel and stick air barrier membrane. Angle will be interrupted by joist shoes.*
10. DRYWALL AIR BARRIER WITH VAPOUR BARRIER - *This short piece of drywall extends the air barrier past the steel beam. Cut-out the drywall locally to accommodate the joist shoes and fill and seal the gaps at the joist shoes with insulating foam. The drywall may also have to be boxed around the columns. The poly vapour retarder is continued up the back side of this drywall piece to the 1.22 mm angle.*
11. CAULKED JOINT
12. PEEL AND STICK AIR BARRIER MEMBRANE - *Loop the peel and stick to accommodate vertical differential movement at the joint.*
13. DRYWALL AIR BARRIER WITH POLY VAPOUR RETARDER - *See Item 5 Section D1-5.*
14. INNER AND OUTER TOP TRACK DEFLECTION DETAIL - *Outer top track thickness to be determined when shop drawings prepared. Suggested minimum thickness is 1.52 mm. (This is a minimum requirement only - thicker material may be required structurally). The flexibility of this detail will have to be checked by the structural engineer responsible for the design of the steel stud wall system. For the inner top track use 1.22 mm minimum thickness. (This is a minimum requirement only - thicker material may be required structurally). Unlike Detail D-1, the local deformations in the inner and outer top track detail do not add to the overall flexural deflection of the system.*

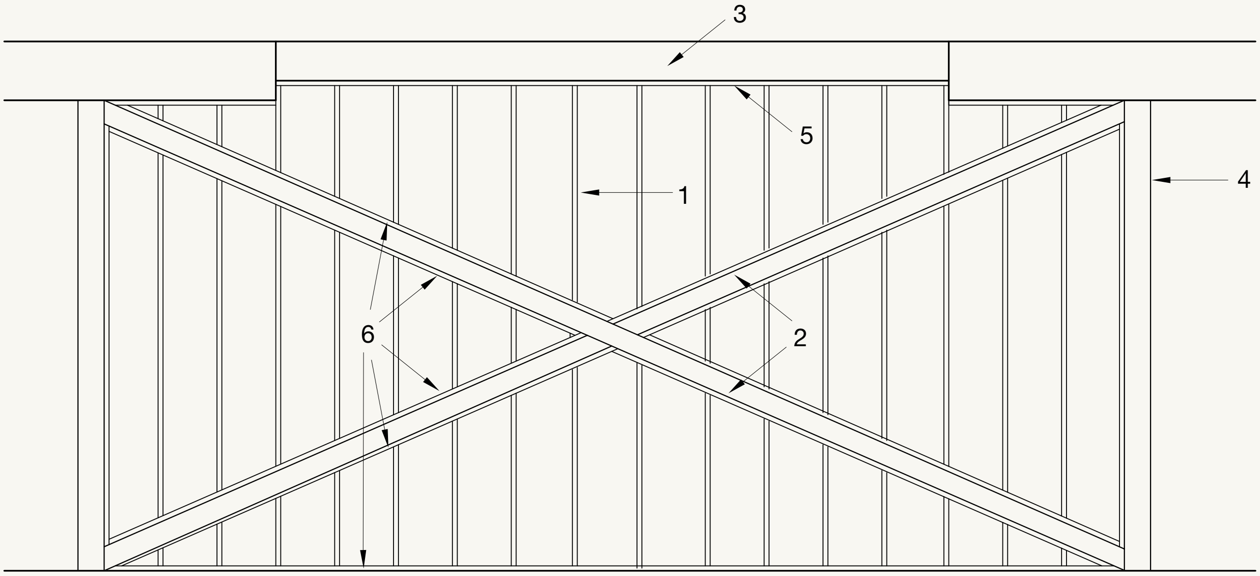
Detail D2-2



Design Example D2 – Detail D2-3

1. STUD INFILL - *The studs are cut to fit between the structural cross bracing. Provide a sloping top and bottom track connection to the cross bracing and an inner and outer top track connection detail to the underside of the beams. See D2-2 Item 14.*
2. STRUCTURAL CROSS BRACING - *The cross bracing (typically HSS members) must be designed structurally to carry the wind load reaction from the studs that frame in, with wind load deflections limited as required by the brick veneer design requirements.*
3. ROOF BEAMS
4. COLUMN
5. INNER AND OUTER TOP TRACK DEFLECTION DETAIL
6. ORDINARY TRACK

Detail D2-3



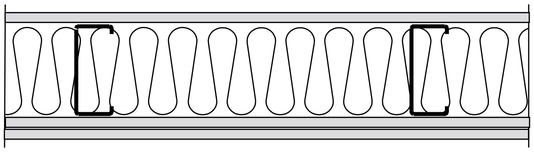
APPENDIX A

STC and Fire Performance Ratings for LSF Wall and Floor Assemblies

Fire Endurance Periods

Non-Loadbearing Walls

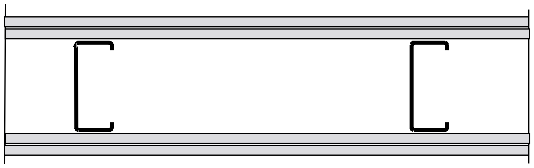
- 1 layer gypsum board
- Steel studs (0.46 mm thick)
- Insulation
- 2 layers gypsum board



Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		Fire Endurance (min.)
			Type	Thickness (mm)	Type	Thickness (mm)	
F-07	31 x 92	610	None	-	Type X	12.7	65
F-09	31 x 92	610	Glass fibre	90	Type X	12.7	65
F-10	31 x 92	610	Mineral fibre (584 mm wide)	90	Type X	12.7	60
F-10B	31 x 92	610	Mineral fibre (615 mm wide)	90	Type X	12.7	100
F-11	31 x 92	610	Cellulose (Sprayed)	90	Type X	12.7	62

Notes:
1. Reference report IRC-IR-675

- 2 layers gypsum board
- Steel studs (0.46 mm thick)
- Insulation
- 2 layers gypsum board



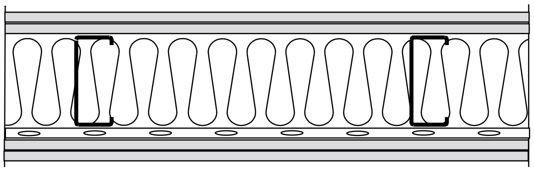
Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		Fire Endurance (min.)
			Type	Thickness (mm)	Type	Thickness (mm)	
F-03	31 x 92	610	None	-	RL	12.7	63
F-05	31 x 92	610	None	-	RH	12.7	69

Notes:
1. Reference report IRC-IR-674
2. RL = low density gypsum board (7.35 kg/m^3) RH = low density gypsum board (7.80 kg/m^3)

Fire Endurance Periods

Loadbearing Walls

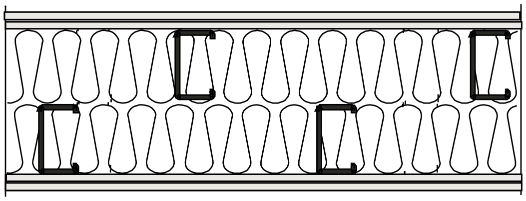
- 2 layers gypsum board
- Steel studs
- Insulation
- Resilient channels (R.C.)
- 2 layers gypsum board



Test No.	Stud Thickness (mm)	Stud Spacing (mm)	R.C. spacing (mm)	Insulation Type	Insulation Thickness (mm)	Gypsum Board Type	Gypsum Board Thickness (mm)	Fire Endurance (min.)
41 x 92 Loadbearing Studs								
F37	0.91	406	406	None	-	Type X	12.7	77
F39	0.91	406	None	None	-	Type X	12.7	83
F27	0.91	406	406	Glass Fibre	90	Type X	12.7	56
F35, F36	0.84	406	406	Glass Fibre	90	Type X	12.7	68, 63
F38	0.91	406	406	Mineral Fibre	90	Type X	12.7	59
F28	0.91	610	406	Mineral Fibre	90	Type X	12.7	74
F31	0.91	406	406	Cellulose	90	Type X	12.7	71

Notes:
1. Tests are from reference report IRC-IR-833.

- 2 layers gypsum board
- Steel studs and insulation
- Gap
- Steel stud and insulation
- 2 layers gypsum board



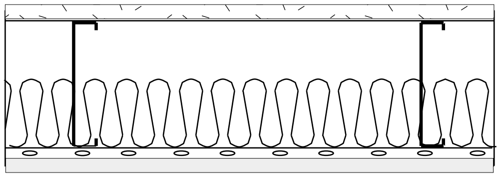
Test No.	Stud Thickness (mm)	Stud Spacing (mm)	Insulation Type	Insulation Thickness (mm)	Gypsum Board Type	Gypsum Board Thickness (mm)	Fire Endurance (min.)
41 x 92 Loadbearing Studs							
F30, F30R	0.91	406	None	-	Type X	12.7	100, 102
F26	0.91	406	Mineral Fibre	90	Type X	12.7	84

Notes:
1. Tests are from reference report IRC-IR-833.

Fire Endurance Periods

Floors

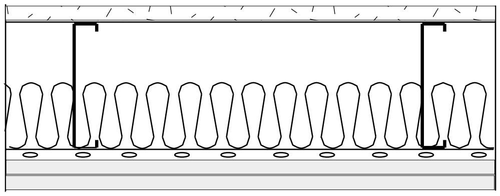
- 1 layer sub-floor sheathing
- Steel floor joists
- Insulation
- Resilient channels (R.C.) at 406 mm o.c.
- 1 layer 12.7 mm Type X gypsum board



Test No.	Joist			Sub-floor		Insulation		Fire Endurance (min.)
	Depth (mm)	Thickness (mm)	Spacing (mm)	Type	Thickness (mm)	Type	Thickness (mm)	
FF-25	203	1.22	406	Plywood	15.9	Mineral fibre	90	46

Notes:
1. Reference report IRC-IR-764

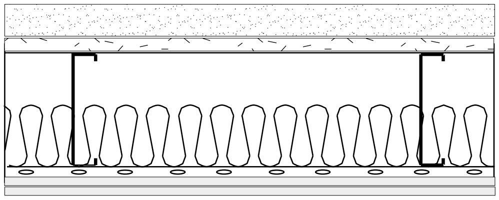
- 1 layer sub-floor sheathing
- Steel floor joists
- Insulation
- Resilient channels (R.C.) at 406 mm o.c.
- 2 layers 12.7 mm Type X gypsum board



Test No.	Joist			Sub-floor		Insulation		Fire Endurance (min.)
	Depth (mm)	Thickness (mm)	Spacing (mm)	Type	Thickness (mm)	Type	Thickness (mm)	
FF-22	203	1.22	406	Plywood	15.9	None	-	74
FF-23	203	1.22	406	Plywood	15.9	Glass fibre	90	68
FF-24	203	1.22	610	Plywood	15.9	Glass fibre	90	69

Notes:
1. Reference report IRC-IR-764

- 38 mm concrete
- 1 layer sub-floor sheathing
- Steel floor joists
- Insulation
- Resilient channels (R.C.) at 406 mm o.c.
- 2 layers 12.7 mm Type X gypsum board



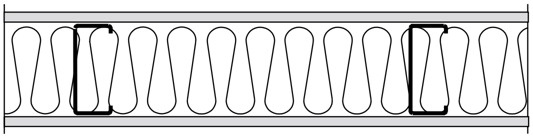
Test No.	Joist			Sub-floor		Insulation		Fire Endurance (min.)
	Depth (mm)	Thickness (mm)	Spacing (mm)	Type	Thickness (mm)	Type	Thickness (mm)	
FF-27	203	1.22	406	Plywood	15.9	Glass fibre	90	60

Notes:
1. Reference report IRC-IR-764

Acoustic Tests

Non-Loadbearing Walls

- 1 layer gypsum board
- Steel studs (0.46 mm thick)
- Insulation
- 1 layer gypsum board



Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 64 mm Non-Loadbearing Studs							
057	31 x 64	406	None	-	Type X	15.9	35
058	31 x 64	406	Glass Fibre (G1)	64	Type X	15.9	39
064	31 x 64	406	Mineral Fibre (M1)	64	Type X	12.7	36
061	31 x 64	406	Mineral Fibre (M1)	64	Type X	15.9	38
069, 070	31 x 64	406	Mineral Fibre (M1)	64	Regular	12.7	33, 34
067	31 x 64	406	Mineral Fibre (M2)	64	Type X	12.7	35
059	31 x 64	406	Mineral Fibre (M2)	64	Type X	15.9	36
060	31 x 64	406	Mineral Fibre (M3)	57	Type X	15.9	36
068	31 x 64	406	Mineral Fibre (M3)	57	Regular	12.7	36
032	31 x 64	610	None	-	Type X	15.9	35
038	31 x 64	610	Glass Fibre (G1)	64	Type X	12.7	45
033, 073	31 x 64	610	Glass Fibre (G1)	64	Type X	15.9	44, 44
041, 043, 044	31 x 64	610	Glass Fibre (G1)	64	Regular	12.7	42, 43, 43
047	31 x 64	610	Mineral Fibre (M1)	64	Type X	12.7	43
034	31 x 64	610	Mineral Fibre (M1)	64	Type X	15.9	42

Acoustic Tests

Non-Loadbearing Walls

Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 92 mm Non-Loadbearing Studs							
418	31 x 92	406	None	-	Type X	15.9	38
422, 425, 344	31 x 92	406	Glass Fibre (G1)	90	Type X	12.7	45, 45, 46
419, 443, 444, 074, 075, 325, 326, 352, 360, 026, 027, 028, 029	31 x 92	406	Glass Fibre (G1)	90	Type X	15.9	47, 45, 44, 47, 46, 49, 49, 46, 46, 46, 46, 46, 46
428, 347, 361, 365	31 x 92	406	Glass Fibre (G1)	90	Regular	12.7	42, 41, 39, 40
445, 327, 328	31 x 92	406	Mineral Fibre (M1)	90	Type X	15.9	46, 47, 47
343	31 x 92	406	Mineral Fibre (M2)	40	Type X	12.7	40
340	31 x 92	406	Mineral Fibre (M2)	40	Type X	15.9	41
002, 335, 336	31 x 92	406	Mineral Fibre (M2)	75	Type X	15.9	42, 45, 44
080	31 x 92	406	Mineral Fibre (M2)	90	Type X	12.7	40
001	31 x 92	406	Mineral Fibre (M2)	90	Type X	15.9	43
081	31 x 92	406	Mineral Fibre (M3)	90	Type X	12.7	39
339	31 x 92	406	Mineral Fibre (M3)	83	Type X	12.7	40
338, 003	31 x 92	406	Mineral Fibre (M3)	83	Type X	15.9	41, 39
439	31 x 92	406	Cellulose (C1)	40	Type X	15.9	45
049	31 x 92	406	Cellulose (C1)	90	Type X	15.9	45
438	31 x 92	406	Cellulose (C2)	90	Type X	15.9	44
376	31 x 92	610	None	-	Type X	15.9	38
413	31 x 92	610	Glass Fibre (G1)	90	Regular	12.7	47
410	31 x 92	610	Glass Fibre (G1)	90	Type X	12.7	48
348, 367, 399, 324	31 x 92	610	Glass Fibre (G1)	90	Type X	15.9	48, 49, 48, 50
396	31 x 92	610	Mineral Fibre (M2)	40	Type X	15.9	45
026	31 x 92	610	Cellulose (C2)	90	Type X	12.7	48

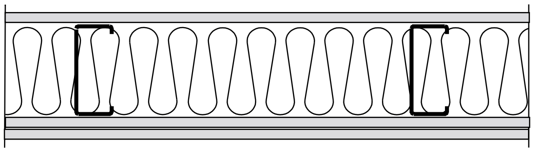
Acoustic Tests

Non-Loadbearing Walls

Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 152 mm Non-loadbearing Studs							
299	31 x 152	610	Glass Fibre (G1)	152	Type X	12.7	52
298	31 x 152	610	Glass Fibre (G1)	152	Type X	15.9	51

Notes:
1. Reference report IRC-IR-761

- 1 layer gypsum board
- Steel studs (0.46 mm thick)
- Insulation
- 2 layers gypsum board



Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 64 mm Non-loadbearing Studs							
065	31 x 64	406	Mineral Fibre (M1)	64	Type X	12.7	42
062	31 x 64	406	Mineral Fibre (M1)	64	Type X	15.9	45
071	31 x 64	406	Mineral Fibre (M1)	64	Regular	12.7	38
039	31 x 64	610	Glass Fibre (G1)	64	Type X	12.7	51
036	31 x 64	610	Glass Fibre (G1)	64	Type X	15.9	51
035	31 x 64	610	Glass Fibre (G1)	64	(2) Type X (1) Reg.	15.9/12.7	49
045	31 x 64	610	Glass Fibre (G1)	64	Regular	12.7	49
055	31 x 64	610	Mineral Fibre (M1)	64	Type X	12.7	49
048	31 x 64	610	Mineral Fibre (M1)	64	(2) Type X (1) Reg.	12.7	48

Acoustic Tests

Non-Loadbearing Walls

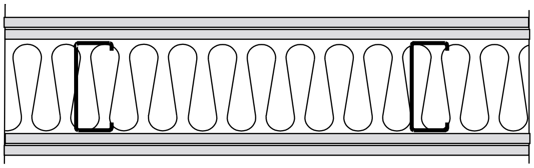
Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 92 mm Non-Loadbearing Studs							
423, 426, 345	31 x 92	406	Glass Fibre (G1)	90	Type X	12.7	51, 50, 51
420, 350	31 x 92	406	Glass Fibre (G1)	90	Type X	15.9	52, 52
429, 348, 364, 366	31 x 92	406	Glass Fibre (G1)	90	Regular	12.7	48, 47, 44, 46
329	31 x 92	406	Mineral Fibre (M1)	90	Type X	15.9	53
341	31 x 92	406	Mineral Fibre (M2)	40	Type X	15.9	47
333	31 x 92	406	Mineral Fibre (M2)	75	Type X	15.9	50
337	31 x 92	406	Mineral Fibre (M3)	83	Type X	15.9	46
440	31 x 92	406	Cellulose (C1)	40	Type X	15.9	51
050	31 x 92	406	Cellulose (C1)	90	Type X	15.9	49
437	31 x 92	406	Cellulose (C2)	90	Type X	15.9	49
411	31 x 92	610	Glass Fibre (G1)	90	Type X	12.7	52
415	31 x 92	610	Glass Fibre (G1)	90	Regular	12.7	51
368	31 x 92	610	Glass Fibre (G1)	90	Type X	15.9	54
370	31 x 92	610	Glass Fibre (G1)	90	(2) Type X/ (1) Reg.	15.9/12.7	55
397	31 x 92	610	Mineral Fibre (M2)	40	Type X	15.9	51
027	31 x 92	610	Cellulose (C2)	90	Type X	12.7	53

Notes:
1. Reference report IRC-IR-761

Acoustic Tests

Non-Loadbearing Walls

- 2 layers gypsum board
- Steel studs (0.46 mm thick)
- Insulation
- 2 layers gypsum board



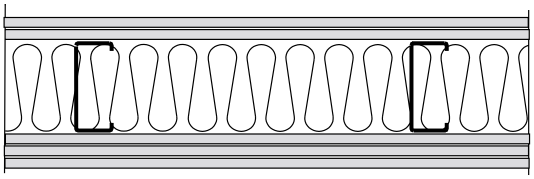
Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 64 mm Non-Loadbearing Studs							
072	31 x 64	406	Mineral Fibre (M1)	64	Regular	12.7	44
066	31 x 64	406	Mineral Fibre (M1)	64	Type X	12.7	48
063	31 x 64	406	Mineral Fibre (M1)	64	Type X	15.9	52
040	31 x 64	610	Glass Fibre (G1)	64	Type X	12.7	55
046	31 x 64	610	Glass Fibre (G1)	64	Regular	12.7	52
037	31 x 64	610	Glass Fibre (G1)	64	Type X	15.9	55
056	31 x 64	610	Mineral Fibre (M1)	64	Type X	12.7	54
31 x 92 mm Non-Loadbearing Studs							
424, 427, 346	31 x 92	406	Glass Fibre (G1)	90	Type X	12.7	55, 55, 52
421, 351	31 x 92	406	Glass Fibre (G1)	90	Type X	15.9	56, 56
430, 349, 363, 367	31 x 92	406	Glass Fibre (G1)	90	Regular	12.7	53, 49, 48, 53
441	31 x 92	406	Cellulose (C1)	40	Type X	15.9	53
331, 332	31 x 92	406	Mineral Fibre (M1)	90	Type X	15.9	55, 55
342	31 x 92	406	Mineral Fibre (M2)	40	Type X	15.9	52
077, 334	31 x 92	406	Mineral Fibre (M2)	75	Type X	15.9	52, 54
051	31 x 92	406	Cellulose (C1)	90	Type X	15.9	52
435, 436	31 x 92	406	Cellulose (C2)	90	Type X	(1) 12.7/(3) 15.9	54, 54
412	31 x 92	610	Glass Fibre (G1)	90	Type X	12.7	55
416	31 x 92	610	Glass Fibre (G1)	90	Regular	12.7	53
369	31 x 92	610	Glass Fibre (G1)	90	Type X	15.9	58
398	31 x 92	610	Mineral Fibre (M2)	40	Type X	15.9	55
028	31 x 92	610	Cellulose (C2)	90	Type X	12.7	56
387	31 x 92	610	Cellulose (C2)	90	Type X	15.9	51

Notes:
1. Reference report IRC-IR-761

Acoustic Tests

Non-Loadbearing Walls

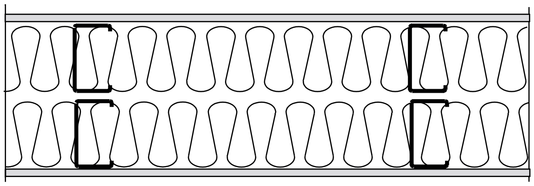
- 2 layers gypsum board (Type X)
- Steel studs (0.46 mm thick)
- Insulation
- 2 layers gypsum board (Type X)
- 1 layer gypsum board (Regular)



Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 92 mm Non-Loadbearing Studs							
371	31 x 92	610	None	-	Type X/ (1) Regular	15.7/ 12.7	54

Notes:
1. Reference report IRC-IR-761

- 1 layer gypsum board
- Steel studs and insulation (Studs 0.46 mm thick)
- 65 mm Gap
- Steel studs and insulation (Studs 0.46 mm thick)
- 1 layer gypsum board



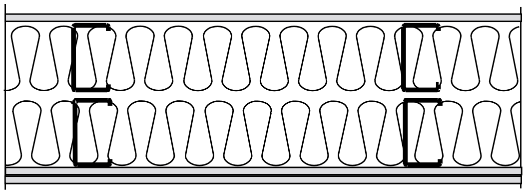
Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation		Gypsum Board		STC Rating
			Type	Thickness (mm)	Type	Thickness (mm)	
31 x 40 mm Non-Loadbearing Studs							
306	31 x 40	610	Mineral Fibre (M2)	40	Type X	12.7	53
309, 310	31 x 40	610	Mineral Fibre (M2)	40	Type X	15.9	54, 55
31 x 64 mm Non-Loadbearing Studs							
303	31 x 64	610	Glass Fibre (G1)	64	Type X	12.7	54
300	31 x 64	610	Glass Fibre (G1)	64	Type X	15.9	55

Notes:
1. Reference report IRC-IR-761

Acoustic Tests

Non-Loadbearing Walls

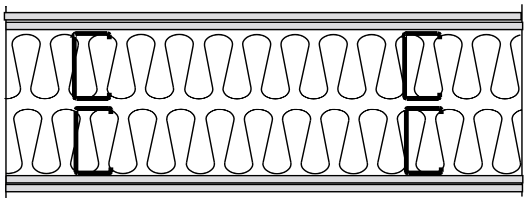
- 1 layer gypsum board
- Steel studs and insulation (Studs 0.46 mm thick)
- 65 Gap
- Stud and insulation (Studs 0.46 mm thick)
- 2 layers gypsum board



Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation Type	Insulation Thickness (mm)	Gypsum Board Type	Gypsum Board Thickness (mm)	STC Rating
31 x 40 mm Non-Loadbearing Studs							
307	31 x 40	610	Mineral Fibre (M2)	40	Type X	12.7	59
31 x 64 mm Non-Loadbearing Studs							
304	31 x 64	610	Glass Fibre (G1)	64	Type X	12.7	60
301	31 x 64	610	Glass Fibre (G1)	64	Type X	15.9	61

Notes:
1. Reference report IRC-IR-761

- 2 layers gypsum board
- Steel studs and insulation (Studs 0.46 mm thick)
- 65 Gap
- Stud and insulation (Studs 0.46 mm thick)
- 2 layers gypsum board



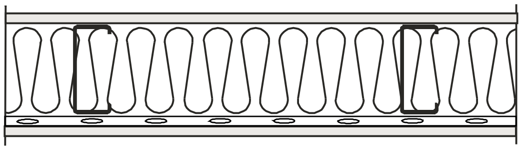
Test No.	Stud Size (mm)	Stud Spacing (mm)	Insulation Type	Insulation Thickness (mm)	Gypsum Board Type	Gypsum Board Thickness (mm)	STC Rating
31 x 40 mm Non-Loadbearing Studs							
308	31 x 40	610	Mineral Fibre (M2)	40	Type X	12.7	63
320, 321	31 x 40	610	Mineral Fibre (M2)	40	Type X	15.9	65, 65
31 x 64 mm Non-Loadbearing Studs							
305	31 x 64	610	Glass Fibre (G1)	64	Type X	12.7	62
302	31 x 64	610	Glass Fibre (G1)	64	Type X	15.9	64

Notes:
1. Reference report IRC-IR-761

Acoustic Tests

Loadbearing Walls

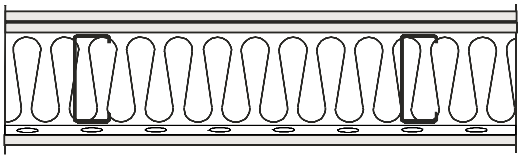
- 1 layer gypsum board
- Steel studs
- Insulation
- Resilient channels (R.C.)
- 1 layer gypsum board



Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 Loadbearing Studs								
TLA-105	0.91	406	406	Glass Fibre (G1)	90	Type X	12.7	45
TL-022 TLA-095	0.91	406	610	Glass Fibre (G1)	90	Type X	12.7	48 47
TL-025 TLA-089	0.91	406	610	Glass Fibre (G1)	90	Type X	15.9	49 49
TL-354	1.22	406	610	Glass Fibre (G1)	90	Type X	15.9	50
TL-355	1.52	406	610	Glass Fibre (G1)	90	Type X	15.9	49
41 x 152 Loadbearing Studs								
TL-353	1.22	406	610	Glass Fibre (G1)	90	Type X	15.9	50

Notes:
1. "TL" tests are from reference report IRC-IR-761. "TLA" tests are from reference report IRC-IR-832.

- 2 layers gypsum board
- Steel studs
- Insulation
- Resilient channels (R.C.)
- 1 layer gypsum board



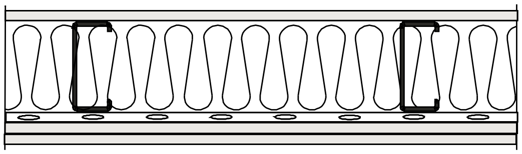
Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 mm Loadbearing Studs								
TL-019	0.91	406	610	Glass Fibre (G1)	90	Type X	12.7	54
TL-023	0.91	406	610	Mineral Fibre (M1)	90	Type X	12.7	54
TL-016	1.52	406	610	Glass Fibre (G1)	90	Type X	12.7	53
TL-013	1.52	406	610	Mineral Fibre (M1)	90	Type X	12.7	53

Notes:
1. Reference report IRC-IR-761

Acoustic Tests

Loadbearing Walls

- 1 layer gypsum board
- Steel studs
- Insulation
- Resilient channels (R.C.)
- 2 layers gypsum board



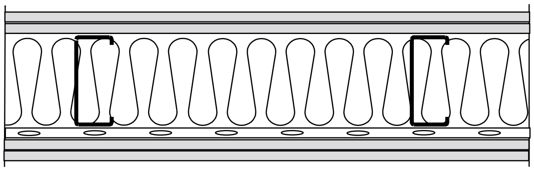
Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 Loadbearing Studs								
TLA-103	0.91	406	406	Glass Fibre	90	Type X	12.7	51
TLA-069	0.91	406	406	Glass Fibre	90	Type X	15.9	51
TLA-127	0.91	406	406	Mineral Fibre	90	Type X	12.7	51
TLA-067	0.91	406	406	Cellulose Fibre	92 (blown)	Type X	12.7	51
TLA-083	1.52	406	406	Glass Fibre	90	Type X	15.9	50
TL-021 TLA-097	0.91	406	610	Glass Fibre	90	Type X	12.7	54, 54
TLA-091	0.91	406	610	Glass Fibre	90	Type X	15.9	54
TL-018	1.52	406	610	Glass Fibre	90	Type X	12.7	53
TLA-123	0.91	406	610	Mineral Fibre	90	Type X	12.7	52
TLA-137	0.91	610	406	Mineral Fibre	90	Type X	12.7	55

Notes:
1. "TL" tests are from reference report IRC-IR-761. "TLA" tests are from reference report IRC-IR-832.

Acoustic Tests

Loadbearing Walls

- 2 layers gypsum board
- Steel studs
- Insulation
- Resilient channels (R.C.)
- 2 layers gypsum board



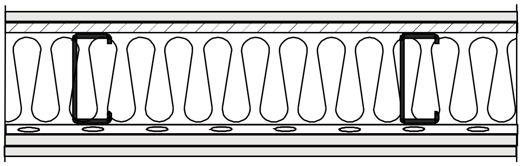
Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 Loadbearing Studs								
TLA-065	0.91	406	406	Glass Fibre	90	Type X	12.7	57
TLA-071	0.91	406	406	Glass Fibre	90	Type X	15.9	58
TLA-079	1.52	406	406	Glass Fibre	90	Type X	12.7	57
TLA-081	1.52	406	406	Mineral Fibre	90	Type X	12.7	56
TLA-085	1.52	406	406	Glass Fibre	90	Type X	15.9	57
TLA-063	0.91	406	610	None	-	Type X	12.7	50
TL-020 TLA-099	0.91	406	610	Glass Fibre	90	Type X	12.7	60 59
TL-024	0.91	406	610	Mineral Fibre	90	Type X	12.7	60
TLA-075	0.91	406	610	None	-	Type X	15.9	51
TLA-073 TLA-093	0.91	406	610	Glass Fibre	90	Type X	15.9	59 59
TL-017	1.52	406	610	Glass Fibre	90	Type X	12.7	59
TL-014	1.52	406	610	Mineral Fibre	90	Type X	12.7	59

Notes:
1. "TL" tests are from reference report IRC-IR-761. "TLA" tests are from reference report IRC-IR-832.

Acoustic Tests

Loadbearing Walls

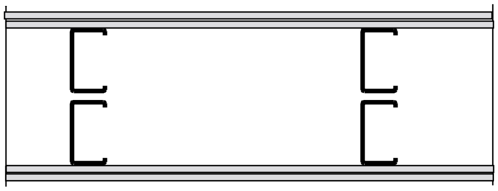
- 1 layer gypsum board
- 1 layer 11.7 mm OSB
- Steel studs
- Insulation
- Resilient channels (R.C.)
- 2 layers gypsum board



Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 mm Loadbearing Studs								
TLA-135	0.91	406	406	Mineral Fibre	90	Type X	12.7	57

Notes:
1. "TLA" tests are from reference report IRC-IR-832.

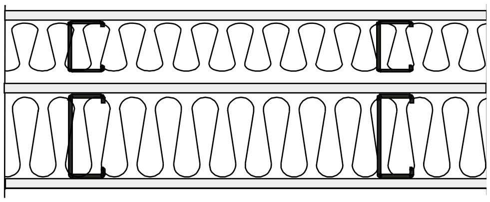
- 2 layers gypsum board
- Steel studs
- 25 mm air space
- Steel studs
- 2 layers gypsum board



Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 mm Loadbearing Studs								
TLA-061	0.91	406	-	None	-	Type X	12.7	52

Notes:
1. "TLA" tests are from reference report IRC-IR-832.

- 1 layer gypsum board
- 65 mm non-loadbearing steel studs and insulation
- 25 mm Gap
- 1 layer gypsum board
- 92 mm loadbearing steel studs and insulation
- 1 layer gypsum board



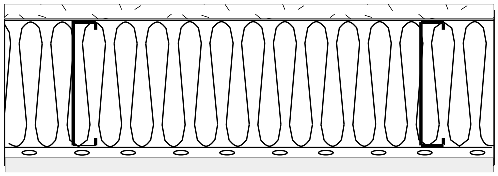
Test No.	Stud		R.C. spacing (mm)	Insulation		Gypsum Board		STC Rating
	Thickness (mm)	Spacing (mm)		Type	Thickness (mm)	Type	Thickness (mm)	
41 x 92 mm Loadbearing Studs								
TLA-077	0.46, 0.91	406	-	Glass Fibre	90	Type X	15.9	48

Notes:
1. "TLA" tests are from reference report IRC-IR-832.

Acoustic Tests

Floors

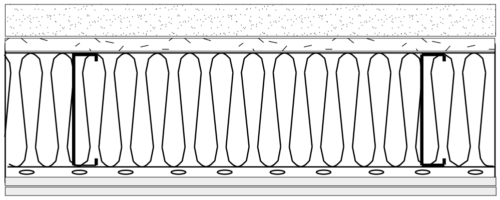
- 1 layer OSB
- Steel floor joists
- Insulation
- Resilient channels (R.C.) at 610 mm o.c.
- 1 layer 15.9 mm Type X gypsum board



Test No.	Joist			Sub-floor		Insulation		STC Rating	IIC Rating
	Depth (mm)	Thickness (mm)	Spacing (mm)	Type	Thickness (mm)	Type	Thickness (mm)		
TLF-061/030	203	1.22	406	OSB	15.1	Glass fibre	152	50	44
TLF-009/004	203	1.52	406	OSB	15.1	None	-	44	35
TLF-059/029	203	1.52	406	OSB	15.1	Glass fibre	152	51	45
TLF-001a/001	203	1.52	406	OSB	15.1	Glass fibre	152	50	43
TLF-005/002	203	1.52	406	OSB	15.1	Mineral fibre	140	51	45
TLF-011/005	203	1.52	406	OSB	15.1	Cellulose	90	51	44
TLF-013/006	203	1.52	406	OSB	15.1	Cellulose	140	52	45
TLF-057/028	203	1.91	406	OSB	15.1	Glass fibre	152	52	45
TLF-065/032	254	1.52	406	OSB	15.1	Glass fibre	152	51	44
TLF-069/034	305	1.52	406	OSB	15.1	Glass fibre	152	52	44
TLF-063/031	203	1.52	610	OSB	15.1	Glass fibre	152	53	44
TLF-067/033	203	1.52	610	OSB	15.1	Glass fibre	152	53	44

Notes:
1. Reference report IRC-IR-766

- 25 mm gypsum concrete
- 1 layer OSB
- Steel floor joists
- Insulation
- Resilient channels (R.C.) at 610 mm o.c.
- 1 layer 15.9 mm Type X gypsum board



Test No.	Joist			Sub-floor		Insulation		STC Rating	IIC Rating
	Depth (mm)	Thickness (mm)	Spacing (mm)	Type	Thickness (mm)	Type	Thickness (mm)		
TLF-079/039	203	1.22	406	OSB	15.1	None	-	55	24
TLF-081/040	203	1.52	406	OSB	15.1	Glass fibre	152	60	28

Notes:
1. Reference report IRC-IR-766

APPENDIX B

Thermal Resistance Data for LSF Wall Assemblies

Introduction

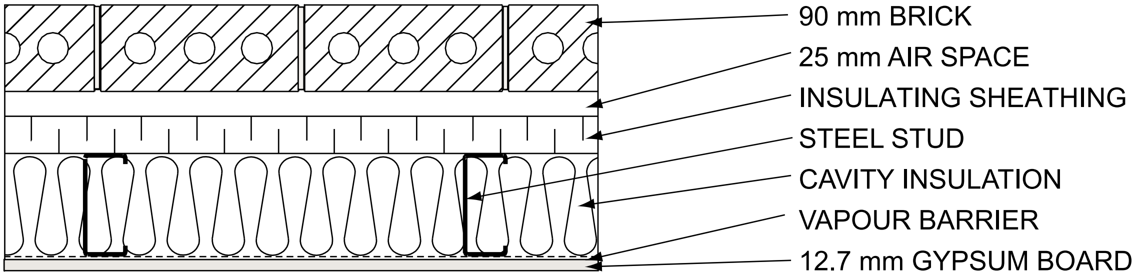
This information has been developed as a guide in selecting common steel framed wall assemblies to meet specific thermal resistance targets. Note the following:

1. The RSI-values of steel framed walls is not significantly affected by the thickness of the steel stud. The tables were calculated based on a 0.84 mm thick stud with a 41 mm wide flange at 406 mm centres.
2. The most important components of the wall assembly to develop the thermal resistance is the insulation. Exterior insulation is needed to control thermal bridging through the steel studs.
3. The insulation sizes shown are intended to be representative of typical types used and not an exhaustive list. There are many types of insulation available that can be used with steel framing.
4. The RSI-values for stud spacings at 610 mm o.c. will be higher than the values shown for 406 mm o.c.. The values given in this publication may be used since they are conservative, or specific calculations can be conducted.

Calculation Procedure

The calculation of these thermal resistance values was determined using the thermal properties listed in the Appendix to the Model National Energy Code (MNEC). Computer modeling was conducted using the FRAME program which is an accepted calculation procedure recognized by the MNEC.

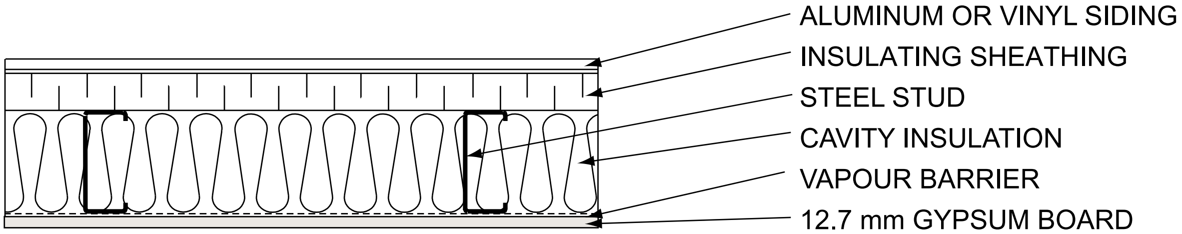
Thermal Resistance: Brick Veneer



	92 mm Studs	152 mm Studs
	BATT CAVITY INSULATION	
INSULATING SHEATHING	RSI 2.11 (R12)	RSI 3.52 (R20)
RSI 0.88 (R 5)	2.46 (14.0)	2.95 (16.7)
RSI 1.32 (R 7.5)	2.89 (16.4)	3.39 (19.3)
RSI 1.76 (R 10)	3.30 (18.7)	3.84 (21.8)

Note:
If building paper is used, add RSI 0.01 (R 0.06).

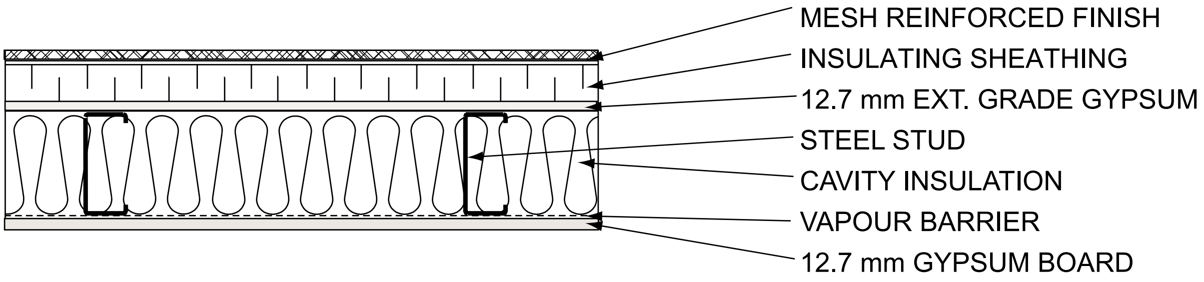
Thermal Resistance: Aluminum or Vinyl Siding



	92 mm Studs	152 mm Studs
	BATT CAVITY INSULATION	
INSULATING SHEATHING	**RSI 2.11 (R12)**	**RSI 3.52 (R20)**
RSI 0.88 (R 5)	2.33 (13.2)	2.80 (15.9)
RSI 1.32 (R 7.5)	2.76 (15.7)	3.25 (18.5)
RSI 1.76 (R 10)	3.17 (18.0)	3.69 (21.0)

Note:
If building paper is used, add RSI 0.01 (R 0.06).

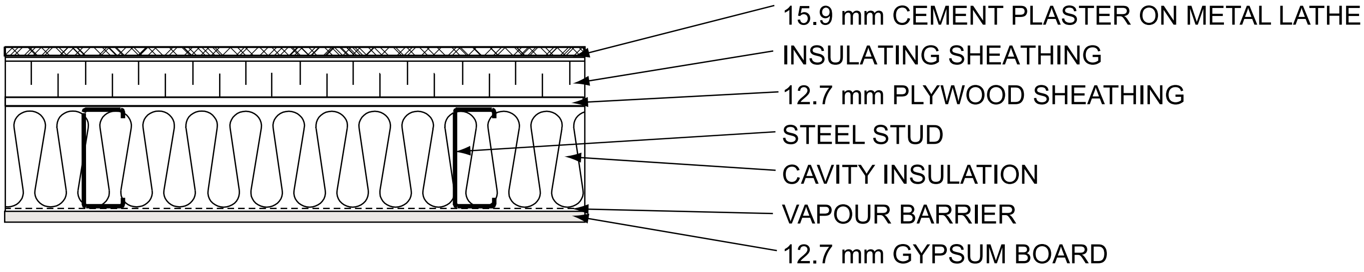
Thermal Resistance: Exterior Insulation Finish System (EIFS)



	92 mm Studs	152 mm Studs
	BATT CAVITY INSULATION	
INSULATING SHEATHING	**RSI 2.11 (R12)**	**RSI 3.52 (R20)**
RSI 0.88 (R 5)	2.19 (12.4)	2.57 (14.6)
RSI 1.32 (R 7.5)	2.60 (14.7)	3.02 (17.1)
RSI 1.76 (R 10)	3.00 (17.0)	3.46 (19.7)

Note:
If building paper is used, add RSI 0.01 (R 0.06).

Thermal Resistance: Stucco



	92 mm Studs	152 mm Studs
	BATT CAVITY INSULATION	
INSULATING SHEATHING	RSI 2.11 (R12)	RSI 3.52 (R20)
RSI 0.88 (R 5)	2.27 (12.9)	2.65 (15.0)
RSI 1.32 (R 7.5)	2.68 (15.2)	3.07 (17.4)
RSI 1.76 (R 10)	3.08 (17.5)	3.51 (19.9)

Note:
If building paper is used, add RSI 0.01 (R 0.06).

APPENDIX C

Air Barrier Design Data

NBCC/95 Clause 5.4.1.2 requires that " ... sheet and panel type materials intended to provide the principal resistance to air leakage shall have an air leakage characteristic not greater than 0.02 L/s-m2 measured at a pressure difference of 75 Pa."

This leakage requirement only applies to the material in the air barrier system not to the overall air barrier system including joints. Although NBCC/95 does not specify a maximum leakage rate for the complete air barrier system, recommendations are provided in Appendix A
Table A-5.4.2.1.

Table C-1: Tested Air Flow Rates

Material Description	Measured Air Flow Rate Through the Material at 0.75 Pa Pressure			Meets 0.02 L/(s-m^2) Limit
	Average (L/s-m^2)	Minimum (L/s-m^2)	Maximum (L/s-m^2)	
Sheet steel	negligible	negligible	negligible	Y
2 mm smooth surface roofing membrane	negligible	negligible	negligible	Y
2.7 mm modified bituminous torch on grade membrane (glass fibre mat)	negligible	negligible	negligible	Y
Aluminum foil vapour barrier	negligible	negligible	negligible	Y
1.3 mm modified bituminous self-adhesive membrane	negligible	negligible	negligible	Y
2.7 mm modified bituminous torch on grade membrane (polyester reinforced mat)	negligible	negligible	negligible	Y
9.5 mm plywood sheathing	negligible	negligible	negligible	Y
38 mm extruded polystyrene [XEPS - extruded expanded]	negligible	negligible	negligible	Y
25.4 mm foil back urethane insulation	negligible	negligible	negligible	Y
24 mm phenolic insulation board	negligible	negligible	negligible	Y
42 mm phenolic insulation board	negligible	negligible	negligible	Y
12.7 mm cement board	negligible	negligible	negligible	Y
12.7 mm foil back gypsum board	negligible	negligible	negligible	Y
8 mm plywood sheathing	0.0067	0.0000	0.0222	Y
16 mm flakewood board	0.0069	0.0006	0.0181	Y
12.7 mm gypsum board (M/R)	0.0091	0.0055	0.0118	Y
11 mm flakewood board	0.0108	0.0075	0.0134	Y
12.7 mm particle board	0.0155	0.0121	0.0178	Y
Reinforced non-perforated polyolefin	0.0195	0.0171	0.0218	Y

Table C-1: Tested Air Flow Rates

Material Description	Measured Air Flow Rate Through the Material at 0.75 Pa Pressure			Meets 0.02 L/(s-m²) Limit
	Average (L/s-m²)	Minimum (L/s-m²)	Maximum (L/s-m²)	
12.7 mm gypsum board	0.0196	0.0170	0.0219	Y
15.9 mm particle board	0.0260	0.0130	0.0375	N
3.2 mm tempered hardboard	0.0274	0.0184	0.0422	N
Expanded polystyrene type 2 [EPS - moulded expanded]	0.119	0.0214	0.280	N
30 lb roofing felt	0.187	0.167	0.208	N
15 lb non-perforated asphalt felt	0.271	0.248	0.296	N
15 lb perforated asphalt felt	0.396	0.327	0.477	N
Glass fibre rigid insulation board with spunbonded olefin film on one face	0.488	0.431	0.578	N
11 mm plain fibreboard	0.822	0.737	0.892	N
11 mm asphalt impregnated fibreboard	0.829	0.746	0.894	N
Spunbonded olefin film	0.959	0.841	1.07	N
Perforated polyethylene #1	4.03	2.56	5.93	N
Perforated polyethylene #2	3.23	2.80	3.72	N
Expanded polystyrene (type 1) [EPS - moulded expanded]	12.2	9.46	15.2	N
Tongue and groove planks	19.1	18.1	20.2	N
Glasswool insulation	36.7	23.0	88.0	N
Vermiculite insulation	70.4	32.4	109	N
Cellulose insulation	86.9	75.2	100	N

Notes for Table C-1:

1. Data is taken from "Air Permeance of Building Materials - Summary Report", by AIR-INS Inc., prepared for Canada Mortgage and Housing Corporation, June 17, 1988.

   This report is referenced in NBCC/95, Appendix A, Clause A-5.4.1.2 (1) and (2) as a suggested source for air leakage rates.

2. The 0.02 L/s-m² limit is assumed to apply to the average measured air flow rate.

APPENDIX D

Product Standards and Durability

Table D-1: Preferred Thicknesses and Colour Codes

Standard Colour Code	Preferred Nominal Thickness Exclusive of Coating	
	(inches)	(mm)
Red	0.033	0.84
White	0.036	0.91
Brown	0.044	1.12
Yellow	0.048	1.22
Green	0.060	1.52
Orange	0.075	1.91
Black	0.090	2.29
Blue	0.105	2.67
Grey	0.120	3.05

Notes for Table D-1:

1. The standard colour code is typically painted on one end of the member only. Positioning all studs or joist with the colour code at the same end should ensure alignment of web cut-outs.

2. Thicknesses shown are nominal exclusive of coating.

3. Refer to CSA S136 for permitted thickness tolerances.

4. For information on interpreting the obsolete gauge designation, refer to CSSBI Sheet Steel Facts No. 10, Sheet Steel Gauges: What They Mean, November 1998.

Table D-2: Metallic Coatings

Coating Type	Imperial Designation	Metric Designation
Hot-Dip Zinc-Iron Alloy	A25	ZF75
Hot-Dip Galvanized	G40 G60 G90 G115	Z160 Z180 Z275 Z350
Hot-Dip 55% Aluminum-Zinc Alloy Coated	AZ50 AZ55 AZ60	AZM150 AZM165 AZM180

Notes for Table D-2:

1. For additional information on the effect of metallic coating thicknesses on the overall thickness measurement of coated sheet steel, refer to CSSBI Sheet Steel Facts No. 10, Sheet Steel Gauges: What They Mean, November 1998.

2. As a guide to determining corrosion protection equivalence of zinc versus 55% aluminum-zinc alloy coatings, the Canadian Sheet Steel Building Institute recommends that AZM150 (55% aluminum-zinc) be considered equivalent to Z275 (zinc).

Durability

The durability of LSF products depend on appropriate building science detailing and protective metallic coatings. The most common coatings are outlined in Table D-2 with additional detail provided in the discussion that follows. Refer also to CSSBI Specifications S5 and S6 for information on recommended minimum coating weights for LSF products.

Lightweight steel framing can be used for commercial applications with long service lives equal to or exceeding those of traditional construction materials. Lightweight steel framing is coated with zinc or 55% aluminum-zinc alloy to provide superior corrosion protection and ensure a long service life. The metallic coating protects steel in two ways; first as a barrier coating, isolating the steel from the corrosive attack by moisture. Secondly, zinc provides sacrificial protection, corroding in place of the steel when the base steel is exposed. The aluminum provides excellent barrier protection

The life of any building material depends on the conditions of use, and for metallic coated steel, the type and thickness of the coating also plays a role. There are two types of metallic coatings currently in use on lightweight steel framing in Canada: galvanized and Galvalume™.

Hot-dip galvanized steel is the most common zinc coated steel product. The zinc coating is essentially pure zinc with minor amounts of aluminum (< 0.5%). The coating has good formability and provides the highest sacrificial corrosion resistance.

Galvalume™ is a 45% zinc – 55% aluminum coating (by weight). The high aluminum level of Galvalume™ provides the highest barrier protection along with sacrificial protection of zinc.

The zinc coating used to protect the steel will corrode in place of the steel so the coating thickness of the zinc is an important factor in determining the life of the lightweight steel framing. Coating thickness codes and specifications for the various types of coatings are presented in Table D-2.

The corrosion rates of zinc coatings used for lightweight steel framing are very low, since the material is used primarily in protected environments. In fact, the results of corrosion studies conducted by the International Lead and Zinc Research Organization on steel framed homes in North America and Europe in rural, urban, and marine environments indicate that the expected lifetimes of the zinc coating on lightweight steel framing should last more than 100 years.

APPENDIX E

Masonry Veneer Steel Stud Deflection Limits and Tie Design

For masonry veneer steel stud (MVSS) construction in NBCC Part 4 buildings, the design of ties, appropriate deflection limits and installation requirements are mandated in the following structural standards:

- S304.1-94 Masonry Design for Buildings, Limit States Design
- A370-94 Connectors for Masonry
- CAN3-A371-94 Masonry Construction for Buildings

The provisions of S304.1 and A370 are presented here in a summary form that is incomplete. For further detail, refer to the standards. For installation requirements, refer to A371.

1. MVSS Deflection Limit

The deflection of steel studs supporting masonry veneer is controlled by the requirements of the masonry design standard, CSA S304.1 (Clause 13.3.3). Two calculation methods are allowed[1]:

(a) Method 1

Veneer deflections are limited to L/600 where L is the span of the steel stud. The veneer deflection is calculated at the design specified load and is defined as the sum of the stud flexural deflections, the tie deformations and tie mechanical play.

In addition, tie stiffness and mechanical play must conform to the requirements of CSA A370 Connectors for Masonry.

A370 Clause 8.3.2.2 requires that the total free play of multi-component ties, including any free play between a tie component and the structural backing, when assembled, shall not exceed 1.2 mm.

A370 Clause 8.3.2.3 requires that when tested under a compressive or tensile load of 0.45 kN, the sum of the displacement and free play of the tie shall not be more than 2.00 mm. Displacement includes all secondary deformations of the structural backing.

(b) Method 2

Stud flexural deflections are limited to L/720 where L is the span of the steel stud backup. To use this approach, a tie with less deformation due to loading and mechanical play than that specified by CSA A370 is required.

S304.1 Clause 13.3.3 Note 2 (b) requires that the tie deflection due to one half the total mechanical play plus a tension or compression load of 0.45 kN shall not exceed 1.0 mm.

While these two design approaches will produce similar results, the L/720 approach in Method 2 is simpler and therefore generally preferred.

2. Tie Design

This section describes tie design requirements with respect to strength, mechanical play, stiffness, corrosion protection and spacing.

2.1 Design for Strength[2]

The loads acting on ties are given in S304.1 and the methods for deriving the resistance of ties to these loads are given in A370.

2.1.1 Factored Loads on Ties

For flexible backups (*see footnote 1*) S304.1 (*Clause 13.2.3*) requires that all ties shall be designed for 40% of the tributary lateral load on a vertical line of ties, but not less than double the tributary lateral load on the tie. Alternatively, the loads could be derived using a detailed stiffness analysis (such as finite elements) but this approach is generally impractical for routine design.

For limit states design, the applied loads are to be multiplied by the appropriate load factors to obtain factored loads.

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[1] The two calculation methods apply provided the steel stud backup is defined as "flexible" with a stiffness, EI, less than 2.5 times the uncracked stiffness of the veneer. Most MVSS systems meet this "flexible" criterion.

[2] A370-94 permits Limit States Design and Working Stress Design. Only Limit States Design has been included here.

2.1.2 Factored Resistance for Ties

A370 (*Clause 8.4.2.1.1*) requires that ties should have sufficient strength such that their factored resistance is greater than or equal to the effect of factored loads.

The factored resistance for a tie is given by multiplying the tie ultimate strength *(as defined in A370 Clause 8.2.1)* by the appropriate resistance factors (as defined in A370 Clause 8.4.2.1.2).

Note that the tie ultimate strength is to be determined by engineering analysis or testing (*in accordance with the principles of A370 Clause 12*) except that a tie must have an ultimate strength of at least 1000 N (*A370 Clause 7.1*).

2.2 Design for Stiffness and Mechanical Play

The stiffness and mechanical play requirements for MVSS ties are a function of the design method to be used for checking the deflection of the MVSS wall system. See Item 1 above.

2.3 Design for Corrosion Protection

A370 requires various levels of corrosion protection for ties in exterior walls depending on the height of the building and the driving rain index for the geographical location.

2.4 Spacing

S304.1 (Clause 13.2.1) requires ties to be spaced at not more than 800 mm o.c. horizontally and 600 mm vertically – not staggered. This requirement means that for typical stud spacings (*less than or equal to 600 mm o.c.*), ties are to be spaced horizontally to match stud locations and vertically at 600 mm o.c.

A370 (*Clause 6.1.3*) requires ties within 300 mm of the top of an unsupported portion of wall and within 400 mm of the bottom where the support does not provide adequate lateral resistance (*such as low friction flashing material between the brick and the support*).

A370 (*Clause 6.1.2*) requires ties spaced not greater than 600 mm o.c. around openings located not more than 300 mm from the opening.

Design for Corrosion Protection

Building Height	Driving Rain Conditions	Required Tie Corrosion Protection	
< 11 m (36 feet)	All	Hot-dipped galvanized after fabrication	Level II
> 11 m (36 feet)	Sheltered	Hot-dipped galvanized after fabrication	
	Moderate to Severe	Stainless Steel	Level III

See A370, Figure 1, for an Annual Driving-Rain Index map of Canada.

APPENDIX F

Maximum Height Tables for Interior Non-Loadbearing Partitions

Introduction

This Appendix includes tables with the maximum heights for interior partitions framed with steel studs. Tables are provided for composite and non-composite assemblies. **Non-composite** walls are designed based on the strength of the steel framing members alone, while the **composite** walls include the strength of the steel studs and the gypsum drywall acting together.

General Notes to Tables

- These tables were engineered by Prof. R.M. Schuster, University of Waterloo, in accordance with the Canadian Standards Association (CSA) Standard S136, *North American Specification for the Design of Cold-Formed Steel Members*, 2001.
- A yield strength of 33 ksi was used.
- The strength of the composite assemblies is based on a series of wall tests conducted at the Oregon State University, as documented in *Final Report on Composite Wall Tests*, July 1997, by Y. Lee and T.H. Miller.
- The design thicknesses, inside corner radii and stiffening lip length are given in the following table.

Section Designations

The tables include standard designators to identify the products. This is a four-part code that identifies the size (both depth and flange width), member type, and minimum base steel thickness.

Example: 600S125-31

Member depth:	All member depths are taken in 1/100 inches. 6" deep = **600**, 3-1/2" deep = **350**
Member type:	**S** = stud or joist, **T** = track, **U** = channel, **F** = furring channel
Flange width:	All flange widths are taken in 1/100 inches. 1-1/4" = **125**, 1-1/2" = **150**
Minimum thickness:	Material thickness is the minimum base steel thickness in mils (1/1000 of an inch). 31 mils = 0.031 in.

Thickness – Steel Components

Minimum Thickness(1) (mils)	Design Thickness (in.)	Inside Corner Radius (in.)	Reference Gauge No.
18	0.0188	0.0843	25
31	0.0330	0.0781	Light 20

(1) Minimum thickness represents 95% of the design thickness, and is the minimum acceptable thickness of the base steel (without metallic coatings) delivered to the jobsite.

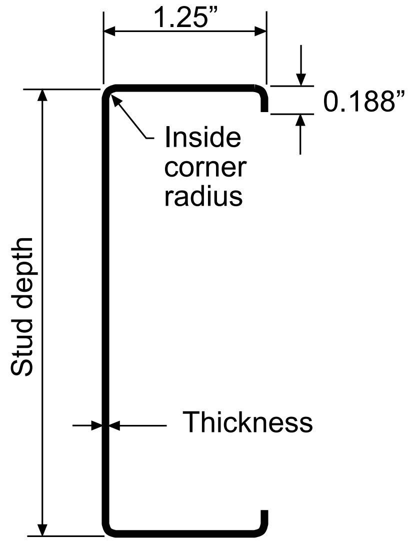
Design Stiffening Lip Length

Section Designation	Flange Width (in.)	Design Stiffener Lip Length (in.)
S125	1-1/4	0.188

Interior Non-Composite Limiting Wall Height Table

Stud Designation	Spacing o.c. (in.)	5 psf			7.5 psf			10 psf		
		L/120	L/240	L/360	L/120	L/240	L/360	L/120	L/240	L/360
250S125-18	12	12'-6"	10'-6"	9'-2"	10'-2"	9'-2"	8'-0"	8'-10"	8'-4"	7'-4"
	16	10'-10"	9'-6"	8'-4"	8'-10"	8'-4"	7'-4"	7'-7"	7'-7"	6'-7"
	24	8'-10"	8'-4"	7'-4"	7'-2"	7'-2"	6'-4"	6'-2"	6'-2"	5'-10"
250S125-31	12	16'-5"	13'-0"	11'-4"	14'-4"	11'-4"	9'-11"	12'-5"	10'-4"	9'-0"
	16	14'-11"	11'-10"	10'-4"	12'-5"	10'-4"	9'-0"	10'-8"	9'-5"	8'-2"
	24	12'-5"	10'-4"	9'-0"	10'-1"	9'-0"	7'-11"	8'-8"	8'-2"	7'-1"
350S125-18	12	15'-1"	13'-7"	11'-11"	12'-5"	11'-11"	10'-5"	10'-8"	10'-8"	9'-5"
	16	13'-1"	12'-5"	10'-10"	10'-8"	10'-8"	9'-5"	9'-4"	9'-4"	8'-7"
	24	10'-8"	10'-8"	9'-5"	8'-8"	8'-8"	8'-4"	7'-7"	7'-7"	7'-6"
350S125-31	12	21'-2"	16'-10"	14'-8"	18'-0"	14'-8"	12'-10"	15'-7"	13'-5"	11'-8"
	16	19'-1"	15'-4"	13'-5"	15'-7"	13'-5"	11'-8"	13'-6"	12'-1"	10'-7"
	24	15'-7"	13'-5"	11'-8"	12'-8"	11'-8"	10'-2"	11'-0"	10'-7"	9'-4"
600S125-31	12	31'-6"	25'-11"	22'-7"	25'-8"	22'-7"	19'-10"	22'-4"	20'-7"	18'-0"
	16	27'-4"	23'-6"	20'-7"	22'-4"	20'-7"	18'-0"	19'-4"	18'-8"	16'-4"
	24	22'-4"	20'-7"	18'-0"	18'-2"	18'-0"	15'-8"	15'-10"	15'-10"	14'-4"

Notes:
1) Studs are 0.0179 in. and 0.0314 in. minimum base steel thickness.
2) Limiting heights are based on continuous support of each flange over the full height of the stud.
3) Heights based on steel properties only, calculated in accordance with CSA-S136-2002.
4) For 365S125 members, use values listed for 350S125.



Interior Composite Limiting Wall Height Table

Stud Designation	Spacing o.c. (in.)	5 psf			7.5 psf			10 psf		
		L/120	L/240	L/360	L/120	L/240	L/360	L/120	L/240	L/360
250S125-18	12	14'-5"	12'-0"	10'-5"	11'-10"	10'-5"	9'-1"	10'-2"	9'-6"	8'-4"
	16	12'-11"	11'-4"	9'-10"	10'-7"	9'-10"	8'-6"	9'-2"	8'-11"	-
	24	11'-4"	10'-5"	9'-1"	9'-4"	9'-1"	-	8'-1"	8'-1"	-
250S125-31	12	17'-7"	13'-10"	12'-0"	15'-4"	12'-0"	10'-4"	13'-10"	10'-10"	9'-4"
	16	16'-4"	12'-10"	11'-0"	14'-1"	11'-0"	9'-6"	12'-10"	9'-11"	8'-7"
	24	14'-10"	11'-7"	9'-11"	12'-10"	9'-11"	8'-6"	11'-6"	8'-11"	-
350S125-18	12	16'-11"	15'-4"	13'-4"	13'-7"	13'-2"	11'-6"	11'-8"	11'-8"	10'-5"
	16	15'-1"	14'-4"	12'-5"	12'-1"	12'-1"	10'-10"	10'-5"	10'-5"	9'-8"
	24	13'-0"	13'-0"	11'-5"	10'-5"	10'-5"	9'-11"	8'-11"	8'-11"	8'-11"
350S125-31	12	22'-2"	17'-7"	15'-5"	19'-5"	15'-5"	13'-5"	17'-7"	13'-11"	12'-2"
	16	20'-6"	16'-2"	14'-1"	17'-11"	14'-2"	12'-4"	16'-2"	12'-10"	11'-2"
	24	18'-5"	14'-7"	12'-8"	16'-0"	12'-8"	11'-0"	14'-7"	11'-6"	10'-0"
600S125-18	12	21'-5"	21'-5"	19'-6"	17'-2"	17'-2"	16'-10"	14'-10"	14'-10"	14'-10"
	16	19'-0"	19'-0"	18'-2"	15'-2"	15'-2"	15'-2"	13'-0"	13'-0"	13'-0"
	24	16'-2"	16'-2"	16'-2"	12'-11"	12'-11"	12'-11"	11'-0"	11'-0"	11'-0"
600S125-31	12	33'-4"	26'-5"	23'-1"	29'-1"	23'-1"	20'-1"	26'-5"	21'-0"	18'-4"
	16	30'-6"	24'-1"	21'-2"	26'-7"	21'-1"	18'-5"	24'-0"	19'-2"	16'-8"
	24	27'-0"	21'-5"	18'-8"	23'-6"	18'-8"	16'-4"	19'-0"	17'-0"	14'-8"

Notes:

1) Studs are 0.0179 in. and 0.0314 in. minimum base steel thickness.

2) Composite wall sheathed both sides full height with 1/2" gypsum wallboard.

3) Sheathing attached with #6 screws min. at 12" o.c. max.

4) For 365S125 members, use values listed for 350S125.

5) Maximum heights are also applicable to walls sheathed with gypsum board greater than 1/2 in. thick and multiple layers of gypsum board.

APPENDIX G

Bibliography

Building Science Topics

Air-Ins Inc., "*Air Permeance of Building Materials*", for Canada Mortgage and Housing Corporation, June 17, 1988

Air-Ins Inc., "*Airtightness Test on Components Used to Join Different or Similar Materials of the Building Envelope*", for Canada Mortgage and Housing Corporation, September 27, 1991

Baskaran, A., "*Review of Design Guidelines for Pressure Equalized Rainscreen Walls*", Institute for Research in Construction Internal Report #629, March 1992

Boundary Layer Wind Tunnel Laboratory, "*The Influence of Unsteady Pressure Gradients on Compartmentalization Requirements for Pressure-Equalized Rainscreens*", University of Western Ontario, for Canada Mortgage and Housing Corporation, 1998

Brand, R., "*Architectural Details for Insulated Buildings*", published by Van Nostrand Reinhold, 1990

Brook, M.S., "*Rationalizing Wall Performance Criteria*", Proceedings, Sixth Conference on Building Science and Technology, Toronto, March 1992

Brown, W.C. and Poirier, G.F., "*Testing of Air Barrier Systems for Wood Framed Walls*", Institute for Research in Construction, for Canada Mortgage and Housing Corporation, June 3, 1988

Canadian Roofing Contractors Association, "*Roofing Specifications Manual*", (Revised), November 1990

Canam Building Envelope Specialists Inc., "*Practical Guidelines for Designers, Contractors, and Developers on the Installation of Air Leakage Control Measures in New and Existing High-Rise Commercial Buildings*", for Canada Mortgage and Housing Corporation, 1999

CMHC, "*Exterior Wall Steel Stud Systems - Acceptance Bulletin*", Central (now Canada) Mortgage and housing Corporation, Ottawa, Canada

Crise, D.J., "*Thermal Performance of Walls Framed with Steel Studs with Slit Webs*", United States Steel Corporation, November 15, 1972

DMO Associates, "*Drying of Walls with Ventilated Stucco Cladding Parametric Analysis*", for Canada Mortgage and Housing Corporation, 1999

Ganguli, U., Lux, M.E., Brown, W.C. and Perreault , J.C., "*An Air Barrier for the Building Envelope*", Building Science Insight, National Research Council of Canada, 1986

Ganguli, U. and Dalgliesh, W.A., "*Wind Pressures on Open Rain Screen Walls: Place Air Canada*", National Research Council of Canada, Institute for Research in Construction, July 1987

Gibson, L., "*Exterior Insulation Finish System Laboratory Evaluation of Materials and Joints Subjected to Artificial Conditioning*", for Canada Mortgage and Housing Corporation, January, 1995

Gulay, B.W., Stewart, C.D. and Foley, G.J., "*Field Investigation Survey of Air Tightness, Air Movement and Indoor Air Quality in High Rise Buildings*", Summary Report, Wardrop Engineering, for Canada Mortgage and Housing Corporation, July 1993

Handegord, G.O., "*Air leakage, Ventilation and Moisture Control in Buildings*", Division of Building Research Paper No. 1063, National Research Council of Canada 1982

Hutcheon, N.B., and Handegord, G.O.P., "*Building Science for a Cold Climate*", NRCC, published by Construction Technology Centre Atlantic Inc., 1983

Malhorta, A., "*Best Practice Guide Flashings*", for Canada Mortgage and Housing Corporation, 1998

McKay, M.C., Chevrier, A. and Quirouette, R.L., "*Testing of Air Barrier Construction Details II*", Morrison Hershfield Limited, for Canada Mortgage and Housing Corporation, March 1993

Morrison Hershfield Limited, "*A Study of the Rainscreen Concept Applied to Cladding Systems on Wood Frame Walls*", for Canada Mortgage and Housing Corporation, August 3, 1990

Morrison Hershfield Limited, "*Structural Requirements for Air Barriers*", for Canada Mortgage and Housing Corporation, August 13, 1991

Morrison Hershfield Limited, "*CMHC Research Project Testing of Air Barriers Construction Details*", for Canada Mortgage and Housing Corporation, August 26, 1991

Morrison Hershfield, "*Drying of Stucco Clad Walls*", for Canada Mortgage and Housing Corporation, 1999

National Research Council of Canada, "*Canadian Building Digest*", Institute for Research in Construction:

- CBD 40, "Rain Penetration and Its Control", by G.K. Garden, 1963
- CBD 48, "Requirements for Exterior Walls", by N.B. Hutcheon, 1963
- CBD 72, "Control of Air Leakage is Important", by G.K. Garden, 1965
- CBD 131, "Coatings for Masonry Surfaces", by H.E. Ashton, 1970
- CBD 162, "Silicone Water-Repellents for Masonry", by T. Ritchie, 1974
- CBD 170, "Atmospheric Corrosion of Metals", by P.J. Sereda, 1975
- CBD 171, "Vapour Barriers What are They? Why are They Effective?", by J.K. Latta

National Research Council of Canada, "*Construction Practice: Selected Applications in Construction Technology*", Ottawa, March 1993

NAHB, "*Status of Cold-Formed Steel Framing in Residential Construction - Thermal Performance in Exterior Walls*", National Association of Home Builders Research Foundation Inc., for American Iron and Steel Institute, November 1973

Newman, A.J., and Whiteside, D., "*Water and Air Penetration Through Brick Walls - A Theoretical and Experimental Study*", Trans. J. Brit. Ceram. Soc., Vol 80, 1981

Ontario New Home Warranty Plan, "Building Smart":
- Issue No. 1, "Winter Masonry"
- Issue No. 5, "High Rise Windows"
- Issue No. 15, "Summer Masonry Construction"

Parekh, A. and Robinson, T., "*Air Leakage Control Retrofits for Wall Assemblies*", Construction Canada, November/December 1994

Petrone, M.V., "*Rigid Air Barrier Assemblies*", Petrone Architects, for Canada Mortgage and Housing Corporation, July, 1995

Pressnail, K.D., Vollering, B., Handegord, G.O. and Kelk, G.H., "*Protecting Gypsum Sheathing in Insulated Steel-Stud Walls*", for Canada Mortgage and Housing Corporation, May 1997

Public Works and Government Services Canada, "*Air Leakage Control - Guidelines for Installation of Air Leakage Control Measures in Commercial Buildings*", Architectural and Engineering Services, Technology Division, R&D, no date

Quirouette, R.L., "*Moisture Sources in Houses*", Building Science Insight 83, Division of Building Research, National Research Council of Canada, May 1984

Quirouette, R.L., "*The Difference Between a Vapour Barrier and an Air Barrier*", Building Practice Note No. 54, DBR/NRCC, July 1985

Quirouette, R.L., "*The Air Barrier, A Misunderstood Element*", Construction Canada, November 1986

Reginato, R. and Handegord, G.A., "*A Procedure for Estimating the Moisture Performance of Building Envelopes*", TROW Canada, 1990

Rousseau, J., "*Air Barriers: Assemblies and Construction Materials - Part 1*", National Building Envelope Council Digest, June 1994

Russell, P., "*Exterior Insulation and Finish Systems (EIFS) Problems, Causes and Solutions*", for Canada Mortgage and Housing Corporation, May 30, 1991

Shawand, C.Y., and Tamara, G.T., "*Studies on Exterior Wall Air Tightness and Air Infiltration of Tall Buildings*", ASHRAE Transactions, Vol. 82, Part I, 1976

Suter Keller Inc., "*Define the Most Cost-Effective Cladding System in Canada: Results of a Survey*", for Canada Mortgage and Housing Corporation, April 1990

Trow Inc., "*Criteria for the Air Leakage Characteristics of Building Envelopes: Final Report*", for Canada Mortgage and Housing Corporation, December 1989

Wilson, A.G., and Garden, G.K., "*Moisture Accumulation in Walls due to Air Leakage*", Division of Building Research Technical Paper No. 227, National Research Council of Canada 1965.

National Research Council of Canada, "Construction Technology Updates", Institute for Research in Construction, Ottawa:
- "Evolution of Wall Design for Controlling Rain Penetration", Construction Technology Update No. 9, by G.A. Chown, W.C. Brown and G.F. Poirier, December 1997
- "Pressure Equalization in Rainscreen Wall Systems", Construction Technology Update No. 17, by M.Z. Rousseau, G.F. Poirier and W.C. Brown, July 1998
- "Fire Resistance of Floor Assemblies in Multi-Family Dwellings", Construction Technology Update No. 20, by M.A. Sultan, September 1998
- "Control of Floor Vibration", Construction Technology Update No. 22, by D.E. Allen and G. Pernica, December 1998
- "Water Shedding Details Improve Masonry Performance", Construction Technology Update No. 23, by A.H.P. Maurenbrecher, December 1998
- "Controlling the Transmission of Airborne Sound through Floors", Construction Technology Update No. 25, by A.C.C. Warnock, May 1999
- "Effect of Electrical Outlet Boxes on Sound Isolation of Gypsum Board Walls", Construction technology Update No. 27, by T.R.T. Nightingale, J.D. Quirt and M.A. Sultan, May 1999
- "Use of Field-Applied Polyurethane Foams in Buildings", Construction Technology Update No. 32, by M.T. Bomberg and M.K. Kumaran, December 1999
- "Designing Exterior Walls According to the Rainscreen Principle", Construction Technology Update No. 34, by W.C. Brown, G.A. Chown, G.F. Poirier and M.Z. Rousseau, December 1999
- "Low-Permeance Materials in Building Envelopes", Construction Technology Update No. 41, by M.K. Kumaran and J.C. Haysom, October 2000

National Roofing Contractors Association, "*The NRCA Roofing and Waterproofing Manual*", Fourth Edition, 10255 W. Higgins Road Suite 600, Rosemont, IL 60018, USA

Fire Research

Alfawakhiri, F. and Sultan, M.A., "*Numerical Modeling of Steel Members Subjected to Severe Thermal Loads*," Proceedings of the Fire & Materials 2001 Conference (San Francisco, CA., U.S.A. 2001), pp. 483-494, Feb, 2001 (NRCC-44225)

Alfawakhiri, F. and Sultan, M.A., "*Fire Resistance of Loadbearing LSF Assemblies,*" 15th International Specialty Conference on Cold-Formed Steel Structures (St. Louis, Missouri, 2000), pp. 545-561, Oct, 2000

Alfawakhiri, F., Sultan, M.A. and Kodur, V.R., "*Loadbearing LSF Walls Exposed to Standard Fire,*" CSCE 3rd Structural Specialty Conference (London, Ontario, 2000), pp. 114-121, Jun, 2000

Alfawakhiri, F. and Sultan, M.A., "*Fire Resistance of Loadbearing Steel Stud Walls Protected with Gypsum Board: A Review*," Fire Technology, 35, (4), November, pp. 308-335, Nov, 1999

Alfawakhiri, F., and Sultan, M.A., "*Fire Resistance of Loadbearing Steel Stud Walls Protected with Gypsum Board*", Proceedings of the 6th International Conference on Fire and Materials, San Antonio, Texas, Interscience Communications Ltd., February 1999, pp. 235-246

Alfawakhiri, F., Sultan, M.A. and MacKinnon, D.H., "*Fire Resistance of Loadbearing Steel Stud Walls Protected with Gypsum Board: A Review,*" Fire Technology, 35, (4), November, 1999, pp. 308-335

Kodur, V.R., Nwosu, D.I., Sultan, M.A. and Franssen, J-M., "*Application of the SAFIR Computer Program for Evaluating Fire Resistance*," 3rd International Conference on Fire Research and Engineering (Chicago, IL., U.S.A. 1999), pp. 287-295, 1999

Kodur, V.R., Sultan, M.A., and Alfawakhiri, F., "*Fire Resistance Tests on Loadbearing Steel Stud Walls,*" Proceedings of the 3rd International Conference on Fire Research and Engineering, Society of Fire Protection Engineers, Chicago, IL., U.S.A., October 1999, pp. 275-286

Kodur, V. K. R. , Sultan, M. A., Latour, J.C., Leroux, P. and Monette, R.C., "*Fire Resistance Tests on Gypsum Board-Protected Loadbearing Steel Stud Walls*", Internal Report No. 833, Institute for Research in Construction, National Research Council of Canada, Ottawa, March 2002 (IRC-IR-833)

Nightingale, T.R.T., and Sultan, M.A., "*Sound Isolation and Fire Resistance of Assemblies with Fire Stops*", Construction Technology Update, 16, pp. 6, July 1998 Institute for Research in Construction, National Research Council of Canada, Ottawa (NRCC-42656)

Sultan, M.A., "*A Model for Predicting Heat Transfer Through Non-insulated Unloaded Steel Stud Gypsum Board Wall Assemblies Exposed to Fire*", Fire Technology, 32: pp. 239-259, 1996

Sultan, M.A., "*Fire Spread Via Wall/floor Joints in Multi-family Dwellings,*" Fire and Materials, 24, (1), January, pp. 1-8, Jan, 2000

Sultan, M.A., "*Factors Affecting Fire Resistance Performance of Lightweight Frame Floor Assemblies,*" Interflam'99, 8th International Fire Science & Engineering Conference (Edinburgh, Scotland, 1999), pp. 897-910, 1999

Sultan, M.A. "*Fire Resistance of Floor Assemblies in Multi-Family Dwellings*", Construction Technology Update, 20, September, pp. 4, Sep, 1998, Institute for Research in Construction, National Research Council of Canada, Ottawa (NRCC-42874)

Sultan, M.A., "*Fire Stops Performance in Wall/floor Joints of Multi-family Dwellings,*" Fire and Materials '98 International Conference (San Antonio, TX., U.S.A. 1998), pp. 53-64, Feb, 1998 (NRCC-41110)

Sultan, M.A., Alfawakhiri, F., and Bénichou, N., "*A Model For Predicting Heat Transfer Through Insulated Steel Stud Wall Assemblies Exposed to Fire,*" Fire and Materials '2001 International Conference (San Francisco, CA., U.S.A. 2001), pp. 495-506, Feb, 2001 (NRCC-44227)

Sultan, M.A., Bénichou, N. and Kodur, V.R., "*Floor Assemblies: The Fire Resistance of Floor Assemblies in Multi-family Dwellings is Affected by Code Requirements to Dampen Sound,*" Canadian Consulting Engineer, 41, (3), May, pp. 54, 60, May, 2000

Sultan, M.A., Denham, E.M.A., Monette, R.C. and Morwick, D.W., "*Temperature Measurements in Fire Resistance Tests on Small-Scale, Insulated and Non-Insulated, Regular Gypsum Board Assemblies*", Internal Report No. 671, Institute for Research in Construction, National Research Council Canada, November 1994 (IRC-IR-671)

Sultan, M.A. and Kodur, V.R., "*The Effects of Subfloor and Insulation Type and Thickness on the Fire Resistance of Small-scale Floor Assemblies,*" Fire and Materials, 24, (3), May/June, pp. 131-141, Jun, 2000

Sultan, M.A. and Kodur, V.R., "*The Effect of Insulation on the Fire Resistance of Small-scale Lightweight Frame Floor Assemblies,*" Fire and Materials '99, 6th International Conference and Exhibition (San Antonio, Texas, 1999), pp. 223-234, 1999

Sultan, M.A., Kodur, V.R., Richardson, L.R. and McPhee, R.A., "*Fire Resistance of Lightweight Frame Wall Assemblies,*" 4th Japan/Canada Housing R&D Workshop Proceedings (Sapporo, Japan, 1997), pp. III-50-III-56, Dec, 1997 (NRCC-41363)

Sultan, M.A. and Lougheed, G.D., "*Fire Resistance of Gypsum Board Wall Assemblies, Construction Technology Update*," 2, Jan., pp. 4, Jan, 1997 Institute for Research in Construction, National Research Council of Canada, Ottawa (NRCC-40625)

Sultan, M.A., Lougheed, G.D., MacLaurin, J.W. and Denham, E.M.A., "*Temperature Measurements in Fire Resistance Tests on Insulated and Non-Insulated Small-Scale Wall Assemblies Protected by Type X Gypsum Board*", Internal Report No. 677, Institute for Research in Construction, National Research Council Canada, December 1994 (IRC-IR-677)

Sultan, M.A., Lougheed, G.D., Denham, E.M.A., Monette, R.C., and MacLaurin, J.W., "*Temperature Measurements in Full-Scale Fire Resistance Tests on Non-Insulated Regular Gypsum Board Wall Assemblies*", Internal Report No. 674, Institute for Research in Construction, National Research Council Canada, December 1994 (IRC-IR-674)

Sultan, M.A., MacLaurin, J.W., Denham, E.M.A. and Monette, R.C., "*Temperature Measurements in Full-Scale Insulated and Non-Insulated (1x2) Gypsum Board Protected Wall Assemblies with Steel Studs*", Internal Report No. 675, Institute for Research in Construction, National Research Council Canada, December 1994 (IRC-IR-675)

Sultan, M.A., MacLaurin, J.W., Denham, E.M.A. and Morwick, D.W., "*Temperature Measurements in Fire Resistance Tests on Small-Scale Wall Assemblies of Different Cavity Depths, Stud Types and Asymmetrical Installations of Gypsum Board*", Internal Report No. 670, Institute for Research in Construction, National Research Council Canada, November 1994 (IRC-IR-670)

Sultan, M.A., Seguin, Y.P. and Leroux, P., "*Fire Spread in Wall/Floor Joints of Multi-Family Dwellings*", Internal Report, Institute for Research in Construction, National Research Council Canada, 770, pp. 66, Jun, 1998 (IRC-IR-770)

Sultan, M.A., Seguin, Y.P. and Leroux, P., "*Results of Fire Resistance Tests on Full-Scale Floor Assemblies*", Internal Report 764, Institute for Research in Construction, National Research Council Canada, May, 1998 (IRC-IR-764)

Sultan, M.A., Séguin, Y., Leroux, P. and Monette, R.C., "*Results of Fire Resistance Tests on Small-Scale Floor Assemblies*", Internal Report, Institute for Research in Construction, National Research Council Canada, Institute for Research in Construction, 813, pp. 76, July 2000

Sultan, M.A., Richardson, L.R. and McPhee, R.A., "*Fire Resistance of Lightweight Frame Floor Assemblies,*" 4th Japan/Canada Housing R&D Workshop Proceedings (Sapporo, Hokkaido, Japan, 1997), pp. III-64-III-69, Dec, 1997 (NRCC-41364)

Acoustic Research

Halliwell, R.E., Nightingale, T.R.T., Warnock, A.C.C and Birta, J.A., "*Gypsum Board Walls: Sound Transmission Loss Data*", Internal Report No. 761, Institute for Research in Construction, National Research Council of Canada, Ottawa 1998 (IRC-IR-761)

Nightingale, T.R.T., Quirt, J.D. and Sultan, M.A., "*Effect of Electrical Outlet Boxes on Sound Isolation of Gypsum Board Walls*", Construction Technology Update, 27, pp. 4, May, 1999, Institute for Research in Construction, National Research Council of Canada, Ottawa

Nightingale, T.R.T. and Sultan, M.A., "*Sound Isolation and Fire Resistance of Assemblies with Fire Stops*", Construction Technology Update, No.16, pp. 6, July 1998 Institute for Research in Construction, National Research Council of Canada, Ottawa (NRCC-42656)

Quirt, J.D., Warnock, A.C.C and Birta, J.A., "*Summary Report for Consortium on Gypsum Board Walls: Sound Transmission Results*", Internal Report No. 693, Institute for Research in Construction, National Research Council of Canada, Ottawa 1995 (IRC-IR-693)

Sultan, M.A. and Nightingale, T.R.T., "*Safe and Silent: Fire Stops in Cavity Walls Often Work Against the Need to Stop Sound Traveling Between Adjacent Dwellings,*" Canadian Consulting Engineer, 39, (5), Oct/Nov, pp. 54, 56, Oct, 1998

Warnock, A.C.C., "*Controlling the Transmission of Airborne Sound Through Floors*", Construction Technology Update, No. 25, May 1999, pp 4, Institute for Research in Construction, National Research Council of Canada, Ottawa

Warnock, A.C.C., "*Controlling the Transmission of Impact Sound Through Floors*", Construction Technology Update, No. 35, December 1999, pp 4, Institute for Research in Construction, National Research Council of Canada, Ottawa

Warnock, A.C.C and Birta, J.A., "*Summary Report for Consortium on Fire Resistance and Sound Insulation of Floors: Sound Transmission Class and Impact Insulation Class Results*", Internal Report No. 766, Institute for Research in Construction, National Research Council of Canada, Ottawa, April 1998 (IRC-IR-766)

Masonry Veneer Wall Systems

Arumala, J.O. and Brown, R.H., "*Performance Evaluation of Brick Veneer with Steel Stud Backup*", by Clemson University, for the Brick Institute of America and the Metal Lath/Steel Framing Association, April 1982

Brick Institute of America, "*Technical Notes on Brick Construction*":

- "Water Resistance of Brick Masonry Design and Detailing", Part I of III, (Technical Note No. 7 Revised February 1985)
- "Colorless Coatings for Brick Masonry" (Technical Note No. 7E Reissued February 1987)
- "Movement Volume Changes and Effect of Movement", Part I (Technical Note No. 18 Revised January 1991)
- "Movement Design and Detailing of Movement Joints", Part II (Technical Note No. 18A Revised December 1991)

- "Differential Movement - Flexible Anchorage", Part III of III (Technical Note No. 18B Reissued December 1980)
- "Brick Veneer Steel Stud Walls" (Technical Note No. 28B Revised November 1999)

Brown, W.C. and Ullett, J.M., "*Measured Pressure Equalized Performance of a Brick Veneer/Steel Stud Assembly, Report 4*", for Canada Mortgage and Housing Corporation, June, 1995

Burnett, E.F.P., "*Brick-Veneer/Steel-Stud Project - Task 5, Remedial Tie Systems for BV/SS Walls: Summary Report*", Building Engineering Group, University of Waterloo, for Canada Mortgage and Housing Corporation, October 1994

Cowie, J.W., "*The Failure of Steel Studs*", The Magazine of Masonry Construction, February 1990

Cowie, J.W., "*The Failure of Steel Studs*", Encon Loss Control Bulletin, September 1990

Drysdale Engineering and Associates Limited, "*User Reference Manual for a Finite Element Analysis Program for Masonry Veneer/Steel Stud Wall Systems*", prepared for T.W.J. Trestain Structural Engineering as part of a contract with Canada Mortgage and Housing Corporation, December 1993

Drysdale, R.G., Keller, H. and Suter, G.T., "*Seminar on Steel Stud Brick Veneer Wall Systems*", for Canada Mortgage and Housing Corporation, 1989

Drysdale, R.G. and Wilson, J., "*A Report on Behaviour of Brick Veneer/Steel Stud Tie Systems*", McMaster University, for Canada Mortgage and Housing Corporation, March 1989

Drysdale, R.G. and Chidiac, S., "*Defining Better Wall Systems*", for Canada Mortgage and Housing Corporation, May 1989

Drysdale, R.G. and Kluge, A., "*Performance of Brick Veneer Steel Stud Wall Systems Subject to Temperature, Air Pressure and Vapour Pressure Differentials*", McMaster University, for Canada Mortgage and Housing Corporation, May 1990

Drysdale, R.G., Kluge, A. and Roscoe, P., "*A Report on Water Leakage Characteristics of Bricks and Brick Assemblages*", McMaster University, for Canada Mortgage and Housing Corporation, May 1990

Drysdale, R.G. and Wilson. M., "*Tests of Full Scale Brick Veneer Steel Stud Walls to Determine Strength and Rain Penetration Characteristics*", McMaster University, for Canada Mortgage and Housing Corporation, July 1990

Drysdale, R.G. and Suter, G.T., "*Exterior Wall Construction in High Rise Buildings, Brick Veneer on Concrete Masonry or Steel Stud Wall Systems*", for Canada Mortgage and Housing Corporation, 1991

Drysdale, R.G. and Breton, N., "*Strength and Stiffness Characteristics of Steel Stud Backup Walls Designed to Support Brick Veneer*", for Canada Mortgage and Housing Corporation, December 1991

Drysdale, R.G., "*Construction Problems in Multi-Family Residential Buildings*", for Ontario New Home Warranty Plan and Canada Mortgage and Housing Corporation, March 1991

Drysdale, R.G., Hamid, A.A. and Baker, L.R., "*Masonry Structures Behaviour and Design*", Prentice-Hall, 1994

Hatzinikolas, M.A., Lee, R. and Warwaruk, J., "*Factors Affecting the Performance of Metal Stud Walls used as a Back-up System to Masonry Veneer*", Edmonton: Prairie Research Institute, December 1987

Keller, H., Trestain, T.W.J. and Maurenbrecher, A.H.P., "*The Durability of Steel Components in Brick Veneer/Steel Stud Wall Systems*", Proceedings, Sixth Conference on Building Science and Technology, Toronto, March 1992

Keller, H. and Trestain, T.W.J., " *Brick Veneer/Steel Stud Walls - A Repair Solution*", 7th Canadian Masonry Symposium, June 1995

Keller Engineering Associates Inc., "*Performance Monitoring of a Brick Veneer/Steel Stud Wall System*", for Canada Mortgage and Housing Corporation, December 1992

McGinley, Wararuk, Longworth and Hatzinikolas, "*The Interaction of Masonry Veneer and Steel Studs in Curtain Wall Construction*", Structural Engineering Report No. 127, The University of Alberta, May 1985

MLSFA, "*L/360 Here are the Facts About Steel Framing-Brick Veneer Systems Design*", Metal Lath/Steel Framing Association, February 1985

Plewes, W.G., "*A Perspective on Masonry Serviceability*", Proceedings, 3rd Canadian Masonry Symposium, Edmonton, June 1983

Posey, J.B., "*Best Practice Guide Brick Veneer Steel Stud*", Posey Construction Specifications, for Canada Mortgage and Housing Corporation, 1996

Posthma, M.A. and Burnett, E.F.P., "*Brick Veneer/Steel Stud Project Task 2: Four Remedial Tie Systems for BV/SS Walls - Development and Conformance Testing*", Building Engineering Group, University of Waterloo, for Canada Mortgage and Housing Corporation, August 1993

Posthma, M.A. and Burnett, E.F.P., "*Brick Veneer/Steel Stud Project Initial Exploratory Study Draft Report (Task 1)*", Building Engineering Group, University of Waterloo, for Canada Mortgage and Housing Corporation, July 1992

Straub, J.F., "*The Performance of Wall Systems Screened With Brick Veneer*", M.A.Sc. Thesis, University of Waterloo, 1993

Suter Keller Inc., "*Brick Veneer/Steel Stud Wall Design and Construction Practices in Canada*", for Canada Mortgage and Housing Corporation, March 1986

Suter Keller Inc., "*Field Investigation of Brick Veneer/Steel Stud Wall Systems*", for Canada Mortgage and Housing Corporation, Ottawa, November 30, 1989

Trestain, T.W.J., "*The Success of Steel Studs*", Encon Loss Control Bulletin, June 1991

Trestain, T.W.J. and Rousseau, J., "*Technics: Steel Stud/Brick Veneer Walls*", Progressive Architecture, February 1992 (Discussion June 1992)

Trestain, T.W.J., "*Assessment Repair Strategy for Existing Buildings Constructed with Masonry Veneer Steel Stud Walls*", for Canada Mortgage and Housing Corporation, January 1996

Wegner, C.I. and Burnett, E.F.P., "*Brick-Veneer/Steel-Stud Project, Task 3: Remedial Tie Systems for BV/SS Walls - Post Remediation Performance Considerations*", Building Engineering Group, University of Waterloo, for Canada Mortgage and Housing Corporation, April 1994

U.S. Army Corps of Engineers, "*Masonry Veneer/Steel Stud Walls*", Engineering Technical Letter 1110-3-439, July 2, 1992

U.S. Army Corps of Engineers, "*Design of Cold-Formed Loadbearing Steel Systems and Masonry Veneer/Steel Stud Walls*", Technical Instructions, TI 809-07, November 30, 1998

Wegner, C.I. and Burnett, E.F.P., "*Brick-Veneer/Steel-Stud Project, Task 4: Final Remedial Tie System for BV/SS Walls - Development and Conformance Testing*", Building Engineering Group, University of Waterloo, for Canada Mortgage and Housing Corporation, April 1994

Zakrzewski, A.S., "*Masonry Veneer in Highrise Buildings*", Proen Consultants, for Canada Mortgage and Housing Corporation, 1987

LSF Design and Construction

AISI, "*Cold-Formed Steel Design Manual*", 1996 Edition, American Iron and Steel Institute, Washington, DC, 1996

Applied Technology Council, "*ATC Design Guide 1 Minimizing Floor Vibration*", Redwood City, California, 1999

CSSBI 50M-87, "*Lightweight Steel Framing Manual*", Canadian Sheet Steel Building Institute, August 1987

CSSBI 51-91, "*Lightweight Steel Framing Design Manual*", Canadian Sheet Steel Building Institute, July 1991

CSSBI S5-00, "*Guide Specification for Wind Bearing Steel Studs*", Canadian Sheet Steel Building Institute, 2000

CSSBI S6-00, "*Guide Specification for Lightweight Steel Framing*", Canadian Sheet Steel Building Institute, 2000

Ife, L.W., "*Sheet Steel Framing for Residential and Light Construction*", Technical Bulletin No. 17, The Steel Company of Canada Limited, February 1977

Langan, J.E. and LaBoube, R.A., "*Structural Behaviour of Perforated Web Elements of Cold-Formed Steel Flexural Members Subjected to Web Crippling and a Combination of Web Crippling and Bending*", Civil Engineering Study 94-3, University of Missouri-Rolla, May 1994

MLSFA, "*Lightweight Steel Framing Systems Manual*", Second Edition, Published by Metal Lath/Steel Framing Association, (Division of NAAMM), Chicago, IL , 1984

Miller, T.H. and Pekoz, T., "*Studies on the Behaviour of Cold-Formed Steel Stud Wall Assemblies*", Cornell University, for American Iron and Steel Institute, November 1989

Pekoz, T., "*Some Topics on Wall Stud Design*", Cornell University Interim Research Report, for the American Iron and Steel Institute, February 1994

Shan, M.Y. and LaBoube, R.A., "*Behaviour of Web Elements with Openings Subjected to Bending, Shear and the Combination of Bending and Shear*", Civil Engineering Study 94-2, University of Missouri Rolla, 1994

Tarlton, D.L., Schuster, R.M. and Zakrzewski, A.S., "*Criteria for the Testing of Wall Sheathing for Load-Bearing Steel Studs*", for Canada Mortgage and Housing Corporation External Research Program, March 1990

Winter, G., Lansing, W. and McCalley, R., "*Performance of Laterally Loaded Channel Beams*", Four Papers on the Performance of Thin Walled Steel Structures, Cornell University, Engineering Experiment Station, Reprint No. 33, November 1, 1950.

Yu, W.W., "*Cold-Formed Steel Design*", Second Edition, John Wiley & Sons, 1991

Codes and Standards

ASTM (American Society for Testing and Materials) Standards
- ASTM C 755, "Standard Practice for Selection of Vapor Retarders for Thermal Insulations"

ASTM (American Society for Testing and Materials) Special Technical Publications
- ASTM STP 778, Masonry: "Materials, Properties and Performance", G. Borchelt Editor, 1982

- ASTM STP 901, "Building Performance, Function, Preservation and Rehabilitation", Gerald Davis, Editor, October 1983
  - Kellermeyer, K.B. and Chin, I.R., "Lessons Learned from Investigations of Over 500 Distressed Masonry and Stone Facades"
- ASTM STP 1107, "Water in Exterior Building Walls", Thomas A. Schwarz, Editor, October 1990
  - Ruggiero, S.S. and Myers, J.C., "Design and Construction of Watertight Exterior Building Walls"
  - Beal, C., "Sealant Joint Design"

British Standards Institution:

- BS 7543, "Guide to Durability of buildings and building elements, products and components", 1992

Canadian Standards Association:

- S304.1-94 "Masonry Design for Buildings, Limit States Design"
- CAN3-A371-94 "Masonry Construction for Buildings"
- A370-94 "Connectors for Masonry"
- S136-01 "North American Specification for the Design of Cold Formed Steel Structural Members"
- S136.1-01 "Commentary on CSA Standard S136-01, "North American Specification for the Design of Cold Formed Steel Structural Members"
- CAN/CSA - A82.20 Series-M91, "Methods of Testing Gypsum and Gypsum Products"
- CAN/CSA - A82.27 - M91 "Gypsum Board"
- S478 - 1995 "Guideline on Durability in Buildings"

National Research Council of Canada, Ottawa:

- "National Building Code of Canada 1995", Issued by the Canadian Commission on Building and Fire Codes, 1995
- "Users Guide - NBC 1995 Structural Commentaries (Part 4)", Issued by the Canadian Commission on Building and Fire Codes, 1995