National Research Council Canada
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Canadian Commission on Building and Fire Codes

# Commentary on Part 5 Wind, Water and Vapour Protection

National Building Code of Canada 1990

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# Preface

Part 5 of the National Building Code, "Wind, Water and Vapour Protection," covers the design and construction of the those elements of the building which separate dissimilar environments, primarily the building envelope. Improper design or construction may result in the premature deterioration of the envelope or the inadequate separation of environments, leading to unsafe conditions. The requirements also affect energy consumption, proper operation of building services and occupant comfort. Effective environmental separation depends on the interaction, communication and cooperation among all the participants in the design and construction process.

This Commentary discusses Part 5 as it appears in the 1990 National Building Code. The Commentary will give users of the National Building Code (NBC) a better understanding of the requirements in Part 5. Increased knowledge of the objectives of the requirements, and the general principles on which they are based, will help the user to comply with the Code and ensure that the building envelope and other elements separating dissimilar environments meet the required performance levels without premature deterioration of the building fabric.

Part 5 applies to buildings other than those covered by Part 9, "Housing and Small Buildings." The primary objective is the control of building envelope moisture levels. Part 5 covers moisture from indoor humidity, precipitation (rain and snow), and the ground. Moisture from construction materials and processes is not addressed. The various driving forces that move moisture from these sources to areas where it can cause problems are the subject of Sections 5.2 to 5.5. Section 5.6 addresses the durability of the materials that must be installed to control and resist moisture, while Section 5.7 covers the method of installation, so that the control measures will perform effectively.

This commentary has no legal status and is not intended for formal adoption; its purpose is solely informational. Sketches and diagrams are presented to illustrate principles only. Other methods of satisfying the intent of the requirements may be valid.

# Acknowledgements

This Commentary was drafted by a team of researchers from the Institute for Research in Construction of the National Research Council. The members of the team and their areas of responsibility were:

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Final decisions on the content of this Commentary were the responsibility of the Canadian Commission on Building and Fire Codes, on the recommendation of the Task Group. The Task Group had the following membership:

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# Section 5.1 General

## 5.1.1. Scope

**5.1.1.1.** The scope of this Part shall be as described in Section 2.1.

## 5.1.2. Application

**5.1.2.1.** This Part applies to the design of a *building* assembly such as a wall, floor, roof, floor-ceiling combination or roof-ceiling combination with respect to the control of *groundwater*, condensation and the penetration of wind and rain.

## 5.1.3. Definitions

**5.1.3.1.** Words that appear in italics are defined in Part 1.

## 5.1.4. Other Design and Structural Requirements

**5.1.4.1.** The design and structural requirements of other Parts of this Code shall apply.

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## Scope

The primary focus of Part 5 of the National Building Code is the control of moisture movement through those parts of the building that separate dissimilar environments, including those which separate the interior environment from the ground.

While Part 5 is not implicitly limited to the exterior building envelope, the majority of the requirements, such as the control of groundwater and penetration of wind and rain, can only apply to the parts of the building that separate the interior from the exterior environment.

Nevertheless, where applicable, and especially with respect to moisture, the requirements of Part 5 are intended to apply to all situations, including separators of dissimilar interior environments.

According to Section 2.1 of the NBC, Part 5 applies to:

(a) all *buildings* used for *major occupancies* classified as
 (i) Group A, *assembly occupancies*,
 (ii) Group B, *institutional occupancies*, or
 (iii) Group F, Division 1, *high hazard industrial occupancies*, and

(b) all *buildings* exceeding 600 m$^2$ in *building area* or exceeding 3 *storeys* in *building height* used for *major occupancies* classified as
 (i) Group C, *residential occupancies*,
 (ii) Group D, *business and personal services occupancies*,
 (iii) Group E, *mercantile occupancies*, or
 (iv) Group F, Division 2 and 3, *medium* and *low hazard industrial occupancies*.

Essentially it applies to all buildings that are not covered by Part 9.

## Definitions

Generally, words which have a special meaning in the context of the Code are printed in italics and defined in Part 1 of the Code. Part 5 and this Commentary use some additional terms that do not have generally accepted definitions; these are defined in the Appendix to this commentary.

## Control of Moisture Transfer

Part 5 is primarily directed at reduction of moisture movement into or through the building envelope, in order to minimize problems due to moisture accumulation. Moisture can be transported through building materials and assemblies by any combination of the following mechanisms:

- water vapour diffusion driven by water vapour pressure difference,
- moist air flow driven by air pressure difference,
- liquid water flow driven by surface tension (including capillarity), gravity (including hydrostatic pressure), or air pressure difference (wind or mechanical).

The net effect of these moisture flows, combined with the effects of venting and drainage, determines the rate of moisture deposition and drying at any place in the assembly.

Various building assembly designs can prevent, or at least minimize, moisture accumulation in the assembly. The first step is to control moisture movement into the assembly. A design should control moisture movement due to:

- vapour diffusion (Section 5.2),
- air leakage (Section 5.3),
- rain penetration and capillarity (Section 5.4),
- groundwater ingress (Section 5.5).

In view of the likelihood that these preventive measures will not function perfectly, this control should be supported by ventilation and/or drainage to limit accumulation and expedite drying of the assembly.

Not all moisture accumulation leads to problems for the assembly. Moisture accumulated during very cold weather, for example, may not affect the long term performance of the assembly, provided that the moisture dries out or is drained away before it initiates premature deterioration of the building materials.

Although Part 5 focusses on moisture transfer into and through building assemblies, it is also important to consider the movement of moisture through the indoor air to colder interior surfaces. Interior surfaces close to thermal bridges through the insulation may be sufficiently cold to allow surface condensation, possibly leading to deterioration, and growth of fungi and molds. Thus, care must be taken to design and construct the building envelope with as few thermal bridges as possible.

In hygroscopic materials, moisture may accumulate even where the surface temperature is above the dew point temperature of the adjacent air. For example, it has been demonstrated in the laboratory that gypsum and wood-based materials can accumulate measurable quantities of moisture at relative humidities as low as 80%. As this condition may produce corrosion, rotting and general decay at temperatures higher than the dew point, care should be taken to ensure that temperatures are sufficiently high and moisture conditions sufficiently low, to minimize moisture accumulation.

## Control of Air Flow Induced by Wind

Control of air flow induced by wind is discussed in the Commentary, not only in the context of controlling the transfer of moisture (Section 5.3), but also in terms of wind damage to roofs (Section 5.4).

## Envelope Performance and Durability

The materials, components and assemblies that are included within buildings to meet Part 5 must be durable (Section 5.6) and installed in such a way as to perform their intended function (Section 5.7).

The most vulnerable parts of a building envelope are the joints and junctions. These meetings of materials and assemblies are discussed throughout the commentary as they pertain to the requirements of the various sections.

The materials, components and assemblies included within buildings must also meet the fire provisions of Part 3 and the structural requirements of Part 4.

## Occupant Health and Comfort

The requirements of Part 5 have implications for quality control of the indoor environment. Some implications of failing to meet the requirements are:

- Accumulated moisture may support mold and mildew growth. This can contribute to poor indoor air quality and material degradation, including damage to finishes.
- Infiltration can amplify the mold and mildew effect on indoor air quality and bring the additional problem of radon migration.
- Infiltration can also produce unacceptable thermal conditions if it leads to cold drafts in the occupied space.

In other words, meeting the requirements can lead to performance benefits beyond the effects explicitly addressed in Part 5.

# Section 5.2 Control of Vapour Diffusion

## 5.2.1. Vapour Barriers

**5.2.1.1.** Where a *building* assembly that would be adversely affected by condensation will be subjected to a temperature differential and a differential in water vapour pressure, the assembly shall have a continuous vapour barrier at a location that will prevent condensation within the assembly.

## 5.2.2. Assemblies with Low Permeance Exterior Components

### 5.2.2.1. Protection

**(1)** Where a material or combination of materials that have a resistance to water vapour flow equivalent to that of a vapour barrier are used on the low vapour pressure side of the material that has the major thermal resistance in a *building* assembly

(a) a continuous vapour barrier, for use in above-grade *building* construction, shall be installed on the high vapour pressure side, and

(b) an air space ventilated to the outside or other method of equal effectiveness shall be provided for removing the water vapour that may pass from the high vapour pressure side through the material with the major thermal resistance (see Section 2.5).

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## Scope and Definition

Section 5.2 deals with the control of moisture movement by vapour diffusion. Vapour diffusion is moisture flow in vapour phase. Most of the flow is driven by a difference in vapour pressure, with or without a temperature gradient; a small amount can be driven by temperature gradient alone.

Although the properties of a vapour barrier are not specified in the Code, the vapour barrier can be defined either directly, by reference to one of two CGSB standards,[1,2] or indirectly, as providing vapour diffusion resistance equivalent to that specified in the CGSB standards. The standards specify permeances of 15 ng/(Pa•s•m$^2$) for Type 1 vapour barriers, 45 ng/(Pa•s•m$^2$) for Type 2 barriers unaged and 60 ng/(Pa•s•m$^2$) for Type 2 barriers aged. With greater differences in temperature and humidity between conditioned space and the exterior, Type 1 barriers are more generally appropriate.

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**Vapour flow with no difference in vapour pressure?**
Recent research has shown that it is possible to induce vapour flow even where there is no difference in vapour pressure. For example, air at 15°C and 90% RH, and air at 20°C and 65.6% RH both exert a vapour pressure of about 1.53 kPa. The difference in temperature, however, will induce a slow rate of vapour transfer from the warmer air to the cooler. The transfer rate is so slow that it can generally be ignored.

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Buildings occupied in winter are maintained at temperatures higher than exterior conditions. Even without mechanical humidification systems, the building occupants and their activities will generate moisture that will raise the moisture content of the interior above that of the exterior. Assuming that most building assemblies will be adversely affected by condensation, this Section applies to all buildings identified in Article 2.1.2.1. of the NBC.

Some buildings will be maintained at temperatures lower than the exterior conditions. In buildings such as offices that are air-conditioned in the summer, the temperature and vapour pressure gradients are sufficiently shallow and the duration of reversed flow is sufficiently short that designing for vapour diffusion from the exterior to the interior is not an issue in Canada. For other occupancies, such as cold storage plants and freezer buildings, where the interior temperature may be lower than the exterior temperature for a significant portion of the year, vapour diffusion from the exterior to the interior must be considered.

## Vapour Flow and Vapour Resistance

Resistance to vapour flow is provided by a vapour barrier, which is a material having a high resistance to vapour transport by diffusion. It will limit moisture transport by diffusion through the building assembly from the relatively high vapour pressure found in most building interiors to the relatively low vapour pressure of the exterior air during winter. A vapour barrier will also limit moisture flow between spaces in a building with different vapour pressures.

### Dominant vapour resistance on the 'interior'

When the components in a building assembly that provide the greatest vapour diffusion resistance are located on the side of the assembly with the higher vapour pressure and warmer temperatures, the assembly can perform without moisture problems even if a limited amount of moisture is transferred into the assembly by air leakage or rain. This placement of the vapour barrier permits the exterior building envelope assembly, or the separator of two interior spaces, to be maintained in an environment that is essentially at the same absolute humidity as the air outside the building, or in the colder space.

### High vapour resistance on the 'exterior'

The design of the assembly becomes more involved where the exterior cover of the building envelope, or the finish on the colder side of an interior separator, has relatively high vapour diffusion resistance. Although installation of a vapour barrier on the warm side of the major thermal resistance will reduce vapour diffusion, some moisture is always transferred by vapour diffusion and air leakage. This moisture may condense and accumulate on the inside surface of the exterior wall cladding or roof cover because the temperature of the surface is below the air dew point.

Section 5.2 requires that, in these cases, a space be provided between the cladding or covering and the thermal insulation. This space permits venting to the colder side of the assembly to ensure that the wall or roof dries out when conditions are favourable.

In a wall, temperature differences within the cavity will encourage natural convection to assist in moisture removal. The required width of such a cavity will vary depending on the type of construction. Proper flashings and drainage are required to remove water, in a controlled manner, from the bottom of the cavity and over window and door penetrations.

Depending on how one interprets 'ventilated,' this requirement may be at odds with recommended detailing for pressure-equalized rainscreen walls. That is, a pressure-equalized rainscreen wall limits the location of vent holes in the cladding to the bottom of the cladding in order to limit convective flow (Section 5.4). Adequate ventilation, however, may require vent holes at the top and bottom to encourage convective flow. Unless further research indicates the need for vent holes at the top of the cavity, installation of vent holes at the bottom of the cavity appears to provide adequate air circulation and drainage.

A difficult building assembly to design in conformance with the Code for moisture control is a roof system where the insulation layer is immediately below the roof membrane. Requirements for roof spaces in houses and small buildings, specified in Section 9.19, use ventilation to reduce moisture accumulation. In the case of a flat roof system for a large building, the insulation layer may be enclosed between the roof membrane and the vapour barrier. This standard design, however, does not conform with the requirement in Clause 5.2.2.1.(1)(b). For these roofs, the design is intended to provide sufficient control of moisture flow into the 'sealed' roof space and to depend on summer drying to remove any moisture that is transferred into the space.

## References


1 CGSB Standard CAN/CGSB-51.34-M86, "Vapour Barrier, Polyethylene Sheet for Use in Building Construction." Canadian General Standards Board, Ottawa, 1986.

2 CGSB Standard CAN2-51.33-M89, "Vapour Barrier, Sheet, for Use in Building Construction." Canadian General Standards Board, Ottawa, 1989.

# Section 5.3 Control of Air Leakage

## 5.3.1. Air Barriers

### 5.3.1.1. Locations

**(1)** Where a *building* assembly will be subjected to a temperature differential, a differential in water vapour pressure and a differential in air pressure due to stack effect, mechanical systems or wind, the assembly shall be designed to provide an effective barrier to air exfiltration and infiltration, at a location that will prevent condensation within the assembly, through

(a) the materials of the assembly,
(b) joints in the assembly,
(c) joints in components of the assembly, and
(d) junctions with other *building* elements.

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## Scope and Definitions

Air leakage is uncontrolled air flow through a building element. Infiltration is air leakage into a building, while exfiltration is air leakage out of a building. Air leakage may also occur between two interior spaces. Air leakage is unplanned and can lead to a number of unexpected consequences. The most widely reported are the deposition of moisture within the building assembly from exfiltration, and rain penetration from infiltration caused by negative pressures. This moisture can produce problems ranging from surface staining to premature deterioration of the assembly.

Air leakage, and the holes associated with it, can also have a detrimental effect on the indoor environment including:

- difficulty in controlling temperature and humidity,
- poor indoor air quality, including entry of soil gases such as radon,
- excessive transmission of exterior noise,
- increased energy use,
- freezing of water pipes,
- fire-related problems, such as fire spread and diminished smoke control.

These problems can occur in any building envelope assembly unless due care is exercised in the design and construction. However, the Code primarily addresses the problem of condensation. Hence, Section 5.3 only requires that air leakage be controlled if differentials of temperature, water vapour pressure and air pressure exist in combination:

- A temperature differential will exist in the heating season.
- A water vapour pressure differential will exist because the occupants and their activities add moisture to the interior air; mechanical humidification may further increase the moisture load.
- An air pressure differential will be generated by the temperature differential (referred to as stack or chimney effect), possibly by mechanical ventilation, and certainly by wind.

Thus, all three differentials can be expected to exist in an occupied building in Canada in winter and the requirements of Section 5.3 will apply to all buildings listed in Section 2.1.

Although there is almost always enough air pressure difference to drive air leakage, leakage will only occur if there are holes in the building envelope through which the air can flow. Such holes do not have to be straight through the envelope but could consist of a combination of gaps in or between low permeability materials and of the many small holes in high permeability or porous materials. Thus the implied intent of Section 5.3 is to produce building envelopes without holes for air leakage.

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**Stack effect – What is it?**
The same difference in pressure that drives warm air up a chimney or smoke stack drives warm air upward through the interior of a heated building. As air is heated, it expands, becomes less dense and rises above colder air. Where there are intentional or unintentional openings through the building envelope, the warm air will escape through the higher openings and be replaced by colder air entering through lower openings. This process is referred to as stack effect or chimney effect.

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## What is 'Effective'?

The requirement for an 'effective' barrier does not imply a perfect barrier. An effective air barrier system is one that is close enough to perfection to prevent condensation problems. The majority of Canadian buildings do not have condensation problems, even though their air barrier systems fall short of perfection and some condensation occurs within the building assembly. Experience has shown that, in a building where the humidity is controlled to reasonable levels in winter and which is not subject to significant positive pressurization, the air barrier system can be less than perfect and still achieve the intent of this Section. In buildings with higher winter humidity levels or which are positively pressurized, the air barrier system would have to be closer to perfection to be effective. Additional benefits could be gained from decreasing building pressurization.

How much leakage is acceptable before problems occur? This question is difficult to answer with the current level of knowledge but efforts to define an appropriate number[1] are continuing. Condensation is the controlling parameter for acceptable air leakage with respect to the requirements of Section 5.3. The amount of condensation that will occur with a given amount of leakage depends on a number of factors. These include the indoor environment, the outdoor environment and the length and size of the leakage path. Different construction systems will tolerate different levels of condensation before a problem arises and some systems in some locations will permit drying over the summer. Zero leakage is obviously a safe condition to strive for, but realistically it is not likely to be attained.

To meet the requirement of this Section, the designer must consciously design, and the builder must consciously construct a barrier to minimize air leakage paths and this barrier must be effective over the entire building envelope. A proper design requires more than air impermeable materials to control the passage of air; such materials must also be assembled with essentially leak-free joints. The combination of air impermeable materials with essentially leak-free joints in a 'constructable' system (see Section 5.7) provides effective control of air leakage.

## Vapour Diffusion versus Air Leakage

Two mechanisms move water vapour from an interior space into the building envelope or into an assembly separating dissimilar interior environments:

- vapour diffusion (movement at the molecular level through building materials [see Section 5.2]) and
- air leakage (transporting moisture through openings in or between materials).

(See Figure 1).

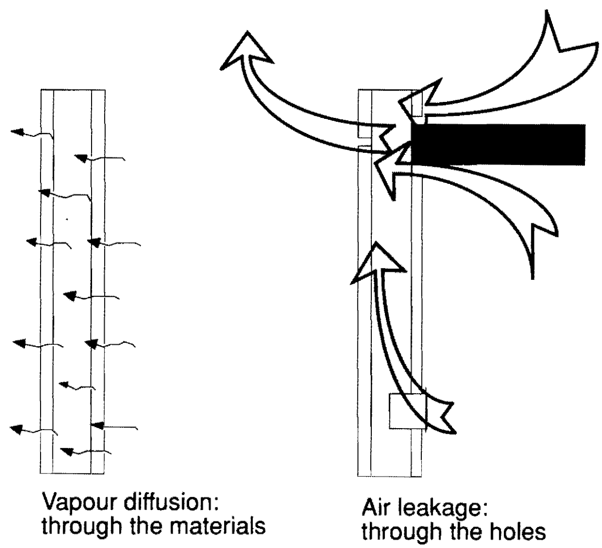


Figure 1 Vapour diffusion transfers moisture much more slowly than air leakage

Air leakage is usually the culprit when condensation problems within environmental separators are investigated. This does not mean that the vapour barrier can be ignored; it does mean that the barrier to air leakage should be paramount throughout the design and construction process.

**Air leakage, infiltration and exfiltration**
The terms air leakage, infiltration and exfiltration are all used in discussions of air flow through the building envelope.

Air leakage is a generic term that includes both infiltration and exfiltration.

Infiltration refers to the transfer of air from outside a space to inside that space. It generally refers to air leakage from the outdoors into a building or space.

Exfiltration refers to the transfer of air from inside a space to outside that space. It generally refers to air leakage from inside a building or space to the outdoors.

The use of the terminology may become confusing when referring to air transfer between two indoor spaces. In this case, any of the terms may be used, but it is important to identify where the air is moving from and where it is going to; that is, air leakage from space A to space B, infiltration from space A into space B, or exfiltration from space A to space B.

## Requirements for an Air Barrier System

To meet the intent of Section 5.3, the barrier to air leakage, or air barrier system, must exhibit a number of functional characteristics[2]. These include:

- low air permeability and continuity,
- structural integrity,
- durability.

The primary objective of the air barrier system is control of air leakage. This is achieved with low permeability materials assembled with leak-free joints. Since air leakage is driven by an air pressure difference and the loads generated by that difference must be resisted by the air barrier system, the system must have structural integrity. Finally, control of air leakage must continue for the life of the building. An effective air barrier system begins at the designer's drawing board and continues through the builder's construction efforts.

### Permeability and continuity

*Materials*

The primary elements within an air barrier system are the materials, which must have low permeability to air flow. These may be materials used in the building envelope for structural or finish purposes, such as poured concrete, glass or aluminum. However, if the building materials allow large quantities of air to flow through them, as does a concrete block wall, for example, then impermeable materials must be added to produce the low air permeability required for the air barrier system.

Many materials can provide the airtightness required for an air barrier system. Information on the resistance to air flow of common building materials is available from various sources, including manufacturers' data sheets. The resistance of 36 building materials is reported in a publication[3] available from Canada Mortgage and Housing Corporation. Most of these materials can provide the necessary airtightness for the primary element of the air barrier system. (The air barrier material must also meet the durability requirements of Section 5.6.)

*Joints and junctions*

Joints and junctions are both identified in the requirements specified in Section 5.3. 'Joints' is used in this Commentary to refer to the meeting of single materials and components in the building envelope. 'Junctions' refers to the intersection of larger building elements such as walls and roofs; junctions may contain many joints.

Various trades may be involved in the construction of joints in the building assembly. As a result, they are potentially the weakest parts of the air barrier system and require additional care to design and build.

In addition to meeting all requirements of a basic air barrier, the air barrier at a joint must accommodate movement. This includes movement due to static and dynamic loads, and to thermal expansion and contraction. The material sealing the joint must be air impermeable and must be installed in such a manner that it bridges the gap between the air barrier materials on either side of the joint. That is, in order to maintain the integrity of the air barrier system, the designer and the builder must both have a clear idea as to which element on either side of the joint is performing the air barrier function.

Joints may be sealed with sealants. Proper selection and installation is critical to the long term performance of a sealant.[4] Sealants must have the necessary cohesion (internal strength) to remain intact and enough adhesion to remain bonded to the surfaces while undergoing the movement inherent in joints.

If a joint is too wide to be bridged effectively by a sealant, then it must be bridged by an airtight material or component with sufficient elasticity to absorb the joint movement while still remaining tight to all sides of the joint.

*Components*

Prefabricated components of a building assembly typically conform to a product standard which will generally include a requirement for airtightness. For example, windows in Canada can be tested to conform to CAN/CSA A440 "Windows."[5] Though the Code does not specify required airtightness levels, several levels of airtightness are included in the CSA standard. Special Publication A440.1, "User Selection Guide to CSA Standard CAN/CSA A440 Windows,"[6] provides guidance on the level of airtightness appropriate for the building being designed. Standards that are referenced in the NBC are listed in Table 2.7.3.A. of the Code.

To ensure continuity between building components, such as doors and windows, and adjoining envelope assemblies, the elements in the assembly and in the component that provide the airtightness function must be identified. Drawings must clearly show the connection between the air barrier in the wall and in the component. Some window frame designs facilitate joining between the wall and the window system by providing a pre-designed location where the wall air barrier material can be clamped against the window air barrier material. This allows the air barrier system to maintain structural integrity under wind forces, and to resist failure by deterioration or separation of the joint.[7]

### Structural performance

The air barrier system must be designed to resist the loads imposed by stack effect, mechanical pressurization and wind. This means that the airtight materials in the air barrier system must themselves be capable of resisting the load, or they must be supported by a material that is. Specific attention must be paid to the materials sealing joints and junctions, since the method of installation, and specifically attachment, of these materials will affect their ability to resist air pressure loads. Since the pressure load will ultimately be carried by the structure of the building, the air barrier system must be designed so that the load is transferred.

The structural loads induced by stack effect and fan pressurization will not be the largest loads imposed on the air barrier material by air pressure difference, but they will be endured for longer periods than wind loads. The air barrier material must be installed in such a manner that it will not detach from its support or fail in creep under these loads.

The largest forces that must be considered in the structural performance of air barrier systems are those from pressure differences induced by wind. These include sustained wind loads and gust wind loads. Chapter 1 of the Supplement to the National Building Code[8] lists hourly design wind pressures for many locations in Canada. Rather than the 1-in-10 values applied to cladding, the values tabulated for the 1-in-30 chance of occurrence are recommended as sustained design loads for air barrier systems, since repair of a damaged air barrier can be very difficult and expensive. Gust wind loads must also be considered; these can be determined using procedures documented in Commentary B in Chapter 4 of the Supplement, and in Section 4.1 of the National Building Code. These procedures are especially important when designing air barrier systems for tall buildings.

### Durability (see also Section 5.6)

The air barrier system has to perform as long as the building operates. The materials in the system should have a proven track record or otherwise demonstrated durability (for example accelerated aging testing). Failing this, the materials must be positioned so that they are accessible for inspection and maintenance.

Durability is not an intrinsic property, but depends largely on how a material reacts to specific environmental factors such as moisture, temperature, solar radiation, and adjacent materials. Materials and components often must withstand several different environments during their service life, one during construction and others after the building has been completed. The environment that the air barrier system sees only briefly during construction may nonetheless be detrimental to the long term performance of some of the materials that comprise it. These materials should always be adequately protected from or resistant to rain, extremes of temperature, solar radiation, and mechanical damage during construction.

## Location

The location of the airtight material within the building envelope is governed to a large extent by the same principles that govern the location of the vapour barrier. In theory, a plane of airtightness anywhere within the building assembly will stop through air leakage. In practice, it is generally safer to locate the highest resistance to air flow inside the dew point plane; that is, on or near the warm side of the insulation. This has three advantages:

- the air barrier is in a much more stable environment, protected from major temperature and moisture variations;
- if there are leaks in the air barrier system, the exfiltrating air will probably pass quickly to the outside and not linger within the assembly, where the probability of condensation would increase;
- many materials have low air permeability in combination with low vapour permeability. In other words, most materials that are suitable for controlling air leakage will also perform to some extent as vapour barriers. In this case, the rules governing the location of the vapour barrier will also apply to the air barrier material.

Adopting the face-sealed approach to control rain penetration requires that the exterior surface of the envelope assembly also serve as the plane of airtightness, with consequent disadvantages (Section 5.4).

## Testing

New construction materials and systems should be tested prior to installation in a building. Tests on sections of the building assembly may be made in-situ. Whole building tests after completion of construction are expensive and difficult, and the results are generally inconclusive.

### Laboratory testing

Except for factory assembled components, few standards address methods of assessing the air leakage performance of building envelope assemblies. ASTM Standard E 283 "Standard Test Method for Rate of Air Leakage Through Windows, Curtain Walls and Doors"[9] can be used as a test procedure for laboratory assessment of the air leakage of building components; ASTM Standard E 330 "Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference"[10] can be used as a test procedure for assessment of structural performance. Both standards describe standard test apparatus and procedures for measuring performance, but they prescribe neither a test pressure difference nor a pass/fail criteria. They did form the basis for a series of laboratory evaluations of air barrier systems for wood frame walls,[11] and air barrier membranes for masonry walls.[12] Another standard, AAMA Standard 501 "Methods of Test for Metal Curtain Walls,"[13] can be used for laboratory assessment of the air leakage control obtained with metal curtain walls.

### Field testing

Laboratory procedures can identify the potential performance of an air barrier system. Actual field performance of a given system will depend on the 'constructability' of the system and on the workmanship of the trades involved in its installation. Testing full scale mock-ups of building facades that include realistic construction details can aid in confirming the performance of the air barrier system or in identifying flaws in its design or constructability.

ASTM standard E 783, "Standard Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors"[14] can be used to assess the performance of air barrier systems installed in buildings. This procedure will give an overall assessment of the degree of airtightness achieved with a given installation.

Non-standard and non-quantitative techniques involving smoke pencils and infrared and acoustic sensors have been used to locate local leaks in installations of air barrier systems. These latter procedures can be used to locate flaws in an otherwise acceptable installation.

## Air Leakage and Ventilation

As indicated at the outset, controlling air leakage can achieve benefits beyond the control of moisture transfer. Although air leakage has been relied upon in the past to provide ventilation for the occupants and processes planned for the building, this approach is highly weather dependant and is now generally recognized as inefficient, unreliable and often ineffective. Reliance on air leakage becomes completely unworkable when the airtightness requirements are met. Although natural ventilation can sometimes be used, mechanical systems are generally installed to provide the required volumes of fresh air when and where it is needed. Subsection 6.2.2. addresses ventilation requirements for buildings covered by Part 5.

## Supplemental Reading

Construction Specifications Canada. Tek-AID on Air Barrier Systems, Master Specifications and Digest, Toronto, 1990.

Ontario New Home Warranty Program. Condominium Construction Guide. 1993 Edition, North York, Ontario.

1991 Annual Book of ASTM Standards, Vol. 04.07, Building Seals and Sealants; Fire Standards; Building Constructions. American Society for Testing and Materials, Philadelphia, 1991.

## References

1 Criteria for the Air Leakage Characteristics of Building Envelopes. Report prepared for Canada Mortgage and Housing Corporation by Trow Inc., Ottawa, December 1989.

2 An Air Barrier for the Building Envelope - Proceedings of Building Science Insight '86. Institute for Research in Construction, National Research Council Canada, Ottawa, 1989.

3 Air Permeance of Building Materials. Report prepared for Canada Mortgage and Housing Corporation by AIR-INS Inc., Ottawa, 1988.

4 Ashton, H.E. and Quirouette, R.L. "Coatings, Adhesives and Sealants." Performance of Materials in Use - Proceedings of Building Science Insight '84. Institute for Research in Construction, National Research Council Canada, Ottawa, 1984.

5 CSA Standard CAN/CSA-A440-M90, "Windows." Canadian Standards Association, Rexdale, Ontario, 1990.

6 CSA Special Publication CAN/CSA-A440.1-M1990, "User Selection Guide to CSA Standard CAN/CSA-A440-M90, Windows." Canadian Standards Association, Rexdale, Ontario, 1990.

7 Window Performance and New Technology - Proceedings of Building Science Insight '88. Institute for Research in Construction, National Research Council Canada, Ottawa, 1988.

8 Supplement to the National Building Code 1990. Chapter 1, Climatic Information for Building Design in Canada. Associate Committee on the National Building Code, National Research Council Canada, Ottawa, 1990.

9 ASTM Standard E283, "Standard Test Method for Rate of Air Leakage through Windows, Curtain Walls and Doors." American Society for Testing and Materials, Philadelphia, 1991.

10 ASTM Standard E330, "Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference." American Society for Testing and Materials, Philadelphia, 1991.

11 Testing of Air Barrier Systems for Wood Frame Walls. Report prepared for Canada Mortgage and Housing Corporation by W.C. Brown and G.F. Poirier, Institute for Research in Construction, National Research Council Canada, Ottawa, December 1989.

12 Development of Test Procedures and Methods to Evaluate Air Barrier Membranes for Masonry Walls. Report prepared for Canada Mortgage and Housing Corporation by G. Hildebrand, Ortech, Ottawa, November 1990.

13 AAMA Standard 501-83, "Methods of Test for Metal Curtain Walls." Architectural Aluminum Manufacturers Association, Chicago, 1983.

14 ASTM Standard E783, "Standard Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors." American Society for Testing and Materials, Philadelphia, 1991.

# Section 5.4 Control of Rain Penetration

## 5.4.1. Joints

**5.4.1.1.** Joints in *exterior cladding* and the junctions of different *exterior claddings* shall be constructed to minimize the entrance of rain water into the *building* assembly.

## 5.4.2. Openings

**5.4.2.1.** An opening in an exterior wall or roof shall be so constructed as to prevent the entrance of rain or snow into the *building*.

## 5.4.3. Roofing

### 5.4.3.1. Installation

**(1)** Roofing shall be installed so as to
- (a) shed or drain water effectively,
- (b) reduce the likelihood, when the roofing is comprised of overlapping units, of water backing up under the units due to ice damming or other cause, and
- (c) be resistant to damage due to wind.

## 5.4.4. Parapets

### 5.4.4.1. Protection

**(1)** Where the top of a wall is exposed to the weather
- (a) it shall be capped, and
- (b) a through-wall flashing shall be installed immediately under a segmented or pervious cap, and at such other points in the wall as are necessary to divert rainwater to the outside.

## 5.4.5. Exterior Wall Cladding

**5.4.5.1.** Exterior wall cladding shall be so installed that it sheds water to prevent its entry into other components of the *building* assembly. Where there is a likelihood of some penetration, drainage shall be provided to take water to the outside.

## Scope

Section 5.4 focuses on the requirements for roofs, parapets, wall cladding, and joints and openings in walls and roofs, primarily with the aim of resisting rain penetration.

Before discussing requirements for joints, openings and parapets, however, the general requirements for roofs and walls must be identified. Thus, rather than following the order of the requirements as presented in Part 5, this section of the Commentary discusses, in the following order:
- general conditions that allow rain penetration and general principles for controlling ingress,
- requirements for roofs,
- requirements for joints and openings in roofs,
- requirements for walls,
- requirements for joints and openings in walls,
- requirements for roof-wall junctions, including parapets.

Designing for snow, ice and wind are also mentioned in Section 5.4 and are included in the discussion below.

## Conditions that Allow Rain Penetration and Measures to Control Ingress

When rain gets into a building envelope, the natural tendency is to look for holes in the outside surface of the wall or roof, that is, the cladding or roof covering. In fact, holes and the presence of water are not sufficient to cause rain penetration; the holes simply supply an entry point where forces which are present can cause water entry. Three conditions are required for rain penetration:
- rain
- entry paths
- forces.

In some situations, exposure of various building envelope surfaces to rain may be reduced by incorporating overhangs in the design.

The forces which can lead to water entry include (Figure 2):

- gravity
- kinetic energy (raindrop momentum)
- capillarity
- surface tension and
- air pressure difference.

either conventional or protected membrane systems, membrane waterproofing is used.

### Controlling the forces

The 'rainscreen' principle can be applied to walls and sloped roofs. Rather than attempting to eliminate all the holes that let the water in, joints are detailed to control some of the forces that drive rain inside and means are provided to drain any water that does penetrate the envelope. As drainage is an essential characteristic of rainscreen assemblies, it can be applied only to roofs with sufficient slope to prevent any accumulation of water on the surface.

Techniques to counteract the forces that drive rainwater into or through a building envelope are illustrated in Figure 3.

- Except in the case of nominally flat roofs that are sloped to interior drains, nominally horizontal surfaces and horizontal joints in vertical surfaces should have a positive slope to

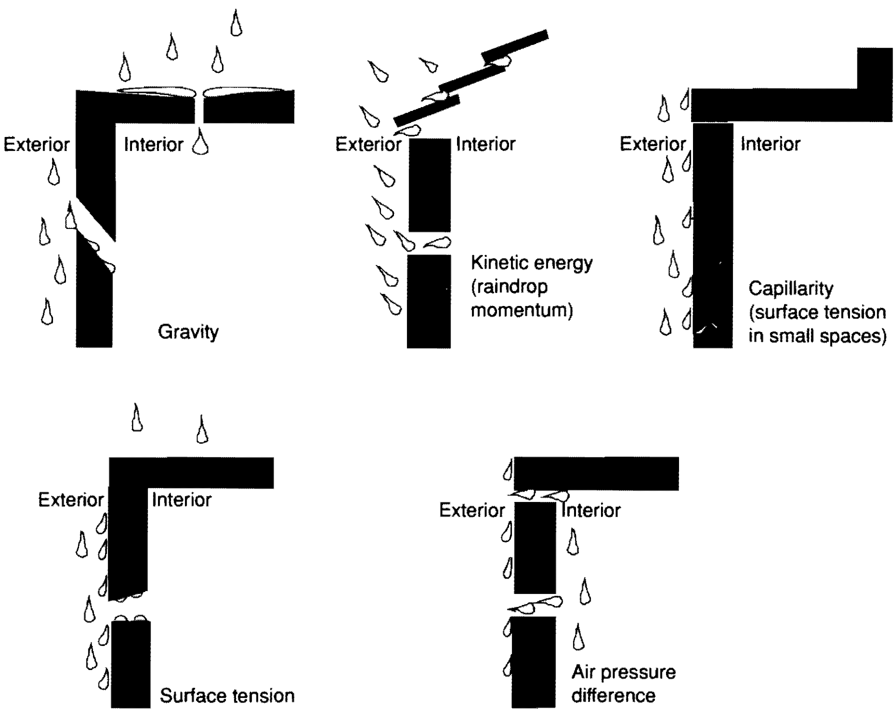


Figure 2 Forces acting to cause rain entry

Two main approaches are followed to control or eliminate rain penetration. The first involves eliminating holes through which water can penetrate; the second involves counteracting the forces that drive the water through the envelope or using those same forces to keep or lead water out of the building envelope.

### Surface sealing

This approach aims at eliminating any holes in the wall cladding or roof cover and their joints since, without a passageway, water will not get in. For walls, this is known as face sealing; for flat roofs, drain outward so that gravity works for them. Joints in horizontal surfaces may be capped to shed water away from them.

- At openings and interfaces with other components such as windows, raindrop momentum may be controlled with a shield, not airtight or watertight, installed on the outside of or within the joint.
- Surface tension can be controlled by a rapid change in direction (a drip) in the top of a horizontal joint, which forces water to detach from the surface and to fall down in the drainage channel.
- Creating a vented airspace behind the cladding will reduce the air pressure difference across the cladding, break capillary flow and provide a drainage path for any water that passes the cladding.

## Roofing

A roof is exposed to harsh environmental forces, such as solar radiation, extreme temperatures, precipitation and wind. Roofing materials must have the physical and chemical properties to resist these attacks or must be protected. Seven functions are performed by various roof components[1]:

- securement against wind uplift
- structural support
- control of water ingress
- control of air flow
- control of water vapour diffusion
- control of heat flow
- surface protection.

The requirements of Section 5.4 of the Code focus on:

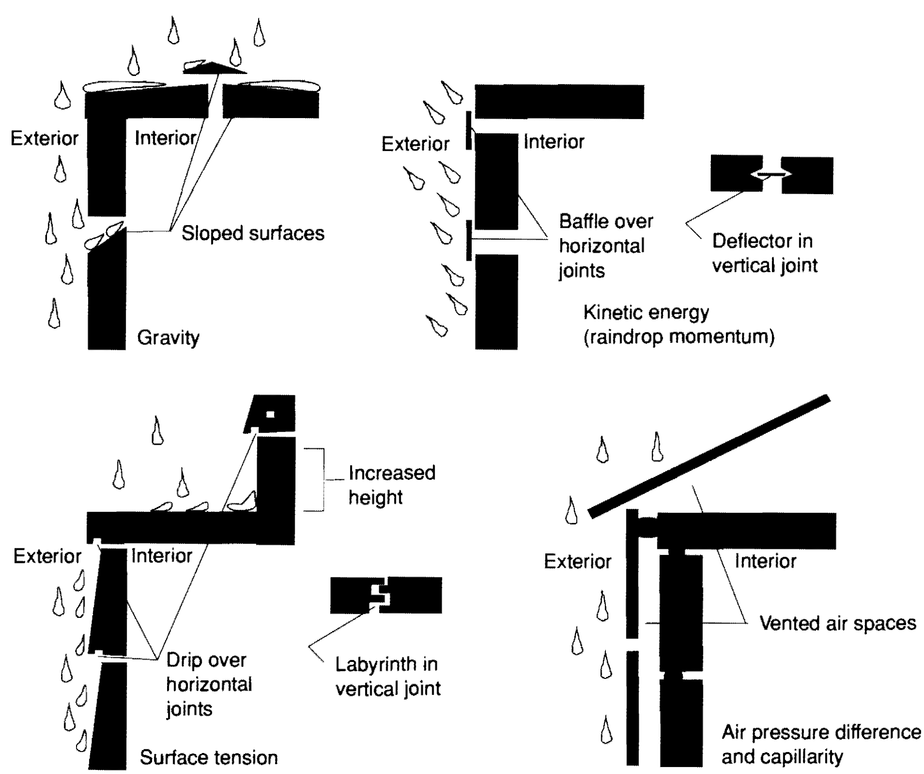


Figure 3 Details to control rain penetration forces

- control of water ingress [Clauses 5.4.3.1.(1)(a) and (b)], and
- securement against wind uplift [Clause 5.4.3.1.(1)(c)].

**Controlling water ingress**

Whether a roof system is sloped or nominally flat, it must be designed to drain effectively. This is necessary to the long term durability of many roofing materials, to reduce structural loading and to allow maintenance.

Nominally flat roofs are effectively surface sealed and rely on a waterproof membrane to eliminate leakage routes through the envelope. The membrane is sloped to the edges of the roof or to internal drains. The slope is preferably achieved by sloping the structure but, where this is not possible, may be achieved by installing a sloped topping on the deck or tapered insulation under the waterproof membrane. The Canadian Roofing Contractors Association recommends a 2% slope to allow for construction tolerance and deflections. The drainage system must be designed in accordance with the provisions of the Canadian Plumbing Code.

On steeply sloping roofs, either the face seal or rainscreen approach may be followed. In the latter, rain protection is provided by overlapping units that will shed water. (In fact, it was the good performance of shingled roofs on Norway's windswept coasts that led to the 'discovery' of the rainscreen principle.) The lower portion of the roof must be protected from water leakage resulting from ice damming. This is normally accomplished by installing a membrane under the overlapping units.

**Ice damming**

Ice damming is a winter phenomenon which is common to poorly insulated sloped roofs. Heat loss through the roof melts the snow and the water flows down the roof. The roof surface beyond the exterior walls, however, will be colder than the surface over interior space. When the water reaches this surface, it may freeze and build up a 'dam' at the edge of the roof. Water from the melting snow collects behind the dam, and can back up under the shingles and leak into the building.

**Securement of roofing against wind uplift**

Roofing materials must be secured to the building structure at the perimeter, and at expansion joints and penetrations, to restrict lateral movement. They must be fastened, adhered or ballasted across the surface of the roof to resist wind uplift and internal air pressures.[1, 2]

## Joints and Openings in Roofs

Any interruption in the watershedding or waterproofing component of the roof must be carefully designed and constructed to ensure continuity of the water control system. The following focuses on nominally flat roofs. Although these roofs are sloped to drain, water will accumulate, for example, when drains become blocked by debris or when ice and snow prevent flow to the drains. For this reason, vulnerable connections of the roofing system with joints and openings should be raised well above the surface of the roof.

Although the figures below show those elements required for the control of rain penetration, continuity of other components, such as air barriers and insulation, is essential.

### Joints

Expansion/contraction joints are intentional discontinuities that are built into roof systems to accommodate movement.

A curb is built on either side of the joint to raise the effective height of the joint above the level to which water might accumulate. To maintain continuity of the waterproofing across the joint, base flashings are sealed to the roof membrane and adhered to the curb; counter flashings protect the top of the curb. A membrane loop or sufficient non-adhered material, and membrane flexibility are required to ensure that the stresses induced by movement are distributed over a large area. The sloped cap and counter flashings shed rain off the curb and minimize the likelihood of leakage at the membrane joints (Figure 4).

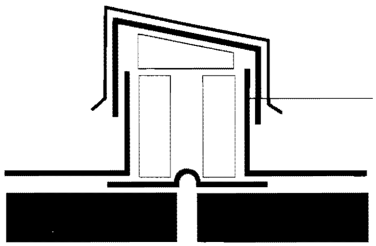


Figure 4 Continuity of waterproofing membrane at expansion joint on flat roof

### Openings

Openings in flat roofs, such as skylights and roof hatches, are best detailed in a fashion similar to joints. That is, base and counter flashings are applied to a simple supporting structure to shed rainwater and to raise the most vulnerable membrane joints above the level to which water might accumulate.

Penetrations are a type of opening and are handled in a similar manner (Figure 5).

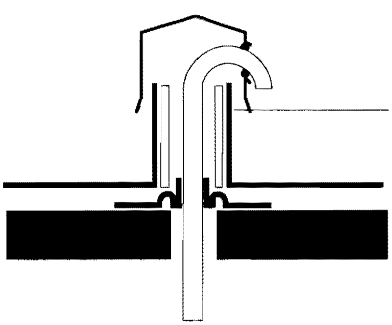


Figure 5 Continuity of waterproofing at penetration in flat roof

## Wall Cladding

Rain penetration into or through walls may be controlled by face sealing or by following the rainscreen principle. Mass walls, such as poured concrete shear walls, may be designed not to be clad; given proper care to control cracking and to seal construction joints, these are, by definition, face sealed. For walls that are clad, the Code requires the cladding to shed water and, if rain penetration is possible, drainage to the outside must be provided; the latter requirement suggests the rainscreen wall.

### Face sealed walls

Face sealing is most commonly applied to cladding systems with small joint areas relative to the overall cladding area. Such systems include precast concrete cladding, stucco, metal and glass curtain walls, and sheet metal cladding. Masonry has many joints and is permeable to water, so designers and contractors should not attempt to make this cladding airtight and water tight.

The face seal approach consists of using an impervious exterior cladding combined with one-stage sealed joints to act as the air barrier system as well as the watertight assembly. (Two-stage joints are discussed under Joints and Openings in Walls.) This technique relies solely on the use of sealants installed in the joints between materials such as precast concrete panels (Figure 6) and components such as

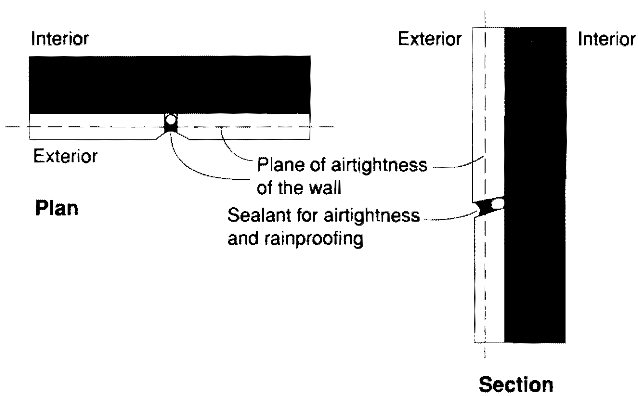


Figure 6 Face sealed wall with one-stage joint

windows to ensure the continuity of air and watertightness; durability of the sealants is therefore critical to the performance of the envelope.

In a face sealed wall system, the air barrier system is on the outside of the assembly, that is, directly exposed to the most severe conditions:

- solar radiation
- water
- pollution
- freeze-thaw cycles.

The sealants are also subject to large movement of the substrates at times when the sealants' ability to accommodate movement is limited (in winter). These severe conditions reduce the durability of sealants in the Canadian climate.

When the sealants of a face sealed cladding fail, the walls lose their watertightness and airtightness; this translates into severe disability of the envelope in performing its intended functions. As a consequence, face sealed walls require frequent and costly maintenance during the life of the building. The approach has little to recommend it and is considered impractical for buildings in Canada.

### Rainscreen walls

Rainscreen walls are designed to shed water; the cladding is not waterproof, but the wall accommodates the various forces that lead to rain penetration.

A rainscreen wall has the following attributes to control rain penetration:

- a vented air space behind the cladding to break capillary flow and reduce the air pressure difference across the cladding,
- joints detailed to respond to gravity, surface tension and raindrop momentum,
- horizontal joints and flashings sloped to the exterior to drain any water that does enter the joints or air space.

(See Figure 7.)

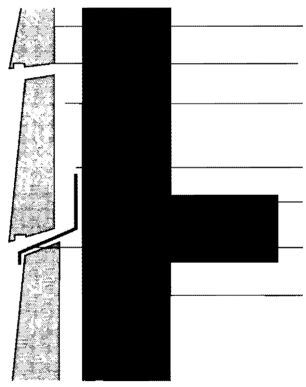


Figure 7 Rainscreen wall

On-site construction conditions affect the performance of these walls. For example, an air space that is ample on the drawings may end up as nil on the building due to construction tolerances, and accumulation of mortar droppings or other debris.

For effective drainage of the water reaching the air space, the installation of the flashing at the bottom of the space is important. It must be continuous and durable, sloped towards the outside and extended beyond the face of the cladding. Improper installation is the source of many problems. Finally, the drainage channels (weep holes in masonry) must remain free from obstructions.

A rainscreen wall is sometimes used for the main part of the wall in combination with a face seal at the junction with other components, such as windows, doors, roofs and other cladding systems. This can lead to problems if the sealants fail because no provision has been made for draining and flashing this interface (see Joints and Openings in Walls).

### Pressure-equalized rainscreen walls

A further refinement of the rainscreen wall is the pressure-equalized rainscreen.

One purpose of the cavity behind the cladding, as noted previously, is to reduce the pressure difference between the outside air and the air space. The pressure-equalized rainscreen is intended to further reduce this pressure difference. For this to happen, the following conditions must be satisfied:

- the wall must have an effective air barrier system on the interior side of the air space (Section 5.3),
- the air space must be adequately vented to the exterior,
- the air space must be vertically and horizontally compartmented.

Since the air barrier may not be completely tight, venting must be designed to ensure that the cladding is leakier than the air barrier (Figure 8). Channels provided for drainage may not be sufficient for this purpose. Any additional holes should be located at the bottom of the air space to avoid convection through the air space that may induce leakage.

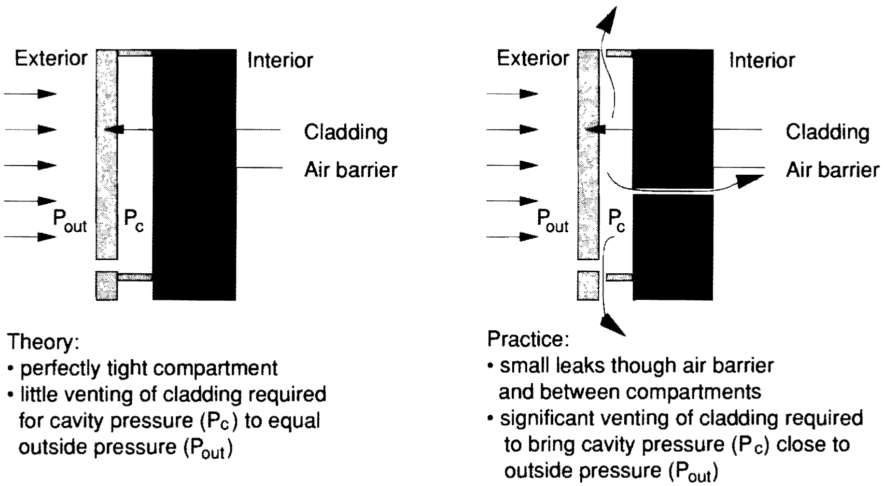


Figure 8 Relation between cladding venting and compartment leakage

As wind induces different pressures across the face of the cladding, it also induces lateral air flow in the cavity. To achieve pressure equalization over any area of the wall, that area must be separated from other areas that may be subject to a different pressure. Tops and corners of buildings are usually exposed to extremes of this phenomenon. Thus the cavity behind the cladding should be divided into compartments, with the compartment sizes inversely related to the pressure ranges expected. Since wind pressures are usually more uniform in the centre of a facade than at the edge, compartments can be larger in the centre than at the corners.

## Joints and Openings in Walls

### Joints

As with the main part of the walls, joints between cladding elements can be designed using face sealing or the rainscreen principle, the latter commonly known in this context as a "two-stage joint." A two-stage joint consists of:

- a deflector on the outside of the joint
- an air seal on the inside
- holes, usually at the lower part of the joint, to provide venting and drainage (Figure 9).

Additional information on joints is provided in Sections 5.3 and 5.7.

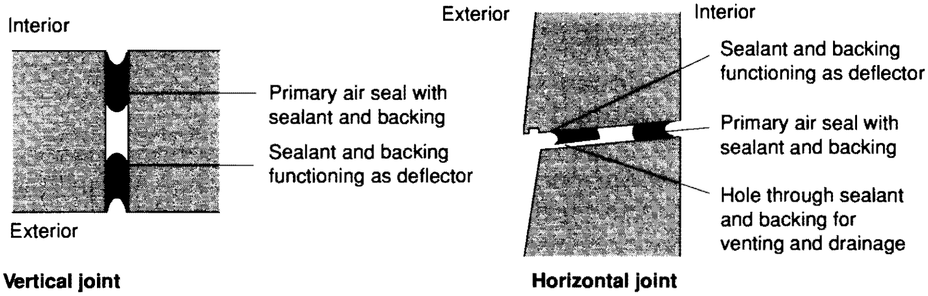


Figure 9 A two-stage joint

### Openings

Openings in walls must also be constructed so as to prevent the entry of rain or snow into the building. This demands that both the component installed in the opening, and the junction between the component and the wall, be properly detailed.

Most components for openings in walls, such as windows, doors and vents, are factory-made. Standard CAN/CSA-A440 [3] rates prefabricated windows for their ability to control rain penetration when subjected to a range of air pressure differences. Similar standards exist for other prefabricated components. Standards for such components referenced by the NBC, primarily in Part 9, are listed in Table 2.7.3.A. of the Code.

Joints between these prefabricated units and a face sealed wall again depend on the effectiveness and durability of the sealant. In the case of windows, failure of the sealant can lead to water entry in the window head, and accelerated deterioration of sealants in a factory sealed glazing can result.

Joints between these prefabricated units and a rainscreen wall should be detailed to drain any water that might penetrate the joint (Figure 10).

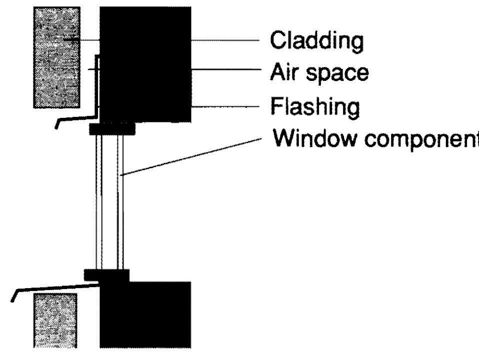


Figure 10 Window in a rainscreen wall

## Roof-Wall Junctions

Like joints within building assemblies, junctions between assemblies require special attention to control rainwater penetration. Part 5 specifies some particular requirements for parapets; other wall-roof junctions should also be considered.

Wall-roof junctions must be designed so as not to interrupt the integrity of the water shedding or waterproofing elements and to allow for any differential movement that may occur between the components.

### Parapets

Junctions between walls and the outside edges of flat roofs can be very vulnerable to rain ingress and wind damage. Parapets are the preferred way to handle this junction, especially on higher buildings.

Typical detailing is similar to that used for joints in roofs (Figure 11). Positive securement of the roof membrane to the perimeter of the deck and the base flashing to the parapet is essential to protect the roofing from wind up-lift. The waterproof membrane must also be sealed directly or indirectly to the components that comprise the air barrier in the roof and wall. This is necessary to protect the whole roof from wind up-lift and to restrict ingress of wind-driven rain.

Where a high parapet wall is required, a through-wall flashing may be installed at a suitable height above the roof to limit the height of the membrane flashing on the inside face. The portion of wall above the through-wall flashing, however, must be designed to limit water penetration. Providing structural connection to the parapet above the through-wall flashing while maintaining the integrity of the waterproof flashing requires careful selection of the flashing material and careful installation.

New membrane materials which may be installed up the full height of and over the parapet eliminate the need for through-wall flashing and all its complications.

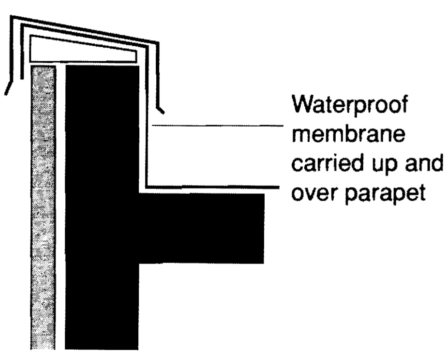


Figure 11 Continuity of waterproof membrane at parapet

### Walls rising above a roof

Where a wall rises above a roof, the same problems of continuity and accommodation of movement arise. Detailing becomes more difficult where the wall passes through the roof rather than resting on the roof (Figure 12).

## Supplemental Reading

*Walls*


Building Science Forum '82 - Exterior Walls: Understanding the Problems. NRCC 21203, National Research Council Canada, Division of Building Research, Ottawa, 1982.

Garden, G.K. Rain Penetration and its Control. Canadian Building Digest No. 40, National Research Council Canada, Division of Building Research, Ottawa, 1963.

Kerr, Dale D. Annotated Bibliography on the Rain Screen Principle. Bibliography No. 45, National Research Council Canada, Division of Building Research, Ottawa, Dec. 1985.

Building Science Insight '86 - An Air Barrier for the Building Envelope. NRCC 29943, National Research Council Canada, Institute for Research in Construction, Ottawa, 1989.

Ritchie, T. Cavity Walls. Canadian Building Digest No. 21, National Research Council Canada, Division of Building Research, Ottawa, 1961.

Latta, J. K. Walls, Windows and Roofs for the Canadian Climate. NRCC 13487, National Research Council Canada, Division of Building Research, Ottawa, 1973.

Rousseau, M. Z. Facts and Fictions of Rain Screen Walls. Construction Canada, Volume 32, Number 2, March/April 1990, p. 40-47.

Masonry Council of Canada. Guide to Energy Efficiency in Masonry and Concrete Buildings. Downsview, Ontario, April 1982.

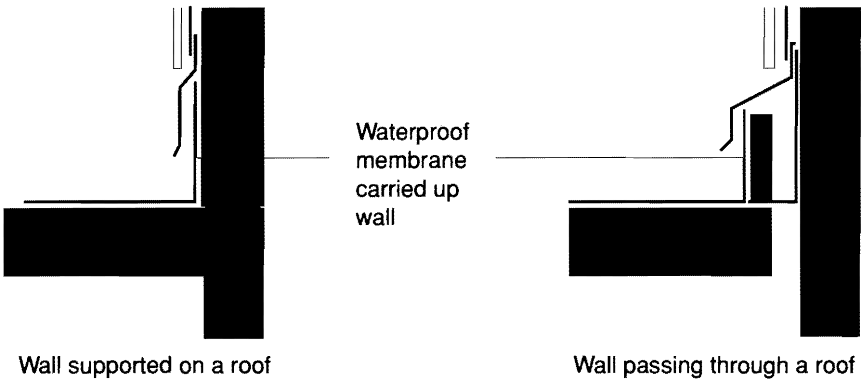


Figure 12 Continuity of waterproof membrane where a wall rises above a roof

*Roofs*

Alberta Roofing Contractor's Association Ltd. Manual on Good Roofing Practice and Accepted Systems. Calgary, 1991.

L'Association des Maitres Couvreurs du Québec. Devis Couvertures. Montreal, 1990.

Building Science Insight '89 - Roofs that Work. National Research Council Canada, Institute for Research in Construction, Ottawa, 1989.

Baker, M. Roofs. Multiscience Publications Ltd., Montreal, 1980.

Canadian Roofing Contractors' Association. Roofing Specifications. Ottawa, 1978.

Roofing Contractors' Association of British Columbia. Roofing Practices Manual. Vancouver, February 1993.

## References


1 Chown, G. Adaire. "Roof Functions, Requirements and Components." Construction Practice: Selected Applications in Construction Technology. Section 2, 1993. NRCC 35475, IRC-P-3108.

2 Supplement to the National Building Code of Canada 1990, Chapter 4, Commentaries on Part 4 of the National Building Code of Canada 1990, Commentary B Wind Loads. Associate Committee on the National Building Code, Ottawa, 1990.

3 CSA Standard CAN/CSA-A440-M90, "Windows." Canadian Standards Association, Rexdale, Ontario, 1990.

# Section 5.5 Control of Groundwater

## 5.5.1. Through-Wall Flashing

**5.5.1.1.** Where moisture from the ground can move upward into a wall and cause deterioration of the materials in the wall assembly, a through-wall flashing shall be installed in the wall below the materials likely to be so affected.

## 5.5.2. Dampproofing and Waterproofing

**5.5.2.1.** The portion of an exterior *basement* wall below ground level or any floor slab in contact with the ground shall be dampproofed or waterproofed as appropriate. (See Appendix A.)

> **A-5.5.2.1. Dampproofing and Waterproofing.** For simple structures, requirements in Part 9 may be referred to as a guide in dampproofing and waterproofing below ground level. More complex structures may require additional provisions not contained in Part 9.

## 5.5.3. Crawl Spaces

**5.5.3.1. Ground Cover.** Crawl spaces shall be provided with a ground cover. (See Appendix A.)

> **A-5.5.3.1. Crawl Spaces.** For simple structures, requirements in Part 9 may be referred to as a guide for providing ground cover for crawl spaces. More complex structures may require additional provisions not contained in Part 9.

**5.5.3.2. Slope.** Unless *groundwater* levels and site conditions are such that water will not accumulate in the crawl space, the crawl space shall be sloped to drain to a sewer, ditch or dry well.

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## Scope and Definitions

Section 5.5 focuses on the control of moisture transfer (water vapour, rainwater and groundwater) from the ground into and through those parts of the building envelope which are in contact with the ground.

The title of Section 5.5. indicates that the principle concern is the control of groundwater. Groundwater is defined by the NBC as "a free standing body of water in the ground." The requirements presented in Section 5.5, however, go beyond protection against water from a free standing body and include water vapour, water flowing through the soil from either surface or ground sources, and moisture released from permafrost. This commentary discusses requirements for controlling water and water vapour, standing or moving, regardless of source.

The requirements of Section 5.5 are largely stated in terms of envelope components (walls and floors) and the related spaces (basements and crawl spaces). Components other than those identified can also be in contact with the ground and thus require treatment. This commentary pertains to all building envelope components in contact with the ground, regardless of the space enclosed.

## Protection against the Intrusion of Water from the Ground

Four techniques are employed to minimize the risk of water intrusion from the ground into a building. These are:

- avoidance/diversion,
- isolation (provision of a capillary break),
- disposal, and
- dampproofing and waterproofing.

Part 9 of the Code addresses most of these defences and defines the minimum acceptable measures for housing and small buildings.[1] More stringent requirements may be necessary for buildings covered by Part 5, depending on site conditions, building use, expected life, and potentially greater moisture loads at greater depths below grade.

Though Section 5.5 focuses on dampproofing and waterproofing, with some comments on the drainage of crawl spaces, different approaches will be required in different situations. For buildings located on well drained sites never subjected to high water table levels, avoidance and dampproofing may be sufficient. For buildings with basements below the water table, waterproofing may be the only practical solution. For buildings on poorly drained sites subject to intermittent high water levels, all of the defences may be required for the adequate on-going performance of the below-grade building envelope. Site investigations should determine which defences are appropriate. This commentary provides some information on each.

### Avoidance/diversion

The first defence against groundwater penetration is elimination of the source. As rainwater is one source of groundwater, removal of rainwater from the vicinity of the building will reduce the load on the envelope. This is achieved through proper site grading and drainage, including:

- sloping the ground away from the building
- introducing swales
- providing catch basins
- diverting rainwater from the roof through interior drains and eaves troughs.

(See Figure 13.)

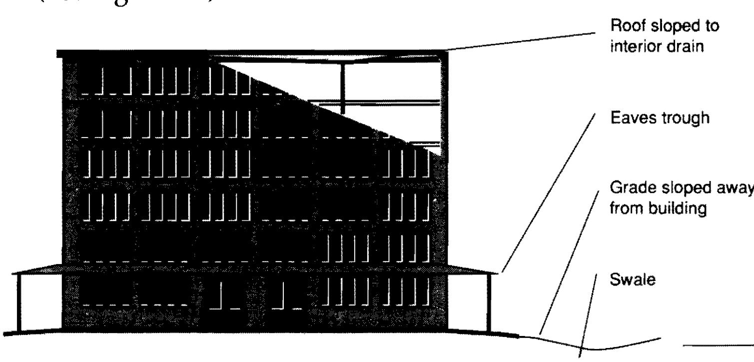


Figure 13 Diversion of rainwater

Water already in the ground can sometimes be avoided, controlled or diverted. Where the water table is high, alternatives to standard full-height basements, including shallow basements, crawl spaces, slabs-on-grade, and raised floors, should be considered. Where a building is located on a watercourse, above or below the ground surface, drainage systems may be employed in some cases to divert the water. Rock faces can sometimes be sealed against seepage.

### Isolation: provision of a capillary break

The second defence involves minimizing or essentially preventing exposure of the envelope to water. Although, except by site selection, one cannot control the properties of the native soil, a designer can specify the installation of permeable material immediately outside the envelope. This provides a number of advantages:

- earth covered roofs — reduces both structural and moisture loading,
- walls — breaks capillary flow and allows water to percolate quickly to the drainage system,
- floors — breaks capillary flow and can also be used as an extraction plenum should soil gases pose a problem.

Permeable materials used include granular back-fill (see Figure 14), geosynthetic* drainage products or mineral fibre 'insulation' board with oriented fibres to facilitate drainage. Where a granular material is used, it should be protected from contamination by fines from the adjacent native soil, or

* Geosynthetics are synthetic materials designed for installation in conjunction with the ground for the purpose of modifying the performance of the soil. They are generally classified as geo-membranes (non-porous), geo-textiles (woven and porous) and geo-grids (composites and three-dimensional systems). Typical geosynthetic drainage products include:

- corrugated or dimpled panels that provide an air gap between the foundation wall and the soil;
- composites comprised of a filter fabric and a profiled non-porous panel, the space between the fabric and the panel allowing the free flow of water.

additional material should be installed to ensure that an adequate thickness of the granular material remains free of fines.

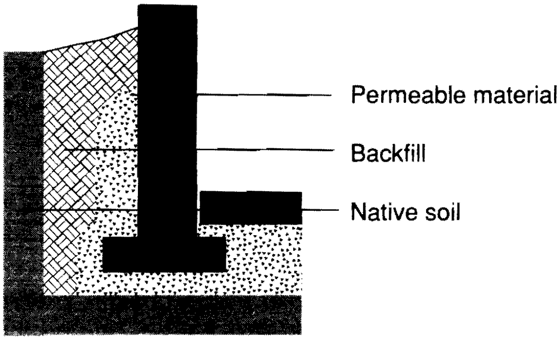


Figure 14 Granular capillary break outside foundation wall and floor

A potential disadvantage may be encountered with soil draining materials where eaves troughs discharge at the foundation wall. Unless the water is diverted away from the foundation or the isolation layer is protected by a low permeance cap, the water will flow quickly through the permeable material and collect at the lowest level. The water must be removed rapidly by a drainage system or the bottom of the wall may require waterproofing to prevent water ingress. Surge loads on the municipal drainage system may also be increased. On the other hand, geosynthetic panels that provide resistance to moisture flow from the soil and a free air space against the foundation will avoid these problems.

## Disposal

The third defence is the removal of water that accumulates on earth-covered roofs, around the footings or under the floor. This may be accommodated by the native soil, where it provides good drainage and where the building is sufficiently high above the water table, or it may be achieved through the use of a drainage system designed for the purpose. Except as it applies to crawl spaces, drainage is not addressed explicitly in Part 5. Disposal to a sewer, ditch or dry well, however, is critical to the control of moisture transfer from the ground.

Roofs below ground should be sloped to drain. Drainage to the edges will minimize roof penetrations. Landscaped roofs above grade, where adjacent lower areas within the property lines do not exist, and roofs that extend to the property line must necessarily be drained to interior drains.

Water that accumulates at the base of a foundation wall of a basement or crawl space is generally collected by a drainage pipe at the footings (Figure 15). The pipe is placed on undisturbed or compacted soil, with the top of the pipe below the bottom of the basement floor slab or floor of the crawl space.

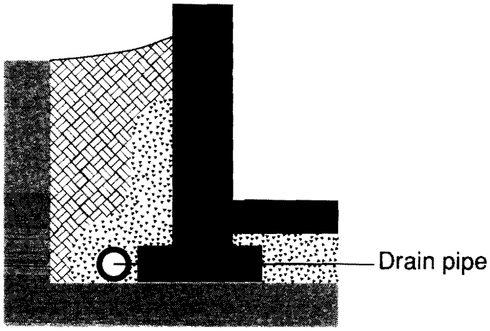


Figure15 Drainage at base of foundation wall using conventional drainage pipe

A horizontal drainage layer of permeable material under the floor and footings may be used in lieu of drainage pipe at the footings.

In most cases, water that accumulates under a basement floor slab is assumed to be drawn down from the slab by the drain pipe around the footings. Where groundwater levels are high, drainage pipe under the slab connected to the drain pipe around the footings may also be needed. Where a sump pump is required for water disposal, drain pipe under the floor slab and footings leads water from the footings to the sump.

Crawl space floor and access trenches must be sloped to drain unless groundwater levels and site conditions are such that water will not accumulate in a crawl space.

Accumulation of water under slabs-on-grade can generally be avoided through proper grading of surrounding ground. Perimeter drainage pipe may be required in areas subject to high moisture loading.

### Dampproofing and waterproofing

Section 5.5 focuses on the requirements for the fourth defence – the building envelope itself. The purpose of dampproofing and waterproofing is to restrict the transfer of moisture from the ground into the building envelope and the interior spaces. Moisture may be transferred through a building envelope by vapour diffusion, capillarity or leakage. Leakage may be caused by water flowing over the surface of the envelope or by hydrostatic pressure.

*Dampproofing*

Dampproofing means the treatment of a surface to resist the passage of water in the absence of hydrostatic pressure, that is, by vapour pressure, capillarity or gravity-driven leakage[2].

Moisture transfer is controlled by the installation of a low water or vapour permeance material in the envelope system. The permeances of materials commonly used for dampproofing range from about 4 to 40 ng/Pa•s•m$^2$ (0.07 to 0.7 perm); a lower number indicates a higher resistance to the passage of moisture. Lower permeance materials are recommended for larger, more complex buildings, buildings subject to high moisture loads, buildings housing materials, equipment or processes that are moisture sensitive, or habitable basements.

Only those dampproofing materials and systems capable of crack-bridging and of spanning control, construction and expansion/contraction joints can be recommended.

Wherever ground level is higher outside the foundation wall than inside, the foundation wall must be dampproofed on the exterior from the footing to grade (Figure 16).

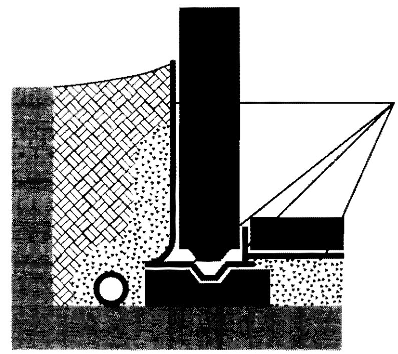


Figure 16 Exterior dampproofing

Where a below-grade space is finished on the interior with materials that are susceptible to moisture deterioration, these materials must be protected from dampness that may enter through 'moisture bridges,' such as the footings. In smaller buildings, this is generally achieved by installing a low permeance material between the susceptible materials and the structure on the interior from the floor to grade. Larger buildings generally rely on continuity of the exterior dampproofing, as shown in Figure 16.

Even in situations where exterior dampproofing of foundation walls is not required, control of moisture transfer may still be needed. This is reflected in the requirement in Subsection 5.5.1. for a 'through-wall flashing.' The Code terminology may not be entirely appropriate in this case. Through-wall flashing generally refers to a flashing designed to deflect to the exterior rainwater or condensate from within a wall cavity. 'Dampproof course' refers to a low permeance material, such as a modified bitumen membrane or metal sheet, designed to control the wicking of water from the ground upward into building components above grade (Figures 17 and 18). 'Dampproof course' is a more appropriate term to reflect the intent of Subsection 5.5.1.

A dampproof course is needed whenever there is both a source of moisture and a transfer medium. Any porous material can wick moisture from the ground. Where the soil is well drained or wet for only short periods of time, this type of moisture protection is generally not needed. Soils that are poorly drained and moist for longer periods of time can present significant load and are subject to the requirements of 5.5.1.

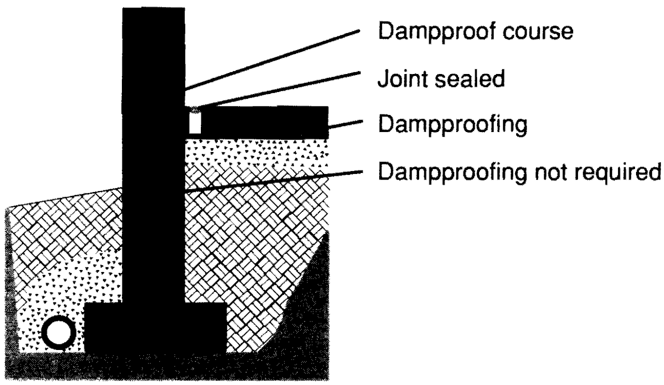


Figure 17 Dampproof course

All floors in contact with the ground should be dampproofed. Where a finished floor is to be installed over an on-ground floor slab, the dampproofing may be installed either above or below the slab. If no finished floor is to be installed, the dampproofing must be installed below the slab.

Article 5.5.3.1. refers specifically to floors of crawl spaces. These must be treated to minimize transfer of moisture from the ground, through the crawl space and into the building structure and occupied spaces above (Figure 18). Materials which have been used as ground cover include polyethylene, type S roll roofing, Portland cement concrete and asphalt. Recent research has indicated that the permeability of concrete may be too high to perform the function adequately by itself.[3] Joints in sheet material must be lapped and the material must be weighted down to prevent displacement.

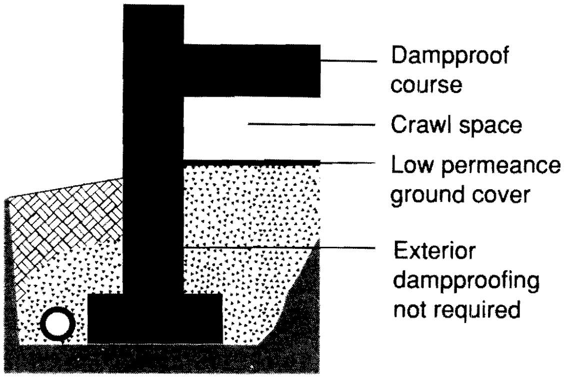


Figure 18 Crawl space with dampproof course and ground cover

The wall-floor junction may be sealed by caulking, by sealing the floor dampproofing to the interior of the walls, or by continuing the floor dampproofing under the walls or footings to seal with the dampproofing on the exterior of the walls (Figure 19). Where the dampproofing is installed between the wall and the footing, continuity of the structure is achieved through the use of a keyway in the footing.

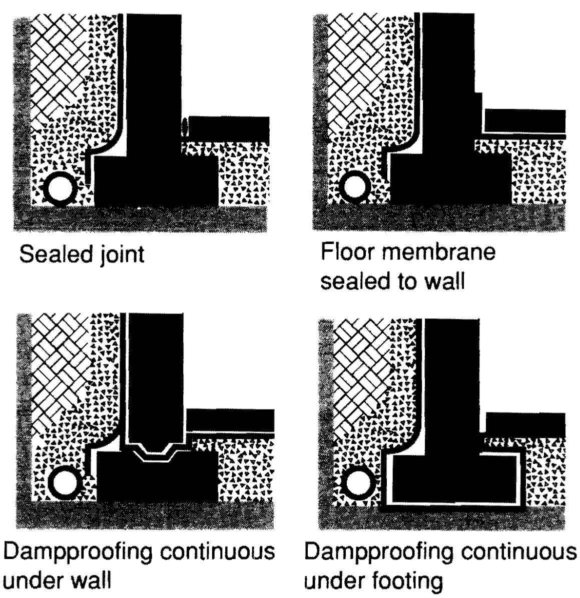


Figure 19 Dampproofing at wall-floor junction

*Waterproofing*

Waterproofing means the treatment of a surface to prevent the passage of water driven by hydrostatic pressure.[2] Waterproofing systems generally depend on the interaction of two components – a water impermeable material and the structure. That is, waterproofing, much like an air barrier, must be:

- impermeable and continuous, capable of bridging cracks and joints in the substrate and capable of accommodating movement at joints;
- either sufficiently strong and rigid to withstand imposed hydrostatic pressure or supported by other envelope components with the requisite strength and rigidity;
- durable.

Where at all possible, structures designed to resist hydrostatic pressure should be of monolithic construction, and reinforced to minimize shrinkage cracks and eliminate joints in the substrate that would otherwise require sealing. Cast-in-place concrete is most widely used as the structural substrate for waterproofing.

The appropriate solution for a given situation depends on the hydrostatic loads exerted on the below-grade building envelope. Structural design must meet the requirements of Part 4.

Specific requirements for the waterproofing and installation of the material depend to a great extent on the waterproofing material selected. Where preformed sheet materials are used, care must be taken to ensure that all joints are sealed. Different materials have greater or lesser crack-bridging capabilities. In some cases, multiple material thicknesses may be sufficient to bridge smaller cracks and narrow joints; in others, the material must be structurally supported across the joint and a waterstop installed as backup.

Floor waterproofing may be installed under the floor slab, between two slabs or between a slab and an overlay which provides adequate support and restraint to resist upward water pressure.

*Materials and applications*

A variety of waterproofing and dampproofing materials are available. Technical considerations for selecting dampproofing and waterproofing materials should include:

- durability and stability of the material in the underground environment (for example, material compatibility with the soil, substrate, and other building components; effects of extended exposure to water and other liquids and gases in the soil);
- ability to withstand movements and to bridge cracks and joints (including properties such as strength, shrinkage, bond to the substrate, and integrity of seams in sheet materials);
- ease of locating and repairing leaks (depending, for example, on whether the material is liquid applied, fully adhered or loose-laid);
- installation issues (including skills required of the installers and weather conditions);
- the location and orientation of the material in the building envelope system, and the complexity of the envelope form (for example, whether the material is protected from contact with the soil, installed horizontally or vertically, applied to a simple rectilinear form or over complex geometric shapes and around protrusions).

Relevant standards and manufacturers' specifications should be strictly adhered to.

*Continuity*

The above discussion of waterproofing and dampproofing has addressed the requirements for protection against moisture transfer from the ground without reference to other requirements of the building envelope either above or below grade. Junctions between different materials and components have proven to be weak links in building envelope systems. The design should therefore take into account the complete envelope system and the relationships between the dampproofing or waterproofing and other components. Maintaining continuity of the air barrier, vapour barrier, insulation, dampproofing and waterproofing should be a prime objective in the design and material selection process.

## Supplemental Reading

Anderson, Brent. Underground Waterproofing. WEBCO Publishing, Stillwater, Minn. 1983.

Construction Specifications Canada. Hot Applied Rubberized Asphalt Waterproofing/Roofing. CSC TEK-AID. Construction Specifications Canada, Toronto, 1990.

## References

1 National Building Code of Canada 1990, Section 9.13 Waterproofing and Dampproofing, Section 9.14 Drainage, Section 9.16 Slabs on Ground, Section 9.18 Crawl Spaces. Associate Committee on the National Building Code, National Research Council Canada, Ottawa, 1990.

2 CSA Standard CSA-A123.4-M1979, "Bitumen for Use in Construction of Built-Up Roof Coverings and Dampproofing and Waterproofing Systems." Canadian Standards Association, Rexdale, Ontario, 1979.

3 Sheltair Scientific Ltd. Investigation of Crawl Spaces Ventilation and Moisture Control Strategies for B.C. Houses. Report prepared for CMHC, Ottawa, June 1991.

# Section 5.6 Materials

## 5.6.1. Specifications

**5.6.1.1.** Materials used for *exterior claddings,* vapour barriers, air barriers, flashings, thermal insulation or fastening devices shall comply with the appropriate standards listed in Part 2. ( See Appendix A.)

> **A-5.6.1.1. Materials.** Part 3 contains additional requirements to regulate fire properties. Part 4 contains requirements to regulate the structural design.

## 5.6.2. Deterioration

**5.6.2.1**. A material exposed to corrosive conditions shall be corrosion-resistant or shall be resistant to deterioration under those conditions.

## 5.6.3. Fastening Devices

**5.6.3.1.** Fastening devices shall be made of a material which is compatible with the materials to be so joined and shall be resistant to the type of corrosion likely to be present.

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### Scope

Section 5.6 is concerned with selecting and combining materials in the building envelope to ensure that they will perform the functions for which they were intended. Material durability and fastenings are highlighted.

### Specifications

Building construction specifications indicate what materials and components are to be used in the construction of the building envelope, or indicate the properties or performance characteristics that these elements must have. The ability of a building element to perform its intended function depends both on the properties of the element and the environment in which it is intended to function. The elements should be selected, or their properties or characteristics specified, keeping their respective environments in mind. These include conditions during construction, and environmental and structural loads in situ.

Article 5.6.1.1. requires that materials used in the building envelope conform to the standards listed in Table 2.7.3.A of Part 2 of the Code. Most of the standards listed which relate to wind, water, and vapour protection, however, pertain to Part 9, Housing and Small Buildings and may not be appropriate for larger or more complex buildings, since environmental and structural loading may be more severe.

Materials installed to meet Part 5 requirements must also meet requirements for fire properties in Part 3 and structural design in Part 4.

### Deterioration

Subsection 5.6.2. focuses on deterioration due to corrosion. Other deterioration processes, however, may be equally critical to the performance of the building envelope. Among those that must be considered are: hygrothermal, electrochemical and biochemical.

These are presented on the following pages, with additional information on the roles of salt and acid rain in electrochemical degradation, and on cathodic protection.

## Hygrothermal

*Freeze-thaw cycling*

Deterioration due to expansion on freezing of water absorbed by the material

- deterioration is proportional to the degree of saturation of porous materials, such as concrete block, clay brick and sandstone
- materials that comply with CSA Standard CAN/CSA A82.1, "Burned Clay Brick"[1] or CSA Standard CAN3-A165.1, "Concrete Masonry Units"[2] should provide satisfactory service

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*Thermal expansion and contraction*

Differential movement within or between materials due to differences in temperature or different coefficients of expansion and contraction

- temperature variations within a material can cause cupping and curling as the warmer surfaces or areas expand relative to the cooler ones
- where two materials are joined together, differences in temperature between the materials or temperature variations affecting materials with different coefficients of expansion can introduce differential movement, leading to separation between elements

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*Ice lensing*

Occurs when ice crystals reduce local vapour pressure and draw water from warmer regions in a wicking action

- can cause severe deterioration due to expansion, spalling and cracking
- affects low elasticity materials such as masonry, particularly in mortars used to back up stone facings at or near grade

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## Electrochemical

*Oxidation*

Combination of a material with oxygen, creating a new material

- general term which may apply to metallic or non-metallic materials
- causes molecular breakdown leading to rusting of metals and degradation of plastics, often with reduced durability and structural strength

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*Aggressive electrolyte action*

Corrosion of metal controlled by the aggressiveness of the electrolyte, such as acid rain

- microcell process
- electrolyte aggressiveness is the driving force
- corrosion is usually uniform, since the anodic and cathodic sites are closely spaced

| | |
|---|---|
| *Galvanic action* | |
| Corrosion due to electrical potential developed between two dissimilar metals and conductivity through an electrolyte | • macrocell process<br>• material difference is the driving force; one metal acts as the anode, the other as the cathode (Table 1)<br>• rate of deterioration depends on dissimilarity between and relative sizes of anodic and cathodic materials<br>• degree of dissimilarity depends to some extent on the environment; some environments, for example, may support formation of protective surface films, changing a material from active to passive<br>• water or snow with very little salt content can act as an electrolyte |
| *Aeration cell* | |
| Corrosion in a crevice or confined area | • the moist metal with ample oxygen acts as the cathode while the less aerated region serves as the anode where corrosion takes place |
| *Solar radiation* | |
| Breaking of molecular bonds by radiation energy, particularly ultraviolet | • causes embrittlement, making materials vulnerable to cracking and shearing<br>• materials affected include some foam plastic insulations, clear polyethylene film, organic binders in inorganic insulations, bituminous materials |
| **Biochemical** | |
| *Biological attack* | |
| Deterioration by algae and fungi | • conditions sufficient to support biological attack are moderately warm temperatures, water, and a supply of what the organisms use as food<br>• some organic materials and even some inorganic materials, such as pyritic shale, are susceptible<br>• the most common form is the rotting of wood |
| *Intrusion* | |
| Colonization by insects and rodents | • encouraged by the insulating effect of some building materials |

Least Noble, Anodic, Active, Electro-Positive
Magnesium
Zinc
Aluminum
Carbon steel
Cast iron
Stainless steel (active)
Lead
Tin
Nickel (active)
Brass
Copper
Bronze
Cupronickel
Nickel (passive)
Stainless steel (passive)
Titanium
Silver
Monel
Most Noble, Cathodic, Passive, Electro-Negative

Table 1 Galvanic series of some commercial metals and alloys[3, 4]

Though this series is for metals and alloys in sea water, it is broadly applicable in other natural waters and uncontaminated atmospheres.

## Environmental factors — acids, alkalis and other reagents

*Airborne salts and acid rain*

Spreading salt on streets and highways to minimize ice build-up presents a major problem for the maintenance of building materials. The lower sections of metal buildings in particular are highly susceptible to corrosion. Steel reinforcing in concrete is attacked by saline solutions resulting from melted snow containing street salt. Discretion must be used in the choice of materials for these critical areas.

Airborne sea spray, with its inherent salt content, requires care in coastal areas in the selection and positioning of materials susceptible to corrosion.

Acid rain and smog are general terms used to describe air pollution. Air pollution comprises airborne particles, aerosols and gases that contaminate rain, fog and other forms of precipitation.

Mechanisms of deterioration resulting from these pollutants include:

- erosion
- oxidation
- galvanic action
- dissolving of carbonates, binders, plasticizers and solvents
- vaporization of plasticizers and solvents
- efflorescence
- hydration/dehydration expansion and contraction.

The mechanisms of deposition affect the severity of deterioration. Acid rain is the most familiar form of wet deposition, which provides pollutants with the means of surface attachment. As well, acid rain has the potential to act in consort with airborne particles of stone dust and chemical compounds (dry deposition) and gaseous pollutants (gaseous deposition).

*Soil-sulphate attack*

Portland cement concrete is susceptible to attack by soluble sulphate salts that occur in some soils and groundwaters. The rate and degree of deterioration depend on sulphate concentration, presence of water and properties of the concrete. Products which result from a chemical reaction between sulphate ions and components in the cement have a higher volume than the reactants, and create stresses that can break down the cement and the concrete.

Protective measures include:

- the use of sulphate resistant concrete,[5]
- installation of water resistant coverings or materials that provide a capillary break,
- removal of sulphate-bearing soils or drainage of water away from the concrete.[6]

## Cathodic protection

Cathodic protection is defined as the reduction or elimination of corrosion when the metal to be protected acts as a cathode by impressed direct current or attachment to a sacrificial anode, such as magnesium, aluminum or zinc. Cathodic protection may be used, for example, to reduce corrosion of reinforcing, and metallic cladding and fastenings.

## Fastening Devices

Subsection 5.6.3. emphasizes requirements for fastening devices as critical structural components in the envelope system. Fastening devices must support the dead load of the cladding and any live loads transferred to it.

As corrosion occurs where oxygen and moisture can combine, cladding systems and their fastenings are particularly susceptible to this type of deterioration. If the building fails to meet the intent of Sections 5.2 to 5.5, then the probability of serious corrosion of the fastenings is greatly increased. The following information relates specifically to material compatibility and corrosion resistance of fastening devices for cladding.

### Fastening devices for masonry

Masonry is generally supported on metal ledger angles and tied to structural back-up with masonry ties.

The alkaline condition of mortar may initially inhibit corrosion of the metal components, but this does not last, due to carbonation and pollutants such as acid rain. Contrary to the CSA standard A371 "Masonry Construction,"[7] salts are sometimes added to mortar to reduce the probability of freezing; this is not advisable, since the salts may greatly increase the rate of corrosion.

Although a variety of materials are used for fastening devices, the two most common are galvanized steel and stainless steel. The performance life of galvanized ties depends on the thicknesses of the steel and the zinc coating, as well as the corrosiveness of the environment to which the ties are exposed. Use of galvanized ties is not appropriate in locations where the ties would be exposed to sea or road salts, acid rain, or long periods of high humidity. Minimum galvanizing requirements are provided in CSA A370, "Connectors for Masonry."[8] Stainless steels, for example type 304 (chrome-nickel steel), are becoming more commonly specified, since they are highly corrosion resistant.

Crevice corrosion occurs in fine crevices, such as between a nut and a bolt or a dense grout and a fixing. If the steel is subject to crevice corrosion in the presence of chlorides, as in areas exposed to high salt concentrations such as sea spray, then type 316 (chrome-nickel-molybdenum steel) should be used.

Additional information related to metal connectors, reinforcing members and fastening devices for masonry construction can be found in CSA Standard CAN3-A370, Appendix D, "Corrosion Resistance of Connectors."

### Fastening devices for cut stone

The selection of anchors for cut stone is not covered by standards, although some guidance may be found in CSA Standard CAN3-A370. While the type of anchor required is not documented, standard details for anchors for cut stone are provided.

### Fastening devices for metal

Metal cladding or cladding comprising metal components, such as in metal curtain walls, can have considerable potential for corrosion. Care must be taken to select fasteners of a material that has the same or similar galvanometric properties as the cladding.

## References


1 CSA Standard CAN/CSA A82.1-M87, "Burned Clay Brick." Canadian Standards Association, Rexdale, Ontario, 1987.

2 CSA Standard CAN3-A165.1-M85, "Concrete Masonry Units." Canadian Standards Association, Rexdale, Ontario, 1985.

3 Baboian, Robert. "Galvanic Corrosion" from Forms of Corrosion: recognition and prevention, C.P. Dilon, Ed., National Association of Corrosion Engineers, NACE Handbook 1, Houston, 1982.

4 Lula, R.A. Stainless Steel. American Society for Metals, Ohio, 1986.

5 CSA Standard CAN/CSA-A23.1-M90, "Concrete Materials and Methods of Construction." Section 16. Canadian Standards Association, Rexdale, Ontario, 1990.

6 Swenson, E.G. Concrete in Sulphate Environments. Canadian Building Digest No. 136, Division of Building Research, National Research Council, Ottawa, 1971.

7 CSA Standard CAN3-A371-M84, "Masonry Construction." Canadian Standards Association, Rexdale, Ontario, 1984.

8 CSA Standard CAN3-A370-M84, "Connectors for Masonry." Canadian Standards Association, Rexdale, Ontario, 1984.

# Section 5.7 Practices

## 5.7.1. Installation

**5.7.1.1. General.** *Exterior claddings*, vapour barriers, air barriers, thermal insulation, sheathing papers, flashings and fastening devices shall be installed in such a manner as to effectively perform their intended functions. (See Appendix A.)

> **A-5.7.1.1. Installation.** For simple structures, requirements in Part 9 may be referred to as a guide for the installation of exterior claddings, vapour barriers, thermal insulations, sheathing papers, flashings and fastening devices. More complex structures may require additional provisions not contained in Part 9.

**5.7.1.2 Glass.** Glass shall be designed and installed to resist the loads specified in Section 4.1. (See Appendix A.)

> **A-5.7.1.2. Glass Design.** Information on the design of glass can be found in the Commentary on Glass Design in Chapter 4 of the Supplement to the NBC 1990.

**5.7.1.3. Exterior Cladding**

**(1)** *Exterior cladding* shall be securely fastened to backing that is
- (a) an integral structural element of a *building*, or
- (b) an element added to the structure for the purpose of supporting such *exterior cladding*.

**(2)** Backing for *exterior cladding* as provided for in Sentence (1) shall be suitably located, secured and of a kind suitable for the type of fasteners to be used for attachment.

**(3)** *Exterior cladding* shall be designed, constructed and attached so as to accommodate stresses and deformations within the structure, the cladding system and all points of attachment caused by wind, earthquake and temperature effects. (See Appendix A.)

> **A-5.7.1.3.(3). Deformations in Building Components.** Information on the effects of deformations in building components can be found in the Commentary on Effects of Deformations in Building Components in Chapter 4 of the Supplement to the NBC 1990.

## Scope

Section 5.7 is concerned with the selection and installation of building envelope components to resist loads, accommodate stresses and deformations, and ultimately perform the functions for which they were intended. In addition to the envelope components specifically identified in Section 5.7, all components in roof, wall and floor envelope systems, both above and below grade, should be considered.

To ensure that the building envelope will perform to the required level, the following factors should be considered:
- structural loads placed on the envelope components,
- interior and exterior environmental loads imposed on the envelope,
- stresses sustained, deformations resisted and deflections accommodated,
- the properties of the different materials, components and assemblies that make up the building envelope,
- the interactions between these various elements,
- methods for installing these elements.

For smaller, simpler buildings, Part 9 of the Code provides specific requirements for the selection and installation of building envelope elements. Considerable information is available on the subject for smaller buildings.[1,2] Buildings covered by Part 5 may be larger or more complex, or subject to greater structural or environmental loads; in these cases, more stringent requirements may be necessary. Some information is provided in the Supplement to the National Building Code of Canada 1990,[3] in various CSA material and installation standards and in previous sections of this commentary.

## Installation

A successful building element installation depends not only on the properties and functions of the materials and components being installed. It also depends on an understanding by both the designer and the builder as to the design intent, prevalent or preferred construction practices, and on the constructability of the building envelope details.

Constructability is the ease with which a building design and its intent can be successfully translated into a built product. Four of the basic considerations which enhance constructability[4] are:

- a standard approach,
- techniques that are as simple as reasonably possible,
- flexibility to respond to changes in design, construction schedules or conditions that arise during construction,
- sequence of construction.

Following a standard approach reduces installation errors and encourages consistent quality and high productivity. It is better to redesign a detail for use in a number of different locations than it is to design more details.

Simplicity is a very important requirement for constructability. Consideration should be given to the technical expertise and degree of perfection required to install the various building envelope materials, components and assemblies. The simpler the design, the fewer steps and fewer trades will be required for proper construction and the less likelihood of errors. Complications often arise at the junctions between different assemblies, for example, between walls and roofs and between different types of wall assemblies. With fewer junctions and fewer unique junction details, fewer problems can be expected.

Flexibility of timing and approach with respect to overall project construction and individual tasks will also enhance constructability. Trades may have techniques that are more familiar to them. The schedule of construction may be interrupted due to trades availability, material availability and weather. The designer must be aware of the order of the steps in assembling the building envelope elements, in order to avoid designing details that are difficult or impossible to execute because of inaccessibility. He or she must convey the intent of the design to the contractor. The contractor must understand the designer's intentions in order to plan the work sequence in a manner that will allow those intentions to be implemented.

### Loads and stresses

Building envelope components and assemblies are subject to a variety of loads and stresses. Though other loads must not be ignored, Section 5.7 refers specifically to loads from wind, earthquakes and temperature effects, and to loads imposed on glass and cladding. Refer to Part 4 of the Code and to the Supplement for detailed information on these loads. Care must be taken to ensure that dead and live loads are not inadvertently transferred to building envelope components that are not intended to support them. For example, a common mistake is to overlook the fact that the air barrier may be subject to the full indoor-outdoor air pressure difference.

### Accommodating movement and deformation

The building envelope must accommodate both permanent and cyclic movement and deformation. The former may be due to initial settling and creep of the structure, and to shrinkage of materials as they dry. The latter may be due to loading from wind, earthquakes, occupancy and use, intermittent thermal or moisture stresses, or fluctuating hydrostatic loads. The building envelope must be able to accommodate the permanent movement while also accommodating cyclic movement.

Proper joint design requires a prediction or measurement of joint movement, including direction and amplitude. This depends on the nature of the materials involved, the environmental and structural loads imposed on them, and the geometry of the components and anchorage points.

Where the building envelope bridges a joint in the structure or back-up, care must be taken to ensure continuity of critical elements, such as the air barrier and insulation. Materials selected to bridge joints must be capable of accommodating movement at the joint.

### Connection and support

A building envelope component may be:

- an inherent part of a structural component and thus be self-supporting
- adhered, or
- mechanically fastened.

Except in the first case, positive securement and allowance for movement are primary considerations.

Section 5.7 emphasizes requirements for support and connection of cladding. The type, number, arrangement and function of the connections will vary depending on the cladding and back-up materials selected, and on the structural system.

## Conclusion

Section 5.7 suggests that a successful building envelope depends not simply on good design and construction but on an overall coordinated approach to these tasks. Effective design and construction practice demands interaction, communication and cooperation among a number of participants who have different areas of expertise and levels of knowledge and skill. Building projects benefit where designers, builders, and suppliers work as a team from the outset, developing a common vision and understanding of the intended product and the process for achieving that product.

## References

1 Code and Construction Guide for Housing. Ontario New Home Warranty Program. North York, 1990.

2 Condominium Construction Guide. Ontario New Home Warranty Program. North York, 1993 edition.

3 Supplement to the National Building Code of Canada 1990, Chapter 4, Commentaries on the National Building Code of Canada 1990, National Research Council Canada, Ottawa, 1990.

4 Buildability: an assessment. Construction Industry Research and Information Association, London, 1983.

## Appendix A Definitions

### 1.1.3. Definitions of Words and Phrases

*Basement* means a *storey* or *storeys* of a *building* located below the *first storey*.

*Building* means any structure used or intended for supporting or sheltering any use or *occupancy*.

*Building height* (in *storeys*) means the number of *storeys* contained between the roof and the floor of the *first storey*.

*Exterior cladding* means those components of a *building* which are exposed to the outdoor environment and are intended to provide protection against wind, water or vapour.

*First storey* means the uppermost *storey* having its floor level not more than 2 m above *grade*.

*Grade* (as applying to the determination of *building height*) means the lowest of the average levels of finished ground adjoining each exterior wall of a *building*, except that localized depressions such as for vehicle or pedestrian entrances need not be considered in the determination of average levels of finished ground. (See *First storey*.)

*Groundwater* means a free standing body of water in the ground.

*Occupancy* means the use or intended use of a *building* or part thereof for the shelter or support of persons, animals or property.

*Storey* means that portion of a *building* which is situated between the top of any floor and the top of the floor next above it, and if there is no floor above it, that portion between the top of such floor and the ceiling above it.

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## Definitions of Words and Phrases Used in Part 5

The definitions above are found in Part 1 of the NBC. The terms that follow are not specifically defined in the NBC but for the purposes of this commentary are defined as follows.

*Air barrier system* means the elements of the building envelope that provide a continuous effective barrier to the movement of air through the building envelope.

*Assembly* means a construction of more than one material or component assembled on site to create an identifiable unit. Examples of assemblies include the total building envelope, or individual walls, roofs, or parapets.

*Component* means a prefabricated building unit. These may be simple units, such as cladding anchors, or more intricate units, such as windows and doors.

*Deterioration* means the breakdown of a building material by means of rotting, erosion, corrosion, delamination or any other environmental or man-made means.

*Element* means any building material, component or assembly.

*Corrosion* means electrochemical deterioration in metals.

*Corrosion resistant* means that a metal will resist corrosion in the environment in which it is to be installed but not be immune to some degree of deterioration.

*Dampproofing* means the treatment of a surface to resist passage of water in the absence of hydrostatic pressure.

*Joint* means the meeting of materials or components within a component or assembly. The term does not necessarily suggest a connection between the elements.

*Junction* means the meeting of larger building elements such as walls and roofs. A junction would generally comprise a number of joints. Again, a connection between the elements is not necessarily implied.

*Vapour barrier* means the element of the building envelope that is installed to control the diffusion of water vapour through the building envelope.

*Waterproofing* means the treatment of a surface to resist passage of water driven by hydrostatic pressure.