Introduction

Driving rain is typically the largest source of moisture for the above-grade building enclosure, and moisture is involved in the majority of building enclosure failures. Hence, the control or management of rainwater should be one of the most important considerations for designers. Despite thousands of years of experience, avoiding rain-related building damage is still one of the most difficult tasks designers and builders face. There are, however, effective approaches to controlling rain penetration based on both traditional details and modern understanding.

This practice guide will consider rain penetration control from a general to a specific level. The following sections will cover: driving rain as a moisture load on walls; a classification system of the various rain control strategies available for walls; and finally, good design practices for several different types of wall systems.

The scope of this guide is limited to rain water management of new exterior above-grade wall systems used for buildings in Ontario.

Rain Control Strategies

Regardless of the approach taken to wall design, building shape and site design choices can reduce the amount of rain deposited on walls. Depending on materials, details workmanship and exposure, a wall can either be designed to drain any water that penetrates, store and subsequently dry it, or exclude all rain perfectly. Finally, despite our best efforts, some rain often is absorbed into materials or penetrates through imperfections so drying must be provided to remove this incidental moisture.

This Canadian holistic approach to rain control can be described by the three-D's [1]:

1. **D**eflection,
2. **D**rainage/Storage/Exclusion, and
3. **D**rying.

The next three sections of this guide will investigate each component in this strategy in turn.

Deflection

Both climate and site play a large role in defining the rain exposure that a building is exposed to. Most parts of Ontario experience a significant amount of wind-driven rain, and high-rise buildings in suburban settings are often seriously exposed. Choosing appropriate siting and massing can often significantly reduce the amount of rain deposited on walls.

Exposure to the prevailing driving rains can be reduced in low-rise buildings (i.e., 3 to 4 stories) by planting, landscaping, and placement near other buildings. Buildings of equal height located within 2 building heights will provide a significant amount of protection.

The shapes of the roof and overhang also have an important impact, especially for low-rise buildings. Field measurements [2] and computer modelling [3] have shown that overhangs and peaked roofs reduce rain deposition by approximately 50%. A damage survey of wood frame buildings in British Columbia [4] found that the size of a buildings overhang correlated directly with the probability of rain-related damage. Peaked roofs and overhangs protect a wall from rain both by shadowing and redirecting airflow (Figure 2). Hipped roofs provide an opportunity to shelter walls from rain on all four sides of the building. Laboratory studies [5] suggest that the same strategies can also be used on high-rise buildings by reducing both peak deposition rates and the area over which these peaks occur.

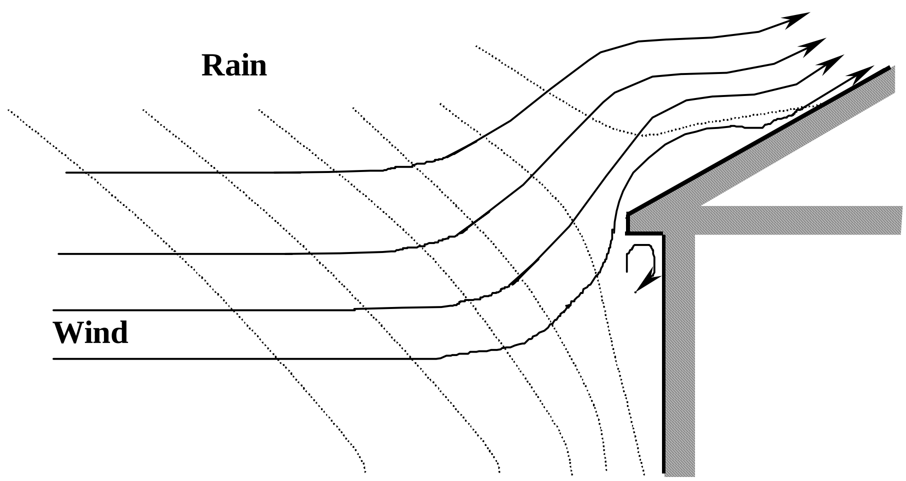


Figure 2: Influence of Overhangs and Pitched Roofs on Wind and Rain Flow

Field measurements [6,7,8,9], computer modelling [10,11], and wind tunnel testing [5] have provided an indication of the quantity of driving rain deposition that can be expected on vertical walls. For low-rise situations, the amount of rain deposited is in the order of 10 to 20% of the product of wind speed and rainfall intensity. Thus the amount of rain deposited on the walls of low-rise buildings erected on exposed Ontario sites could be in the order of a hundred of litres per square meter per year. Sheltered locations and single-storey houses with wide overhangs will be exposed to much less rain deposition (e.g., perhaps one-fifth as much).

Exposed cubical buildings tend to have very high rain deposition in the upper corners, top and side edges (Figure 3). The higher deposition is due to the higher wind speeds and unrestricted flow patterns around tall buildings. The amount of rain deposition on the upper corners of a tall building will often be two to four times that on a similarly shaped low-rise building.

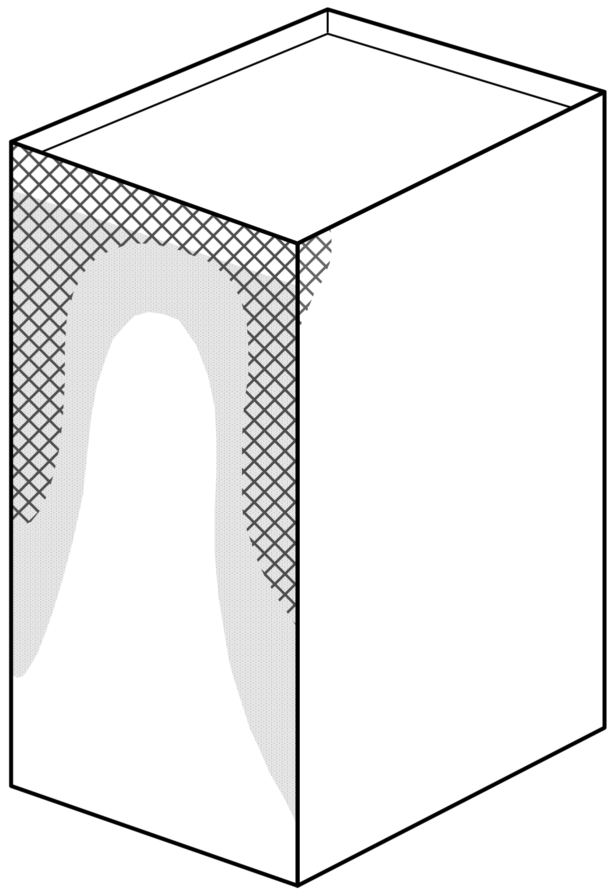


Figure 3: Rain Deposition Distribution on High-rise Buildings

Once rain water is on the wall it will form a film and begin flowing downward under the force of gravity. Wind flowing over the surface will tend to deflect the flow from this path and, in extreme cases, may even force water upward. Surface features such as trim, surface texture, and openings can greatly affect the flow paths of this surface drainage, either concentrating or dispersing surface flows. Water is removed from the base of the wall by sloping the grade. The siding and drain opening should be kept at least 200 mm above grade to protect it from splashes.

Traditional surface details on old and vernacular buildings often served the function of directing water away from sensitive areas (e.g., windows) and distributed surface water in such a way as to prevent the concentrated streams which cause staining. The copious use of drip edges and slopes also ensured that surface water was removed from the building surface as often as possible. Modern designs can use similar approaches of rain deflection to change the rain load placed on the wall system (Figure 4).

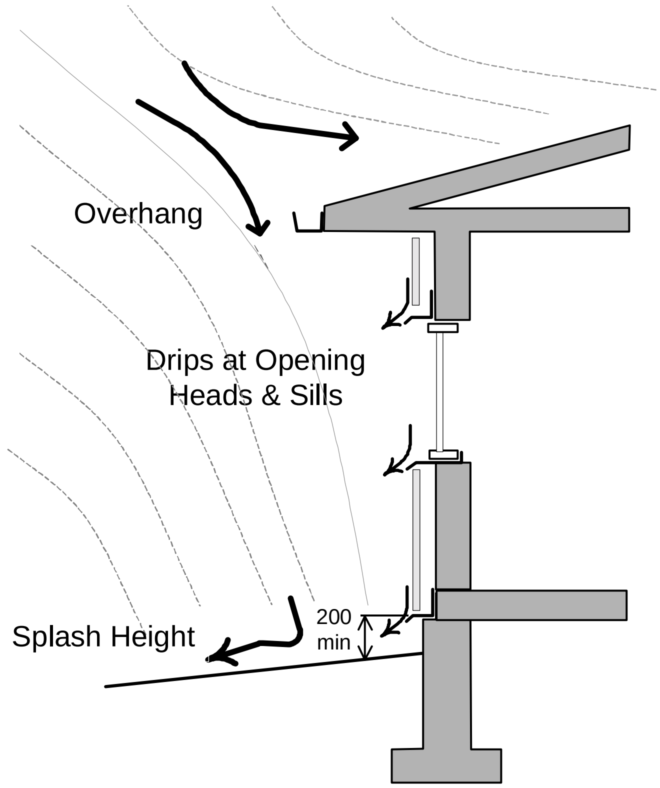


Figure 4: Summary of Principles of Rain Deflection

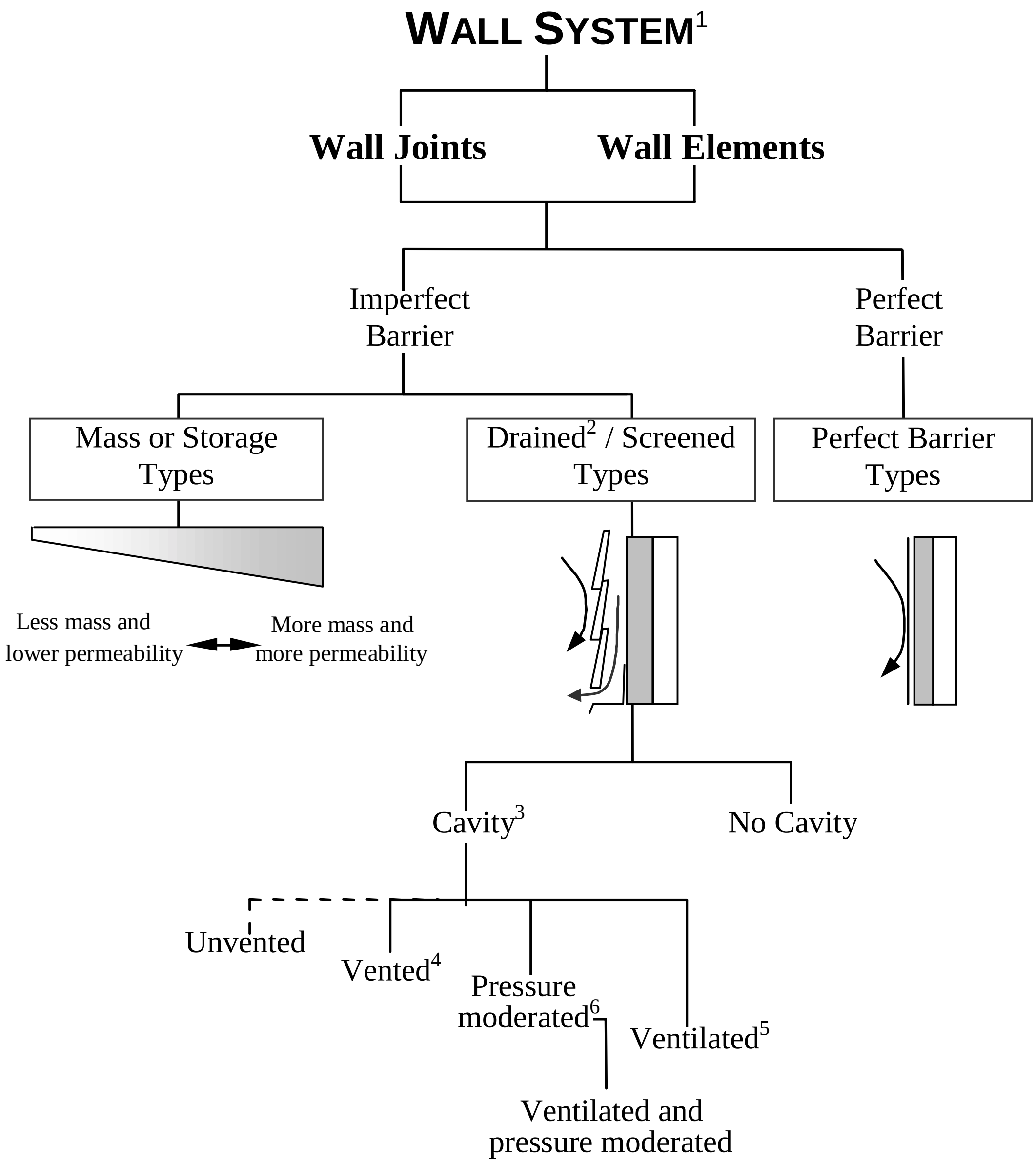
Drainage/Storage/Exclusion

Siting, building shape, and surface rainwater control rarely provide complete rain control (although deep wrap around porches may eliminate the need for rain control under them). Hence, some strategy to deal with the rainwater that strikes the surface of the wall must be employed.

There are three fundamental rain control strategies available to the designer [12]. In order of historical priority, they are:

1. Storage (storage or mass walls),
2. Exclusion (perfect barrier walls), and
3. Drainage (drained and screened walls).

This categorisation has been developed based on basic observations and physical facts. Rain deposited on a wall can either be face drained (shed), absorbed (by capillarity), or transmitted (penetrate) further into the wall. Each layer of a multi-layer wall responds in a similar manner. If water penetrates through the entire wall assembly, the wall is generally considered to have failed. However, transmission of rain water into any sensitive layer of a wall assembly may also cause damage, degrade performance and affect durability. In fact, it is hidden water penetration into moisture sensitive materials within walls that causes the most problems for modern wall systems.



Notes:

1. The walls are categorized based on actual behavior, not necessarily design intent.

For the purposes of this classification system, the following definitions are necessary:

2. Drained: the large majority of the water that penetrates the screen is removed by gravity.
3. Cavity: a clear space or a filled space that facilitates gravity drainage and air flow and resists the lateral transfer of water (a capillary break).
4. Vented: allows some degree of water vapor diffusion through vents and by air mixing.
5. Ventilated: allows a significant flow of air largely to promote drying by vapour movement.
6. Pressure-moderated: an approach that moderates air pressure differences across the screen.

Figure 5: Wall Classification System by Rain Penetration Control

It is useful to consider walls as comprised of **elements** and the **joints** between these elements (Figure 5). Both the elements and joints are subject to the rain penetration control classification system. This categorisation has been developed to be independent of materials or design intent and is based solely on the method by which a wall system controls rain penetration.

The primary classification is whether a wall is a perfect barrier or an imperfect barrier. There are two classes of imperfect barriers: storage and drained.

Storage or mass walls are the oldest strategy. This approach requires the use of an assembly with enough safe storage mass to absorb all rainwater that is not drained or otherwise removed from the outer surface. In a functional massive storage wall this moisture is eventually removed by evaporative drying before it reaches the inner surface of the wall. Although enclosures employing this strategy might be best termed "moisture storage" systems, "mass" is often used because a large quantity of material is required to provide sufficient storage. The maximum quantity of rain that can be controlled is limited by the storage capacity available relative to drying conditions. Some examples of mass walls include adobe, solid multi-wythe brick masonry, and single-wythe block masonry (Figure 6).

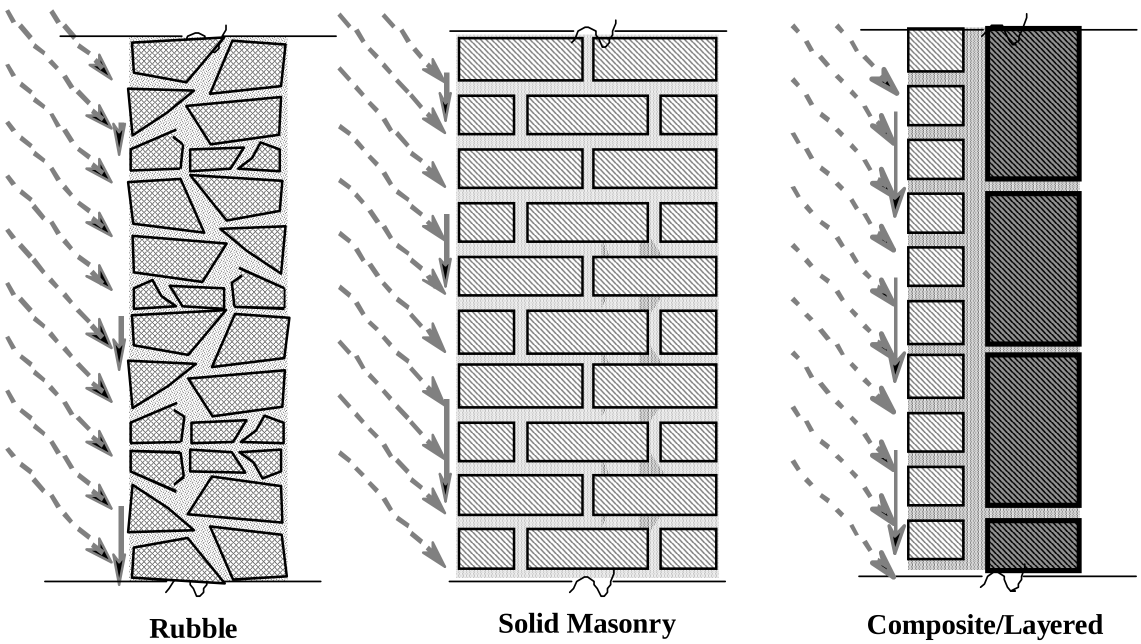


Figure 6: Examples of Mass or Storage Wall Systems

Perfect barrier systems stop all water penetration at a single plane. Such perfect control required the advent of modern materials. Perfect barrier systems that use the exterior-most layer as the rain control plane are termed *faced-sealed*. Because it is very difficult to build and maintain a perfect barrier wall, most walls are designed as, or perform as, imperfect barrier wall systems of either the mass type or the screened type. The rain control plane in face-sealed walls is exposed to the full range of environmental conditions but has strong aesthetic requirements and hence is prone to rapid deterioration.

The joints between perfect barrier elements may also be designed as perfect barriers (e.g. a single line of caulking). Such joints have a poor record of performance and should not be relied upon to control rain entry. Some example systems that are designed as perfect barrier wall elements are metal panels, some window frames, and face-sealed Exterior Insulated Finish Systems (EIFS) (Figure 7).

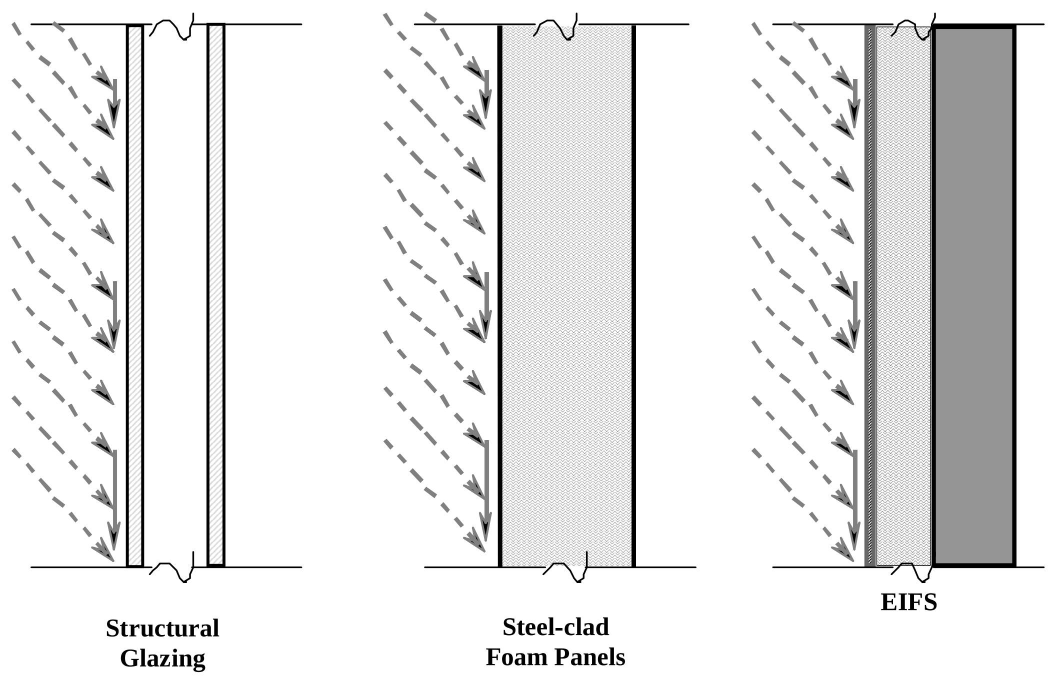


Figure 7: Examples of Perfect Barrier Wall Systems

Screened-drained walls assume some rain water will penetrate the outer surface (hence the cladding "screens" rain) *and* remove this water by designing an assembly that provides drainage within the wall. Since it has often been shown that lap siding (vinyl, fiber cement, or wood) and masonry veneers leak significant amounts of water, this design approach is the most realistic and practical for walls with such cladding.

Supplementary mechanisms, such as a capillary break and a water barrier (collectively termed a drainage plane), are usually employed to resist further inward movement of water that penetrates the inevitably imperfect cladding. Some examples of drained wall systems include cavity walls, masonry and natural stone veneers, vinyl siding, two-stage joints, and drained EIFS (Figure 8). It should be noted that the screen is much more than a rainscreen; it must also resist wind, snow, solar radiation, impact, flame spread etc.

Field testing and some field experience has shown that small gaps may be sufficient to provide drainage. For example, the space formed between two sheets of building paper (especially if those sheets have a texture) can allow excellent drainage. The small space behind lap siding is often sufficient to allow drainage.

An air space is often provided to improve the drainage capacity and to act as a very effective capillary break between the cladding and the remainder of the wall. An effective drainage cavity space becomes more important as the rain loading and the screen water permeance increases since it is expected that more water will drain within this space more often. A true drainage cavity should be at least 3 to 6 mm wide, since this is approximately the gap size that can be spanned by water. Since dimensional tolerances must be accounted for, a dimension of 10 mm is usually quoted. If ventilation drying is desired a larger airspace must be provided (see Drying).

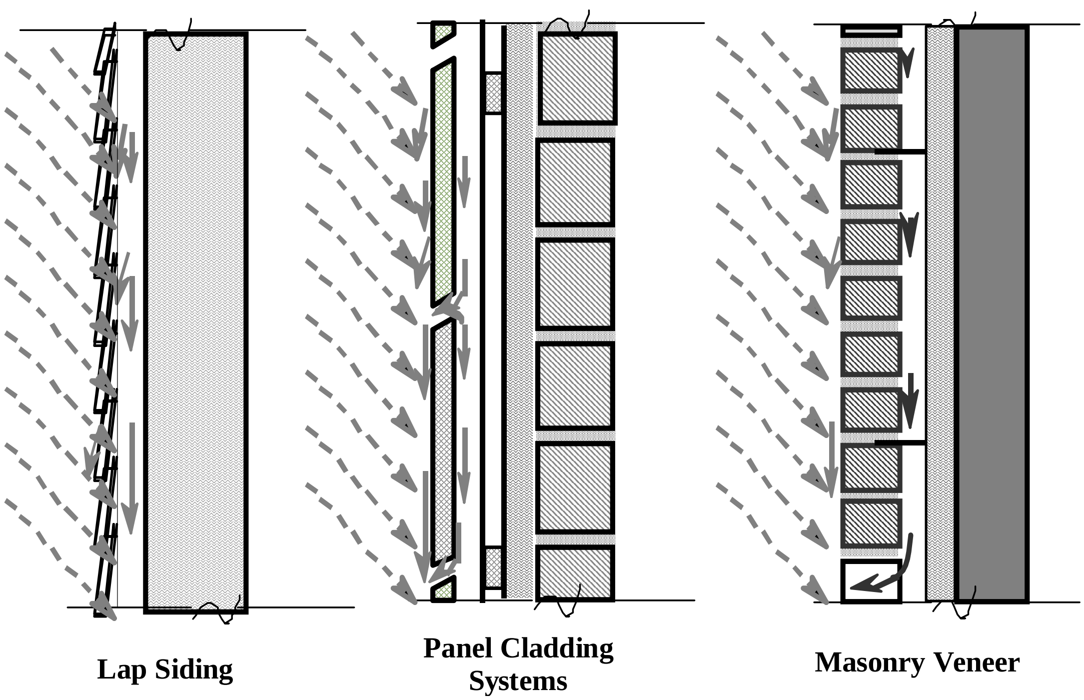


Figure 8: Examples of Drained-Screened Wall Systems

A vented airspace also allows for both some degree of pressure moderation and ventilation. Pressure equalisation is the term given to the mechanism whereby wind pressure differences across the cladding are reduced by connecting an air space behind the cladding with the wind-induced pressure acting on the exterior (Figure 9). By reducing air pressure differences across the cladding, rain will not be forced across openings by this force, while the standard features of capillary break, drainage, and flashing deal with the other rain penetration forces. Field measurements [13,14,15] have shown that pressure equalisation is rarely achieved in practice, but that moderation of the pressure can be practical and beneficial for some types of wall systems. For these reasons, pressure moderated wall systems is the preferred and more accurate term.

Experience from coast-to-coast in Canada [16] and in the rainy regions of the US [17] has shown that drained and screened cladding systems are the preferred approach to reliably provide rain control. Drainage within the wall complements the drainage approach on the exterior surface (Figure 10). Pressure moderation can help reduce the amount of rain that penetrates systems that are prone to air-pressure driven rain penetration (e.g., primarily joints in non-absorbent materials, metal joints, etc).

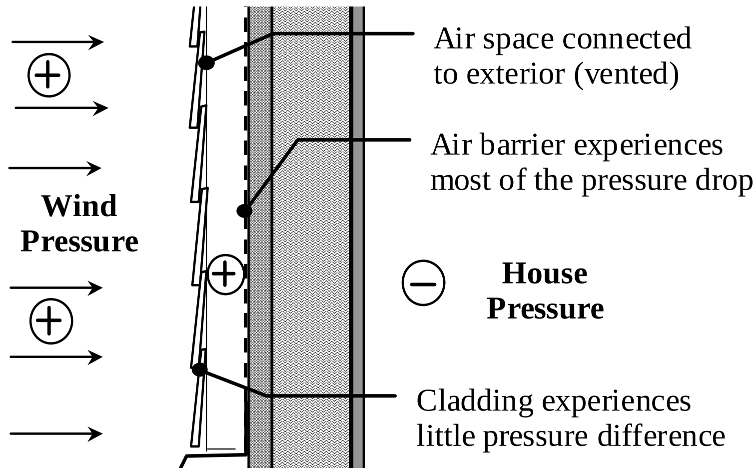


Figure 9: Pressure Moderated Air Space

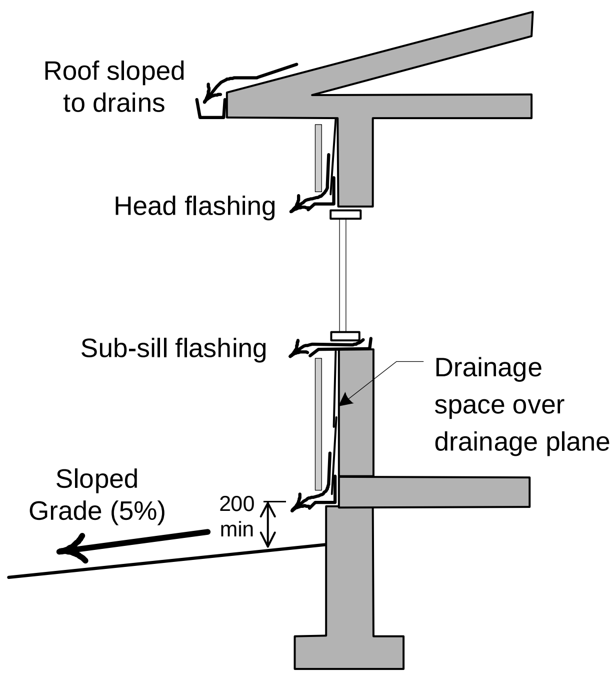


Figure 10: Drainage and Flashing Concepts

Drying

Despite all attempts to resist and drain water, field experience has shown that some water may still penetrate or be built in during construction. Drying of this moisture must be provided for.

Moisture can be removed from a clad wall by (Figure 11):

1. evaporation from the inside or outside surfaces (with water wicked to either surface through capllary active materials);
2. vapour transport by diffusion, air leakage, or both, either outward or inward;
3. drainage, driven by gravity; and
4. ventilation, if provided for.

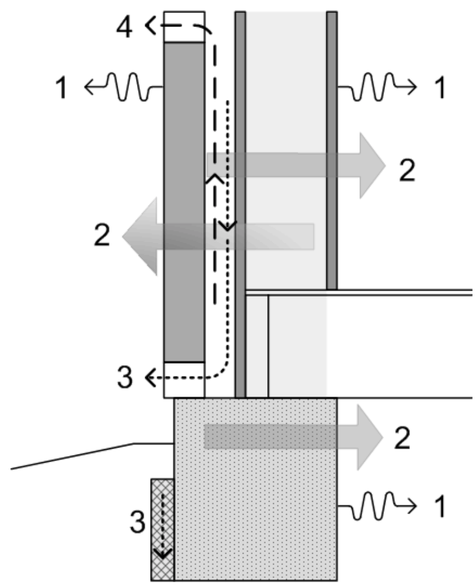


Figure 11: Drying Mechanism in Walls

Drainage is capable of removing the greatest volume of water in the shortest period of time. Hence, as described above, it is a very important mechanism for moisture control. Provided a drainage path exists (e.g. cavities, slopes, drainage openings), a large proportion of rain water penetration[1] can flow out of a wall.

A small but significant amount of water will usually remain attached to surfaces by surface tension and absorbed into materials by capillary forces even in walls with excellent drainage. Sidings of wood and cement will also absorb and store moisture. This moisture can only be removed from a wall system by either diffusive drying or air movement.

[1] Drainage is also useful for removing cold weather air leakage condensation that can form on the back side of cladding

Diffusive drying can dry in either direction, depending on the wall system and the climate. In colder weather the vapour flow is outwards. During warm weather and especially when the sun heats the surfaces of the walls, inward drying can be an important mechanism.

Air movement (or leakage) through the enclosure can, under the proper conditions, move a large quantity of moisture. While both cold weather air leakage outward and warm weather air leakage inward can cause condensation and hence potentially damaging wetting, the opposite conditions (e.g. inward flow in cold weather) will provide some drying. In some cases, this drying can be significant. Because air leakage through the enclosure is difficult to control, expensive in terms of energy, and potentially dangerous for indoor air quality, the modern approach is to limit airflow through the wall to nearly zero. This also eliminates the potential for airflow drying, so drying must be secured by other means.

Ventilation, or exterior air flow behind the cladding driven by wind pressure differences on the face of the building or solar heated air rising, is useful since it accelerates drying. Ventilation bypasses the high vapour resistance of claddings such as vinyl siding, metal panels, and dense natural stone, thereby allowing outward drying. A recent Canadian study [18] and previous European research [19] has shown that ventilation drying occurs and may be important. This research shows that a clear space of at least 19 mm should be provided to encourage ventilation, and that clear large vents (of the order of 0.4 to 2%of wall area) should be placed at the top and bottom of the cavity for the most effective ventilation (Figure 12).

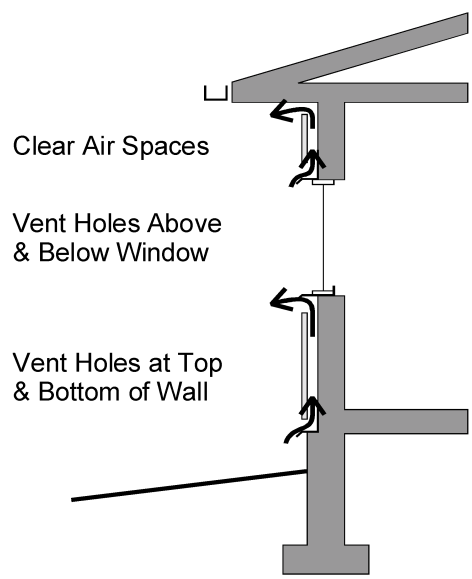


Figure 12: Ventilation Drying Concepts

Claddings such as stucco, brick, wood and cement-board absorb water. When these materials are heated by the sun during warm weather very large inward vapour drives develop (which accelerate drying of the cladding). These inward drives can cause dangerous summertime condensation within framed walls, especially if a very permeable exterior assembly and a low-permeance interior vapour barrier (e.g., polyethylene) is used [20, 21, 22]. Experience suggests that this mechanism may be a concern in warmer Southern-Ontario climates. Ventilation may be able to reduce or control these inward vapour drives, by safely redirecting the vapour to the exterior even in hot-humid conditions [23].

Applications

A designer should have a well-conceived strategy for rain control for each enclosure and joint type for an entire project. This section will discuss the application of various rain control details for several different commonly used wall assemblies.

1. Masonry Veneers
2. Natural Stone, Metal Panels, and Precast
3. Vertical and Lap Siding
4. Solid Masonry and Concrete
5. Stucco
6. EIFS
7. Curtainwalls
8. Joints and Penetrations

Some Comments on Perfect Barrier Systems

Perfect barrier systems, especially face-sealed versions, often fail to perform as designed, if not initially, then after many years of exposure. The perfect barrier systems that appear to function in the field usually lend their performance to the fact that other layers are providing drainage and/or storage: in effect these "face-sealed perfect barrier systems" are acting as screened systems or mass systems. Perfect barrier wall elements built with tight quality control in factory conditions and connected in the field with drained-screened-types of joints may be able to provide good performance for a long service life. Examples include curtainwalls, EIFS, and some metal panel systems. In almost all cases, drained systems with the same amount of material and labour will provide better, longer-lasting rain control.

Quality control is essential on site for perfect barrier systems, and maintenance is important. These systems may be acceptable if:

1. assembled under tight quality control (e.g., glazing units are face-sealed and rarely fail, although joints between the IGU and the frame do leak)
2. used for low exposure conditions (e.g. below a porch or balcony with a large overhang),
3. used in assemblies in which a rain leak will not be catastrophic (e.g., substrates of solid concrete or masonry).

Regardless of which strategy or assembly is considered, reducing the amount of rain deposited (i.e., controlling exposure by the judicious choice of site and building shape) and increasing the fraction shed from the exterior face will reduce the moisture load on the assembly. Controlling water by the use of generous overhangs, proper window sills, and other surface drainage features should almost always be the first and most important step in designing for the control of rainwater penetration.

1. Masonry Veneers

Drained masonry veneer and cavity walls wall systems are inherently more forgiving than either mass or perfect barrier systems. Properly designed and built drained-screen wall systems will provide reliable and durable rain penetration control.

Experience, laboratory and field tests have shown that all single-wythe masonry veneers will leak significant quantities of rain water. Hence, unobstructed drainage and good **flashing** are critical to rain control. The most common cause of rain penetration problems in veneer walls is the absence, poor design, or improper installation of flashing at the base of the wall, penetrations, and intersections. A common source of concern is the leakage of water through and around windows. This can be managed using subsill flashing of the type shown in Figure 13.

Drainage behind the cladding can be assured by the use of wide air spaces (40 to 50 mm), large clear weep holes, and by job-site inspection. Weep holes are best provided by open head joints at 600 mm on center. It is simple to visually inspect drain holes to ensure they are clean. Providing open head joints at the top and bottom of clear cavities behind veneers will likely improve ventilation drying.

Flashing should return up the wall at least 150 mm and must be well sealed at joints to render it waterproof. Although veneer walls are forgiving because they provide drainage, flashing must be waterproof, and hence requires detailed design, good materials workmanship, and inspection. All flashing must have end dams where it ends. The flashing should return up behind the drainage plane within the air space. To reduce water penetration and improve mortar durability, specify tooled concave joints and inspect work to ensure that head joints are reasonably well-filled. It should be noted that pressure equalization is unlikely to provide any real rain control benefits for masonry veneer walls.

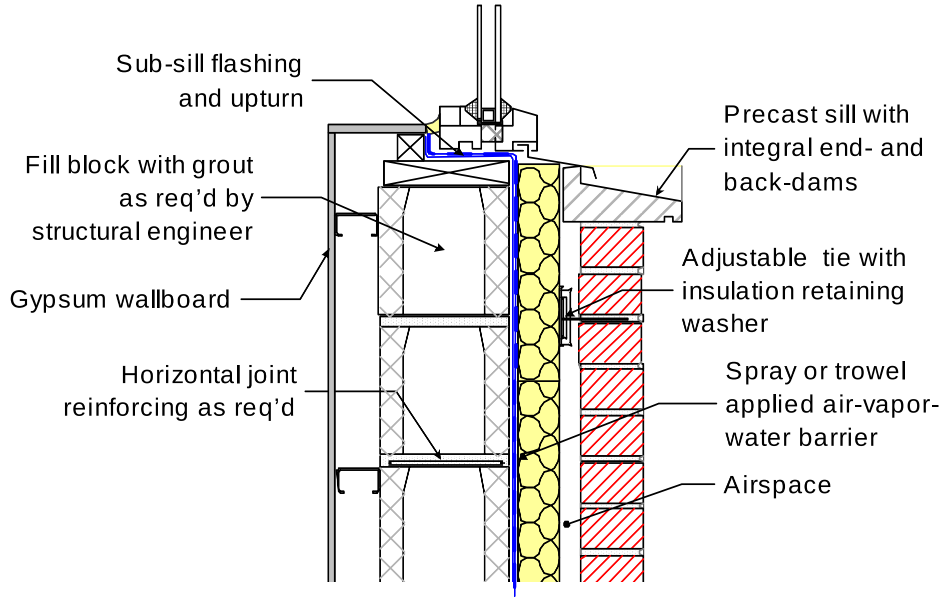


Figure 13: Window Sub-sill flashing detail

2. Natural Stone Panels, Metal Panels, and Precast

Natural stone, metal panels, and architectural precast concrete wall cladding systems are similar in that they are large format panels that are attached at discrete points to their structural backup (Figure 14). Unlike masonry veneers, the panels themselves rarely leak -- 40 mm of granite, 1.2 mm of aluminum and 4" of concrete are all essentially perfect barriers. However, the large numbers of joints between panels do often leak, since sealant cannot be perfectly applied and will not last indefinitely. Hence, these systems should be designed as drained systems. It is relatively easy and inexpensive to apply a drainage plane and a cavity behind such systems. Most of the philosophy and details of masonry veneers can be applied to these cladding types, with the exception of the need for flashing at shelf angle supports.

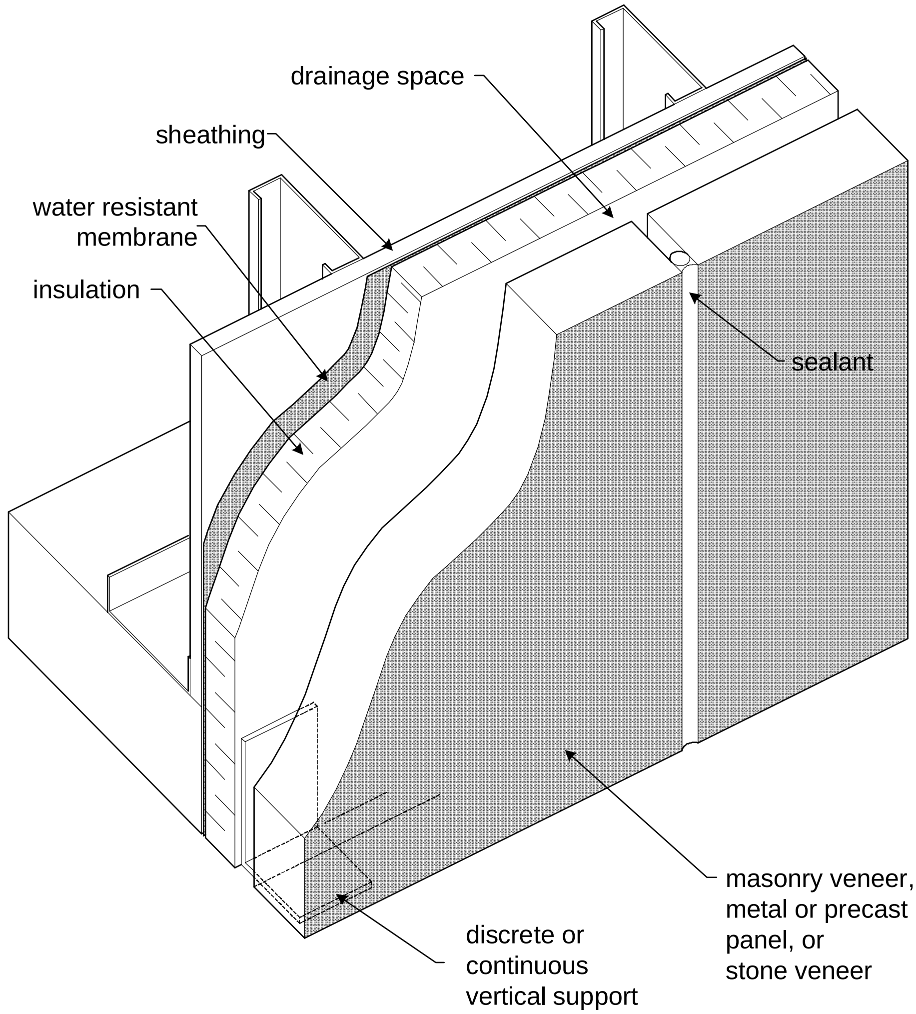


Figure 14: Representative Drained Masonry Veneer, Metal or Precast Panel, or Stone Veneer System

3. Lap and Vertical Siding

Wood, metal, fiber cement and vinyl lap and vertical siding (Figure 15) should always be considered to be permeable to rainwater, and hence designed as drained systems. Rain water will penetrate the cladding at joints, laps and penetrations. Water that penetrates tends to concentrate at J-trim, the top of each lap siding, and other interruptions of the drainage space. Because of its shape, vertical siding tends to drain more effectively, retaining less moisture.

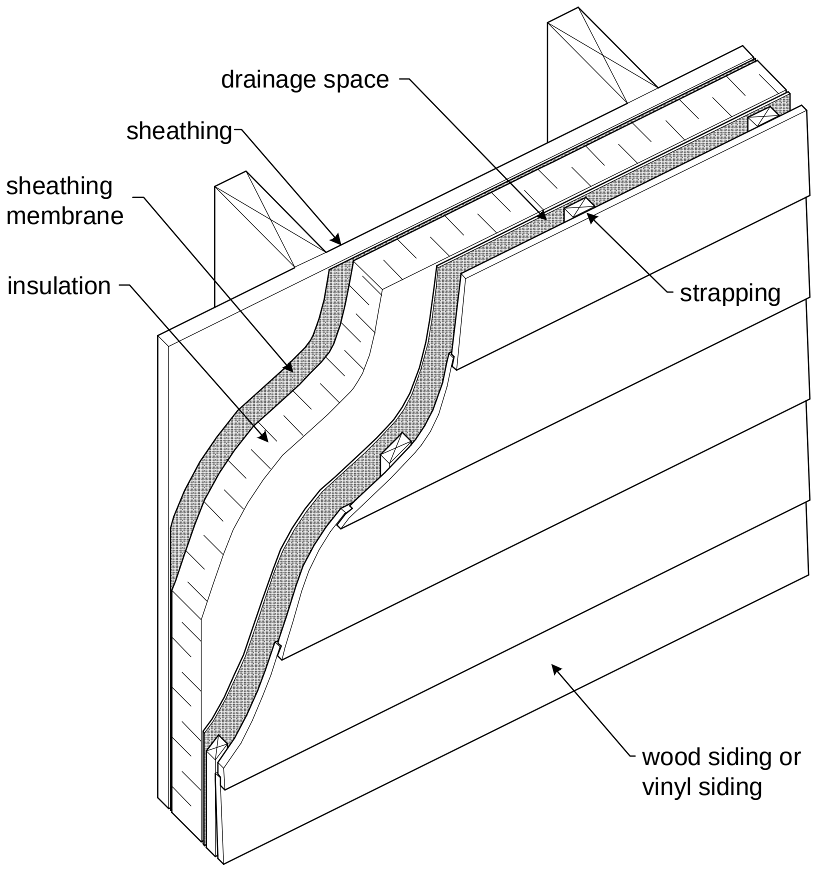


Figure 15: Representative Lap Siding System

The water that penetrates the siding system should be removed by drainage through the drainage space and redirected to the exterior by the use of waterproof (i.e., all lap joints sealed) flashing at the base of the wall and at all penetrations. A capillary break in the form of building paper, housewrap or similar is required to prevent further absorption or penetration into the wall assembly. A full water resistant barrier may be required in high exposure situations.

Water will remain within the drainage cavity and will be absorbed into wood and fiber cement cladding. This water should be removed by drying to the exterior and the interior by ventilating the space behind the cladding. Wood is more sensitive to retained moisture than the other materials commonly used, and so ventilation behind the siding is often desirable for exposed or long-life projects.

4. Solid Masonry and Concrete

Solid masonry exterior walls were traditionally, and often successfully, used to control rain water penetration. These solid masonry walls were comprised of several wythes and very thick blocks. Modern solid reinforced concrete walls often perform as well or better than walls comprised of masonry (Figure 16). Both systems control rain penetration by storing the small amount of water that is absorbed into their face or penetrates through the inevitable cracks. Since reinforced concrete tends to have many fewer and smaller cracks than a masonry wall, less concrete thickness is required for a specific application.

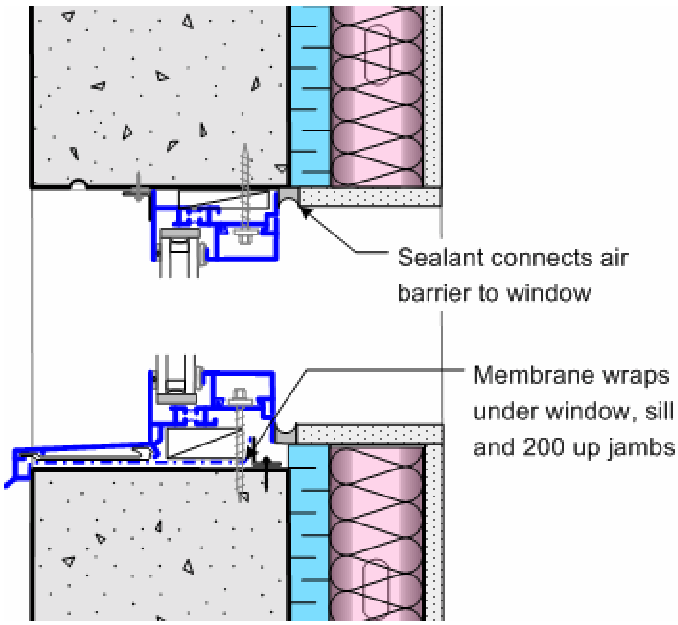


Figure 16: Reinforced Concrete Shear Wall with Drained Window Penetration

Masonry and concrete can employ the storage approach because they are very moisture tolerant materials with a large storage capacity. However, storage walls may become prohibitively expensive (in materials, structural weight, or floor space) for high rain exposure conditions. Single- and double-wythe brick masonry should be assumed to be very permeable to water and designed as drained screened systems.

Storage walls are often used in low-rise industrial / light-commercial (e.g., single-wythe concrete block), and some high-rise residential buildings (e.g., exposed concrete shear walls). Provided that the absorbency and safe storage capacity are well matched to the local exposure and climatic conditions, storage walls may be a reasonable choice. Failure of joints (often incorrectly designed as face-sealed perfect barriers) between wall elements or the interface with windows, doors, balconies, etc. is often the cause of rain penetration problems, even if the wall element itself remains functional. Hence, care should be taken to design drained or protected sealant joints.

The design strategy should be to deflect as much rain from the building as possible with good details so that a reasonable amount of storage capacity can be provided.

For example, a single-wythe split-faced concrete masonry wall system can rarely provide sufficient rain control for an exposed high-rise apartment building, but may perform well for a sheltered one-storey strip mall.

5. Stucco

Inorganically-bonded (cement, lime, and earth) exterior finish systems have been applied over masonry substrates for literally thousands of years throughout the world. Most modern stucco is cement bonded with an occasional additive such as lime to improve workability. Stucco absorbs and transmits rainwater rather freely. The addition of a high quality synthetic organic coating (usually an acrylic and/or silicone-based product) will dramatically reduce this, as well as increasing colour and texture uniformity. However, while preferred, this increases cost and does not fundamentally change the approach to rain control.

Regardless of finishes, stucco must be assumed to leak, and rain penetration often occurs at joints and penetrations. These joints should be designed and built as "two-stage" drained joints. A sheathing membrane acts as a capillary break over moisture-sensitive substrates (e.g., wood and gypsum), and provides the possibility of a small amount of drainage. The use of two layers of water resistant sheet materials behind stucco is highly recommended, since field testing has shown that a considerable amount of drainage capacity is available between the sheets. For example, an inexpensive variant involves covering a building with housewrap as soon as it is framed. This first layer provides temporary weather protection during construction and one drainage layer/capillary break. Paper-backed metal lath (widely available in most areas of North America) is then installed by the stucco mechanic and provides the second layer.

Stucco installed over moisture tolerant, absorptive substrates like concrete block often controls rain using a storage or mass strategy, although the stucco may act to reduce the moisture absorption in the field of the wall (see Figure 5). In these cases, sheathing membranes are not necessary. However, the use of such systems is limited by the combined effect of the level of rain exposure and available safe moisture storage capacity (see Solid Masonry and Concrete Walls).

Cement-lime based inorganic stucco over a building paper, rigid insulation (expanded polystyrene or mineral fibre) and a secondary building paper / housewrap (often combined with a drainage media for high exposure locations) over sheathing are modern high performance stucco systems (Figure 17). They require similar joint and penetration detailing as EIFS with organic-based coatings (see below), but the location of their drainage plane often makes detailing easier.

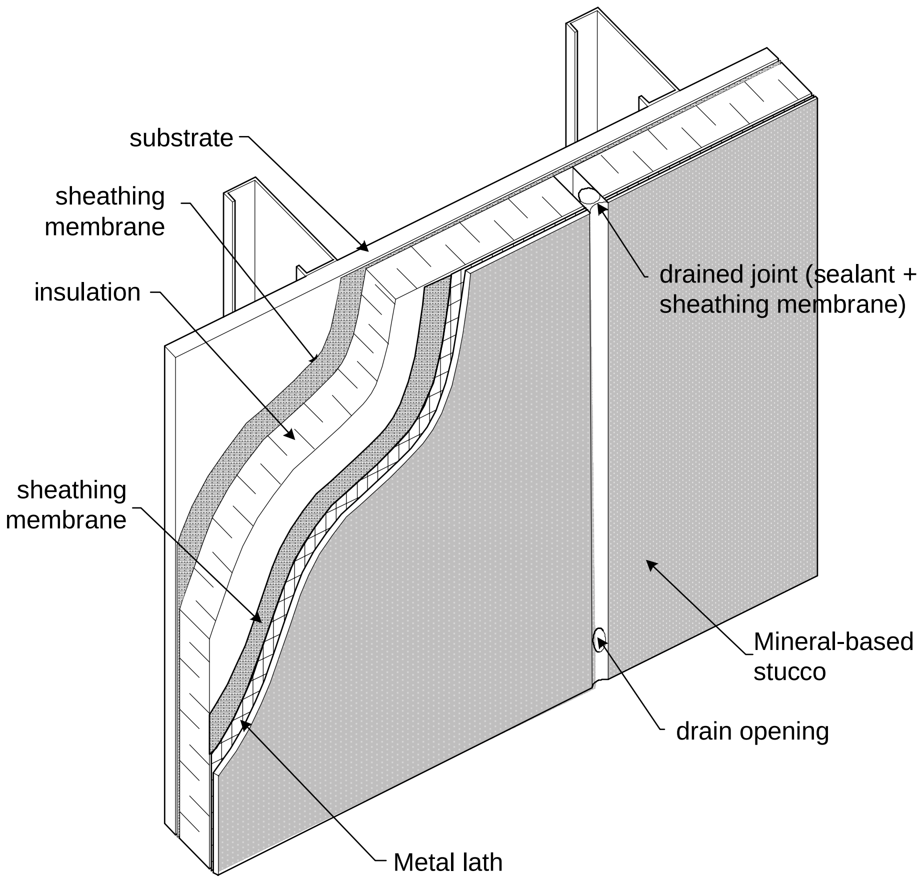


Figure 17: Drained Exterior Insulated Stucco System

6. Exterior Insulated Finish System

EIFS (pronounced "eefs") are an increasingly popular form of cladding and re-cladding buildings. EIFS, an acronym for Exterior Insulated Finish System, can be defined as a lightweight exterior cladding system consisting of a rigid insulation board (usually Expanded Polystyrene – EPS or white "beadboard" and occasionally mineral wool) mechanically or adhesively attached to a wind-load-bearing substrate, and covered with an integrally reinforced base coat and a protective surface finish. The EIFS industry is rife with special terminology -- some of the most important terms listed in the Glossary at the end of this report.

EIFS Rain Control Design Strategies

In the last five years, many new EIF systems have entered the market, partly in response with rain penetration control problems. These systems may have increased the cost and complexity of EIFS, but they do offer the potential for improved moisture performance.

Several classes of rain control design strategy, in order of increasing performance, are commonly available:

- FS -- Face-sealed perfect barrier systems assume that a perfect barrier to rain penetration is provided at the exterior face (i.e., by the lamina and sealant). (Fig 18).
- FS/DJ -- Some FS systems employ drained joints and penetrations (assumed to be the only leakage locations) to improve rainwater management at these sensitive and failure-prone points (this approach is sometimes termed Source Drained). (Fig 19)
- DB -- Dual barrier systems assume that the primary face seal may fail, and thus employ a secondary concealed water barrier that covers and protects the substrate. In all cases these systems should have drained joints at all penetrations. (Fig 20)
- D –Drained walls presume that the lamina and joints will fail, allowing in so much water that a water barrier (as in a DB) and a full drainage system are provided. (Fig 21)
- PM -Pressure-moderated and drained systems build on drained systems by explicitly adding a system of vents to encourage the moderation of wind pressures across the lamina, thereby reducing the amount of water that penetrates.

Face-sealed EIFS with exposed one-stage joints are not recommended for exterior applications. If the system is applied over a moisture tolerant and massive substrate such as concrete or masonry, a face-sealed element with drained joint approach can be recommended for all but high rain exposures. The dual barrier with drained joints approach (DB/DJ) should be used as a minimum approach over framed and other moisture sensitive substrates. Drained joints in all cases means below windows and at balcony penetrations in the form of drained sub-sill flashing.

The rain control strategy selected for EIFS depends on three primary variables:

Exposure - a combination of the climate and the shape, size orientation, and siting of the building

System Quality - a combination of design, materials (including the moisture tolerance of the substrate), workmanship, the confounding effects of weather during installation and the economic situation.

Performance Expectations - a function of the clients' expectations, minimum code requirements, etc.

Minimum Recommended EIFS Wall Rain Control Strategies

	Exposure A	Exposure B	Exposure C
Quality 1	FS†	DB/DJ	DB/DJ
Quality 2	DB/DJ	DB/DJ or D	D
Quality 3	DB/DJ	D	PM

† Face-sealed EIFS are not recommended for any architecturally-designed applications, and will not be covered by the OAA Indemnity Plan.

Exposure Classes

A - Two-stories or less, with good overhangs and suburban or urban exposure

B - Low-rise without overhangs, mid-rise suburban or urban exposure. Open or seaside exposure for A

C - high-rise, all exposures. Open or seaside exposure for B

Note: different orientations and heights may have different exposures.

Quality Classes

1 - full time third party inspection, experienced crew, detailed design and documents (e.g., 3-D isometrics for details)

2 - intermittent inspection, average crew, average design and documents

3 - little or no inspection, inexperienced or rushed crew, simple design and limited documents

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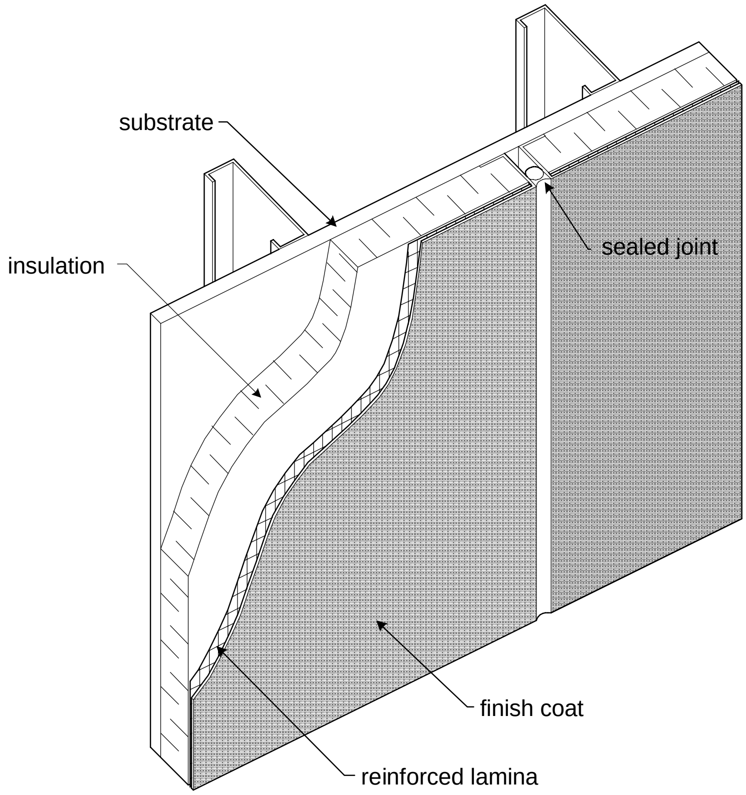


Figure 18: Representative Face-Sealed System at a Joint

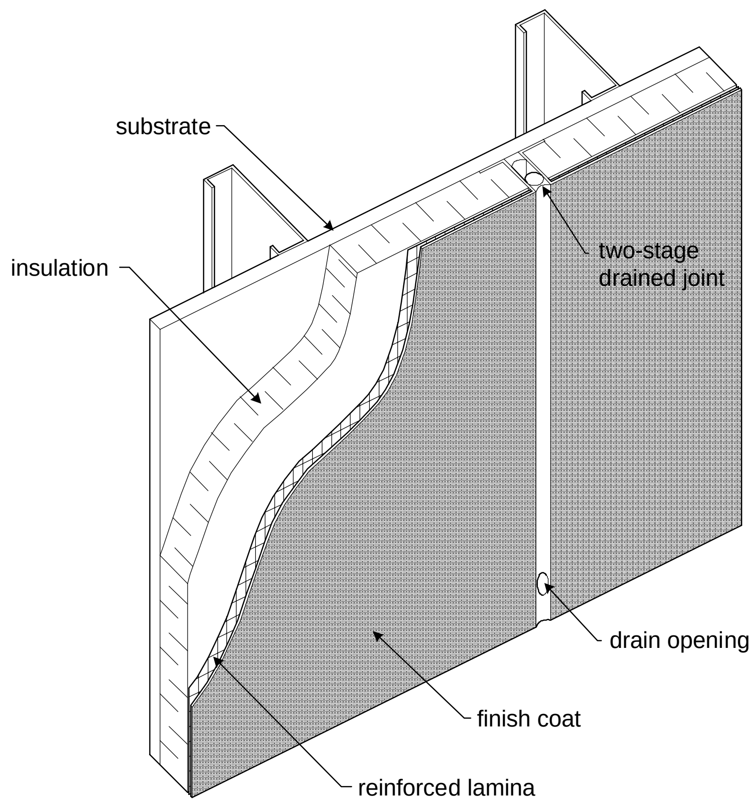


Figure 19: Representative Face-Sealed System with Drained Joints

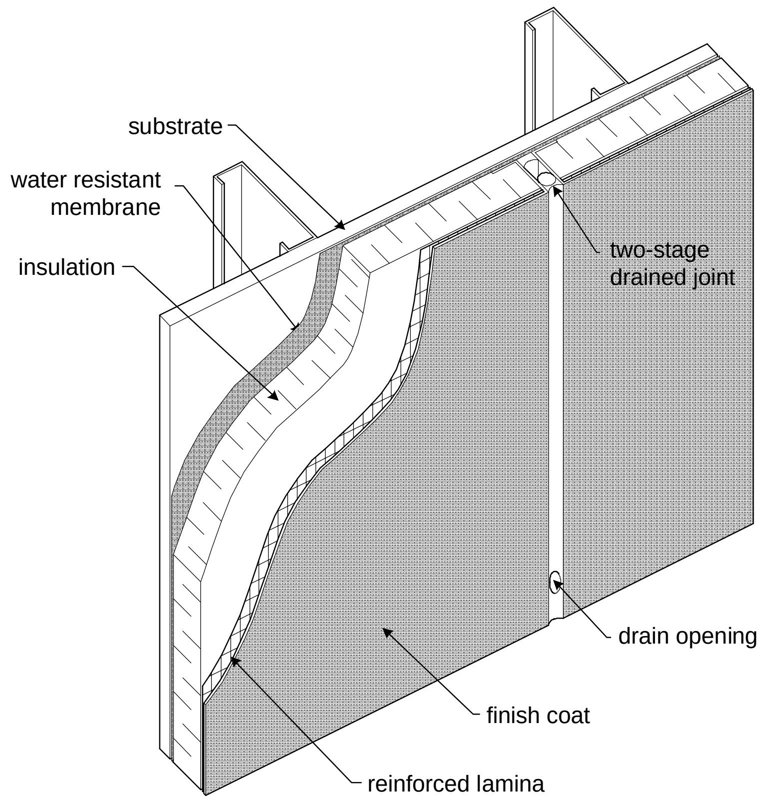


Figure 20: Representative Dual Barrier System with Drained Joints

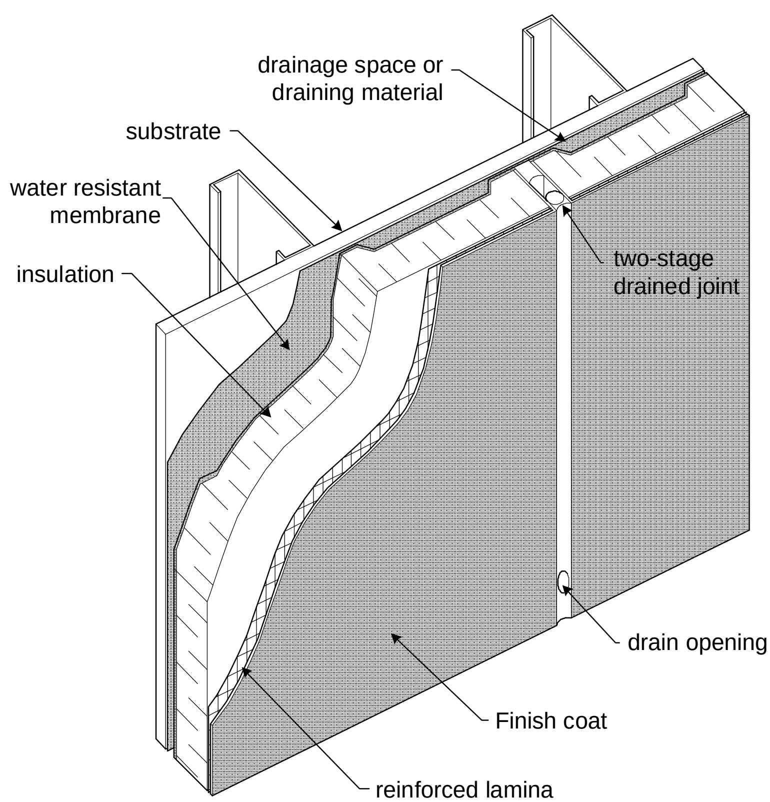


Figure 21: Representative Drained System at Drained Joint

7. Curtainwalls

Curtainwalls are a popular building enclosure choice for many commercial buildings, and are often seen as synonymous with modern architecture. Curtainwalls are non-loadbearing building enclosures formed from a grid of aluminum (and occasionally steel) elements with glass and stone infill. Most curtainwall systems are suspended in front of the primary structural elements, which can be structure of concrete, steel, masonry or even wood.

In the past curtainwalls made extensive use of exposed sealants (i.e. a face-sealed perfect barrier approach) to control rain penetration. Because such seals demand the impossibilities of perfect workmanship and materials that do not deteriorate, they often failed and caused rain penetration problems. It should be assumed that all exterior joints between the insulated glazing unit or infill and the framing will eventually fail and allow water to pass into the system. A curtainwall system should use drained (or even pressure-moderated) joints that redirect water that penetrates through failed joints to the outside (Figure 22). Such drained systems still require careful detailed design, but offer a much more reliable and durable means of controlling rain water penetration.

Rain penetration can be a problem at three-dimensional intersections of drained systems, such as the meeting of a vertical and horizontal mullion, the interface between the curtainwall system at the parapet, at grade, and between other enclosure systems. These interfaces should be given special consideration during the development of details. Sealant within a curtainwall systems (e.g., at mitred corners) is much more likely to be durable since the sealant is protected from UV, most water and temperature changes. Full-scale rain penetration testing of mockups is generally recommended, as are drainage capacity tests.

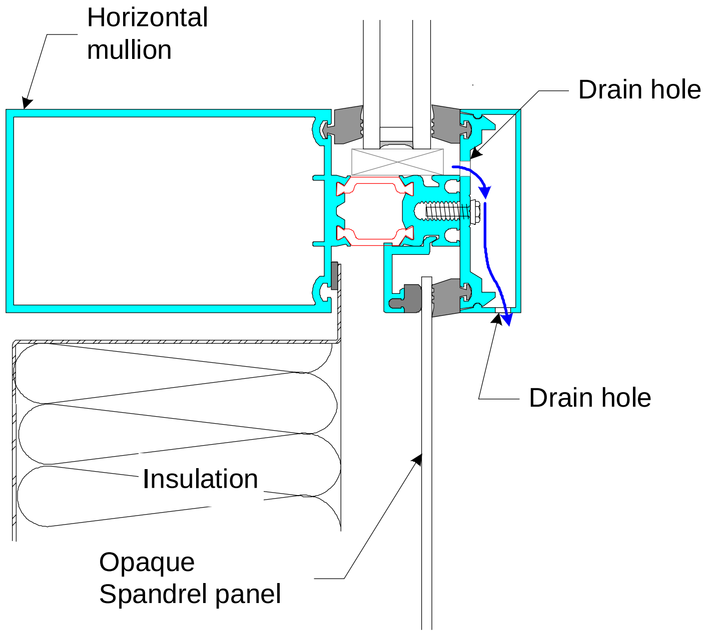


Figure 22: Drained Curtainwall Mullion

8. Joints and Penetrations

Although drained wall systems provide excellent rain penetration control, and some pre-manufactured components (such as insulated glazing units, metal panels and architectural precast) can act as perfect-barrier face-sealed elements, problems can and often do develop at interruptions of the drainage plane to face-sealed components. Joints are shown as a separate component in the classification system presented in Figure 5. A different rain control approach can, and often should, be applied to joints.

As often alluded to above, polymeric sealants used to seal joints have a life span that is usually significantly less than the wall elements. Sealant is also difficult to apply in a perfect manner under site conditions. Hence, experience has shown that exposed sealant joints cannot practically be relied upon to exclude rain water, i.e., act as a perfect barrier face-sealed system.

Two-stage drained joints are the time proven method of using sealant to control rain penetration (Figure 23). This approach uses the exterior exposed sealant bead as a rain screen, and hence is expected to fail and allow rain penetration. A second, interior weather protected sealant acts as the drainage plane, with a drainage space between the two joints.

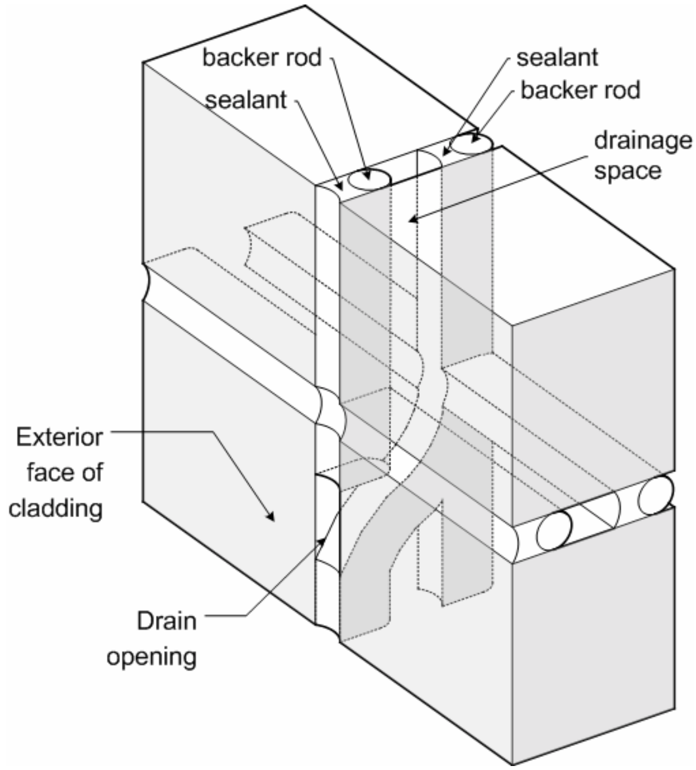


Figure 23: Drained Two-stage Sealant Joint

Windows, decks, air conditioning units, cantilevered balconies and canopies, and the termination of walls at grade all create conditions where rain can more easily penetrate if the interface is not properly detailed. Flashing must be provided at these penetrations to direct water in the drainage space to the exterior.

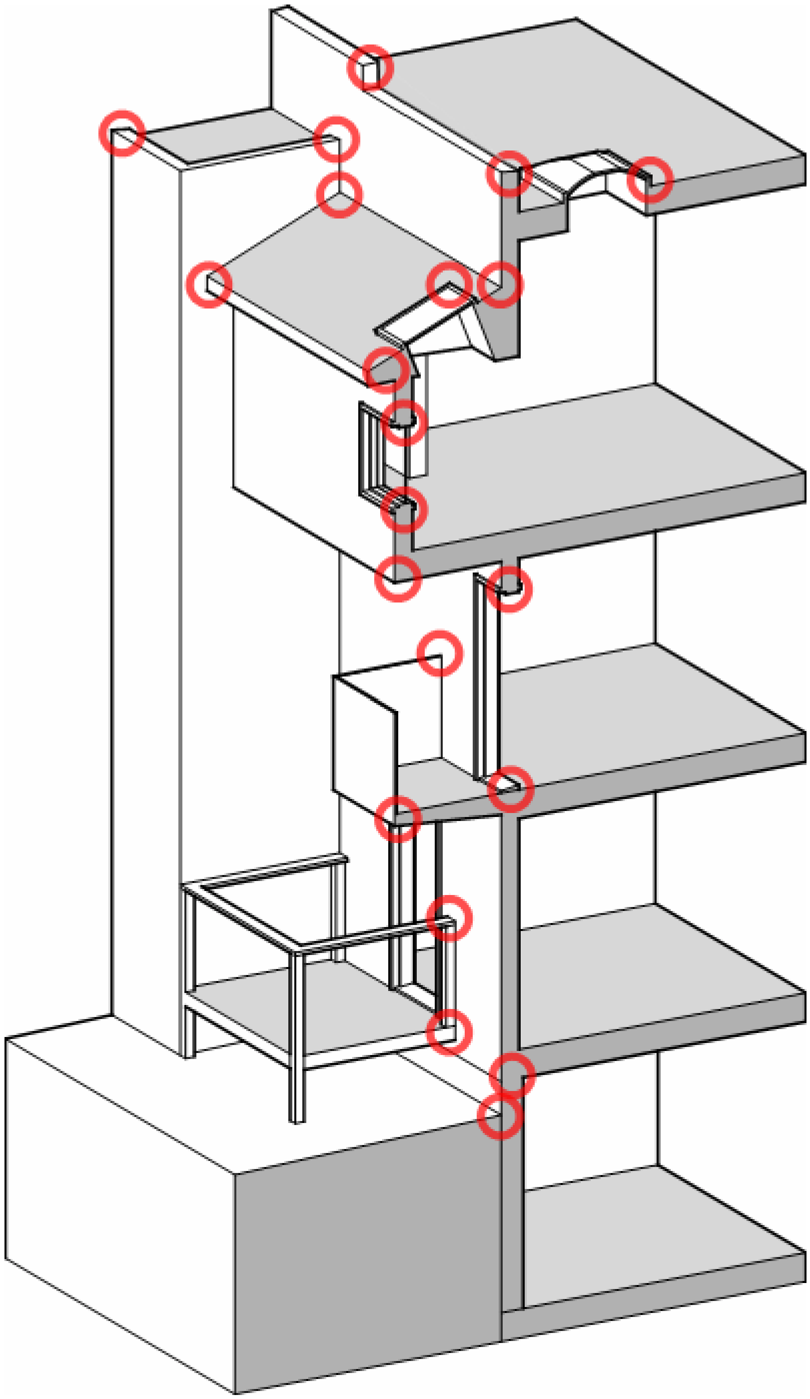
Flashing must be made of a waterproof material[2] since it is installed in a nearly horizontal manner. Flashing must be installed in a continuous manner with an outward slope. Leaks often occur at the laps between lengths of flashing, so these should be sealed, not just lapped. CMHC has prepared a Best Practice Guide for Flashing which provides guidance for material choice, specifications and detailed drawings for the use of flashing in a wide range of wall and roof conditions [24].

Windows, mitred corners, window-wall joints, and especially mulled window joints can leak significant quantities of rain water into the wall. To deal with this eventuality (some would say likelihood), sub-sill flashing should be installed below the window. Since the joint between the wall and the window is sensitive to workmanship, the head of the window should also be protected with flashing. This flashing directs water on the surface of the wall and in the drainage space behind the cladding safely back out. The flashing should extend past the window jamb by at least 50 mm so that water flowing laterally on the flashing does not concentrate at the jamb but runs

[2] Building paper is not waterproof when exposed to standing water. Materials such as thick PVC, metal, peel and stick membranes, special tapes, etc are more appropriate choices for flashing.

down the drainage space. Essentially the rough window opening should be prepared in such a way as to make it water resistant and draining to the exterior.

Figure 24: Typical Intersections Requiring Details



References

[1] *Wood-frame envelopes in the coastal climate of British Columbia: Best Practice Guide*, Canada Mortgage and Housing Corporation, Ottawa, 1999.

[2] Straube, J.F., *Moisture Control and Enclosure Wall Systems*. Ph.D. Thesis, Civil Engineering Department, University of Waterloo, April, 1998.

[3] Blocken, B., Carmeliet, J., "Driving Rain on Building Envelopes—I. Numerical Estimation and Full-Scale Experimental Verification", *J. of Thermal Insulation and Bldg Envelopes*, Vol 24, No 4, 2000, pp. 61-110.

[4] *Survey of Building Envelope Failures in the Coastal Climate of BC*. Report by Morrison-Hershfield for CMHC, Ottawa, Nov. 1996.

[5] Inculet, D.R., Surry, D., "Simulation of Wind-Driven Rain and Wetting Patterns on Buildings," Report BLWT-SS30-1994, U. of West. Ontario, London, Nov, 1994.

[6] Lacy, R.E., *Driving-Rain Maps and the Onslaught of Rain on Buildings*. Building Research Station Current Paper 54, HMSO Garston, U.K., 1965.

[7] Straube, J.F., and Burnett, E.F.P.,"Driving Rain and Masonry Veneer", *Water Leakage Through Building Facades*, *ASTM STP 1314*, R. Kudder and J.L. Erdly, Eds., American Society for Testing and Materials, Philadelphia, 1997, pp. 73-87.

[8] Künzel, H.M., *Regendaten für Berechnung des Feuchtetransports*, Fraunhofer Institut für Bauphysik, Mitteilung 265, 1994.

[9] Frank, W. *Entwicklung von Regen and Wind auf Gebaeudefassaden*, Verlag Ernst & Sohn, Bertichte aus der Bauforschung, 1973, Vol 86, pp. 17-40.

[10] Choi, E.C.C., "Determination of the wind-driven-rain intensity on building faces", J. *of Wind Engnrng and Ind. Aerodynamics*, Vol 51, 1994, pp. 55-69.

[11] Karagiozis, A., and Hadjisophocieous, G., "Wind-Driven Rain on High-Rise Buildings",*Proceedings of BETEC/ASHRAE/DOE Thermal Performance of Building Envelopes VI*, Dec., 1995, pp. 399-406.

[12] Straube, J.F. and Burnett, E.F.P., "Rain Control and Design Strategies". *J. Of Thermal Insulation and Building Envelopes*, July 1999, pp. 41-56

[13] Quirouette, R., *Laboratory Investigation and Field Monitoring of Pressure-Equalized Rainscreen Walls*, CMHC Research Report, September, 1996.

[14] Inculet, D., Surry, D., *The Influence of Unsteady Pressure Gradients on Compartmentalization Requirements for Pressure-Equalized Rainscreens*, CMHC Research Report by the Boundary Layer Wind Tunnel, University of Western Ontario, June, 1996.

[15] Laviolette, S., and Keller, H., *Performance Monitoring of a Brick Veneer / Steel Stud Wall System*, CMHC Research Report by Keller Engineering, June, 1993.

[16] *Rain Penetration Control Guide*, Morrison Hershfield for CMHC, Ottawa, 2000.

[17] Lstiburek, J., *Builders Guide for Mixed Climates*, Building Science Corporation, Westford, MA, 1999.

[18] Straube, J.F. Burnett, E.F.P., *Vents, Ventilation Drying, and Pressure Moderation*. Building Engineering Group report for CMHC, Ottawa, 1995.

[19] Popp, W., Mayer, E., Künzel, H., 1980. *Untersuchungen über die Belüftung des Luftraumes hinter vorgesetzten Fassadenbekleidung aus kleinformatigen Elementen*. Forschungsbericht B Ho 22/80: Fraunhofer Institut für Bauphysik, , Holzkirchen, Germany.

[20] Wilson, A.G., "Condensation in Insulated Masonry Walls in the Summer", *Proc. Of RILEM/CIB Symposium*, Helsinki, 1965, pp. 2-7.
[21] Sandin, K., 1991. *Skalmurskonstruktionens fukt- och temperaturbetingelser*. Rapport R43:1991 Byggforskningsrådet, Stockholm, Sweden.
[22] Andersen, N.E.,"Summer Condensation in an Unheated Building", *Proc. of Symposium and Day of Building Physics*, Lund University, August 24-27, 1987, Swedish Council for Building Research, 1988, pp. 164-165.
[23] Straube, J.F. and Burnett, E.F.P., "Drainage, Ventilation Drying, and Enclosure Performance", *Proceedings of Thermal Performance of Building EnvelopesVII*, Clearwater Beach Florida, December 4-7, 1998, pp 189-198.
[24] *Best Practice Guide for Flashing*, Canada Mortgage and Housing Corporation, Ottawa, 1998.

Many of the references are important sources of further information, especially the entire series of CMHC Best Practice Guides, available from CMHC or on line at:

http://www.cmhc-schl.gc.ca

Technical Notes on Brick Construction, "Note 7: Water Resistance of Brick Masonry, Design and Detailing Part 1", Brick Institute of America, Reston, VA, Feb. 1985 (Reissued Feb. 1998), and many other guides for masonry.

Hutcheon, N. B., and G. O. P. Handegord. *Building Science for a Cold Climate*. NRC/IRC, 1983, Order no. NRCC-39017.

All of the 200+ legendary Canadian Building Digests, available from NRCC/IRC, and on line at:

http://www.nrc.ca/irc/cbd/cbd-e.html

Lstiburek, J. *Builder's Guide for Cold Climates*, Building Science Corp, Westford, MA, 2001. Outstanding drawings for excellent rain control and durable, healthy practice for low-rise housing in cold climates. Available for 3 other climates zones from www.buildingscience.com.

Exterior Wall Construction in High-Rise Buildings, CMHC, Ottawa, 1991. ISBN 0-660-13759-3. A must-have guide for Canadian practitioners.

Glossary of Terms

Adhesive A compound used for bonding surfaces together, e.g., insulation board to the substrate in an EIFS, usually applied in the form of a trowel-applied paste. An EIFS adhesive and base coat may be the same material used for different layers.

Air Barrier More precisely, the air barrier system (ABS), a three-dimensional assembly of materials designed to provide the primary resistance to airflow through an enclosure. An air-vapour barrier is a system that combines the function of the ABS with that of the vapour barrier.

Back Wrapping The act of carrying the system reinforcement around the ends of the *insulation* boards and terminating between the insulation and substrate at system interfaces and terminations to firmly attach the base coat to the substrate and protect the edges of the insulation board at these locations. Also refer to End wrapping.

Backer Rod A flexible material (usually closed-cell polyethylene) formed into a circular cross-section and provided in rope form, used to provide backing and a bond breaker for the application of sealant.

Base Coat A compound used to embed and to cover the reinforcing fabric of an EIFS. The base coat also acts as the primary moisture resistant layer.

Bond Breaker A sheet, tape, or liquid applied material that prevents adhesion on a designated surface.

Capillary Action Liquid water is attracted to the molecules on the surfaces of many materials. If such an attractive material makes up a porous body then water will be forcibly drawn into the millions of tiny pores, a process called capillary action. Capillary action explains how liquid water is transported through concrete, wood, brick etc.

Capillary Break A capillary break is a layer or air space in an assembly that permits little or no capillary action, and hence breaks the transport of liquid water through an assembly made up of porous materials. Metals, glass, plastics, bitumen, etc are often used as capillary breaks between, for example, concrete and wood.

Cement Board A sheathing product made of cement-bonded fibre-reinforced composites (typically glass or wood fibres are used as reinforcing). Cement board is moisture and fire resistant and is used as a substrate sheathing. Refer to ASTM C1186.

Control Joint A formed, sawed, or assembled joint acting to regulate the location of cracking, separation, and distress resulting from dimensional or positional change.

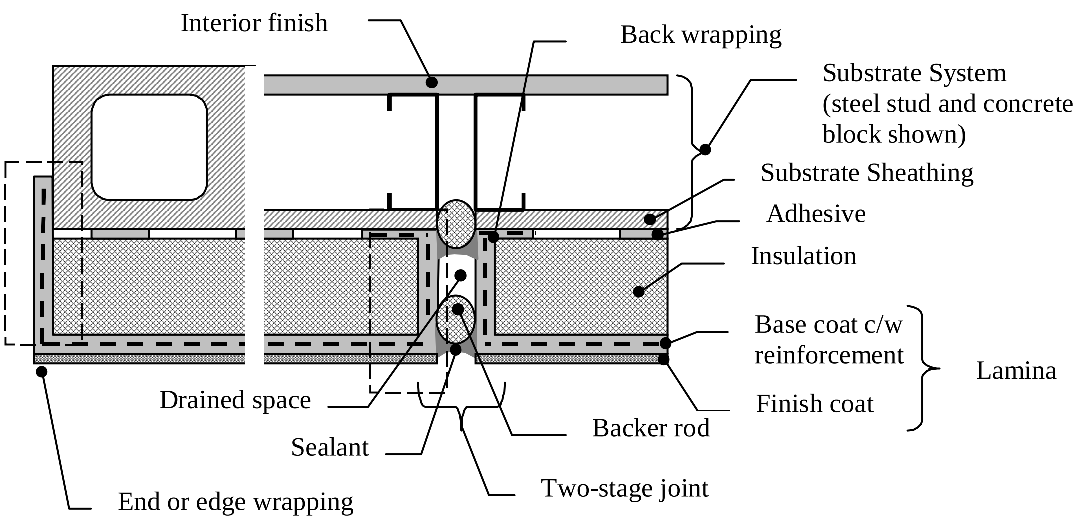
Durability The capability of a building, assembly, component, product, or construction to maintain serviceability for the desired and expected length of time.

Drip A horizontal geometric feature provided on an exterior wall to ensure that flowing water will drip free rather than be pulled back toward a vertical enclosure element by surface tension. A drip groove is commonly employed in solid materials like concrete and EIFS whereas a drip edge is used for thinner sheet materials. The horizontal edge of the material prevents water flowing back to the vertical surface.

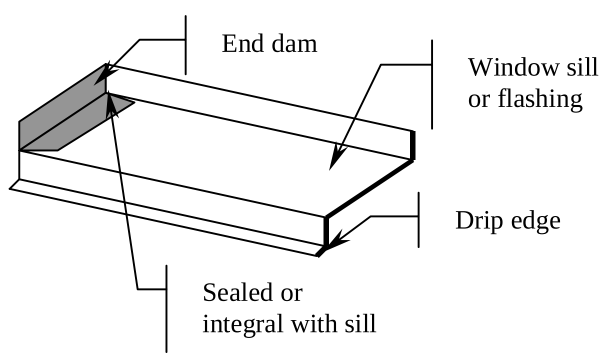
End Wrapping An EIFS term denoting the act of wrapping the reinforcement and basecoat around the edges of the insulation board and terminating and bonding to the substrate at an opening in the substrate. Like back wrapping, end wrapping is a means of securely fixing the lamina where it ends at joints and penetrations.

EIFS An acronym for an Exterior Insulated Finish System, a light weight exterior cladding system consisting of an insulation board mechanically or adhesively attached to a wind-load-bearing substrate, and covered with an integrally reinforced coated fibreglass mesh, base coat and a protective surface finish.

Some EIFS Terms (for a horizontal section)



End-Dam A vertical or near vertical upstand from the end of a *flashing* or window sill, used to prevent water from flowing off the end of the *flashing* or sill.



EPS - Expanded Polystyrene Expanded polystyrene (EPS) is a rigid cellular foamed-plastic insulation material manufactured by expansion of expanded polystyrene beads within a mould. This mould creates an open cell structure filled with air. EPS is the most widely used insulation for EIFS applications and is manufactured in various densities allowing design flexibility for compressive properties.

Extruded Polystyrene (XPS) Extruded polystyrene insulation (XPS) is rigid cellular foamed-plastic insulation

Expansion Joint A structural separation between building elements that allows independent movement without damage to the assembly.

Finish Coat The coating applied to *the base coat* to finish the *lamina.* The *finish coat* provides colour, texture, water repellency, dirt resistance and ultra violet ray resistance.

Flashing A waterproof material used to redirect or shed drained water, or occasionally to act as a capillary break

Non-paper faced Gypsum Sheathing A moisture resistant type of exterior gypsum sheathing. The gypsum core is treated for water repellency and either a glass matt applied to each face as reinforcement (ASTM C1177) or the core is integrally strengthened with distributed cellulose fibres

Gypsum Sheathing Exterior grade gypsum board used as sheathing, typically treated with water repellents. In this guide it is referred to as gypsum sheathing as per ASTM C79.

Joint An interface between elements. Joints may be needed to allow for movement of different parts of a building or assembly, or may be required to make construction sequences practical. In all cases, the functional requirements of the enclosure must be maintained the same as for the body of an enclosure element, although aesthetic requirements may be relaxed.

A joint may pass through the entire enclosure assembly, in which case it is a building movement joint, or more commonly referred to as an expansion joint.

Control joints are surface cuts or intentional geometric features which control the location of shrinkage cracks and are proprietary requirements.

Construction joints are formed between successive building elements parts during construction work.

Lamina The composite material layer installed over the insulation layer, comprised of the reinforcement, base coat and finish coat.

Reinforcement Material or materials used to improve the mechanical properties of the *base coat.* It may consist of one or a mix of polymer fibres, alkali-resistant glass fibres, and , most commonly, plastic coated fibreglass mesh.

Rigid Insulation Rigid board material which provides thermal resistance. Foam plastic such as EPS, XPS, and polyisocyanurate are commonly used, polyurethane and may be found.

Semi-rigid Insulation Board material which provides thermal resistance comprised of mineral fibres. Mineral fibre insulation is normally used for its fire resistance properties and is typically comprised of glass or rock wool.

Sealant A flexible, polymer-based elastomeric material installed wet and used in the assembly of the building enclosure to seal gaps, seams or joints and to provide a clean finish, or waterproof, or airtighten the joint.

Sheathing Membrane A generic term for sheet applied layer that prevents the resists the passage of liquid water through vertical, drained surfaces. Asphalt-impregnated building papers and felts and polymeric housewraps are the most common products available.

Source Drained Another term for a face sealed system that allows water to drain at the joints or penetrations assumed to be the point at which water enters an assembly.

Substrate Sheathing Material to which an EIFS is attached. The substrate sheathing is typically plywood or non-paper faced gypsum board. When the structural wall is comprised of masonry or concrete, EIFS may be applied directly to the masonry or concrete without the use of a substrate sheathing.

Substrate The structural plane of the building to which EIFS is attached, e.g., exterior sheathing, concrete masonry, concrete, etc.

Water Resistant Barrier A sheet, spray- or trowel-applied membrane or material layer that prevents the passage of liquid water even after long or continuous exposure to moisture.