

High Performing Precast Concrete Building Enclosures: Rain Control



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Introduction

Precast concrete has been used successfully to provide durable building enclosures for many decades. As requirements for thermal performance, air leakage and rain penetration control increase in modern buildings, designers are often considering precast concrete to provide a low maintenance, durable, long life solution. Although the exceptional durability of concrete is well understood and has increased over the last 50 years, rain control theory has advanced and there have been radical changes in the expectations for thermal and airflow performance.

Precast concrete enclosure walls stand apart from most “rainscreen” walls in several key respects: how they control rain penetration, how they provide airtightness, and their sequence of construction.

This paper reviews the requirements for high performance enclosures as they apply to precast concrete, with special emphasis on the control of rainwater penetration.

Building Enclosure Requirements

The building enclosure is defined as the physical component of a building that separates the interior environment from the exterior environment: it is an environmental separator. In practice, the building enclosure has to provide the “skin” to the building, i.e., not just the environmental separation but also the visible façade. Unlike the superstructure or the service systems of buildings, the enclosure is always visible, and therefore of critical importance to owners, occupants, and the public. The appearance and operation of the enclosure has a major influence on the interior environment and on factors such as comfort, energy efficiency, durability, and occupant productivity, satisfaction and health.

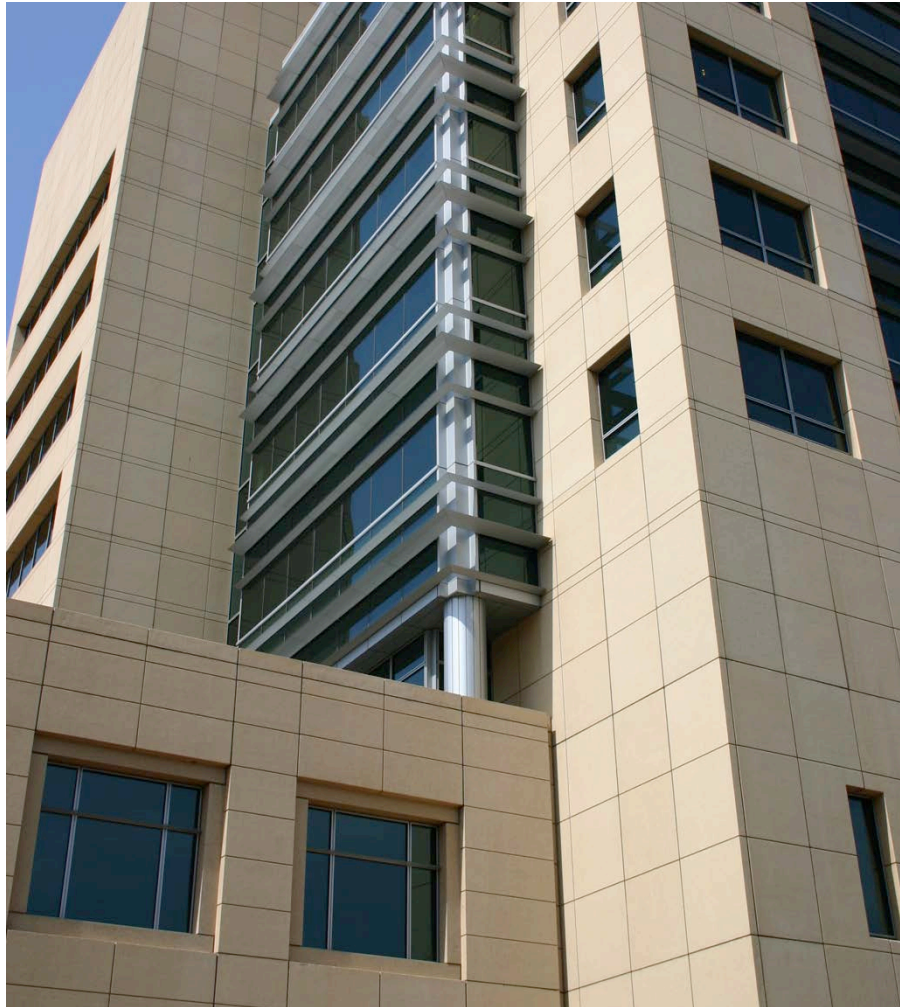


Figure 1: Attention to detail will ensure precast concrete wall panels provide high-performance enclosures.

In general, the physical function of environmental separation can be further grouped into three useful sub-categories as follows:

1. **Support**, i.e., to support, resist, transfer and otherwise accommodate all structural loading imposed by the interior and exterior environments, by the enclosure, and by the building itself. The enclosure, or portions of it, can sometimes be an integral part of the building superstructure either by design or in actual performance.
2. **Control**, i.e., to control, block, regulate and/or moderate all the loadings due to the separation of the interior and exterior environments. This largely means the flow of mass (rain, air, water vapor, pollutants, etc.) and energy (heat, sound, fire, light, etc.).
3. **Finish**, i.e., to finish the surfaces at the interface of the enclosure with the interior and exterior environments. Each of the two interfaces must meet the relevant

visual, aesthetic, durability and other performance requirements.

All practical enclosures must satisfy support, control, and finish functions, however, only the support and control functions are needed everywhere. Control and support functions must continue across every penetration, every interface and every assembly. The lack of this continuity is the cause of the vast majority of enclosure performance problems. The need for finish varies - it is unlikely to find an enclosure that requires a finish on the interior and exterior everywhere.

The **support function** is of primary importance. Without structural integrity, the remaining functions are of no use. The industry has reached a high level of understanding and accomplishment in this area.

For physical performance, the most common required enclosure **control functions** include resistance to: rain penetration, air flow, heat transfer, condensation, fire & smoke propagation, sound and light transmission (including view, solar heat, and daylight), insect infestation and particulate penetration, and human access. As these functions are required everywhere, continuity of these control functions, especially at penetrations, connections and interfaces between materials, is critical to a successful enclosure. The most important control function with respect to durability is rain control followed by airflow control, thermal control, and vapour control. The level of fire and sound control required varies with code requirements and owner requirements.

Unlike the control and support functions, which rely on continuity to achieve performance, the **finish function** is optional, and may not be needed in some areas, such as above suspended ceilings or in service or industrial spaces where the finish is often deemed unimportant. Exterior finish components are often termed “cladding”, but the term is imprecise, since cladding systems and materials often include some control functions (such as UV control, solar control, impact resistance, etc) while also serving their finish function.

As the most important control function, the control of rain penetration deserves special attention in all designs. This document focuses on the rain control of wall systems in general, and precast concrete walls in particular.

The Ontario Association of Architects commissioned the *Rain Penetration Control Practice Guide* (Straube 2005) in response to a rise in insurance claims with certain types of claddings. The guide clearly indicated that some types of enclosure systems do not need to be drained (e.g., glass, precast, low-slope roofs), although it has often been misinterpreted to mean all walls must be drained or even all walls must be “rain screens”. It does recommend the use of drained window openings, and the use of drained, two-stage joints. To supplement the guide, and avoid misunderstanding, a short review of rain control principles is provided next.

Rain Control Principles

There are three recognized design strategies to control rain penetration within and through the enclosure (Straube & Burnett 1999, CMHC 1999):

Storage: Mass or storage is the oldest strategy. Like drained systems, this approach assumes water will penetrate past the outer surface of the enclosure. It requires the use of an assembly of materials with enough moisture storage capacity and moisture tolerance to absorb all rainwater that is not drained from the outer surface. In a functional mass / storage wall, this moisture is eventually removed by evaporative drying from both the inside and outside before it reaches the inner surface of the wall as a liquid. 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 systems include adobe walls, thatched roofs, solid multi-wythe brick masonry, and single-wythe block masonry that is still employed for some modern buildings.

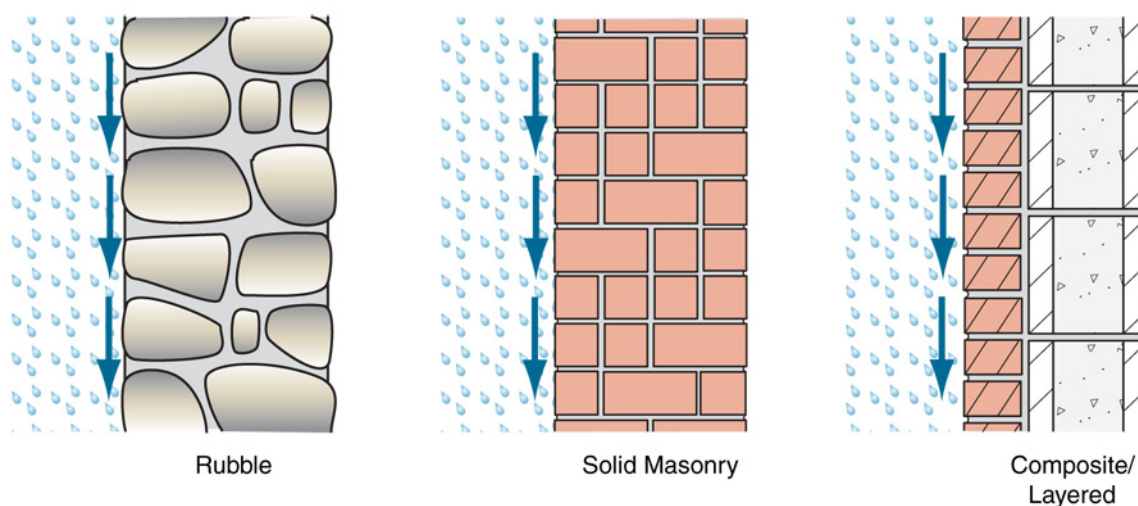


Figure 2: Mass (or storage) enclosure wall assemblies

Drained enclosures assume some rain water will penetrate the outer surface (hence the cladding “screens” the rain) and therefore the assembly must be designed to remove this water by providing drainage (comprised of a capillary breaking drainage plane, a drainage gap, flashing, and weep hole/drain). Many cladding systems, such as brick veneer and stucco, leak, as do the joints between other cladding types, such as shakes, terra-cotta, small metal panels, or natural stone. For these cladding types drainage is a practical and successful system of rain penetration control.

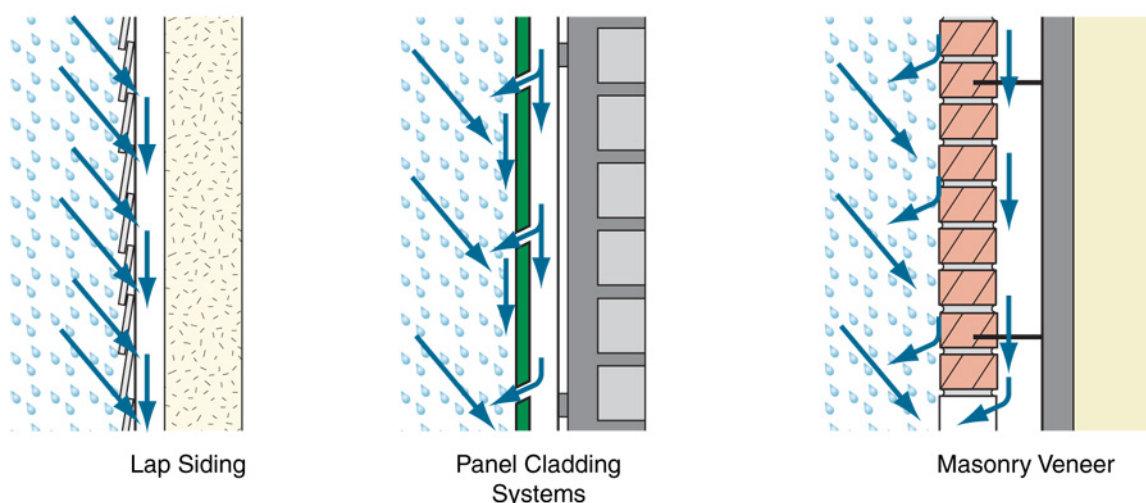


Figure 3: “Screened” and Drained enclosure walls

The term “rain screen” is applied to some drained systems, but the term is imprecise, as it means different things to different people. Drained walls may also be vented (a single, or single line of openings in the cladding connected to the exterior), ventilated (at least two openings through the cladding usually distributed between the top and bottom of the cavity), or even pressure-moderated (the air pressure in vented & ventilated walls tends to follow the exterior wind pressure, thereby “moderating the pressure”). Rain screen is applied loosely to all three different types of drained walls.

As drained systems can accommodate a range of claddings and backup systems, this approach to rain control has justifiably received a lot of attention from researchers and practitioners. However, drained systems are not always appropriate or the best strategy if good rain penetration control is desired. **Existing multi-wythe solid masonry walls, glazing panels, and large-format precast panels are three common wall components that perform better if a strategy other than drainage is used.**



Figure 4: Small-format, handset precast installed as drained system

Perfect Barrier systems stop all water penetration at a single plane. Such perfect control required the advent of modern materials. Because it is difficult to build and maintain a perfect barrier with many materials, it is common to recommend the use of drained walls. However, some systems, usually factory built, provide wall elements that are practical perfect barriers. For example, architectural precast concrete can be considered watertight, as can glazing, and roof membranes (See Figure 5). The joints between perfect barrier elements should almost always be drained joints in the form of two-stage sealant joints or similar.

Perfect barriers may be face-sealed – where the perfect barrier is at the exterior face – or concealed barrier, where the barrier is protected behind other materials. Concealed barrier systems, such as Protected Membrane Roofs (PMR), have a long record of good performance. Others, such as stucco and adhered veneers applied directly over building paper have shown disastrously poor performance in many applications. The difference in experience is directly related to the likelihood of a perfectly waterproof barrier being achieved in construction and maintained over the desired lifespan. EIFS (synthetic stucco) can perform as a perfect barrier but experience has shown that rain leakage at the joints can be trapped within the system and this has caused thousands of failures. Current practise for EIFS is to use two-stage drained joints, and fully-drained systems are now widely available.

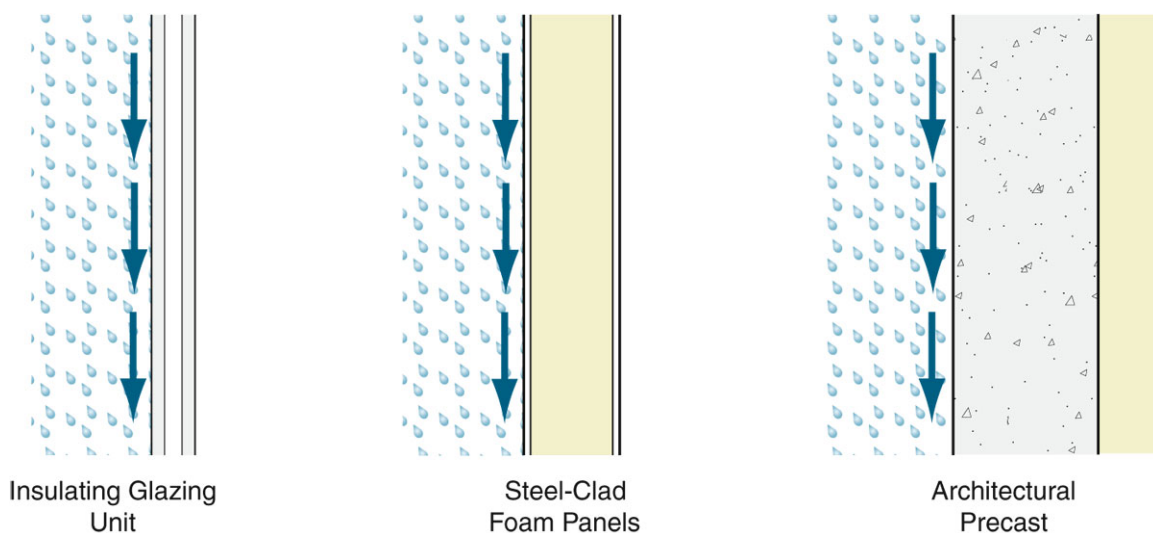


Figure 5: Perfect barrier enclosure walls

Joints

Joints are classified in the same manner as enclosure elements (Figure 66), although the joint and the enclosure element often use different approaches. For example, walls which use mass and perfect barrier elements often use drained joints to form a complete system.

Face-sealed sealant joints (e.g. a single line of exposed sealant) have a poor record of performance and cannot be recommended for controlling rain entry.

Even exposed gaskets, often used to create the joint between insulated glazing units and the window frame, tend to shrink and crack over time. When these seals fail, significant water penetration occurs [Lacasse & Miyauchi 1997]

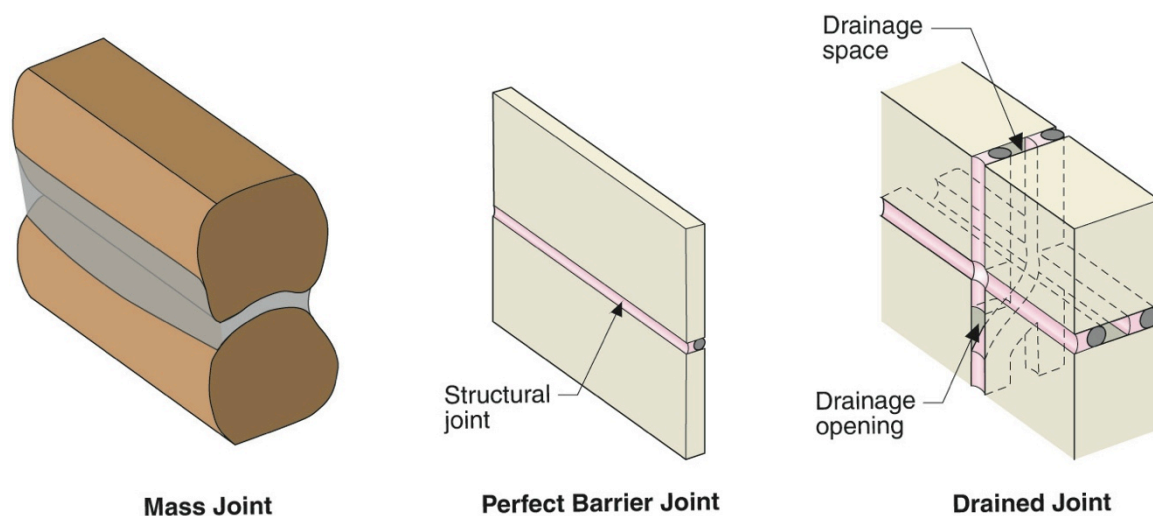


Figure 6: Three different rain control strategies at joints. Two-Stage drained joints are the recommended approach.

Perhaps the most common rainwater control failure occurs at window penetrations [e.g. Finn 1995]. Regardless of which rain penetration control strategy is used, window and door penetrations through enclosure walls should be drained.

Sub-sill flashings (Figure 7) of various types are widely available for this purpose. For drained systems, the flashing can drain into the drainage gap. For perfect barrier (e.g., precast) and mass systems, the flashing must drain water to the exterior face of the assembly.

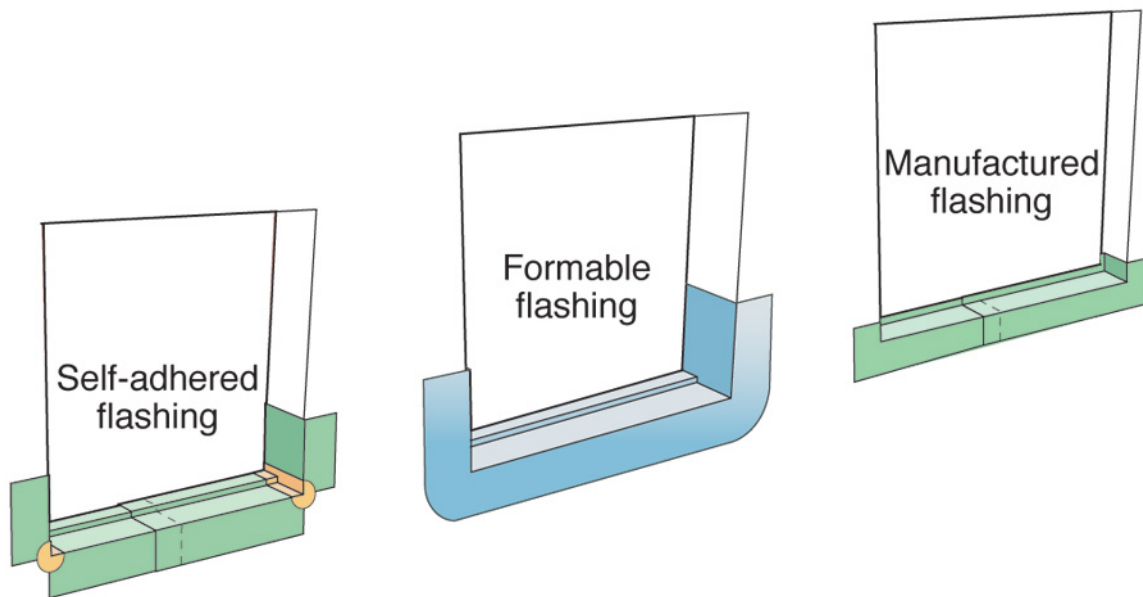


Figure 7: To ensure resistance to rain penetration, sub-sill flashing below all window and door openings is a critical requirement.

Rain Control Principles Applied to Precast Concrete Walls

Three broad categories of architectural precast concrete are available as enclosure wall systems:

Conventional Panels

use precast concrete as large format panels on the exterior acting as the exterior finish and structural component that provides the enclosure support function (that is, they collect wind and self-load and transfer it to the primary structure).

Integrally Insulated Wall Panels (“Sandwich Panels”)

incorporate thermal insulation between an exterior finish wythe and an interior structural wythe. The exterior and interior wythes are connected with ties that maintain the structural integrity of the panel and provide the degree of composite action desired.

Veneer Panels (either Conventional or Integrally Insulated)

comprise a precast concrete backup panel with a range of small panel non-loadbearing cladding products (stone, metal, etc.) attached to the face.

All three types of precast can be successfully designed as drained systems.

However, both conventional and insulated panels provide better resistance to rain penetration and air leakage if designed as perfect barrier – drained joint systems.

Precast panels are reinforced for crack control, and typically made of high-quality concrete with, very low water-to-cement ratios. It is for these reasons that they can act as a reliable barrier to water penetration. Millions of square feet of precast panels installed over the last five decades have provided the real-life proof of this¹. However, the joints between panels and around penetrations (especially windows) and the interfaces with adjacent enclosure systems should not be designed using perfect-barrier face sealed joints.

The Division of Building Research of the National Research Council of Canada, the very agency that originally promoted the idea of drainage and pressure-equalization to the Canadian building industry², considered the special case of precast concrete wall panels in their 1967 document, CBD-94. *Precast Concrete Walls - A New Basis For Design* (Latta, 1967). This CBD explicitly states that when it comes to rain control: “The panel can be taken as essentially impervious and special measures for the control of rain penetration can be confined to joints”. Since then nothing has changed except that concrete quality has improved. Claddings that can be expected to leak in service should be drained, whereas those that do not, e.g., glass and quality concrete, need not be drained but require special attention at the joints. The Ontario Association of Architects also accepts the concept of perfect barrier elements with drained joints in their *Rain Penetration Control Practice Guide* (Straube, 2005).

Two factors must be addressed to reach high levels of rain penetration resistance in precast concrete wall systems: good quality concrete designed to control cracking, and drained details at penetrations, joints and interfaces with other materials. The former is regularly achieved by standard specifications for quality (e.g, minimum concrete compressive strength, minimum steel ratios and maximum reinforcing spacing to control cracking, and a maximum water-cementitious materials ratio). Details need to be developed around all penetrations, to allow for drainage of water that penetrates the outer sealant joint. Examples are shown at the end of this document.

¹ Chin and Gerns (1998) provide case studies of precast concrete failure investigations. Their experience, which mirrors that of this author and Building Science Corporation, is that water does not penetrate through the precast concrete panel but only through joints and penetrations.

² For example, Kirby Garden introduced the concept of pressure-equalization, and highlighted the importance of drainage in *CBD-40. Rain Penetration and its Control*, published in 1963.

Pressure-moderation (this is considered a more realistic term as perfect pressure equalization rarely occurs) provides no benefit to the body of precast concrete panels as wind pressure differences do not cause or increase rain penetration through the concrete. It is important, however, to provide an airtight inner seal and a vented outer seal at two-stage joints, as the joints *do* benefit from pressure moderation.

Sidebar: Air Barriers and Vapour Barriers

A strong, rigid, and air impermeable air barrier system is required in all building enclosures, and critical to high-performance buildings [Straube 2011]. Precast concrete panels can provide an exceptionally rigid, strong and air impermeable component of such a system. Joints, penetrations, and transitions are the critical link in achieving airtightness.

At the joint, the inner seal provides for effective continuity of the air barrier from one panel to another. The drained and vented outer joint cannot, of course, be part of ensuring air barrier continuity.

At penetrations and transitions, details must show how an uninterrupted, strong and airtight plane continues from the concrete layer to the adjoining curtainwall, roof, canopy, etc. while accommodating dimensional construction tolerances and in-service movements. Sealant, sheet metal, and sheet membranes are common components in successful details.

Vapour barriers are required in most enclosure designs. Precast concrete is, by its nature, a vapour barrier with a permeance of less than 57 ng/Pa s m^2 (1 US Perm) in thicknesses of over about 2" (50 mm). As precast concrete is placed on the "cold side in winter", a low vapor permeance material must be used on the interior side to control the flow of vapour to the cold-in-winter concrete. This requirement has been achieved using aluminum foil and polyethylene sheets in the past. Both of these products are difficult to make continuous, and sufficient air may pass through unsealed joints to bypass their vapour control properties. One high-performance solution is the use of spray-applied foam insulation as the air, vapour, and thermal barrier applied directly to the back of a conventional architectural precast panel. Rigid board foam insulation, with carefully and diligently sealed joints can be considered for simple enclosures with few penetrations and obstructions.

At the joints, the backer rod and sealant often provide a good vapour barrier. However, open-cell foam and silicone sealant may be too vapour permeable for some high interior humidity environments such as swimming pools. Urethane and butyl based sealants can be used to provide low-permeance vapour barriers. In all cases, providing venting through the outer joint seal, allows vapour to escape, and essentially removes any vapour resistance that the outer seal materials may provide. Hence, a vented two-stage joint provides a single interior air- and vapour-barrier, with the outer seal acting as a vented rain screen with no air or vapour resistance.

To accommodate the joints between panels, the concept of a drained joint, or two-stage seal has been promoted for almost 50 years [Garden 1968, AAMA 1971] based on solid research [Svendsen 1967, Isaksen 1967, Platts & Sasaki 1965] and widely used with great success for almost as long [Rousseau, 1982].

The interior air seal / drainage plane can be installed from the interior or the exterior. Although installation from the interior has been common in the past, it is often difficult to access the interior joint at columns, floor slabs, perimeter roof beams, shear walls, plate connections, and other obstructions. Providing a design that allows interior access to the interior joint is possible, but in many cases it is easier and more reliable to apply the interior air seal/drainage plane from the exterior.

In general, the inner seal should be held back at least 25 mm (1 inch) behind the backer rod of the outer seal to create a well-ventilated air gap. This requires the installation of tooled sealant on a backer rod installed about 75 mm (3 inches) behind the outer face³.

Weep holes, with a minimum dimension of 12 mm (½ inch) to facilitate drainage, are almost always provided in the vertical joints. A bead of sealant is tied to the interior vertical sealant bead with an outward slope and a drop in height from the horizontal joint of at least 100 mm (4 inches) thereby encouraging outward flow of water and resisting the entry of wind-driven rain.⁴

³ This assumes a 25 to 38 mm (1 to 1.5 inch) diameter backer rod, and a 6 to 12 mm (¼ to ½ inch) minimum thickness sealant joint in a 25 to 30 mm (1 to 1 ¼ inch) wide joint.

⁴ If the weep hole is in a vertical joint 100 mm (4 inches) below the horizontal joint, water in a horizontal joint must travel laterally to a vertical joint and then down 100 mm (4 inches) to exit. If the holes were to be located 100 mm (4 inches) above each horizontal joint then draining water would have to additionally travel the entire height of the vertical joint. Every metre that the water has to travel increases the likelihood that water will come in contact with a flaw in the inner seal. If a slightly outward sloped horizontal joint is used, lateral travel distance in the horizontal joint is not a disadvantage, as the water is held against the exterior seal, away from the interior seal and any potential flaws in it. When water drains within a vertical joint, however, there is no such simple mechanism, and so every metre of drain path length is a metre more of risk (other than joints with washboard edges or other elaborate techniques).

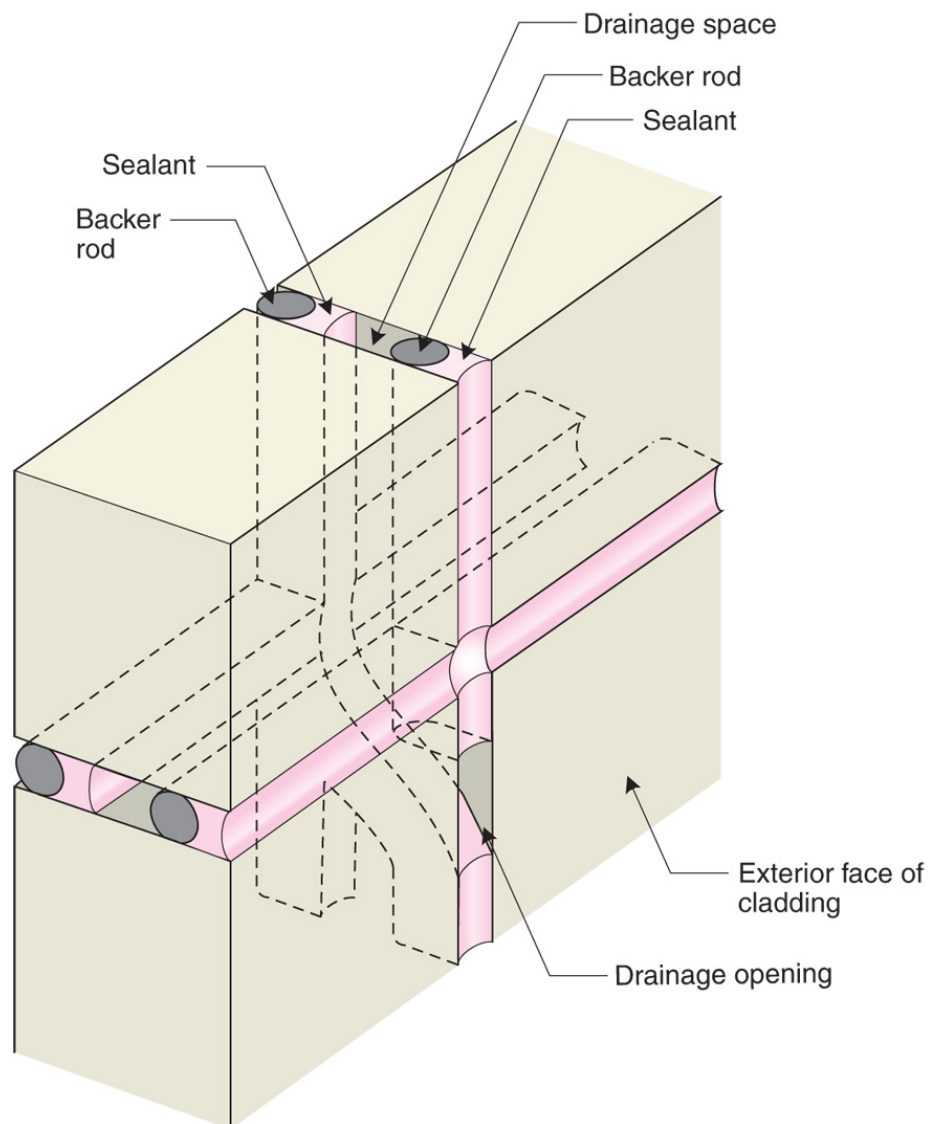


Figure 8: Conceptual arrangement of two-stage joint between precast concrete panels

A mockup before construction and periodic inspection during construction before interior finishes are added is recommended to ensure that the trades are achieving this airtight inner seal. Testing joints during construction is simple: water is injected behind the outer seal at a rate of no more than 1 or 2 litres per minute while visually confirming both drainage from the associated weep hole and the lack of penetration into the building. This simple confirmatory test can be completed in just a few hours on a number of randomly selected vertical and horizontal joints.

Sidebar: Joint Sealant Maintenance

All exposed joint sealants require inspection, maintenance and repair. Typical maintenance issues are water leakage through the joint, visible separation of the sealant from the concrete, and cracking or tearing of the sealant. Inspections of sealants generally detect sealant deterioration before joints have totally failed and allow water passage. In drained joints, the potential consequences of a failed exterior seal are much less due to the interior seal, and hence the inspection and maintenance interval can be increased.

Building owners & managers should keep accurate records of when the exterior sealants were installed, the expected useful service life of the sealant, and the time, nature, and results of each inspection during service. A cursory inspection after one to two years of service acts as a check on the installation quality. Once the sealant has reached 75 percent of its predicted useful life, periodic inspections of the sealants should be conducted. In many cases, the initial evaluation can be undertaken from the ground and the roof. Once the sealants have reached their predicted useful service life, a more extensive evaluation should be performed, including the use of swing stages or access platforms to adequately observe the building sealant joints.

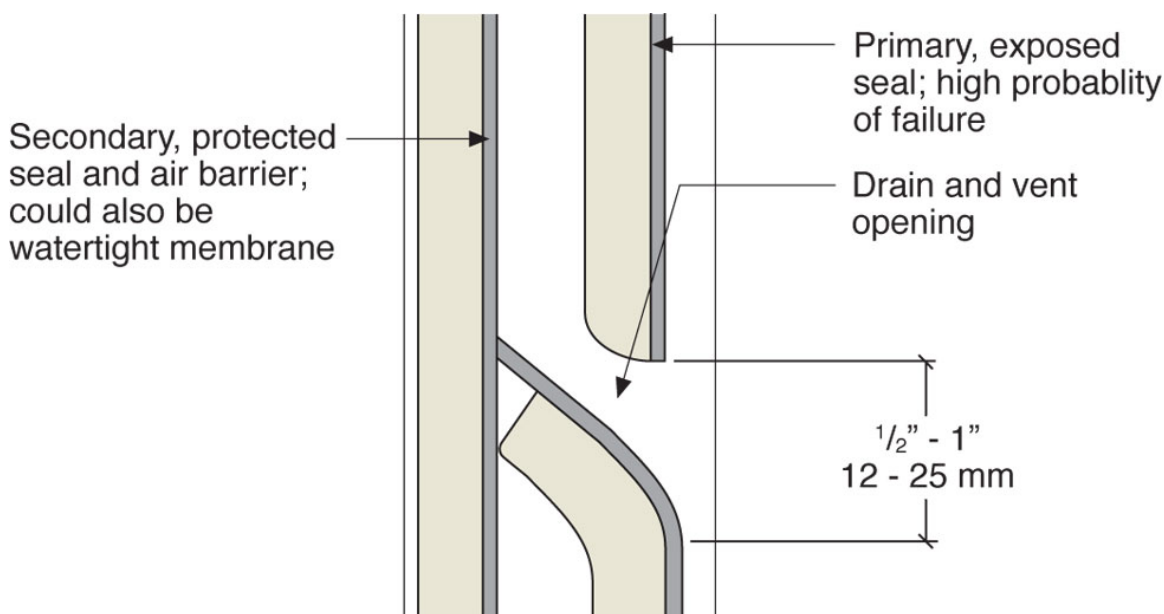


Figure 9: Details of two-stage joint at drain and vent hole. Note the open joint allows for easy drainage. Plastic weep tubes are sometimes inserted to alert trades that an opening is intentional and not to be sealed over, but such tubes do not drain as well.

Risks of Drained Systems

Some designers choose to ignore the unique properties of precast concrete, and design precast systems that attempt to mimic the drained rain control approach of brick, stone, or stucco veneers. As it is well established that precast concrete panels themselves do not allow rainwater to penetrate, **the rain control performance of precast is not improved by draining behind the panels. In fact, there are numerous increased risks that are created by using the drained approach if normal construction sequences are used⁵.**

A major challenge occurs at all structural connections of conventional precast panels to the interior structure if installed over a water-air barrier plane (Levy et al, 2010). The structural connections are penetrations through air and water barriers, and yet, with the panel installed from the exterior, it is difficult to access the area around the connection after erection of the panels to seal these penetrations. Despite solutions that involve interior portholes, special access panels, and spray foam, field experience has shown that such connections are difficult to seal properly. All of these problems and risks can be avoided by using the air and water barrier properties of precast concrete.

In addition, providing an air gap behind architectural precast can create a path for interior air to flow laterally. As the precast concrete is both an air and vapour barrier, it is critical that air from the interior not be able to enter an air gap during cold weather. If it does, the air in the gap will cool, fall, and drag in air from the indoors while connecting any flaws in the interior airtight layers together. The resulting convective loop that can form (see Figure 10) has been observed (by the author) to collect thousands of litres of condensation during cold weather.

Systems which allow a full drainage plane and air barrier to be installed over all supporting structure and made continuous **before panels are installed** can be designed and built reliably as a drained system. For example, small “handset” precast panels, those with many joints and supported on pre-installed anchors, are often successfully and easily built as drained systems (See Figure 4). Structural connections that can be installed blind (e.g., require no access) might be developed to allow for a full air-water barrier to be installed before the precast concrete. Integrally insulated panels can use the inner concrete wythe as the air and water barrier, and hence drainage gaps can be more easily provided behind the outer wythe without compromising the continuity of air or water tightness. There is little performance benefit to this approach but it has been used in practice.

⁵ For a number of practical, economic, and performance reasons, large-format precast walls panels are typically installed over the structural frame, followed by the remainder of the wall assembly.

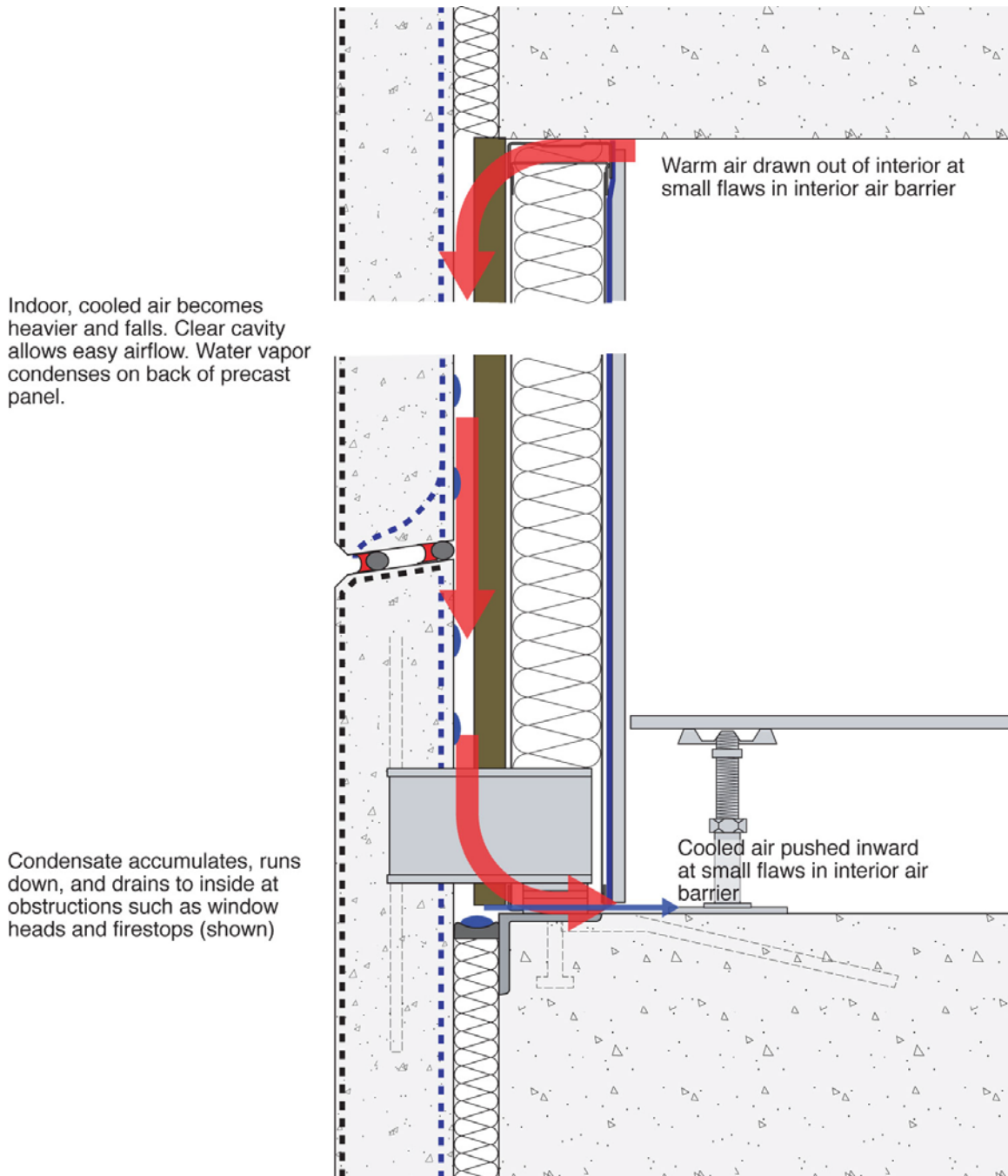


Figure 10: Risky design: an air gap behind a conventional precast wall can allow cold weather condensation to form via internal convection loops, as well as being practically very difficult to seal around structural supports, drain and flash.

Conclusions

High-performance enclosures are those that perform above normal levels in specific, owner specified areas such as rain penetration resistance, airtightness, energy performance, or durability (Straube 2012). Architectural precast concrete wall systems can be an excellent choice for high-performance building enclosures. To achieve **the best control of rain penetration, precast concrete wall designs should employ a perfect barrier-drained joint system** i.e., they should use a drained, two-stage joint between the concrete barrier elements at all penetrations. This approach is theoretically sound, supported by decades of real-life experience, and allows for other high-performance attributes such as excellent airtightness and high thermal resistance.

Recommended Details

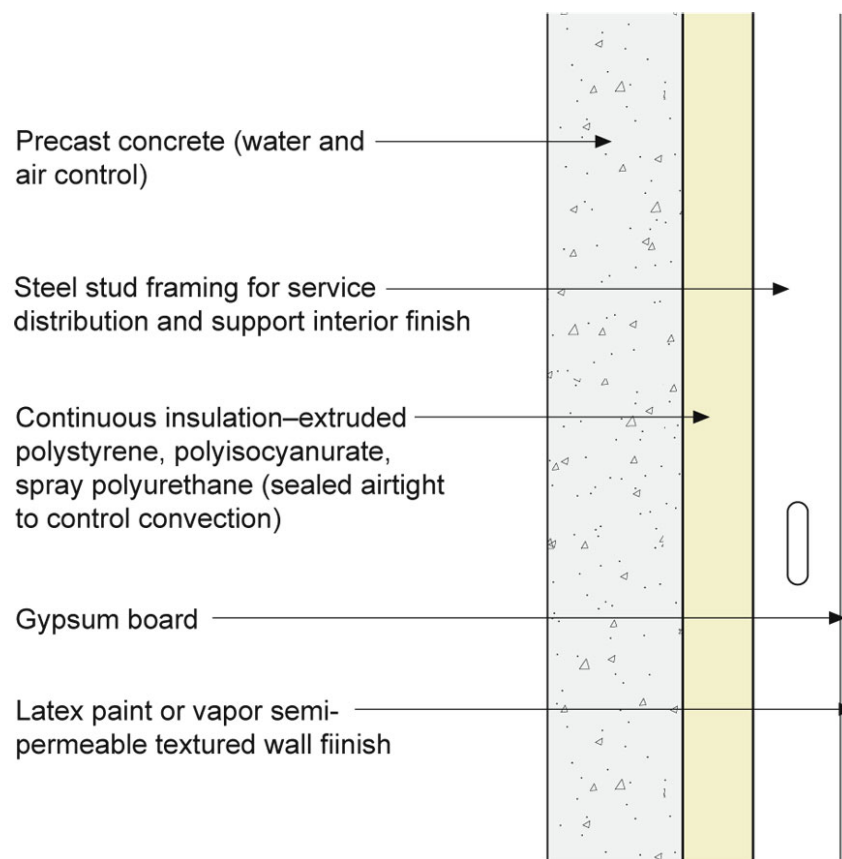


Figure 11: Concept of architectural precast wall panel between joints. Insulation must control internal air convection but one can use sealant or membrane to form interior air barrier continuity over joints.

Figure 12 demonstrates the type of detailing at a floor intersection that can provide high-performance continuity of the water, air, and thermal control. The joints are fully-drained and vented. These types of two-stage joints have a history of successful construction and performance, but it is important that proper inspection and verification during construction be provided and that periodic inspection and maintenance during its service life be conducted, so that the joint will perform over its service life.

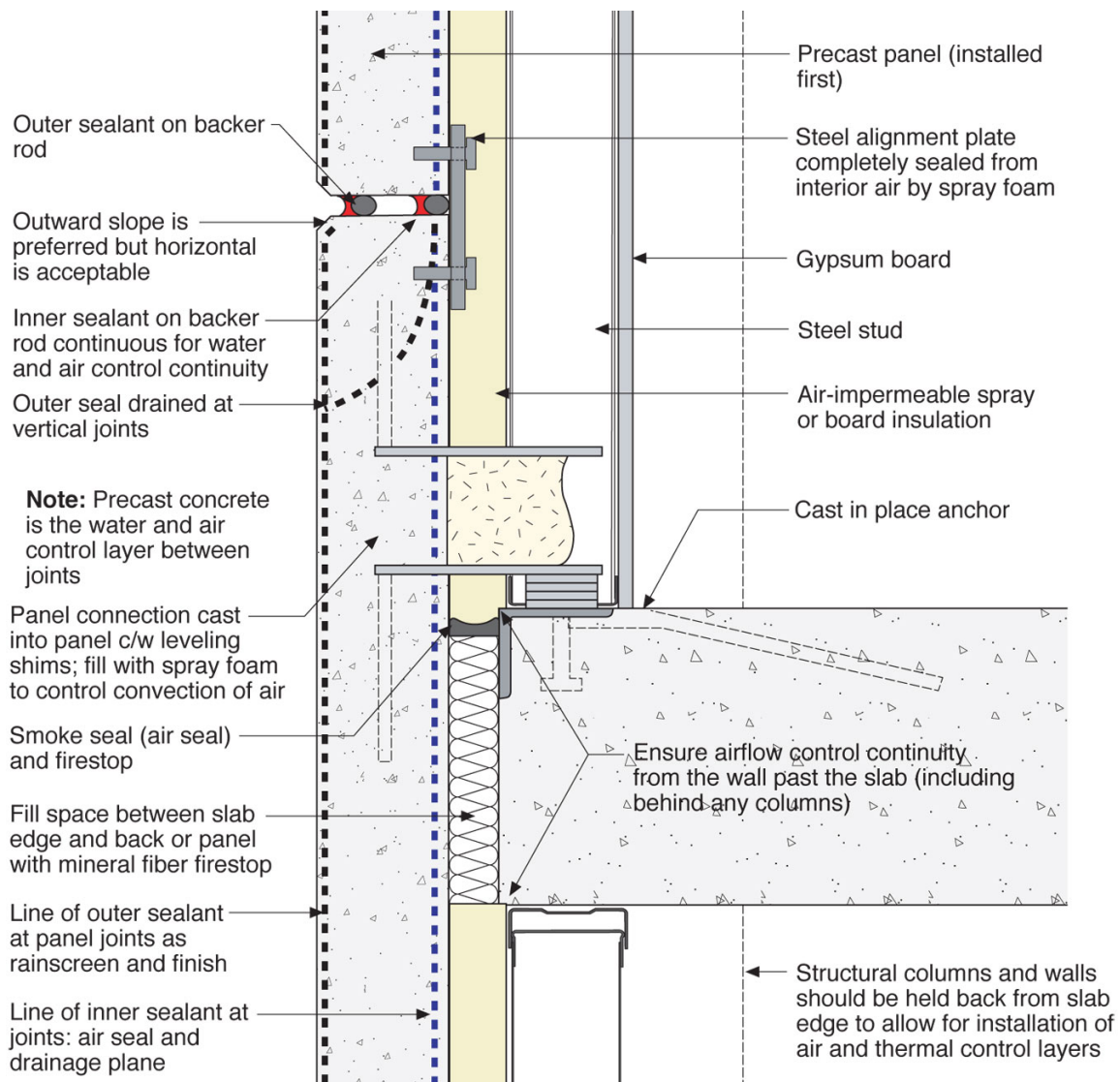


Figure 12: Conventional Architectural Precast Concrete Panel. Detail at horizontal joint and floor intersection demonstrating high-performance continuity of the water, air, and thermal control. Fully-drained and vented rain control at all joints.

In Figures 12 and 13 the top of the panels are shown flat as per normal practice. For higher performance requirements (more exposure to driving rain, more sensitive

interior uses, higher owner expectations) a slope to the outside is recommended. An outward slope of about 5% provides a significant benefit by ensuring that any water that might leak into the horizontal joint (which is the joint most challenged⁶) is directed against the exterior “rainscreen” sealant bead, not against the interior water and air barrier seal. Some precasters feel this small slope increases the risk of chipped edges at the hidden interior edge and prefer dead flat horizontal joints or interior chamfers.

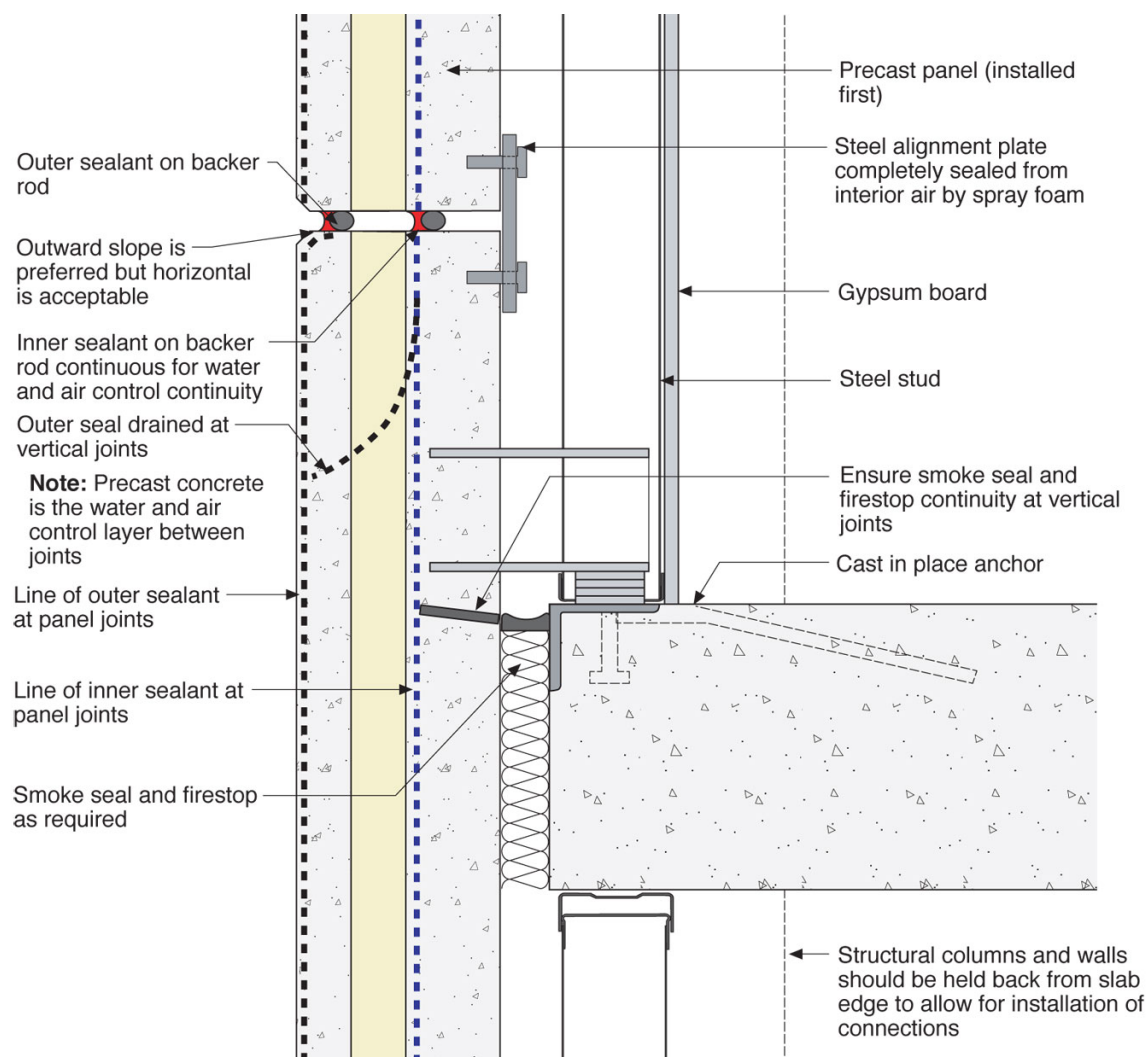


Figure 13: Integrally Insulated Precast Concrete Panel

⁶ Sealant joints are intended to be adhered to the concrete, and the sealant is itself hydrophobic (repelling water from entering small cracks). The vertical joints have as much propensity to leak as the horizontal. However, more water flows over the horizontal joints. As water tends to flow vertically, and is only slightly challenging to vertical joints by wind. Hence, horizontal joints are more likely to let water leak past than vertical joints. Finally, buildings tend to shrink, settle, and sag, all of this movement is accommodated at horizontal joints, which have a tendency to bulge outward. This creates a small lip that further encourages water to leak inward at horizontals.

Figure 13 demonstrates a typical Integrally Insulated Precast wall panel with high performance details. All of the functions of a modern building enclosure can be provided in one prefabricated system if desired, including continuous air barrier and thermal insulation, excellent rain penetration resistance with drained joints and penetrations.

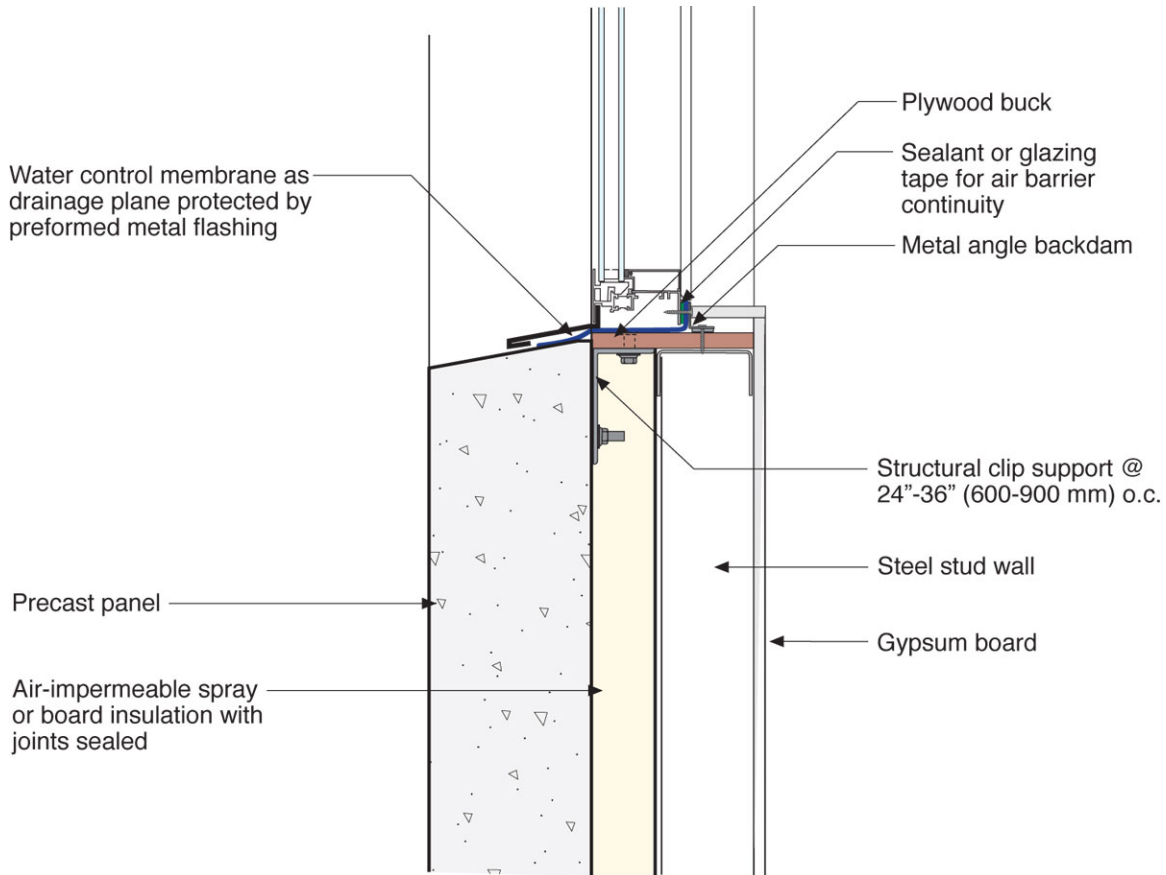


Figure 14: Window sill at architectural precast panel

Figure 14 is an example of one type of window installation in a conventional architectural precast panel system. It is critical to drain all such openings (door, ductwork, etc.), as they are the most likely source of rain penetration. The water control membrane must be made continuous at the jamb-sill intersection and continue upward at least 100 mm (4"), and preferably full height. The wood buck limits thermal bridging at the opening. Note that the thermal break in the window must align with the insulation in the wall panel to prevent thermal short circuiting. In many cases, the air space in the window frame is filled with low-expansion foam or custom preformed rigid insulation inserts. A projecting drip edge is not shown, but such a drip is desirable to limit staining from rain runoff.

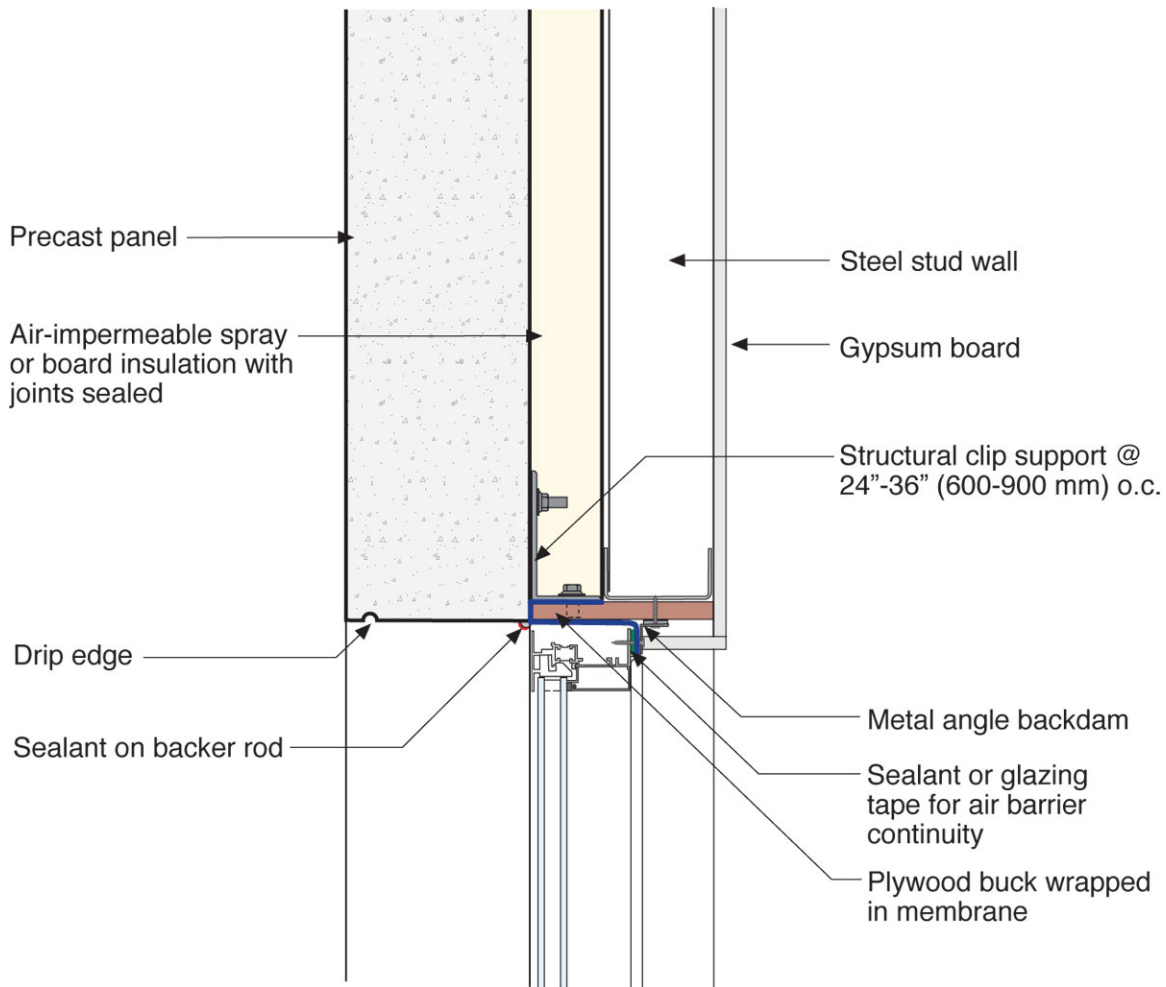


Figure 15: Window head at architectural precast panel

Figure 15 provides example detailing at a window head. The same issues as the sill are present, although the need for drainage is limited. Surface water is controlled via the drip edge, cast into the concrete. The inner bead is primarily a positive air seal but is also the water barrier. The thermal control is made continuous with the wall insulation to the window's Insulated Glazing Unit by passing through the wood buck and thermal break.

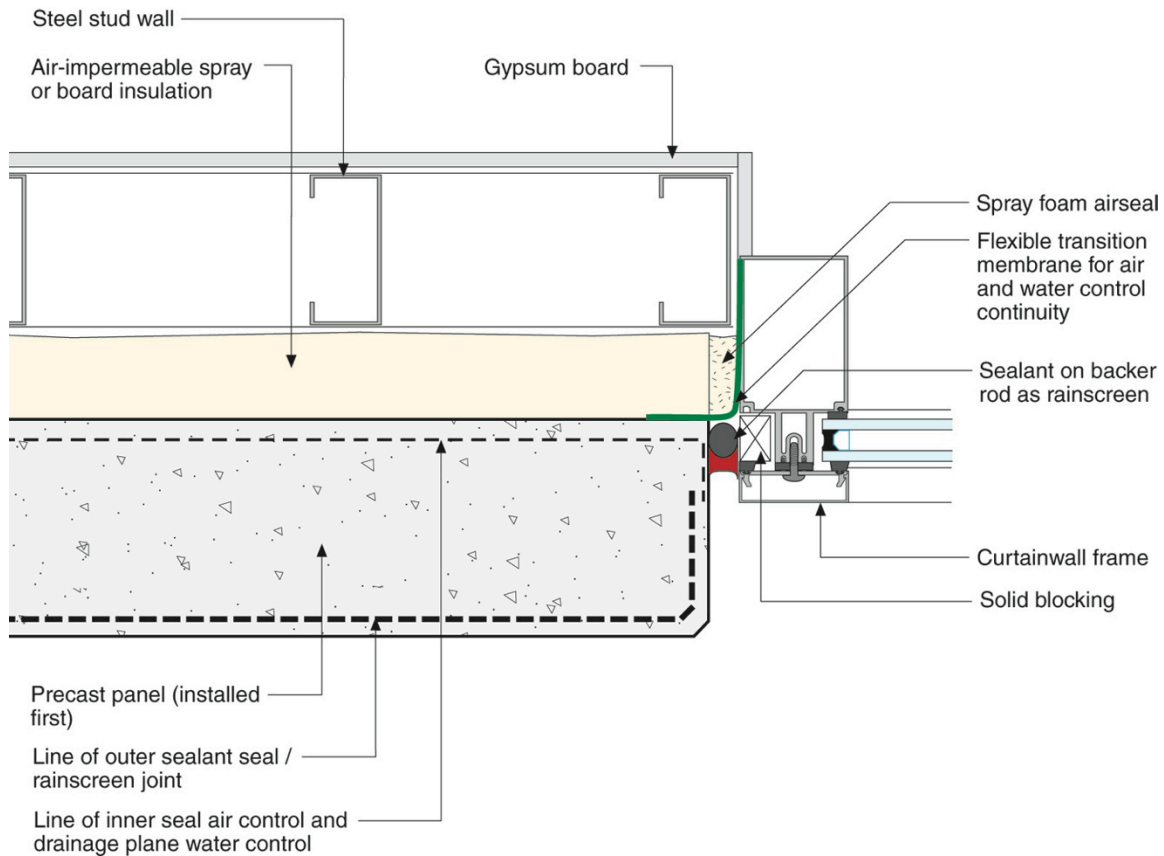


Figure 16: Curtainwall to Architectural Precast Jamb Connection.

Figure 16 shows a jamb detail of a small box curtainwall joined to an architectural precast system. The two-stage joint is drained to the exterior at the sill. An inner flexible membrane is shown as the inner seal, although a sealant joint could also be used. If construction sequencing allows this, a membrane may be clamped into the curtainwall frame at the inner shoulder. Thermal continuity from the wall insulation to the Insulated Glazing Unit is achieved via the backer rod, solid blocking (made of a low-conductivity plastic) and thermal break.

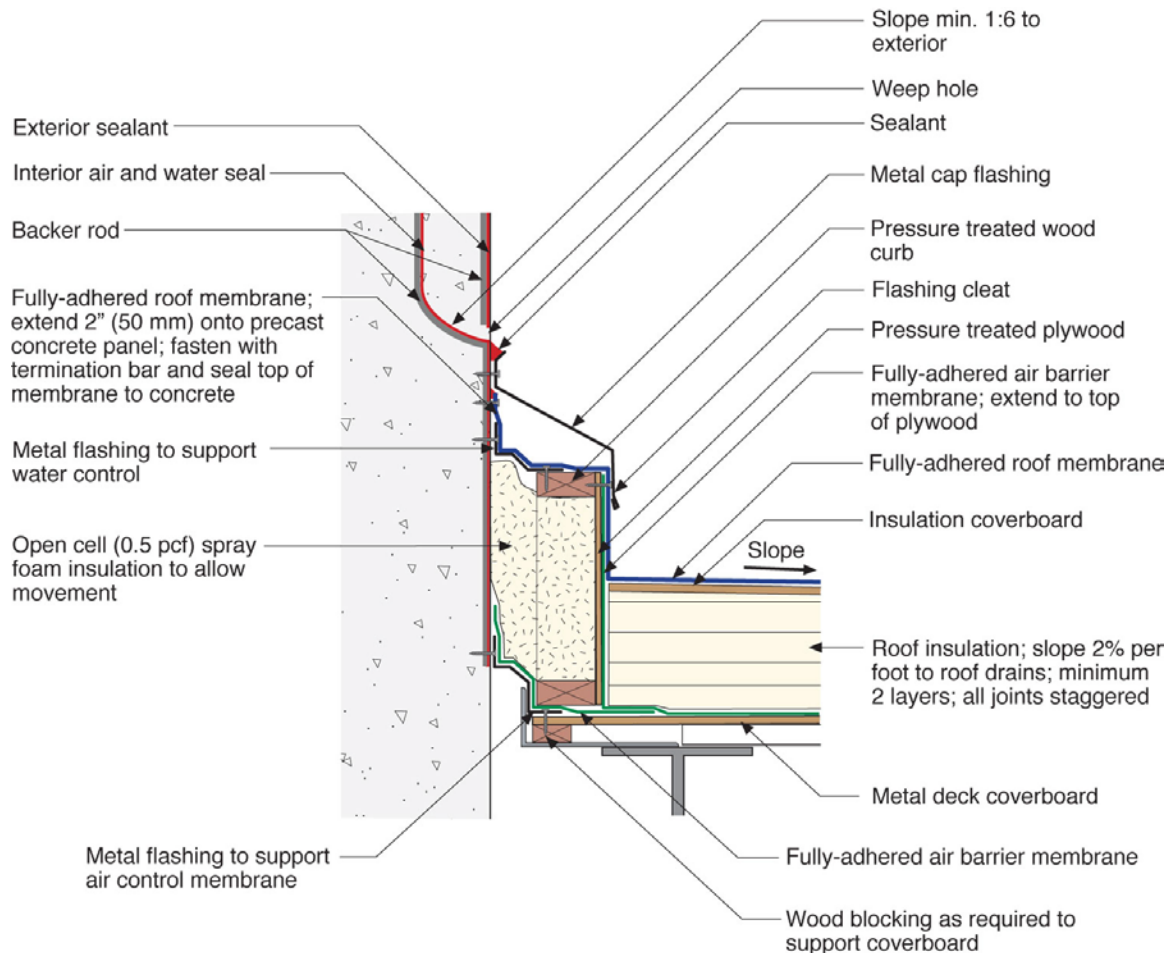


Figure 17: Low-slope roof to precast concrete wall connection.

Figure 17 shows one solution to the challenging transition from a stiff precast concrete wall to a flexible long-span steel roof such as might occur at a one-storey office attached to a high-bay warehouse or manufacturing facility. The transition must ensure water- and air-tightness while allowing for significant, often 50 mm (2 inches) or more differential vertical movement. Note the use of drained joints between the face-sealed perfect barrier roof and the back of the concrete wall, and the accommodation of drainage and airtightness at the joint. The thermal continuity of the connection is imperfect, and managed by increasing the length of the heat flow path through the concrete. More demanding applications would require a different approach to ensure continuity.



Figure 18: Weep hole in a drained two-stage joint

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Glossary

Adhesion

Property that describes a material's ability to bond to a surface physio-chemically or chemically.

Adhesive

A substance or compound used for bonding surfaces together, usually applied in the form of a liquid or paste. An adhesive and sealant or base coat may be the same material.

Adhesive Failure

Loss of adhesion of a material to the surface to which it is applied. Usually applied to a sealant line, floor finish, or coating. See Adhesion.

Adsorption

(1) Process in which fluid molecules are concentrated on a surface by chemical or physical forces or both; (2) surface adherence of a material in extracting one or more substances present in an atmosphere or mixture of gases and liquids, unaccompanied by physical or chemical change.

Aesthetic Joint

A groove cut into cladding system, often EIFS, precast, or stucco, that serves the function of decoration and/or to provide a starting or stopping point for finish coat application: Variants, Aesthetic Reveal

Air Control Layer (formerly Air Barrier)

The complete air control layer system is comprised of materials and assemblies, each with their own performance requirements. *See Air Barrier System.*

Air Barrier Material (Air Control Layer Material)

A material that has sufficiently low air permeance and adequate strength that it can be part of an air control layer system. Recommended maximum air permeance for a material is $0.02 \text{ l}/(\text{s}\cdot\text{m}^2)$ @ 75 Pa ($0.004 \text{ cfm}/\text{sf}$ @ 0.3" WC) when tested according to ASTM E 2178 or E 283. Vapour permeance is not a requirement.

Air Barrier System (Enclosure Air Control System)

Air control layers are three-dimensional systems of materials designed, constructed, and/or acting to control air flow across a building enclosure, or between a conditioned space and an unconditioned space. In multi-unit/townhouse/apartment construction an air control layer system should also separate the conditioned air from any given unit and adjacent units. The pressure boundary of the enclosure

should, by definition, be coincident with the plane of a functional air control layer system.

Air control layer systems are assembled from "materials" incorporated in "assemblies" (or "components" such as windows) that are interconnected to create "enclosures." Each of these three elements has measurable resistance to air flow. The minimum recommended resistance or air permeances for the three components are:

Material $0.02 \text{ l}/(\text{s}\cdot\text{m}^2) @ 75 \text{ Pa}$ ($0.004 \text{ cfm/sf @ } 0.3'' \text{ WC}$)

Assembly $0.20 \text{ l}/(\text{s}\cdot\text{m}^2) @ 75 \text{ Pa}$ ($0.04 \text{ cfm/sf @ } 0.3'' \text{ WC}$)

Enclosure $2.00 \text{ l}/(\text{s}\cdot\text{m}^2) @ 75 \text{ Pa}$ ($0.4 \text{ cfm/sf @ } 0.3'' \text{ WC}$)

Materials and assemblies that meet these performance requirements are said to be air control layer materials and air control layer assemblies. Air control layer materials incorporated in air control layer assemblies that in turn are interconnected to create enclosures are called air barrier systems (enclosure air control systems).

Air Leakage

Uncontrolled and/or unintended airflow through a building enclosure or between units of occupancy. Leakage from indoors to outdoors is known as exfiltration and leakage from outdoors to indoors is known as infiltration. Air leakage can cause indoor air quality problems, condensation, excess energy use, comfort complaints, and smoke transport.

Air Pressure Boundary

The air pressure boundary is the boundary (comprised of a series of planes to form a three dimensional boundary) that generates the largest pressure drop (usually much more than half the total) when the enclosure is subjected to a pressure difference.

Air Infiltration

Uncontrolled inward leakage of air (that may contain entrained water vapour) through cracks and insterstices in any building element and around windows and doors of a building, caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density.

Back wrapping

The carrying of EIFS mesh reinforcement and base coat around the ends of the insulation boards and terminating between the insulation and substrate. Typically

used 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.

Backer Rod

A resilient foam material (typically closed cell polyethylene, but maybe open-cell to allow curing of some sealants) of circular cross-section installed under compression in a joint to provide a backing, to control sealant joint depth, act as a bond breaker to prevent three-sided sealant adhesion, and provide an hour-glass contour of the finished sealant bead.

Barrier System or Perfect Barrier

The general term to describe a rain control approach that relies on the perfection of a single plane of material(s) to resist rain water penetration. Two sub-types, face-sealed and concealed barrier, are commonly used. See also Face-Sealed.

Base Coat

A compound used to embed and to cover the reinforcing fabric of an EIFS, depending on the system type. The base coat acts as the primary weatherproofing layer.

Bead

A line of sealant or adhesive. In glazing, an applied sealant in a joint such as caulking bead, heel bead, glazing bead, etc. Also a molding or stop used to hold glass or panels in position.

Beam

A structural supporting member that resists loads primarily in bending. May be vertical or horizontal and made of any material or composite.

Below Grade

The portion of a building that is below the line of the surrounding ground level.

Bond breaker

A tape, sheet, wax or liquid applied treatment that prevents adhesion on a designated surface. Usually used with sealant to ensure a proper joint. See also Backer Rod.

Building Enclosure

The elements of a building that act as the environmental separator between the interior environment and the exterior environment. Walls, windows roofs slabs, and basements are building enclosures. Note: The enclosure is a special type of

environmental separator. Environmental separators also exist within buildings as dividers between spaces with different environmental conditions.

Building Envelope

An earlier term for the Building Enclosure.

CAD Computer-aided design

Capillary action

The movement of water within the microscopic spaces of a porous material or between two adjoining hydrophilic materials due to the attractive force of surface tension. Only significant in gaps of much less than about 1/8" (3 mm), and grows exponentially in size as the gaps become much smaller. Pressures rise to over 1 psi in gaps of less than 1/1000" (0.03 mm).

Capillary Break

A hydrophobic material or non porous material (such as glass, plastic, or metal) or gap between parallel layers of material (often less than 1/16" or 1.5 mm) sufficient to stop capillary action between two porous materials.

Cap Flashing

A flashing overlapping the vertical leg of base flashing to prevent water from migrating behind the base flashing.

Caulking

Alternate term for sealant.

Cement Board

A rigid sheathing made of cement-bonded fibre-reinforced composites (typically glass or wood fibres are used as reinforcing). Cement board is moisture resistant and non-combustible.

CFM Cubic feet per minute

A unit of volumetric flow rate, often used as a metric of ventilation, airflow, or air leakage.

Cladding

A material or assembly that forms the exterior face of a wall. Examples of cladding include stucco, EIFS, metal panels, brick/stone veneer, wood siding, and vinyl siding.

Cold joint

A visible junction between two liquid applied materials, such as concrete or EIFS coating, caused by allowing one side to cure before the application of the second side.

Commissioning

A set of testing and inspections done prior to occupancy, which should note any problems that should be fixed immediately (fix and tune). Testing should include duct leakage, building enclosure leakage, air pressure relationships under all operating conditions, proper venting of all combustion appliances under all operating conditions, carbon monoxide output of all combustion appliances, and confirmation of airflow and refrigerant charge in the HVAC systems. Additionally, the homeowner/occupants should be educated about the correct operation and maintenance of the building and equipment.

Condensation

The change of state from vapour to liquid. A common factor in moisture damage. Occurs on surfaces, which must be cooler than the air containing vapour next to it. Vapour supply to the condensation surface is usually by airflow but can be by diffusion.

Conditioned Space

The part of the building that is designed to have controlled environmental conditions (particularly temperature) for the comfort of occupants or for other reasons particular to the use of the building.

Control joint

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

Concealed Barrier

An approach to enclosure rain control that employs a single waterproof barrier to rain penetration. The barrier is not on the exposed face of the assembly but concealed behind the cladding and other material layers, which reduces the amount of rainwater reaching the barrier. Drainage is by definition not required for good performance in this approach. A subset of perfect barrier approaches. See also Face-Seal, Drained, Rainscreen.

Corrosion

The deterioration of metal by chemical or electrochemical reaction resulting from exposure to weathering, moisture, chemicals or other agents or media.

Crack

The result of tensile or shear forces that exceed the strength of a material at a particular location resulting in a discontinuity with a high aspect ratio (length:width).

Cure

To develop the ultimate properties of a wet state material by a chemical process. Different than drying, which is not a chemical process, although drying is often a necessary part of a chemical process.

Delamination

A separation along a plane parallel to the surface.

Dehumidification

Removal of water vapour from air.

Diffusion

The movement of individual molecules through a material. The movement occurs because of concentration gradients (and to a much lesser degree) thermal gradients, independent of airflow. A mode of water vapour transport in building enclosures that is much slower than airflow.

DOE U.S. Department of Energy

Drainage Plane

Water repellent materials (building paper, housewrap, foam insulation, etc.) which are designed and constructed to drain water. They are interconnected with flashings, window and door openings, and other penetrations of the building enclosure to provide drainage of water to the exterior of the building. The materials that form the drainage plane overlap each other shingle fashion or are sealed so that water flow is downward and outward.

Drained

A building enclosure rain control strategy (or ground water control) that accepts that some water will penetrate the outer surface (the cladding, which “screens” rain) and removes this water back to the exterior by gravity drainage over a drainage plane, through a drainage gap, and exiting via flashing and weep holes. Many wall systems (lap siding, brick veneer) and sloped roof systems (metal, asphalt shingles) employ drained strategies. Also called Drainscreen. See also *Rainscreen, Drainscreen*

Drainscreen

An enclosure system that controls rain penetration using the drained approach. See also *Drained, Rainscreen, Pressure-Equalized Rainscreen*

Drip edge

A geometric feature provided in an exterior building surface to ensure that flowing water will drip free rather than be pulled back toward a vertical element due to surface tension or gravity. A drip groove is commonly employed in solid materials like concrete whereas a drip edge is used for thinner sheet materials.

Dry

To develop the ultimate properties of a wet state material solely by evaporation of volatile ingredients.

Durability

The capability of a building, assembly, component, product, or building to maintain serviceability over a specified time.

Efflorescence

The deposition of dissolved salts in the material (such as concrete or brick) being transported within water (usually by capillary action) on a visible surface after evaporation of the water.

End dam

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

End wrapping

In EIFS, the act of wrapping the reinforcement and base coat 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.

EPA U.S. Environmental Protection Agency

EPS Expanded polystyrene insulation

A common insulation (see expanded polystyrene insulation)

Expanded Polystyrene Insulation

A rigid cellular foamed plastic insulation material manufactured by expansion of polystyrene beads within a mould. This mould creates an open cell structure filled with air. EPS Type I is the most widely used insulation. Type I has a density of 1 lb /ft³ (16 kg/m³), Type II is a denser, more durable insulation of 1.5 lb /ft³ (24 kg/m³) density: *Variants*, EPS

Expansion Joint

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

External Insulation Finishing System

A system which combines exterior insulation and some type of stucco cladding for buildings. Based on rain control strategy, there are two types of EIFS available in the U.S.—perfect barrier face-sealed systems and drained systems: *Variants*, EIFS

Extruded Polystyrene Insulation

A rigid cellular foamed-plastic insulation material manufactured by extrusion of polystyrene in the presence of a blowing agent. The blowing agent creates a porous structure that resists liquid water penetration and vapour diffusion. The manufacturing process for XPS insulation results in a smooth surface skin. Typical density of 2 lb/ft³ (32 kg/m³) and R-value of 5 per inch (0.029 W/mK): *Variant*, XPS

Façade

Visible exterior face of a building.

Face-seal

A building enclosure rain control strategy that relies on the exterior face of the enclosure to act as a perfect barrier to rain penetration. This method typically relies on exposed sealants and durable materials to provide rain tight joints, and hence is highly reliant on workmanship, material quality and maintenance to achieve performance. Failure is defined as water penetration of the face. It is a sub-set of perfect barrier rain control strategies. See also Drained, Barrier Systems, Concealed Barrier, and Mass.

Fasteners

A general term describing a variety of screws, nails, rivets etc that are used for mechanically securing various components of a building.

Fiberglass-faced gypsum sheathing

Moisture resistant type of exterior gypsum sheathing. The gypsum core is silicone treated for water repellency and the glass mat applied to each face as reinforcement meeting the requirements of ASTM C1177.

Finish coat

The coating applied to the base coat to finish the lamina of an EIFS. The finish coat provides color, texture, water protection, dirt resistance and ultra violet ray resistance.

Fishmouth

A deficiency in the installation of membranes (roofing, self-adhering membranes, etc.) that results in a fold in the edge of the membrane, through which air and/or water can penetrate.

Flash set

The early hardening of stiffness in the working characteristics of a Portland cement paste, usually with the evolution of considerable heat. Stiffness cannot be dispelled nor the plasticity regained by further mixing without addition of water; also known as “quick set.”

Flashing

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

Floor Plan

A horizontal section draw showing the basic layout of a building, which includes placement of walls, windows and doors.

Framing member

Studs, joists, plates (tracks), bridging, bracing, and related accessories manufactured or supplied for wood or light gauge steel framing.

Grade Beam

A foundation wall that is cast at or just below the grade of the earth, most often associated with the deepened perimeter concrete section in slab-on-grade foundations.

Gum Lip

A method of sealing a flashing to a wall surface whereby the top edge of the flashing is bent outwards to form a sealant-filled reveal (typically at the vertical termination of a waterproof membrane).

Habitable Space

Building space intended for continual human occupancy. Such space generally includes areas used for living, sleeping, dining and cooking, but does not generally include bathrooms, toilets, hallways, storage areas, closets, or utility rooms.

Header

Framing members over windows, doors, or other openings. A beam placed perpendicular to joists and to which joists are nailed in framing for chimney, stairway, or other opening: *Variants*, Wood lintel

Housewrap

Any of the numerous artificial polymer rolled sheet goods designed to function as drainage planes, a class of sheathing membranes. Some are also used as part of an air barrier system. Can be made of spun-fiber polyolefin, perforated plastic films, or coated and micro-perforated polymers.

Hydrophobic

Materials that do not attract liquid water, they will force liquid water to form beads on their surface, act as capillary breaks and are non-hygroscopic.

Hygroscopic

Materials that interact with water vapour by adsorbing water vapour into their pore structure as a function of the relative humidity of the surrounding air.

Indoor Air

Air in a conditioned space.

IAQ Indoor air quality

Initial set

A time-related set caused by the hydration process of cement-based mixtures.

Insulating Sheathing

Non-structural insulating board products with varying R-values and a wide variation in vapour permeability and drainage characteristics. Materials include expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate (most often foil-faced), rigid fiberglass, and mineral wool.

Insulation

Thermal - Any material which significantly slows down or retards the flow or transfer of heat. Building insulation types are classified according to form (e.g loose-fill, batt, flexible, rigid, reflective, and foamed-in-place) or material (mineral fiber, organic fiber, foam plastic). All types are rated according to their ability to resist heat flow (R-Value or RSI): *Variants*, Thermal Insulation

Jamb

The vertical side or edge of a doorway, window, or other opening.

Joints

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 or assembly joint, often commonly (and imprecisely) referred to as an expansion joint. Control joints are surface cuts or intentional geometric features which control the location of shrinkage cracks. Construction joints are formed between successive building elements parts during construction work. See also Cold Joint.

Kiln-dried Lumber

Any lumber placed in a heated chamber or "shed" to reduce its moisture content to a specified range or average under controlled conditions. For softwood framing lumber, the moisture content of KD lumber is somewhat based on regional conventions but is most often an average of 12% by weight. In comparison, the moisture content of thoroughly air-dried softwood framing lumber is 15% to 20%.

Latent Heat

Change of enthalpy during a change of phase.

Lamina

Composite layer in EIFS that is installed over the insulation, comprised of the reinforcement, base coat and finish coat.

Low-E

Most often used in reference to a coating for high-performance windows, the "e" stands for emissivity which is the degree of efficiency. A thin metallic oxide coating increases the U-value and/or decreases the SHGC of the window by reducing heat flow from a warm(er) surface to a cold(er) glazing surface. The best location for the coating should be calculated but is often based on whether the primary heat flow control direction is from the inside out (heating climates) or the outside in (cooling climates).

Maintenance

A regular process of inspection, cleaning and minor repairs of buildings elements and exterior systems. Cleaning is for normal activities for those items as required on a regular basis, such as leaves from gutters and drains in the fall, and cleaning lint from dryer vents. Minor repairs encompass small projects that reinstate failed elements such as areas of cracked caulking or peeling paint.

Mastic

Heavy-consistency compound that may remain adhesive and pliable with age. Is typically an airtight waterproof compound applied to exterior walls and roof surfaces, or to provide a robust and durable air seal to air duct distribution systems.

Mechanical Ventilation

Controlled, purposeful introduction of outdoor air to the conditioned space using some mechanical contrivance such as a fan or bellows.

Membrane

A generic term relating to a variety of sheet goods used to control water, vapour or air movement.

Mock-Up

Full-scale but limited extent demonstration of a finished assembly, such as a window in a wall, a roof parapet, or washroom plumbing arrangement.

Mold

A type of fungus that is different from plants, animals and bacteria. Molds are decomposers of dead organic material such as leaves, wood and plants. Molds sometimes can infect living plants and animals. The spores and hair-like bodies of individual mold colonies are too small for us to see without a microscope. When a lot of mold is growing on a surface, it often appears black or green. The color of mold is influenced by the nutrient source and the age of the colony. Mold growing on fabric is called mildew: *Variants*, Mould

Oc On center: *Variants* o.c., O.C.

Occupiable Space

Any enclosed space inside the pressure boundary and intended for human activities, including but not limited to, all habitable spaces, toilets, closets, halls, storage and utility areas, and laundry areas: *Variants*, occupied space

OSB Oriented strand board

Outdoor Air

Air outside of the building: *Variants*, OA

Ozone

An oxygen chemical compound of the form O_3 instead of O_2 (common atmospheric oxygen). This 3-atom molecule is an even more active oxidizing agent than its more common 2-atom relative. At ground level, ozone is a pollutant and in the upper atmosphere it is a UV shield. Ozone's highly reactive nature tends to accelerate the breakdown of synthetic materials such as paints, plastics, and volatile organic compounds.

Pa Pascal

A metric unit of measurement of pressure, defined as a Newton per square metre. One inch of water column is equal to about 250 Pa.

Parapet Wall

A low wall around the perimeter that projects above the level of the top of the adjoining roof level.

Penetration

A hole passing through the building envelope in which ducts, pipes, wires, structural elements, and windows are run between inside and outside. Windows are also a penetration.

Perm See Vapour Permeance, Vapour Permeable, Vapour Impermeable

PEX Cross-linked polyethylene (PE) tubing: *Variants*, pex

Plywood

A wood product made of three or more layers of veneer joined with glue, and usually laid with the grain of adjoining plies at right angles.

Ponding

A condition where water stands on a roof, slab, or any other nominally horizontally surface for prolonged periods due to poor drainage and/or deflection of the surface.

Pot life

The duration of time that the wet state material remains workable after it has been mixed.

Pressure Boundary

The primary air enclosure boundary separating conditioned air and unconditioned air. Typically defined by the air barrier system.

Pressure-Equalized Rainscreen

A specific type of drained wall system that uses spatial compartmentalization, careful vent-to-air leakage ratios, and stiff compartment components to encourage short-term equalization of the drained cavity (also the air chamber) pressures with exterior wind pressures to reduce the net air pressure difference across the screen (or cladding). Such systems rely on effective drains to control rain, and if functional, merely reduce the rainwater that the drained system must accommodate. *See also Drained Rainscreen: Variants, PER*

Primer

A coating intended to prepare the surface of the substrate for the subsequent application of a paint, adhesive or adhered membrane.

Psychrometrics

The study of air and its energy and water vapour contents.

Punched Window

A window installed as a “punched” opening surrounded by cladding, as opposed to being arranged in vertical or horizontal strips.

PV Photovoltaic

Rainscreen

A building enclosure rain control strategy that accepts that some water will penetrate the outer surface (the cladding, which “screens” rain) and removes this water back to the exterior by gravity drainage over a drainage plane, through a drainage gap, and exiting via flashing and weep holes. It is another term for a Drained system, however, some use the term only for systems that have larger drainage gaps (e.g., 1/2") or just for systems that are also ventilated (a ventilated drained approach) or just for systems that attempt to pressure-equalize (a

Pressure-Equalized Rainscreen). *See also Drained, Drainscreen, Pressure-Equalized Rainscreen.*

Relative Humidity

The ratio (expressed as a percentage) of the amount of moisture within the air to the maximum amount of moisture that the air could possibly contain at a specific temperature.

R-value

Quantitative measure of an assembly or material resistance to heat flow for a unit temperature difference and a unit area. It is the reciprocal of the U-factor. The units for R-value are $\text{ft}^2 \text{ } ^\circ\text{F hr/Btu}$ (English) or $\text{m}^2 \text{ } ^\circ\text{K hr/W}$ (SI or metric). As R-value increases, conduction through an assembly or material decreases for the same temperature difference. As an example of the context in to which R-value should be placed, 25% to 40% of a typical buildings energy use can often be attributed to air infiltration, and air conditioning loads are often dominated by solar heat gain.

Radiation

A form of energy in electro-magnetic radiation. At normal temperatures, radiation is in the infra-red region of the spectrum, whereas solar radiation is at visible wavelengths. Controlling radiation is important to both heat transfer through porous insulations and through windows, as well as playing a significant role in daylighting and solar heating.

Water Control Layer or Rain Penetration Control Layer

The water control or rain penetration control layer is the continuous layer (comprised of one of several materials and formed into planes to form a three dimensional boundary) in an enclosure assembly that is designed, installed, or acts to form the rainwater boundary. In face-sealed perfect barrier systems, this is the exterior-most face of the enclosure. In concealed barrier perfect barrier systems it is a plane concealed behind the exterior face. In drained systems the water control layer is the drainage plane behind the drainage gap or drainage layer. In storage reservoir systems the rain penetration control is typically the innermost storage mass layer.

Rainwater Boundary

The rainwater boundary (comprised of one or several materials and formed into planes to create a three dimensional boundary) is the boundary beyond which rainwater is not intended to penetrate or beyond which damage can likely be expected to occur if penetration were to occur.

Rigid Insulation

Rigid board material that provides thermal resistance. Foam plastic such as expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate (polyiso) are commonly used. Polyurethane (PUR/PIR) may also be found.

Rough Opening

The opening in a wall into which a door, window, or other enclosure component is to be installed.

Saddle

The transition of small horizontal surfaces, such as the top of a balcony guardrail or parapet wall, with a vertical surface, such as a wall.

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.

Semi-rigid Insulation

Formed board material which provides thermal resistance comprised of mineral fibers. Mineral fiber insulation is normally used for its non-combustible properties and is typically comprised of glass or rock wool.

Sheathing

A material used to provide structural stiffness to the wall framing and to provide structural backing for the cladding and sheathing paper. Typical materials are OSB (oriented strand board), plywood, or various forms of gypsum board.

Sheathing Membrane

A generic term for a membrane layer that prevents the passage of liquid water (and possibly air and vapour) through vertical, drained surfaces. Asphalt-impregnated building papers and felts and polymeric housewraps are the most common products available, but peel and stick air-water-vapour barrier membranes, trowel applied air and water barriers, etc. are currently available. See also housewrap, drainage plane.

SHGC Solar heat gain coefficient

A metric of a glazing or windows ability to reduce solar heat gain, it is the ratio of the amount of heat transmitted to the interior to the total solar radiation incident on the exterior plane of the glazing or window. Exterior temperature has a small influence on the result, and large angles of incidence will result in lower SHGC than more normal angles.

Siding

The finish covering of the outside wall, whether made of horizontal weatherboards, vertical boards with battens, shingles, or other material.

SIP Structural Insulated Panels

Stucco

An exterior cladding formed in place on the wall made of inorganically bonded sand and small aggregate. Typically Portland cement-based, but with additives of lime, surfactants, water repellents, etc.

Stud

One of a series of wood or light steel vertical structural members placed as supporting elements in walls and partitions.

Subfluorescence

A potentially harmful accumulation of water-soluble salts that re-crystallize just beneath the masonry, stucco, or concrete surface as moisture in the wall evaporates leaving the salts behind.

Surfactant

An agent (e.g., detergent) that, when mixed with water, breaks the surface tension of water drops, thus enabling easier absorption of water through a material. Without surfactants, water would have a greater tendency to remain as drops on the surface of a given material.

TAB Testing, adjusting, and balancing

Thermal Bridge

A material with higher thermal conductivity transferring heat through an assembly with substantially lower thermal conductivity. For example, a steel stud in a wall will transfer more heat than the surrounding insulation, reducing the overall thermal control of the system. [see www.buildingscience.com BSI-005: A Bridge Too Far]

Thermal Boundary

The layer in a building enclosure that controls the transfer of energy (heat) between the interior and the exterior. It is a component of the building enclosure and it may, but does not have to align with the pressure boundary.

Thermal Control Layer

The layer in a building enclosure (comprised of one or several materials and formed into planes to create a three dimensional boundary) that is designed, installed, and/or acts to form the thermal boundary in an enclosure assembly. The latter may be partially penetrated by thermal conductive elements.

Through-Wall Flashing

Flashing that extends completely through a wall system. Designed and applied in combination with counter-flashings, to prevent water which may enter the wall above from proceeding downward in the wall or into a roof deck or roofing system: *Variants, Thru-Wall Flashing*

UA Heat loss coefficient (U value multiplied by area)

U-Value or U-factor

The thermal transmittance of a material or assembly (especially windows) Quantitative measure of the ease of heat flow expressed as an equivalent conductance per unit area and per unit temperature difference, the reciprocal of R-value. While building scientists will use R-values for measures of the resistance to heat flow for individual building materials, U-factor is usually used as a summary metric for the ease of heat transfer through building assemblies.

UL Underwriter's Laboratory

UV

Ultraviolet radiation (from the sun), which has a degrading effect on many membranes, coatings, and sealants.

Vapour Barrier

A material that has a permeance of 0.1 US perm or less. A vapour barrier is a material that is essentially vapour impermeable (e.g., metal, glass, thick plastics, unperforated epoxy paint). A vapour barrier is a Class I vapour control layer. The test procedure for classifying vapour barriers is ASTM E-96 Test Method A—the desiccant or dry cup method

Vapour Control Layer

The element (or elements) that is (or are) designed and installed in an assembly to control the movement of water by vapour diffusion.

Vapour Impermeable

Class I materials with a permeance of 0.1 US perm or less (rubber membranes, polyethylene film, glass, aluminum foil). A Class I vapour control layer. see *Vapour Barrier*.

Vapour Permeance

A layer property that describes the ease with which vapour molecules diffuse through it. It is defined as the quantity of vapour flow across a unit area that will flow through a unit thickness under a unit vapour pressure difference. It is to vapour diffusion what conductance is to heat transfer. The unit of measurement is typically the "perm" or "US perm" ($\text{gr}/\text{h}\cdot\text{ft}^2\cdot\text{in. Hg}$); in metric/SI units, it is stated in terms of $\text{ng}/(\text{s}\cdot\text{m}^2\cdot\text{Pa})$.

Vapour Permeable

Class IV materials with a permeance of greater than 10 US perms (most housewraps, building papers).

Vapour Permeance Classes

Test procedure for determining vapour permeance class is ASTM E-96 Test Method A (the desiccant or dry cup method).

Class I: Materials that have a permeance of 0.1 perm or less (Note: This is the definition of a "vapour barrier").

Class II: Materials that have a permeance of 1.0 perm or less and greater than 0.1 perm (Note: This is the definition of a "vapour retarder").

Class III: Materials that have a permeance of 10 perms or less and greater than 1.0 perm.

Class IV: Materials that have a permeance of greater than 10 perms.

Vapour Retarder

A vapour retarder is a Class II material that has a permeance of 1.0 perm or less and greater than 0.1 perm. A vapour retarder is a material that is vapour semi-impermeable. A vapour retarder is a Class II vapour control layer. The test procedure for classifying vapour retarders is ASTM E-96 Test Method A—the desiccant or dry cup method.

Vapour Semi-Impermeable

Class II materials with a permeance of 1.0 US perm or less and greater than 0.1 US perm (e.g., oil-based paints, most vinyl coverings, quality concrete, thick wood members).

Vapour Semi-Permeable

Class III materials with a permeance of 10 US perms or less and greater than 1.0 US perm (e.g., plywood, OSB, most latex-based paints).

Ventilation

The intentional flow of air into occupied spaces or behind cladding/roofing to move heat and moisture in a desirable manner.

VOC volatile organic compounds

WRB water resistant barrier

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:

Variants, Drainage plane

Weep hole

An opening placed in a wall or window assembly to permit the escape of liquid water from within the assembly. Weep holes can also act as vents.

Wind Washing

The phenomenon of air movement driven by wind pressures, wind passing through or behind the thermal insulation within enclosures, causing significant loss of heat flow control and potentially causing condensation. Typically occurs at exposed building edges, such as at the outside corners and roof eaves because of the large pressure gradients at these locations. This can be thought of as the “wind blowing through the insulating sweater” effect.

Window

A manufactured assembly of a frame, sash, glazing and necessary hardware, made to fit an opening in a wall. Windows are comprised of:

- Window sill: horizontal member at the base of a window opening.
- Window head: horizontal member at the top of a window opening.
- Window jamb: either of the vertical members at the sides of a window opening.
- Mullion: A vertical member between the glazed units.
- Rail: A horizontal member between the glazed units.
- Glazing: The glass portion of the window.
- IGU: Insulated glazing unit. Double or triple panes of glass sealed together to provide insulation value. The still gas between the panes acts as the insulation.
- Condensation track: a channel at the interior sill level of the window intended to intercept small amounts of water condensing on the interior surface of the glass.

Window Frame

The stationary part of a window unit; the window sash fits into the window frame.

WUFI Wärme Und Feuchte Instationär: a modeling program developed by Dr Hartwig Kuenzel of the Fraunhofer Institut for BauPhysik for simulating one-dimensional dynamic heat and moisture transfer through building enclosure

XPS Extruded polystyrene

A type of closed-cell foam plastic insulation.

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