

Maintenance and Inspection Manual for Precast Concrete Building Enclosures

REV. JANUARY 2020



About CPCI

The Canadian Precast/Prestressed Concrete Institute (CPCI) is the body of knowledge for the precast concrete industry in Canada. CPCI represents 37 manufacturing members with a total of 57 plants, along with associate, professional and student members throughout Canada. The CPCI manufacturing members have over 350,000 sq. m of plant space available for producing the precast concrete you require for your project. The inherent benefits of precast prestressed concrete make it the best choice for many projects. Fast production, delivery and erection saves time and money. The creative dimensions of shape, texture, colour and pattern produce attractive buildings. Quality and durability means unsurpassed low maintenance and life-time cost effectiveness.

CPCI Members have the facilities, the people, the products and the desire to make a meaningful contribution to the planning, completion and sustainability of your next project.



Prepared by: RDH Building Science Inc.

167 Lexington Court, Unit 5
Waterloo, Ontario
Canada N2J 4R9

Primary Author:
John Straube, Ph.D., P.Eng.

DISCLAIMER: Substantial effort has been made to ensure that all data and information in this publication is accurate. RDH Building Science Inc. and the Canadian Precast/Prestressed Concrete Institute cannot accept responsibility of any errors or oversights in the use of material or in the preparation of architectural or engineering plans. The design professional must recognize that no design guide can substitute for experienced engineering and professional judgment. This publication is intended for use by professional personnel competent to evaluate the significance and limitations of its contents and able to accept responsibility for the application of the material it contains. Users are encouraged to offer comments to RDH Building Science Inc. on the content and suggestions for improvement. Questions concerning the source and derivation of any material in the design guide should be directed to RDH Building Science Inc.

About this Manual

The Canadian Precast/Prestressed Concrete Institute (CPCI) prepared this manual to assist building owners and maintenance staff in planning the maintenance of precast concrete cladding on buildings. Periodic maintenance will allow the precast system to perform as designed and extend the service life of the precast concrete enclosure. The recommendations and procedures included in this manual will also serve as a resource for architects, engineers, and service contractors involved in the periodic repair and renewal of precast concrete enclosure system components. The information provided on common failures and repair methodology should also allow the designers of new precast enclosures to avoid these pitfalls.

The first section of the guide introduces functional requirements of the building enclosure in its main role as an environmental separator. Included in this is a discussion of the different common precast enclosure technologies which will serve as an identification guide for building owners and operators.

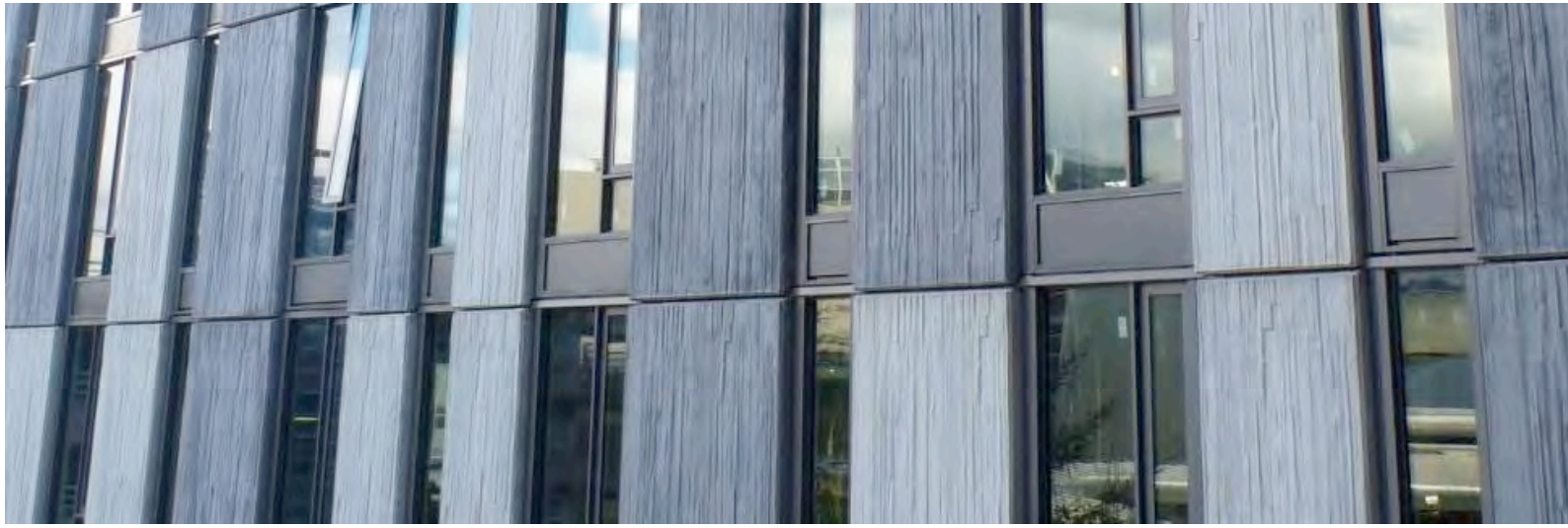
The second section identifies the maintenance requirements of the common type of precast enclosure systems and suggested procedures for inspection. Photographs and drawings of the systems and potential maintenance issues are provided as a visual reference for inspections. **Beyond descriptions of damage that may lead to premature degradation of the concrete panel or panel attachments, the manual does not include information on the assessment of the structural integrity of the precast elements and main building structure. For structural inspections, the owner is advised to retain the services of a licensed structural engineer experienced in the design and construction of precast concrete systems.**

The third section presents example inspection and maintenance checklists that can form the basic maintenance documentation for a precast concrete enclosure.

In the final section of the guide, a collection of resources on more specific topics and the contact information for the CPCI Technical Support help desk has been included.

Contents

1.0 Introduction	4
<i>What every good building enclosure should do</i>	4
<i>Identification of common types of precast facades</i>	6
2.0 Inspection and Maintenance Requirements	13
<i>What Kind of Maintenance is Required?</i>	13
<i>General Maintenance and Inspection Requirements for Precast Enclosures</i>	14
<i>Required Inspection and Maintenance By Component</i>	17
3.0 Planning and Documentation	28
<i>Sample Inspection and Maintenance Plan for Exterior Precast Enclosures</i>	29
<i>Example Precast Enclosure Inspection Checklist – by Component</i>	31
4.0 Resources and References	37



1.0 Introduction

Precast concrete provides many advantages over other systems which make precast building enclosures durable, long-lasting systems with low maintenance requirements both outside and inside the building.

Concrete offers excellent resistance to weathering and corrosion in most climates. High-density, large format precast concrete panels are, by themselves, resistant to air and water penetration. Provided that panel joints are well-designed and properly maintained, the system, as a whole, offers excellent protection from climatic conditions.

In buildings where the panels are used as the interior finish, a precast concrete wall panel offers a smooth, dense surface that may be easily cleaned thereby minimizing the collection of dirt and contaminants. Precast concrete also does not impact the occupants' indoor air quality as it does not off-gas.

Nevertheless, given the environmental exposure that all buildings must endure, all enclosure systems require some maintenance activity over time. This manual examines the expected maintenance requirements that are specific to precast concrete enclosure systems. The following section explains how typical precast concrete enclosures are designed to function so that all readers have a common background when reviewing the maintenance requirements for their building.

What Every Good Building Enclosure Should Do

The following section sets out the purpose and function of the building enclosure to ensure that the role of all components is well understood. This information is important for planning maintenance activities but critical when making plans for major repair or renewal of building enclosure components.

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 facade.

Unlike the superstructure or the service systems of buildings, the enclosure is nearly 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.

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 environmental 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 the 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 and this is true for many precast enclosures where some components such as secondary seals and structural connections are hidden behind other finish materials.

The **support function** is of primary importance. Without structural integrity, the remaining functions are of no use. The precast 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, 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 providing the finish function.

As the most important of the control functions, rain penetration deserves special attention in all designs and is a focus of the maintenance recommendations provided in the following sections.

Identification of Common Types of Precast Facades

While most wall assemblies that rely on concrete as the exposed finish have similar maintenance requirements (for example, cast-in-place concrete, tilt-up panel construction, and precast elements), there are two main types of precast facades that are likely to be encountered. This section describes the difference between “face-sealed” and “drained” systems and explains how each system handles rain water penetration and air flow, and the different approaches to maintenance for each system.

It should be noted that maintenance or renewal activities on older buildings may have switched all or part of the enclosure from one control approach to the other.

Face-sealed Facades

A face-sealed facade is a type of “perfect barrier” approach to rain and air control. Control of rain penetration occurs at the exterior “face” of the system using the concrete panels and (typically) sealant joints. In this approach, there is no secondary layer of rain or water control hidden deeper in the assembly – all important elements are visible at the exterior face. The face-sealed approach is common for some types of glazing and panel systems as illustrated in Figures 1 and 2.

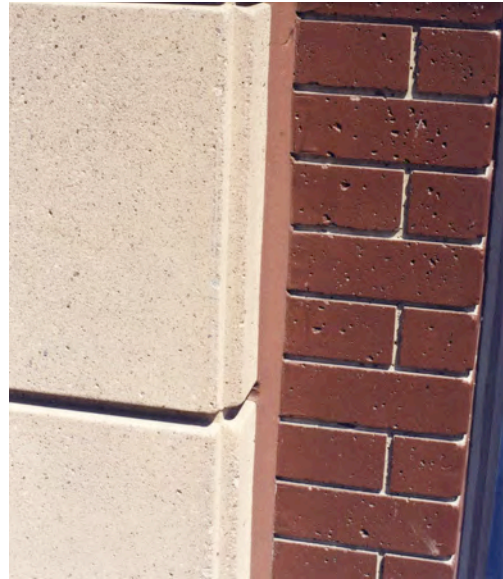


Figure 1: Identification – In a face-sealed system, there will be no visible drainage holes or tubes in the exterior sealant and no visible flashing components between panels. The sealant shown on the left is clearly failing. The photo to the right shows acceptable sealant.

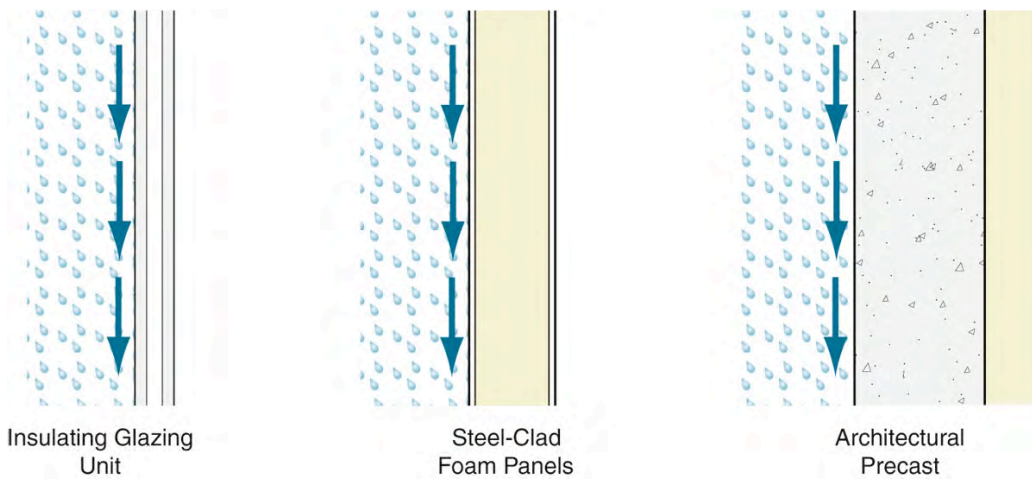


Figure 2: Face-sealed perfect barrier walls.

Precast panels are reinforced for crack control and typically made of high-quality concrete with low water-to-cement ratios and very low water absorption. 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 this.¹ However, the polymer sealants between panels and between panels and other components are susceptible to workmanship flaws during construction and slow deterioration over time.

Definition

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.

In many older precast buildings, the joints between panels and around penetrations (especially windows) and the interfaces with adjacent enclosure systems are most likely to have been made with perfect-barrier sealants – a single, exposed line of rain and air control. Newer precast systems incorporate drained joints between panels and between panels and other enclosure elements. See discussion in “Drained Facades” below.

Drained Facades

To accommodate the joints between panels, the concept of a drained joint, or two-stage seal has been promoted for almost 50 years and widely used with great success for almost as long.

The interior air seal / water 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. It is now recommended that two-stage joints have the interior air seal/drainage plane applied from the exterior (see Figures 3 and 4) to help ensure continuity of both the air and water seal.

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



Figure 3: Identification – A weephole in a Two-stage or Drained-Joint system allows for drainage from the inner seal to the exterior. Note the good condition of the sealant visible.

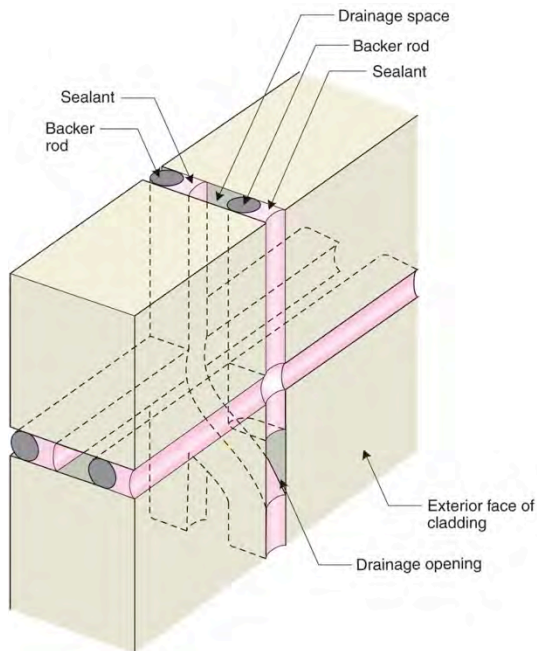


Figure 4: Three-dimensional representation of a Two-Stage Drained Joint oriented both vertically and horizontally between precast panels.

An alternate approach to introduce drainage in some precast wall systems is the inclusion of a drainage plane behind the precast panel. This is unnecessary, however some designers have chosen to ignore the unique properties of precast concrete, and design precast systems that attempt to mimic the drained screen rain control approach of brick, stone, or stucco veneers.

In practice, it can be difficult to properly execute a full drainage plane behind thick, architectural precast panels. The many connections (perhaps thousands over a large building) are difficult to access and require penetrations through the drainage plane that need to be sealed after panel installation. Careful planning can help but any deviation in the system of connections requires new penetrations and additional effort to ensure the drainage plane is restored. In addition, the air gap behind the architectural precast can create a path for interior air to flow laterally. As the precast concrete is both an air and vapour barrier, air from the interior may be able to enter the 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 has been observed (by the author) to collect thousands of litres of condensation during cold weather.

Definition

Drained Screen

A building enclosure rain control strategy that accepts that some water will penetrate the outer surface (the cladding, which “screens” rain) and directs this water back to the exterior by gravity drainage over a drainage plane, through a drainage gap, and exiting via flashing and weep holes. Also called Rainscreen.

It should be noted that the drained screen approach can be used in systems which allow a full drainage plane and air barrier to be installed over all supporting structure and made continuous **before the precast panels are installed**. There are some instances where these systems 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 effectively built as drained systems (Figure 5). This system can also be used on shear walls and elevator shafts with pockets provided in the cast in place concrete.



Figure 5: Identification – A drained precast enclosure system using small, handset precast panels. In this system, joints between panels are generally not sealed and flashing elements may be visible at floor levels and around window openings.

A Note on Veneer Panels

Veneer panels are comprised of a precast concrete backup panel with a veneer material (stone, metal, etc.) attached to the face. The clay brick veneer shown in Figure 6 is a common choice.

The approach to rain penetration control may vary in the veneer panels from a perfect barrier with drained joints (more common for new construction) and a concealed perfect barrier approach (i.e., panels and single line of sealant inset in the joint behind the veneer), which may be found in older construction. Minor repair and planned replacement of the sealant joints may have changed the approach to rain penetration control (in some cases by sealing intentional drainage holes). In some cases (see Figure 7 below) replacement of sealant at the exterior face of the wall (i.e., at the veneer) and at windows interfaces may prevent drainage from panel joints and the interface between the veneer and the precast panel (inadvertently changing the rain control from drained screen to face-sealed.)

When dealing with older buildings, especially those having a history of water ingress problems, the original design and later maintenance records should be consulted before a new maintenance plan is initiated.



Figure 6: Identification – Veneer panels during installation.

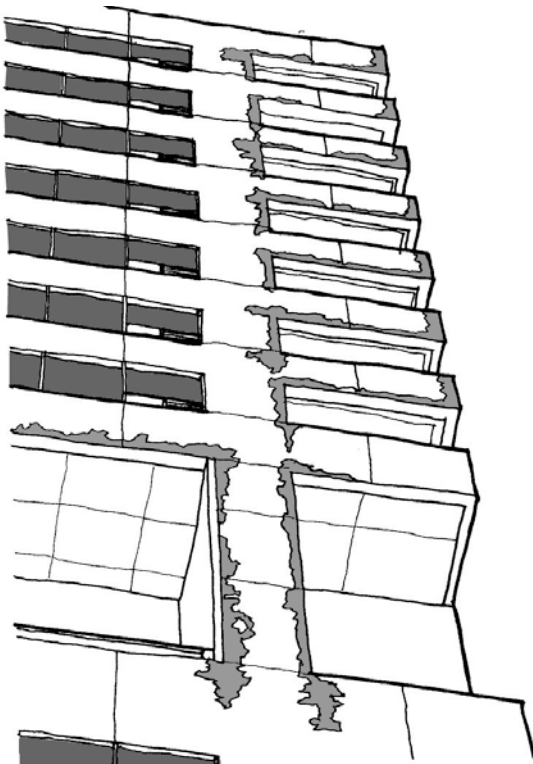


Figure 7: Older veneer panels may have gaps between the veneer units and the precast panel substrate that allow water penetration behind the veneer and joint sealant. The resulting water penetration can cause staining at the edges and damage to the veneer and interior finishes. New systems bond the veneer integrally with the concrete and do not typically exhibit this distress.

The following section uses these types of precast facades to describe the inspection and maintenance requirements of each.



2.0 Inspection and Maintenance Requirements

What Kind of Maintenance is Required?

Maintenance is defined as work to repair deficiencies that develop during the service life of a building component. This work is associated with the normal “wear and tear” on a building rather than work to improve a building – e.g., through renovation. The “deficiencies” addressed by maintenance include issues related to both the functional performance of the enclosure (as described in Section 1 earlier) and also the aesthetic performance – how the building looks over time.

As the service life of buildings and their enclosure components typically span decades (and sometimes centuries), it is helpful to consider maintenance work in several time scales. We can divide maintenance activity into several types:²

- **Corrective Maintenance** – Unscheduled maintenance repairs to correct deficiencies during the year in which they occur. Corrective maintenance is an ongoing task and typically involves small-scale, routine activity.
- **Preventive Maintenance** – Scheduled inspections and servicing undertaken to achieve the expected service life of the building and building components. These preventative maintenance activities include adjustments, localized repairs, and (if required) component replacement to prevent large-scale failures and premature replacement of other enclosure components. These activities are conducted with a frequency of one year or less, and typically demand modest investments of time and money. Preventative activity, when deemed essential, may reduce the long-term operating cost of the building.
- **Recurring Maintenance** – Preventive maintenance activities that recur on a periodic and scheduled cycle of greater than one year, but typically less than ten years.

² These definitions are adapted from the U.S. Department of the Interior’s guide “Common Definitions for Maintenance and Construction Terms”.

- **Component Renewal** – Preventive maintenance activities that recur on a periodic and scheduled cycle of greater than ten years. An example of this type of activity would be the replacement of sealant material that, as a component, has a shorter expected service life than the system as a whole.
- **Emergency Maintenance** – Maintenance activities that are unscheduled repairs, to correct an emergency need to prevent injury, loss of property, or return an asset to service. These repairs are initiated within a very short time period from when the need is identified, usually within hours.

With the obvious exception of Emergency Maintenance, the goals of the activities described above are to:

- Maintain an acceptable level of performance
- Delay the time and expense of renewal or major renovation
- Preserve, or even enhance, the value of the building asset over time

Corrective and Preventative Maintenance will typically be performed by facility staff, building operators, or building owners. Larger buildings may employ service contractors for this maintenance work.

Recurring Maintenance and Component Renewal activities are generally performed by service contractors and in some cases may include engineering and/or contracted Architectural and Engineering (A&E) services that support planning, design, and execution of maintenance activities.

General Maintenance and Inspection Requirements for Precast Enclosures

All building enclosures need periodic condition assessments by building maintenance staff. The frequency of these assessments depends greatly on the types of cladding and other materials used; the exposure of the building to rain, wind, pollution, and other environmental factors; the risks and consequences of failure; and, of course, on the preferences of the building owner. Different elevations of the building may be inspected at different time intervals to respond to the variables listed above.

Definition

Condition Assessment

Periodic inspection by qualified personnel to fully determine and document the condition of a constructed asset and identify maintenance needs.

Precast enclosure systems can be expected to perform for a long service life with little or no significant change from their original specifications. It is, however, recommended that at a minimum the following maintenance and inspection tasks be performed on an annual basis.

1. General Cleaning

The surface of precast panels, like the surface of many other cladding materials (e.g. stone, light-coloured brick, etc.) is susceptible to dirt accumulation and staining even when some surface treatment is used. Glass, although non-absorbent, is typically washed at intervals of six months to two years.

In normal building maintenance, care should be taken to avoid common sources of staining:

- Run-off water and cleaning agents from window cleaning
- Leakage from roof- or wall-mounted mechanical units
- Salts used in snow removal at grade level
- Discharge or exhaust from mechanical and laundry vents

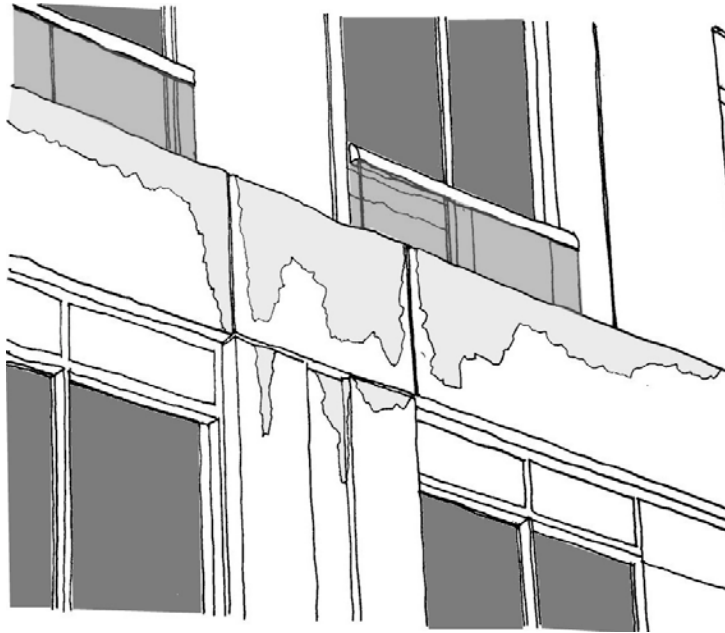


Figure 8: Exposed concrete surfaces may be stained by atmospheric pollution, biological sources, and leaching of chemicals from other adjacent building materials.

To preserve the aesthetic properties of the original surface, cleaning should be conducted as required based on visual inspections. The body of the precast panels should be washed when the surface of the panels has become discoloured sufficiently to be objectionable to the owners or tenants. This can be done on an elevation by elevation basis depending on the extent and level of staining. The following procedure is recommended for concrete surfaces that do not have special coatings:

1. Wet the surrounding concrete using clean water to prevent wash water (containing detergents or chemicals) from being absorbed.

2. Pressure wash the exterior surface, taking care to avoid direct spray on windows and panel joint material – spray away from windows and joints rather than directly towards them.

Note: If finishes or sealers have been applied to the exterior surface, or if pigment was used in the manufacture of the precast panels, careful testing of the cleaning method, including cleaning treatments should be performed in a small inconspicuous area prior to commencing work on the entire area.

3. For buildings that have not been cleaned frequently or that are subjected to harsh environmental conditions, acidic treatment or grit-type cleaners may be used. A mild solution of Trisodium Phosphate (TSP) will remove most stubborn staining.

Note: Some cleaning products may be subject to special regulations regarding time of use and clean up procedures. Test the cleaning procedure on a sample to ensure that the precast panels will not be damaged.

For more specific information on removing specific stains from concrete, see “Removing Stains and Cleaning Concrete Surfaces” (IS214), published by the Portland Cement Association (www.cement.org).

2. General Condition Assessment

The purpose of a condition assessment is to identify any changes from the initial design and as-built condition or the previously recorded condition assessments, and to ensure that the building enclosure continues to perform as designed and satisfy the owner’s service requirements. For precast enclosures, an annual visual assessment conducted from the ground with the use of binoculars is typically all that is needed. As various components such as joint sealant and window systems come close to the end of their expected service life, an assessment conducted from a swing-stage or elevated platform is warranted.

Ensure that adequate safety measures are taken when performing maintenance and repair activities on the exterior walls from elevated work platforms.

It is recommended that all signs of deterioration of the panels, sealant joints, or interfaces with other enclosure elements be documented as part of these condition assessments. Observe and record (photographs) the condition of building elements (particularly those that are part of the rain water management system, such as roofing, parapets, balconies, and overhangs) whose failure or gradual loss of performance could affect the future

performance of the precast system and the enclosure system as a whole. All of this information should be considered when making long term repair and maintenance plans.

The “Planning and Documentation” section of this manual provides an example checklist that can be used to structure these condition assessments. More information is provided in the following section on the inspection of, and maintenance for, specific components of the precast enclosure system.

Required Inspection and Maintenance by Component

There are several key components of a precast enclosure system that should be inspected on a regular basis and may need maintenance either within a year as preventative action or as component renewal. A description of the maintenance required and suggested timeframes for inspection have also been included.

Precast Concrete Units

Other than the periodic cleaning recommended above, very little in the way of maintenance is required for precast concrete panels. There are, however, several issues that may occur with precast panels over the service life of the enclosure. The most common issues are discussed below.



Figure 9: Example of stress fracture pattern

While rare, fractures (Figure 9) may occur over the service life of the building due to movement of the panel system or long-term 'creep' of the building structure (one or more panels bearing on one another). If there is significant damage, the fractured panel may need to be replaced. This is an expensive and long-term option. In many cases, the damaged panel may be located out of view and not of immediate concern. However, the fracture should be sealed immediately to prevent ingress of water that may lead to further damage. As the force causing the fracture may be active, the panel location should also be noted in the condition assessment and monitored in future assessments. The force causing the fracture may also be reduced or eliminated by grinding or sawing the joint if the panels are in direct contact with one another. Evidence of spalling (detachment of large concrete pieces) may be a potential life safety issue and require immediate repair.

Cracking of precast panels should always be recorded in the condition assessment and an estimate (preferably a measurement) of the crack width should be noted so that any "movement" – widening or lengthening – of the crack can be determined.

Cracks that are not moving (or "progressing") can be sealed with a quality sealant after proper surface preparation (follow sealant manufacturer's instructions). Deep cracks and any cracks that are moving should be examined and suitable repair methods should be identified by a structural engineer.

Thermal movements of the enclosure components or movement of the building structure can occasionally create cracking or distress where panels meet, or at their metal connections. It is recommended that a structural engineer investigate all signs of distress related to movement.



Figure 10: A fractured panel sealed to prevent water ingress. If a structural engineer assesses this panel to be safe, it will remain a visual issue but further damage can be mitigated by sealing the cracks, allowing for continued performance of the panel. Cleaning of the panel prior to sealing will greatly reduce the visual issues, but rarely totally eliminate them.

Chipping of panels, especially at exposed corners can be caused by vehicles, snow clearing and maintenance equipment (Figure 11). Although an aesthetic concern, there is usually no direct impact on the functional performance of the panel. Repair of this damage may be possible by grinding, or reshaping of the edge with an appropriate cementitious patching compound. The colour of the patching compound can be adjusted to match the colour of the panel and reduce the visual impact of the patched area. Bollards or similar mechanical barriers are often provided in new design, or retrofit to existing, to avoid this type of damage.



Figure 11: Chipping of panel edges. Physical impact can lead to damage to panel edges, especially at corners (as pictured on left), and where the concrete has been formed into a sharp edge for aesthetic or functional reasons. Careful patching and cleaning, as shown in the photo on the right, can fix such damage.

Panel Attachment to Main Structure

Large-format precast panels are attached to the main building structure with embedded metal components. **A structural engineer (having experience with precast concrete panel systems) should be retained to define the required frequency of inspection and develop an inspection plan that will verify the function, freedom of movement, and condition of connections for the subject building.**

In most cases, structural connections are not visible without removal of the interior finish. Original shop drawings, if available, often will accurately locate the structural embeds that receive the connections.

The number and size of openings can therefore vary significantly, and the cost will vary accordingly. The selection of the number and type of openings inspected will depend heavily on climate, exposure, corrosion protection of the connectors, client risk concerns, past inspections, and historical performance.

An important criteria for assessing the intensity and frequency of inspection is the type of precast wall panel. Drained precast systems expose the connectors to more water more often and may require more frequent inspections. Connections of double-wythe insulated panels to the structure are entirely within the enclosure and require the same intensity and frequency of inspection as structural steel connections within the building. Architectural precast panels with connections embedded in spray foam have become more common; while this foam layer protects the connection from both condensation and leaking water, it also hides the connection from inspection. Inspections will require this foam to be cut away and reapplied. Until further experience and consensus is developed, an inspection interval of 10 to 25 years is suggested for architectural precast panel connections.

The inspection should allow the structural engineer to categorize the level of damage along with degree of risk posed and action required, such as “Significant loss of section, dangerous condition – immediate action required”, or “Corrosion inhibits panel expansion, repair necessary as part of building renewal”, or “Slight surface corrosion, monitor progress – inspect again in 10 years”.



Figure 11: Panel attachments at a typical exterior corner. For the structural system, the inspection should include a visual inspection of all structural components by a structural engineer experienced in the design and construction of precast concrete structures. This connection, photo on the left, is not well protected from corrosion, and hence would require more frequent inspections than the industry recommended hot-dip galvanized connection seen in the photo on the right.

To access the backside of the precast, the structural engineer must list the locations where exploratory openings are necessary; the exploratory openings must be made even if there are no signs of damage. The objective of the openings is to verify the condition of the structural connections. Hence, the openings must allow verification of the conditions of all the materials and components that could pose as a life-safety risk to persons, namely fasteners, anchors, headers, etc.

In the vast majority of cases, a visual inspection confirming the connection is appropriate for its purpose (sized for the load, designed to allow or restrain movement) and in good condition. Scraping any surface rust to confirm depth of corrosion and remaining section would be a minimum level of effort for any connection found in less than pristine condition. If necessary, samples can be taken and sent to a laboratory for further analysis. Observations of the presence of signs of past or current wetting or wetting mechanisms should be recorded.

Joints for Face-sealed Facades

All joint sealants may require inspection, maintenance and repair. For face-sealed facades, the exposed joint sealants are the only line of defense against water intrusion and so regular, rigorous evaluation of the joint sealant is warranted.

Potential maintenance issues are water leakage through the joint, visible separation of the sealant from the concrete, and cracking or tearing of the sealant. Figure 12 below explains common types of sealant failures.

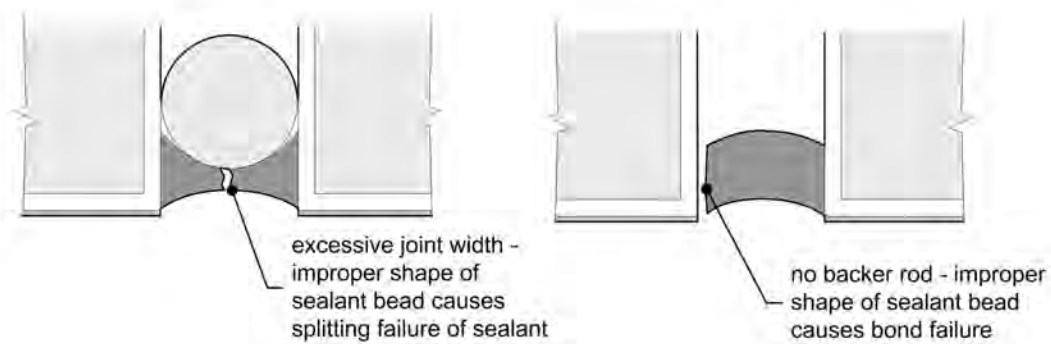


Figure 12: Common Types of Sealant Failure (Straube and Burnett. *Building Science for Building Enclosures*. Building Science Press, Westford 2005)

Sealant deterioration can generally be detected through visual inspection long before joints have totally failed and allow water passage. Building owners and managers should keep accurate records of when the exterior sealants were installed, the expected useful service life of the sealant according to the sealant manufacturer, and the time, nature, and results of each inspection during service.

An initial post-construction inspection should be undertaken as a check on the installation quality. Subsequent annual inspections should then be conducted. In many cases, the annual evaluation can be undertaken (using binoculars) from the ground and the roof. Once repeated or extensive failures of the sealants have been recorded or the sealants have reached 75% of their predicted useful service life according to the sealant manufacturer, a more extensive evaluation should be performed, including the use of swing stages or access platforms to adequately observe the building sealant joints. Contact the sealant manufacturer for more information about sealant service life and condition assessment.

Figure 14 shows details of a well-designed, flexible sealant-on-backer rod seal. The following should be noted:

- A backer rod of closed-cell polyethylene foam should be used (use of other backer rod materials may not prevent the sealant from adhering to the backer rod). The backer rod should be sufficiently compressed in the joint to ensure that it will remain in place during application of the sealant. The sealant is to be shaped by, but not bonded to, the backer rod.

- Surfaces or substrates to which the sealant will adhere must be clean and sound. The surfaces must be capable of accepting sealant adhesion. For example, sealants do not bond well to synthetic waterproof coatings because these coatings are designed to avoid dirt collection, water absorption, graffiti, etc.
- The sealant should be applied and shaped as shown in Figure 14. The sealant should be tooled in a concave form to ensure compaction and good contact, to create a surface skin, and to produce an hour-glass shape. The hour-glass shape helps ensure that the stress in the sealant is greatest in the middle and least at the bond surface. The sealant should be sufficiently flexible, strong, and durable to allow the necessary movement under all climatic conditions.

It is important that the bond contact dimension be no less than half the width of the joint to be sealed. In other words, if J is the design joint width (Figure 14), then the dimension of the sealant contact to the precast should be greater than or equal to $J/2$. Although a 2:1 ratio of depth to bond dimension is considered ideal by leading sealant manufacturers the minimum depth of the sealant must also be controlled, to about 6 mm.

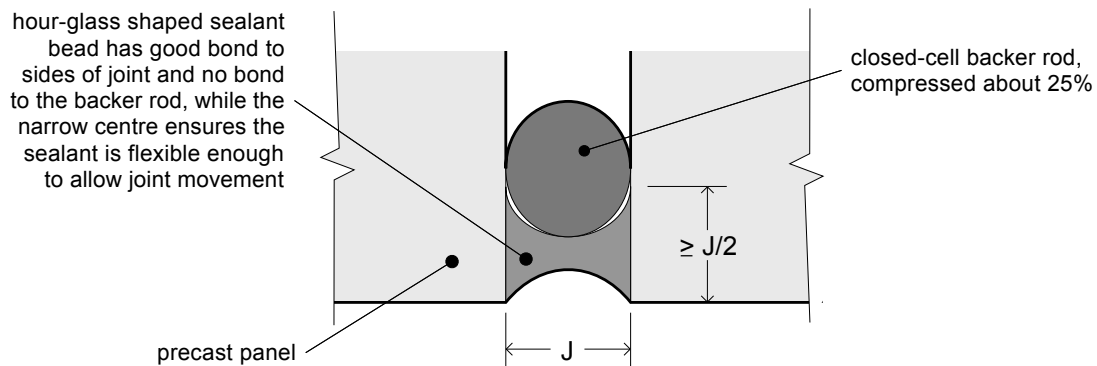


Figure 13: Typical Sealant and Backer Rod Joint (Straube and Burnett. *Building Science for Building Enclosures*. Building Science Press, Westford 2005)

Installation procedures should follow the specifications of the sealant manufacturer and can be expected to vary from material-to-material and from season-to-season. Sealants should not be installed during extremes of heat or cold. Installation quality will be best at average seasonal temperatures. See Figure 14.

Although some minor repair can be performed by maintenance staff on an annual basis, this work should be limited to remedial work between replacements. An experienced service contractor should be retained for surface preparation and installation of joint sealants.

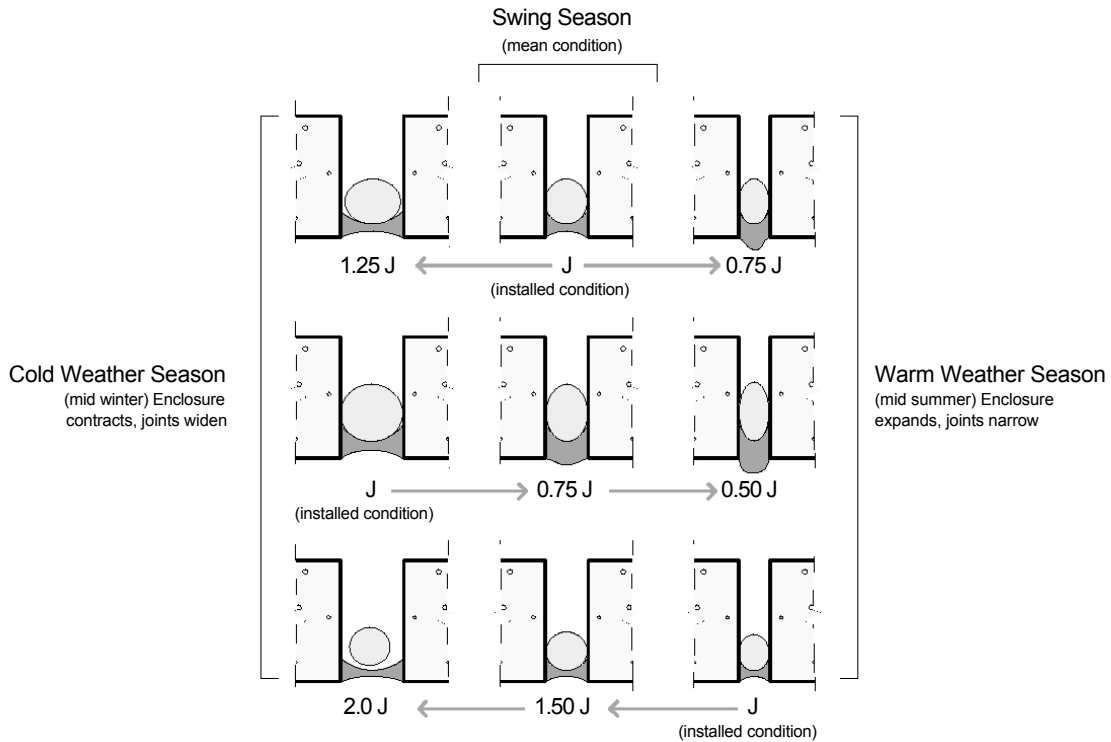


Figure 14: Installation Conditions by Season (Straube and Burnett. *Building Science for Building Enclosures*. Building Science Press, Westford 2005)

Joists for Drained Facades

In drained (two-stage) joints, the potential consequences of a failed exterior seal are much less due to the presence of the interior seal; hence the inspection and maintenance interval can be increased for these systems.

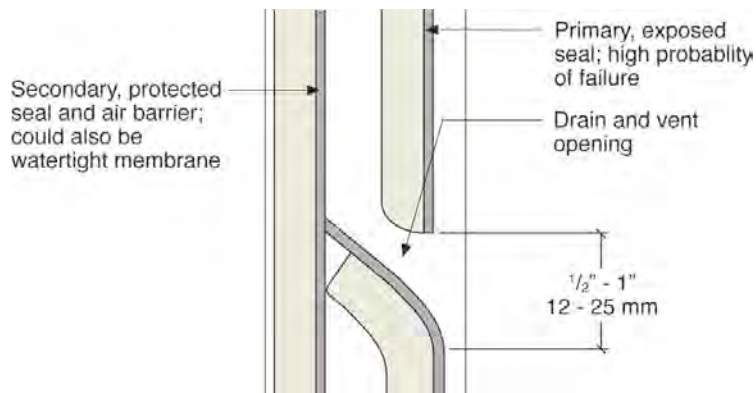


Figure 15: Details of two-stage joint at drain and vent hole. Note the open joint allows for easy drainage. Plastic weep tubes are sometimes inserted to alert trades that an opening is intentional and not to be sealed over, but such tubes do not drain as well, as they can fill up with insects/spiders and dust over time.

In general, the inner seal should be positioned 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 at least 75 mm (3 inches) behind the outer face.

Weep holes, with a minimum dimension of 12 mm (1/2 inch) by the joint width should be used to facilitate drainage. It is most common to provide the weep holes in the vertical joints. A bead of sealant is tied to the interior vertical sealant bead as illustrated in Figure 16. The sealant should be installed with an outward slope of at least 1 in 2 (i.e. almost 30 degrees) to encourage outward flow of water and resist the entry of wind-driven rain.

Where weep holes are not provided, or where they are blocked by sealant replacement, water penetrating the assembly will be forced to find other drainage paths to the interior or exterior (Figure 16).



Figure 16: Drainage without weep holes. The horizontal sealant joint in the photo to the left is cracked and allows water to drain from underneath the window sill above. This is not a planned drainage path.

An extensive amount of information on joint sealant material selection, installation, and common problems are available in CPCI's *Architectural Precast Concrete Walls: Best Practice Guide* by M.E. Hachborn.

Metal Flashing and Drainage Gaps

Drained precast enclosure systems, and other parts of the building enclosure such as parapets, overhangs, and window details, make use of metal flashing to create water-shedding drip edges. Metal flashing components are typically prefinished and do not require re-finishing. Metal flashing is usually light-weight and subject to physical damage and deformation due to building movements.

A simple visual inspection will indicate damage. Repair of “through-wall” flashing (i.e., a flashing component that extends from a drainage plane within the wall to the exterior) may be cost prohibitive and this may preclude replacement. However, if the damage to the flashing increases rain water loading of the enclosure system below, it may be necessary to undertake the repair or risk early deterioration of larger portions of the building enclosure system.

Attachments to Precast Panels

Building elements such as signage, posts, and railings that are directly attached to the precast panels by way of metal fasteners should be carefully inspected.

Holes for fasteners should be filled with anchoring cement or sealant to prevent the ingress of water, which could cause freeze-thaw damage or corrosion of the fasteners. Both issues may lead to cracking of the concrete surface and further ingress of water.

Replace fasteners only with material that is suitable for the exposure conditions (e.g., stainless steel fasteners) and compatible with the adjacent materials.

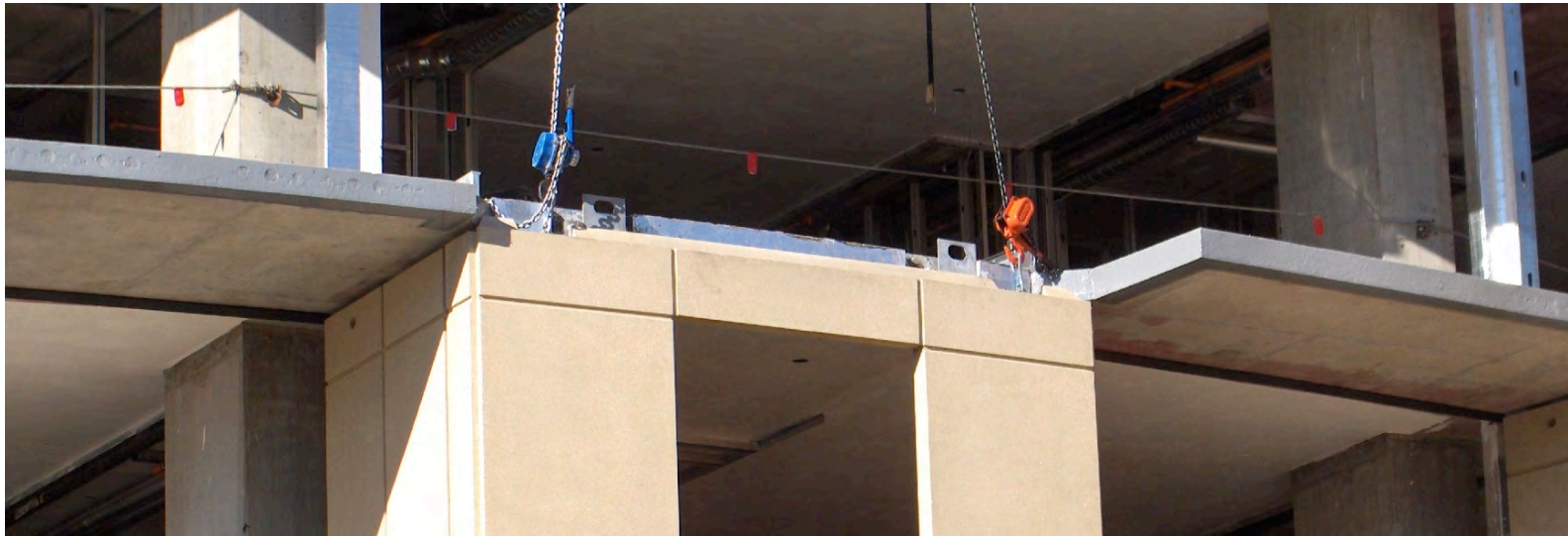


Figure 17: Attachments to precast panels may be structurally viable but, if the attachment points are not sealed to prevent water intrusion, this could lead to cracking of the precast panel.

Grade-level Conditions

At grade level, precast panels and other enclosure components are subject to a range of damage mechanisms including:

- Physical impact from vehicles and pedestrians
- Staining from human and animal activity
- Contamination from de-icing salt
- Additional water loading from:
 - drainage on grade
 - capillary or “rising damp” from below grade moisture sources
 - splash back from hard surfaces adjacent to the building
 - landscaping



3.0 Planning and Documentation

Effective maintenance requires planning that starts as early as the completion of construction and is supported by clear documentation. The building owner or operator should maintain the following documents to assist with planning and the development of repair procedures:

- Architectural, Structural and Mechanical Service Drawings and Specifications
- Shop drawings for the precast panels and connection details, including components constructed as part of the building structure
- Shop drawings for all other building enclosure components
- “As-built” drawings reflecting changes from the design drawings and specifications, made during construction
- Material data sheets and supplier information for sealants and coatings
- A record of all reported performance problems related to the building enclosure and other building systems
- A record of maintenance and repair activity since construction

These documents will be used to understand the initial level of performance expected from the precast enclosure and the steps taken to maintain this performance. A maintenance program can be established, which should include:

1. a maintenance budget,
2. assignment of personnel and service contractors to implement the program,
3. a schedule of maintenance activities,
4. recording procedures to document maintenance activity, and
5. a review system to oversee the program, which may include periodic third-party review.

The maintenance program should be reviewed annually and revised as required to account for new information gathered from the condition assessments and changes to the operation of the building.

In the event of a major performance problem, these records and the maintenance program will allow for a faster, more accurate assessment of the problem and provide significant cost savings during the design and execution of the repairs.

Sample Inspection and Maintenance Plan for Exterior Precast Enclosures

Building Name and Location:	
Activity	Suggested Frequency of Inspection
<p>Exterior Visual Inspection</p> <p>Review exterior of precast panels for signs of staining, discolouration, and distress, such as spalling, cracking or delamination of the concrete. Pay close attention to cracks and construction joints. Contact structural engineering consultant to review large cracks and significant areas of spalling if required.</p> <p><i>Ensure that adequate safety measures are taken when performing maintenance and repair activities from elevated work platforms.</i></p>	[Inspect annually.]
<p>Minor Chipping or Crack Repair of Precast Panels</p> <p>Locally repair precast concrete panels as required.</p>	[Inspect annually; repair as needed.]
<p>Cleaning of Precast Panels</p> <p>Clean exterior coated concrete panel surfaces. Power washing equipment should be used with care at joints and interfaces.</p> <p>Use a mild solution of Trisodium Phosphate (TSP) to remove stubborn staining.</p>	[Visually inspect annually from the ground; clean if required]
<p>Recoating of Precast Panels (Only for Previously coated/sealed panels)</p> <p>Repair of delaminated or spalled concrete should be carried out prior to recoating. Reapplication of the protective coating as required, including preparation of the concrete substrate.</p> <p>Retain sufficient stock of coating and sealant products on-site for localized maintenance and colour matching purposes.</p>	[Visually inspect annually from the ground. Recoat if necessary according to manufacturer's instructions.]
<p>Visual Inspection of Joint Sealants</p> <p>Inspect a random sample of exterior joint sealants for signs of deterioration and leaks, selecting sufficient examples to provide a representative assessment, including each elevation.</p>	[Initial inspection in four years; thereafter, inspect every two years for polyurethane and every 5 years for silicone. This schedule is to be followed unless sealant deterioration is noted, in which case inspections should be conducted annually.]

<p>Inspection of Panel Anchorage/ Connection to Main Structure</p> <p>Visually inspect for corrosion damage. This may require removal of interior finishes and/or inspection at locations such as unfinished interiors, closets, mechanical rooms, etc.</p>	<p>[Initial inspection frequency of approximately 10 to 25 yrs (for example, 10 years for single-wythe panels, since the connections may be more susceptible to condensation, and 25 years for double-wythe insulated panels with hot-dip galvanized connections, since the connections are on the protected side of the building enclosure).</p> <p>Subsequent inspections should be every 5 years unless significant deterioration is noted, in which case, inspection frequency should be increased to biannually or annually depending upon significance of corrosion.]</p>
<p>Visual Inspection of Miscellaneous Steel (Attached to Exterior of Panels)</p> <p>Check handrails, stair treads and landings, metal or precast stair members, walls, signage, and roof for deterioration. Check concrete adjacent to all metal-to-concrete connections for signs of distress.</p> <p>Check exposed metal for corrosion of bearing plates and welded connections. Check grouted connections for rust stains.</p>	<p>[Inspect annually]</p>

Review adequacy of maintenance inspections annually. Update the maintenance record based on environmental conditions, experiences over the preceding year and feedback from service contractors.

Example Precast Enclosure Inspection Checklist – by Component

Building Name:	
Building Location:	
Precast Enclosure Type and Rain Control Strategy	
Date of Inspection	
Name & Credentials of Inspector / Organization	
Have design drawings been reviewed for design intent? Which?	
Have previous inspection reports been reviewed? Which?	

Important Note: Ensure that adequate safety measures are taken when performing maintenance and repair activities on the exterior walls when working from elevated work platforms.

For each item on the checklist identify which area of the enclosure is being referenced, i.e., elevation/orientation, floor, lateral distance from feature such as corner, or if the observation applies to all.

Precast Concrete Units

1. Inspect face of precast concrete units for large cracks. Inspection may be conducted from ground level with the use of binoculars. Conduct the inspection systematically and carefully note location (including orientation and floor level) of cracks observed.

No issues observed.

Issues observed.

Recommended Action: Cracking of precast panels should be recorded and a measurement of the crack width should be noted so that any “movement” – widening or lengthening – of the crack can be determined. Cracks that are not moving (or “progressing”) can be sealed with a two-part polyurethane or a silicone sealant after proper surface preparation (follow sealant manufacturer’s instructions). Deeper cracks and cracks that are moving should be examined and suitable repair methods should be provided by a structural engineer.

Comments:

2. Inspect face of precast concrete units for staining and (if applicable) the condition of the exterior finish.

No issues observed.

Issues observed.

Recommended Action: Some stains may be cleaned using a mild solution of Trisodium Phosphate (TSP). Other cleaning solutions may be required. Power washing equipment should be used with care at joints and interfaces. Cleaning should first be trialed in an inconspicuous location. Exterior finishes that were previously coated may also be restored by recoating (follow the manufacturer's recommendations).

Comments:

Panel Attachment to Main Structure (i.e., panel anchors)

3. Where possible, visually inspect metal structural connections. Note that a licensed structural engineer must be retained to conduct inspections of structural components. If water intrusion has been detected on the building interior, remove interior finishes to view structural connections. Panel anchors are typically made of corrosion-resistant material or have corrosion-resistant coatings – little or no corrosion should be expected.

No issues observed.

Issues observed.

Recommended Action: Retain licensed structural engineer for inspection.

Comments:

Joints for Face-sealed Facades (i.e., face sealed)

4. Inspect condition of joint caulking bead between panels, at window openings, and between precast and other enclosure materials. Look for cracking or tearing at the centre (cohesive failure) or edges (adhesive failure) of the caulking.

No issues observed.

Issues observed.

Recommended Action: Face-sealed systems depend on the joint caulking bead to prevent ingress of rainwater. Damaged or missing caulking must be repaired immediately. An experienced service contractor should be retained for surface preparation and installation of joint sealants.

Note that tearing of sealant joints may be caused by unexpected movement of the precast wall panels. If repaired joints show damage soon after the repair, ask a structural engineer to investigate further.

Comments:

Joints for Drained Facades (i.e., two-stage joints)

5. Inspect condition of exterior sealant beads between panels, at window openings, and between precast and other enclosure materials. Look for cracking or tearing at the centre (cohesive failure) or edges (adhesive failure) of the sealant.

No issues observed.

Issues observed.

Recommended Action: The exterior sealant bead in a drained, two-stage joint provides protection from the elements for the inner sealant bead located towards the interior side of the precast panel. Replacement is not needed for minor cracking or edge separation. Missing sealant or wide gaps should be replaced. An experienced service contractor should be retained for surface preparation and installation of joint sealants.

Comments:

6. Inspect condition of interior sealant bead. Where possible (at drainage or weep hole locations) look for complete sealant beads extending from interior to exterior.

No issues observed.

Issues observed.

Recommended Action: The interior sealant provides water and air control layer between panels and must be continuous to function effectively. Replace if damage is observed. An experienced service contractor should be retained for surface preparation and installation of joint sealants.

Note that tearing of sealant joints may be caused by unexpected movement of the precast wall panels. If repaired joints show damage soon after the repair, ask a structural engineer to investigate further.

Comments:

Metal Flashing and Drainage Gaps

7. Inspect metal flashing for damage. Look for bent or damaged metal, flashing lifted and causing drainage towards the building, and signs of staining below joints in metal flashing pieces.

No issues observed.

Issues observed.

Recommended Action: Bent or displaced metal flashing can typically be repositioned, reformed or reshaped. Gaps between horizontal runs of flashing material may require sealant to prevent water concentration and staining.

Comments:

Attachments to Precast Panels

8. Inspect attachment point of signage, canopies, posts, and railings. Note corrosion of metal fasteners.

No issues observed.

Issues observed.

Recommended Action: Repaint fasteners or replace fasteners with material that is suitable for the exposure conditions (e.g., stainless steel). Note that for the attachment of large objects and railings, corrosion of metal elements may weaken the structure and create a safety hazard. Consult a licensed structural engineer for recommendations.

Comments:

9. Locate any holes where fasteners have been removed from attachment to precast panels.

No issues observed.

Issues observed.

Recommended Action: Holes from removed and unnecessary fasteners should be filled with anchoring cement and/or sealant to prevent the ingress of water, which could cause freeze-thaw or corrosion of the fasteners.

Comments:

Grade-Level Conditions

10. Inspect panels for salt and “splash back” water staining near walkways, roadways, and landscape areas.

No issues observed.

Issues observed.

Recommended Action: Staining may be cleaned using a mild solution of Trisodium Phosphate (TSP). Other cleaning solutions may be required. Power washing equipment should be used with care at joints and interfaces. Cleaning should first be trialed in an inconspicuous location. It is important to address the cause of the staining. This may require a change to winter maintenance, modification of the surface at grade level, or the repair or addition of flashing.

Comments:

11. Inspect panels near entrances, loading and service areas for physical impact damage or fracture.

No issues observed.

Issues Observed.

Recommended Action: Damage to precast panels should be repaired to prevent water ingress and further damage. Bollards or steel plates may be added to protect panels from further impact damage.

Comments:

12. Look for changes to surface water drainage caused by changes to landscaping, settlement at grade-level, and improvements to neighbouring properties.

No issues observed.

Issued Observed.

Recommended Action: Provide minimum 2% slope away from building enclosure. If necessary, install surface drainage feature (swale, berm, etc.) to direct surface water away from building.

Comments:

Name of Inspector:		Company:	
Signature:		Report Date:	

Reviewed By:		Company:	
Signature:		Review Date:	



4.0 Resources and References

CPCI Resources

The Canadian Precast/Prestressed Concrete Institute provides a number of technical references for precast concrete enclosures. The following documents are accessible in print and online for your use.

Architectural Precast Concrete Walls: Best Practice Guide by M.E. Hachborn
Engineering http://www.cpci.ca/en/resources/technical_publications/

High Performing Precast Concrete Building Enclosures - Rain Control by
Dr. John Straube, P.Eng. <http://downloads.cpci.ca/57/downloads.do>

General Precast and Building Science Resources

There are a number of general building science resources that will assist the building owner/operator in understanding the performance of precast concrete enclosures and other components of the building. Many of the following resources are also available online.

CSA A23.4-16, *Precast concrete - Materials and construction*, Canadian Standards Association, Toronto, Ontario, 2016.

NPCA. *Precast Concrete Architectural Repair Guide*. National Precast Concrete Association: Carmel, IL, 2013.

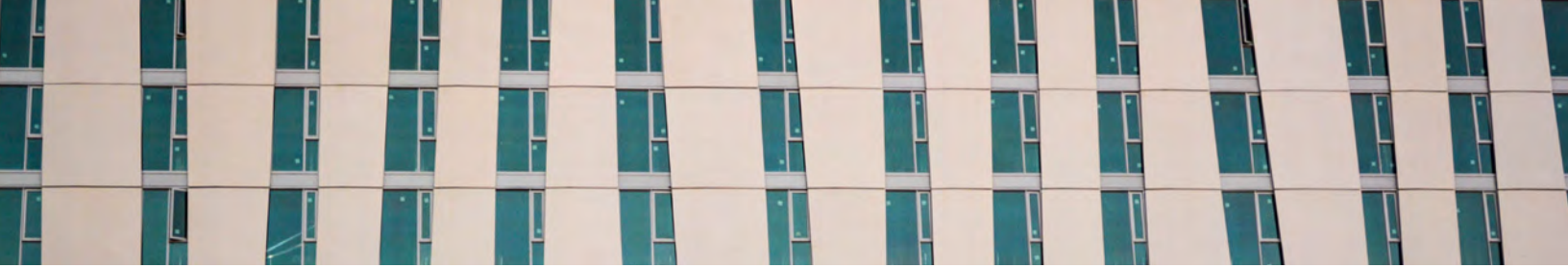
Straube, J.F., *High Performance Enclosures: Design Guide for Institutional Commercial and Industrial Buildings in Cold Climates*. Building Science Press: Somerville, Massachusetts, 2011.

Straube, J.F., *Rain Penetration Control Practice Guide*. Ontario Architects Association: Toronto, Ontario, 2005.

CPCI Technical Support Help Desk

CPCI technical help desk services provide technical information about the use of precast and prestressed concrete products, through investigations and research relative to applications of precast and prestressed concrete and engineering processes for improvement in the design, manufacture and installation of precast products.

CPCI help desk support and customer support are part of a comprehensive CPCI customer support program. Please email us at helpdesk@cpci.ca or call us at 1.877.YES.CPCI (1.877.937.2724).



Distributed by:

RDH Building Science Inc.

167 Lexington Court, Unit 5
Waterloo, ON, Canada
N2J 4R9
Tel: 519.342.4731

www.rdh.com

**Canadian Precast/Prestressed
Concrete Institute**

PO Box 24058 Hazeldean
Ottawa, ON, Canada
K2M 2C3
Tel: 613.232.2619, Toll free: 877.937.2724

www.cpci.ca



DISCLAIMER: Substantial effort has been made to ensure that all data and information in this publication is accurate. RDH Building Science Inc. cannot accept responsibility of any errors or oversights in the use of material or in the preparation of architectural or engineering plans. The design professional must recognize that no design guide can substitute for experienced engineering and professional judgment. This publication is intended for use by professional personnel competent to evaluate the significance and limitations of its contents and able to accept responsibility for the application of the material it contains. Users are encouraged to offer comments to RDH Building Science Inc. on the content and suggestions for improvement. Questions concerning the source and derivation of any material in the design guide should be directed to RDH Building Science Inc..