Adaptation of Rain-Screen Principles in Window-Wall Design

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ABSTRACT

Window-wall systems are building envelope systems in which traditional window extrusions are adapted to span from floor to floor and form the exterior envelope. Over the past decade, window-wall has emerged as an intermediate option between residential windows and metal and glass curtain wall for high-rise residential developments. Initially used for bay windows, the window-wall system was rapidly adapted to create a continuous ribbon of glazing by the use of couplers.

Early window-wall systems were commonly face-sealed systems and as such were often susceptible to water infiltration. Recent innovations have seen rain-screen concepts adapted to window-wall systems in an effort to alleviate some of the chronic water infiltration problems. This paper discusses the one approach to the adaptation of rain-screen design principles in a window-wall system design with a special emphasis on the building science details that have been developed to control rain penetration. It includes a case study of the replacement of a face-sealed window-wall system with a rain-screen window-wall system on a 12-story high-rise building.

INTRODUCTION

Window-wall systems are building envelope systems in which traditional window extrusions are adapted to span from floor to floor and form the exterior envelope. In the past decade, window-wall systems have emerged as an intermediate option between residential windows and curtain wall in high-rise residential developments. Initially used for bay windows, window-wall systems were rapidly adapted to create a continuous ribbon of glazing by the use of coupler mullions.

Early window-wall systems were commonly face-sealed glazing systems and as such have proven to be susceptible to water infiltration. In response to these problems, recent innovations have seen rain-screen concepts adapted to window-wall systems. This paper discusses one approach to the adaptation of rain-screen design principles in window-wall design. It concludes with a case study of the replacement of an early window-wall system with a new rain-screen window-wall system on a 12-story high-rise building.

CHARACTERISTICS OF TYPICAL WINDOW-WALL SYSTEMS

Unlike traditional curtain wall systems that span floor to floor with attachments outboard of the slab edge, the traditional window-wall system is designed to bear on the slab edge and extend up to the underside of the slab edge above. In some systems, a slab band cover is provided to give an appearance similar to curtain wall. Although there are many variations, the typical window-wall system is defined by the following features, as outlined in Figure 1.

- Window extrusions used to span from floor to floor in a premanufactured unitized system typically up to two meters in width.
- A coupler connecting the vertical mullions of each window-wall unit either as a male-female coupler integral to the vertical mullions or as an independent coupler.
- Window-wall systems bear on the slab edge at the floor level and are anchored to a retaining track fastened into the slab.

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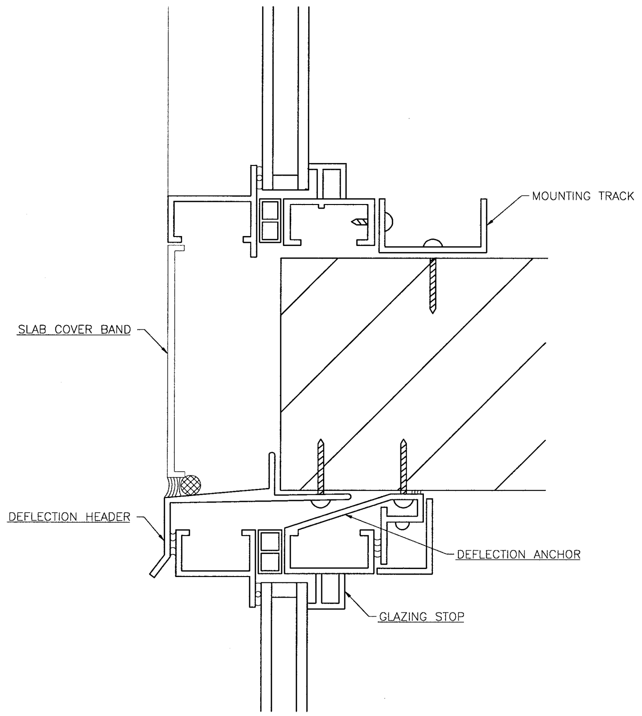

Figure 1 *Typical window-wall section at slab.*

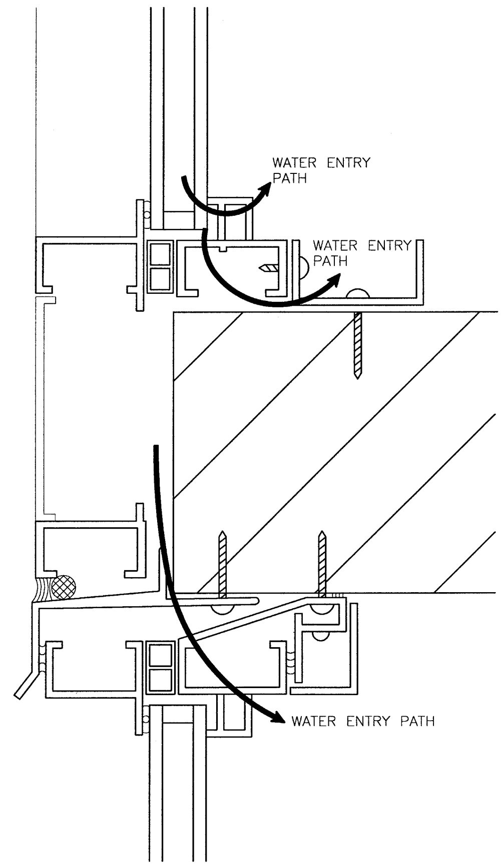

Figure 2 *Typical water entry path.*

- The head of the window-wall system is slotted into a deflection header fastened to the underside of the floor slab, spandrel beam, or structural wall and anchored to the structure with deflection straps.
- Horizontal mullions dividing the window-wall unit into panels of vision glass units, glazed from either the exterior or interior, and glass or metal opaque panels mounted from the exterior.
- Operable units, typically awning or casement windows, swing doors, and sliding doors, mounted within the frame of the window-wall system.
- A slab band cover spanning the depth of the slab that can be installed either independent of the window-wall system or as an extension of the window-wall frame.
- Vent outlets mounted either through opaque panels in the case of below-slab ducts or directly through the slab band cover in the case of in-slab ducts.

TYPICAL WATER INGRESS PROBLEMS EXPERIENCED WITH EARLY WINDOW-WALL SYSTEMS

Early window-wall systems typically used a face sealed approach to their design with respect to water tightness, which is to say that they relied on the continuity of the primary exterior seal to prevent water infiltration. Many of these systems have experienced chronic water infiltration problems as the result of deficiencies in the primary exterior seal. These were often aggravated by air leakage that emphasized the deficiencies in the primary exterior seal under differential pressure. Once the water is past the exterior seal, it often accumulated within the frame, as there was no provision to contain this water or to drain the interstitial cavities. Eventually, the accumulating water overflowed to the interior. Some of the more common water infiltration problems of early window-wall systems include the following:

- Water infiltration through the glazing seals (typically glazing tape) of vision glass units (see Figure 2).
- Water infiltration through the seal on the opaque panels (typically glazing tape for glass spandrels and sealant on metal panels).
- Water infiltration at the operable units as a result of water accumulation between the primary and secondary gaskets sealing the operable unit to the frame.
- Water infiltration through joints between the horizontal and vertical mullions as a result of water accumulating within the frame.
- Water infiltration at the floor-level mounting track as a result of water draining down the vertical mullions (see Figure 2).
- Water infiltration at the head of the window-wall system as a result of leaks in the slab band cover getting in past the deflection header (see Figure 2).

ADAPTATION OF RAIN-SCREEN PRINCIPLES IN WINDOW-WALL DESIGN

The frequent water ingress problems experienced with early window-wall systems based on a face-sealed design led to the adoption in recent years of rain-screen design concepts. The adaptation of rain-screen concepts to window-wall systems was twofold. In the first instance, a second line of protection against water penetration was provided inboard of the original primary exterior seal. Different assemblies within a typical window-wall system require different approaches to providing an effective second line of protection, including

- installation of a secondary seal for the vision units, typically provided by a heel bead of sealant applied between the inside light of glass and the frame of the window-wall system for interior glazed units (see Figure 3);
- installation of a metal back-pan sealed to the frame of the window-wall system behind all opaque panels to act as a secondary seal (see Figure 4);
- installation of a waterproof membrane at the level of the floor slab extending from the vertical leg of the mounting track down the face of the slab and onto the deflection header (see Figure 4).

The primary intent of these measures was to provide redundancy within the system. The seals forming the secondary line of protection are typically better defense from exposure and temperature extremes than the primary exterior seals and can be expected to have a longer service life.

In the second instance, means of draining the interstitial spaces created between the primary and secondary seals are provided so that any water making its way past the primary exterior seal would not accumulate within the window-wall system but would be redirected to the exterior. To reduce the risk of water accumulation within the system, each element of the window-wall must be provided with means of draining, including

- drainage of the glazing cavity and back-pans, either directly to the exterior by way of drain holes through the horizontal mullions (see Figure 3) or down to the deflection header by means of drain holes in the vertical mullions (see Figure 3);
- drainage of the cavity between the primary and secondary gaskets on operable units;
- drainage of the horizontal mullions directly to the exterior;
- drainage of the window-wall system at the level of each deflection header.

The primary intent of these measures is to provide for rapid drainage of any water that will come past the primary

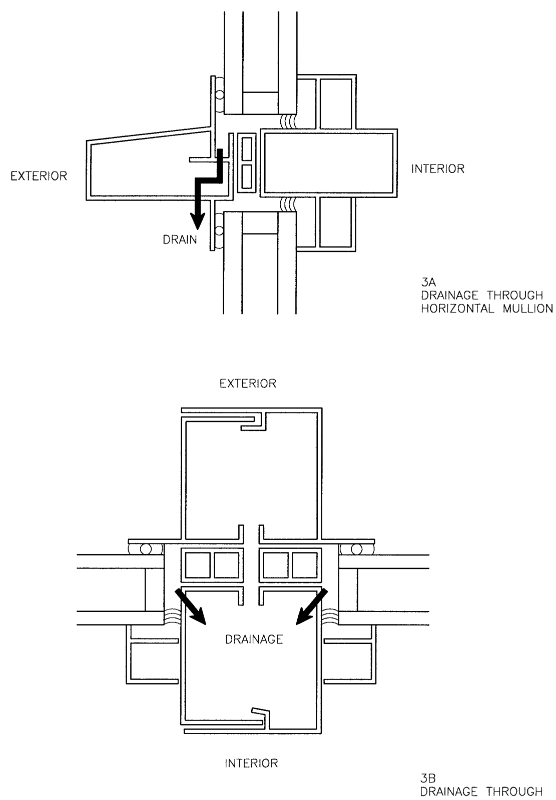

Figure 3 *Drainage of glazing cavity.*

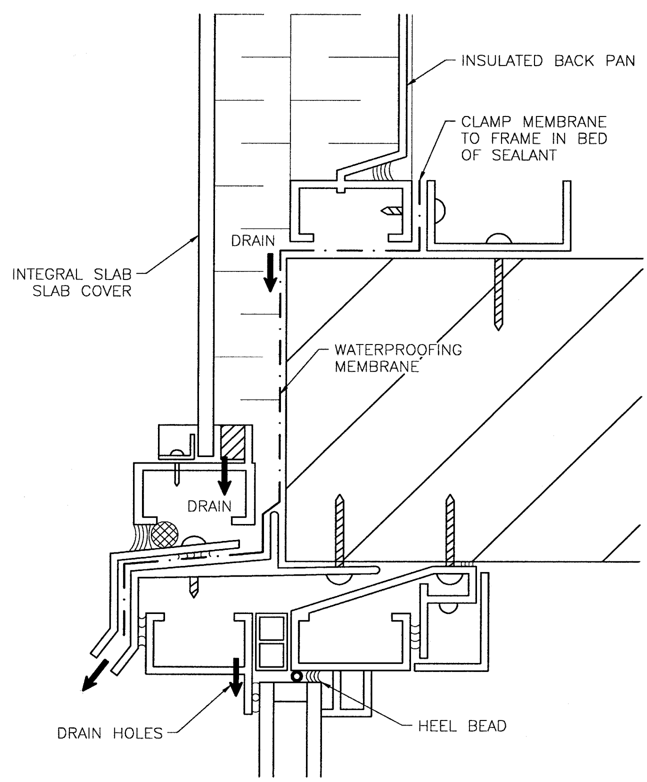

Figure 4 *Improved window-wall details.*

seal and, thereby, reduce the level of water to which the secondary seals will be exposed.

An additional advantage of this twofold approach is that it creates a series of compartmentalized cavities that provide for some measure of pressure moderation across the primary exterior seal. Reducing the pressure across the exterior seal reduces the amount of water that can be driven through the minor imperfections likely to be present in the exterior seal.

The compartmentalization the window-wall system also makes it easier to isolate any eventual leaks. With the earlier window-wall systems, water might find its way down a few stories from its point of entry before any sign of water ingress was visible on the interior. With a compartmentalized system, it is unlikely that water can travel far from its point of entry.

CHARACTERISTIC OF THE WINDOW-WALL ON THE CASE STUDY BUILDING

The building in this case study is a 12-story residential building in North Vancouver, British Columbia. Built in 1989 and primarily clad with face-sealed EIFS, the building made use of an early window-wall system for the projecting rectangular bay windows over the height of the building. The window-wall system consisted of five separate unitized window-wall sections with the following characteristics:

- The window-wall sections were manufactured from the same extrusions as the window systems used in the EIFS clad wall areas. These windows had also shown some of the same problems with respect to water infiltration as the window-wall system.
- These window extrusions were designed for exterior-mounted glazing with a rolled aluminum exterior glazing stop and provisions for draining the glazing cavity back to the exterior by means of drain slots in the horizontal mullions.
- The window-wall sections spanned from the floor slab to a 150-mm-deep structural steel stud header at the underside of the slab above.
- Slab deflection was accommodated within the steel stud header, and the window-wall sections were anchored to the steel stud header with deflection straps.
- Individual window-wall sections were joined together with independent vertical coupler mullions.
- The window-wall sections consisted entirely of fixed glazed units.
- The slab band cover consisted of separate aluminum panels mounted in front of the slab edge between the sections of window-wall.

TYPICAL WATER INGRESS PROBLEMS OBSERVED AT THE CASE STUDY BUILDING

The bay windows of the case study building had a history of water infiltration problems, similar to those described above, dating back to the original construction. The two most commonly reported water ingress problems, aside from some

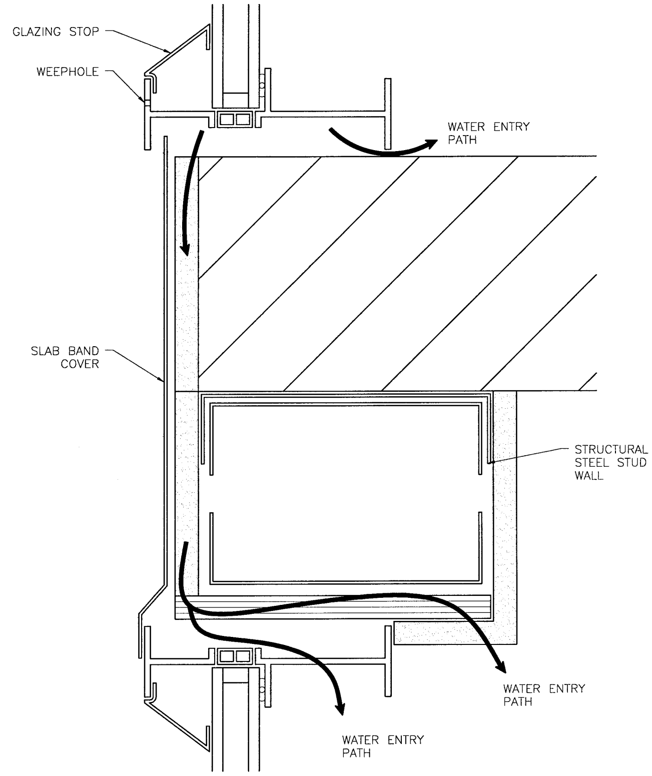

Figure 5 *Window-wall section at slab.*

random leaks around the glazing seals, were water staining of the interior finishes at the head of the window-wall system and water ponding at the floor level. These problems were a result of the low reliability of the face-sealed design of the slab band. Water finding its way past the exterior seals could flow down the vertical coupler to the floor slab (Figure 5). At this point, the water would either enter into the interior, resulting in localized damage of the floor finishing, or would drain over the slab edge and in behind the slab cover band. To this was added additional water from defective seals around the perimeter of the panels of the slab band cover (Figure 5). This water would then make its way into the steel-stud framing at the underside of the slab, resulting in water damage to the interior finishes, or would accumulate in the horizontal mullion at the head of the window-wall system, resulting in leaks at the head of the window-wall. These problems were endemic to all of the bay windows but were accentuated on those bays that were exposed to the predominant winds and therefore subject to frequent wind-driven rain.

As part of a large envelope rehabilitation program to replace the original face-sealed EIFS cladding, which had also proven susceptible to water ingress problems, it was decided to also address the window-wall on the bay windows. Two options were explored. The first was to remove and reinstall the existing system using improved details to address the design of the slab band cover and the drainage of the system at the floor level (Figure 4). The other option was to replace the existing system with a new window-wall system incorporating the recent advances in window-wall systems. A structural review of the existing system revealed that a number of the larger glazing units did not meet structural requirements. This made the option of going to an all new system the more advantageous one as the units would have to be replaced as part of the reinstallation of the existing system.

THE REPLACEMENT WINDOW-WALL SYSTEM FOR THE CASE STUDY BUILDING

The replacement window-wall system selected for the case study building consisted entirely of fixed glazed units with no operable units and matched the five separate unitized window-wall sections of the original with the following modifications.

- These window extrusions were designed for interior-mounted glazing with a PVC interior glazing stop.
- The window-wall sections spanned from the floor slab to a new deflection header mounted to the structural steel stud header at the underside of the slab above.
- Individual window-wall sections were joined using a male-female coupler integral to the frame of the new units with independent vertical coupler mullions used only at the 90 degree corners.
- The slab band cover was integral to the new window-wall system and consisted of an extension of the section of the frame outboard of the thermal break in-filled with an aluminum panel and insulation (see Figure 6).

The new window-wall system incorporates the rain-screen concepts described above, including

- two lines of protection against water ingress consisting of a heel bead of sealant (Figure 6) around the vision units and installation of a waterproof membrane at the level of the floor slab and
- drainage of the glazing cavity directly to the exterior by way of drain holes through the horizontal mullions and drainage of the window-wall system at the level of each deflection header.

The installation of the new window-wall system was typical of current practice and consisted of the following steps:

- Installation of the deflection header to the structural steel stud header at the underside of the slab above.
- Installation of the waterproofed membrane from the slab edge down onto the deflection header (see Figure 6).
- Installation of membrane tie-ins over closer angles along the wall interface on either side of the bay window in a fashion similar to that used at the floor slab.
- Installation of the window-wall section in a linear fashion setting the system on shims over the waterproof membrane to provide a drainage space and clamping the membrane to the frame in a bed of sealant by mechanically fastening the frame to the mounting track or closure angle (Figure 6).
- Fastening of the deflection anchors at the head of the window-wall system into the structural steel stud header.
- Installation of the gasketed termination track along the head of the window-wall to complete the air barrier connection between the window-wall system and the steel stud wall assembly.
- Installation of backer rod and sealant on the exterior between the underside of the slab band cover and the deflection header leaving intermittent weep holes for drainage.

PERFORMANCE OF THE WINDOW-WALL SYSTEM

To confirm that the new window-wall system would perform with respect to water tightness under the expected site conditions, a series of water penetration tests were undertaken during the construction period. The design requirement was for no water penetration under a 500 Pa (10.44 psf) pressure difference. The pressure difference was selected primarily on the basis of the driving rain wind (a measure of wind in combination with precipitation) for this particular geographical

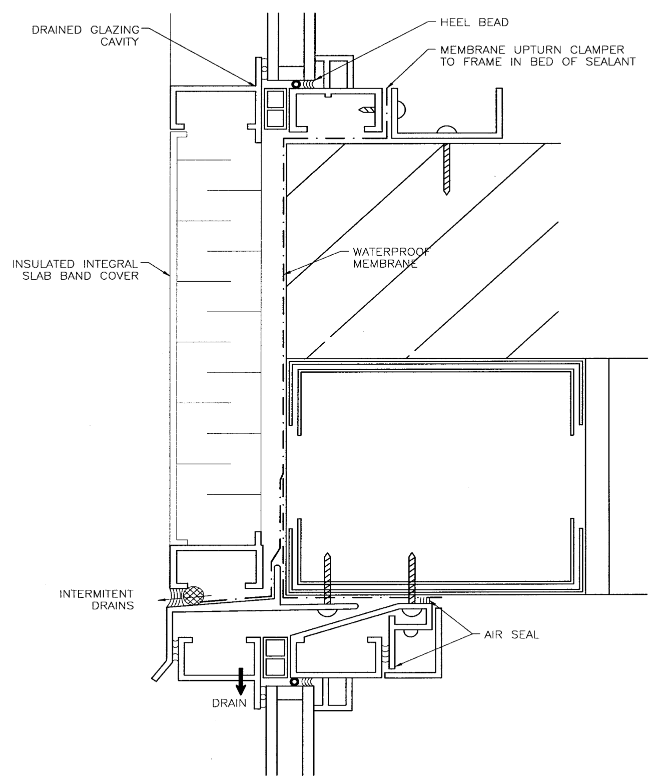

Figure 6 Improved window-wall details.

location, the height of the building, and the site exposure. For each test, a test chamber was built to isolate an entire bay of the new window-wall system. The tests were undertaken in accordance with ASTM E1105 for water penetration under a cyclical static pressure difference.

The tests undertaken demonstrated that the new window-wall system could perform under the expected conditions. Manufacturer's laboratory tests have shown that fixed glazed window-wall systems have been tested successfully to 700 Pa. Typical operables have been tested to 500 Pa for awning and casement windows as well as swing doors and to 300 Pa for sliding doors.

CONCLUSION

Window-wall systems have emerged as an intermediate option between residential windows and curtain wall in high-rise residential developments with glazing spanning from floor to floor. Initially used for bay windows, these systems were rapidly adapted to create a continuous ribbon of glazing by the use of couplers. Early window-wall systems have proven to be susceptible to water infiltration as a result of their reliance on a single continuous seal. In response to these problems, recent innovations have seen rain-screen concepts adapted to window-wall systems. With the adaptation of these rain-screen principles, window-wall system have proven to be a reliable alternative glazing system.