

CANADIAN WINDOW WALL

Design challenges and opportunities



George R. Torok
Building Science Specialist, Morrison Hershfield Limited
gtorok@morrisonhershfield.com



Yvon JA Chiasson
Senior Building Science Specialist, Morrison Hershfield Limited
ychiasson@morrisonhershfield.com

ABSTRACT

One of the defining characteristics of new high-rise residential apartment building design in Canada today is the thermally broken, open-back aluminum frame ‘window wall’ building envelope system. Until recently, Canadian building codes and Canadian and North American fenestration standards have not recognized window wall as a distinct cladding system. Canadian window wall systems have evolved on a largely trial and error basis. This changed earlier this year with the release of the most recent edition of the model National Building Code of Canada that includes, for the first time, a category of ‘other fenestration assemblies’ to address window wall and other glazing systems, setting out required and recommended performance and testing requirements. Work is also in progress on an installation standard under the aegis of the Canadian Standards Association. While performance requirements are being sorted out at home, Canadian window wall manufacturers are promoting their systems in the United States (USA) to compete with similar systems in that market. However, there are significant technical and aesthetic differences between Canadian and USA window wall systems that should be taken into consideration by architects, builders and developers. This paper gives a brief overview of the development of Canadian window wall, design in the context of incoming NBC 2015 requirements, assembly and installation details that could affect the design, construction and performance of the building envelope when used for residential high-rise construction in the USA.

KEYWORDS

window wall, design, installation, performance, air leakage, water leakage, rainscreen

INTRODUCTION

Canadian window wall systems have evolved over time from simple face-sealed ‘punch’ windows as an isolated element surrounded by other cladding to sophisticated building envelope systems that enclose most, if not all of the exterior of high-rise residential buildings. Canadian building codes and window performance standards have evolved more slowly, only recently recognizing window wall as a distinct form of glazing system. The recently released 2015 edition of the model National Building Code of Canada (NBC 2015) includes a category of ‘other fenestration assemblies’ including window wall and setting out specific performance and testing requirements. Work is also in progress on an installation standard under the aegis of the Canadian Standards Association. It will be some time yet until the new NBC 2015 requirements and recommendations and the as-yet to be completed CSA standard requirements are adopted by each Canadian province and are enforced by authorities having jurisdiction. In the meantime, generic building envelope performance requirements in the NBC 2015 must be relied upon, tempered by experience and sound judgment. There are significant differences compared to window wall systems that are manufactured in the USA that should be considered by architects, builders and developers. In this paper, we will discuss the development of Canadian window wall and incoming NBC 2015 requirements to set the stage for a discussion of differences in frame design, installation, structural anchorage and air leakage and water penetration control which could affect the design, construction and performance of the building envelope when used for high rise residential buildings in the USA.

THE EVOLUTION OF CANADIAN WINDOW WALL

Apartment building construction in Canada into the early 1960s was characterized by small, mid-rise buildings with modest amounts of glazing. Most windows were a single product type, such as a horizontal sliding window, or a composite window with two or more openings infilled with fixed single or double glazing and horizontal sliding sashes, set into openings in load-bearing masonry mass walls ('punch' style windows). The advent of reinforced concrete structural frame construction employing 'flying form' technology enabled a rapid increase in building height so that by the 1970s, buildings were reaching upwards. However, exterior walls were still mass masonry but as non load-bearing infill between exposed floor slabs, shear walls and columns. In the late 1970s and through the 1980s window openings were often extended to the floor slab to create vertical bands of windows from top to bottom of the building or extended horizontally to create horizontal bands of windows extending around the width of the building. Beginning in about the mid 1990s and accelerating in the 2000s, vertical and horizontal extension of punch windows merged into what is now known as window wall, with windows spanning from floor to floor, joined together at the jambs to enclose the full perimeter of the building. There is still need for opaque portions of cladding to conceal building structure, services or provide privacy to occupants so floor to ceiling window wall may include fixed and operable sash vision glazing and opaque infill of various types (Fig. 1).



Figure 1: The evolution of Canadian window wall, from punch window (left) to the entire building envelope (right). All Photographs © Morrison Hershfield, 2106.

Interesting features in the evolution of Canadian window technology were the early adoption of open-back, extruded aluminum frames with integral brick mould, thermal breaks and factory installed glazing. Masonry mass walls for apartment buildings, both load-bearing and non load-bearing, were typically two-wythe construction of face brick and concrete masonry units (CMUs) behind with a joint (collar joint) between. The brick mould was used to conceal the collar joint around the perimeter of the window opening. Thermal breaks were at first extruded poly vinyl chloride (PVC) at about mid-depth of the frame interlocked tongue-and-groove style with the aluminum extrusions to the interior and exterior. In the 1980s roll-crimp clamping of aluminum extrusions to the thermal break was introduced which created a rigid composite construction for greater structural strength. This coincided with the increasing use of floor-to-ceiling windows and a general change in masonry wall construction in which the outer wythe of masonry was moved off the floor slab to be supported by shelf angles with the inner wythe moved forward to align with the slab edge. Windows were similarly displaced outwards so that only the inner half of the frame rested directly on the floor slab. Slabs were concealed with masonry cladding at first and later with insulated, prefinished sheet metal covers. In the 1990s, the sheet metal slab cover was replaced by extending the aluminum extrusions outboard of the thermal breaks on the jambs and sill to the bottom of the floor slab, above the head rail of the floor-to-ceiling window below. This 'slab by-pass' has become a defining feature of modern Canadian window wall systems (Fig. 2).



Figure 2: Canadian window wall system during installation. Left, story high panels have been installed with the other half of the frame extended to cover the floor slab.

Centre, view from above showing projection of window frame beyond the slab edge with self-adhesive membrane and metal flashings to shed water.

Right, slab by-pass at a balcony curb showing how 'split frame' approach with aluminum extrusions at jambs outboard of the thermal break are extended downward to allow the spandrel panel to cover the curb face, concealing it from view. All Photographs © Morrison Hershfield, 2106.

NATIONAL BUILDING CODE OF CANADA 2015 REQUIREMENTS

Canadian window performance standards have evolved over the years, merging with US standards in 2008 as AAMA/WDMA/CSA 101/I.S.2/A440-08, NAFS – North American Fenestration Standard/Specification for Windows, Doors, and Skylights (NAFS-08). Canadian windows standards prior to NAFS addressed only 'punch' style windows, ignoring floor-to-ceiling windows and later window walls. NAFS-08 and the updated version NAFS-11 also do not include a window wall product type. As a result, the evolution from 'punch' windows to window wall has fallen into a grey zone between window standards that do not acknowledge the type and generic principles for all types of building envelope systems included in building codes. This changed earlier this year with the release of the model NBC 2015 which for the first time defines 'other fenestration assemblies' including window wall and sets out specific performance and testing requirements and recommendations.

In Appendix A of the NBC 2015, window wall is defined as follows:

A window wall is considered to be a wall cladding fenestration assembly that spans from the top of a primary floor structure to the underside of the next higher primary floor structure. Window wall assemblies do not support vertical load other than their own weight. Primary provision for anchorage occurs at head and sill conditions to the adjoining floor structure. Window wall assemblies may include separate or integral floor edge covers.

The last sentence of the definition allows for older floor-to-ceiling window systems with insulated sheet metal slab edge covers as well as modern window walls with slab by-pass style.

NBC 2015 performance and testing requirements for 'other fenestration systems' are set out in Division B, Part 5 *Environmental Separation*, Subsection 5.9.3. These requirements are described following with commentary, to provide to potential users of such systems in the USA some insight regarding current design capabilities of Canadian window wall systems and how designs may change in the next few years as the NBC 2015 is adopted or adapted across Canada.

- Structural and Environmental Loads, Article 5.9.3.2.: no specific requirements are included for structural design. Instead, reference is made to Article 5.1.4.1 which sets out generic requirements for all building envelope materials, components and assemblies. However, in the non-mandatory Appendix A for Article 5.9.3.2, ASTM E330 is identified as the 'applicable' test method. That is the same test method required by previous Canadian window standards and currently by NAFS for 'punch' windows, doors and skylights. Canadian window wall manufacturers should be able to furnish test reports to this standard. Appendix A also identifies AAMA 501 *Methods of Tests for Exterior Walls*, AAMA 501.4 *Recommended Static Testing Method for Evaluating Curtain Wall and Storefront Systems Subjected to Wind Induced Interstory Drift* and AAMA 501.6 *Recommended Dynamic Test Method for Determining the Seismic Drift Causing Glass Fallout from a Wall System* as other test methods that can be used to assess structural performance. Currently, many Canadian window wall systems are not tested to these AAMA standards.

- Heat Transfer, Article 5.9.3.3: reference is made to Section 5.3. which sets out generic requirements for heat transfer for all building envelope materials, components and assemblies (Sentence 5.9.3.3.(1)) Metal-framed fenestration assemblies are also required to incorporate a thermal break to minimize condensation (Sentence 5.9.3.3.(2)). The accompanying discussion in Appendix A recommends compliance to National Standard of Canada CSA-A440.2, *Fenestration Energy Performance* which in turn references procedures developed by the National Fenestration Rating Council (NFRC) for simulation or physical testing to determine U-factor (NFRC 100 *Procedure for Determining Fenestration U-Factors* and NFRC 200 *Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence*, respectively). Two physical test methods are identified for assessing condensation resistance: the 'Temperature Index' method in CSA-A440.2 or measuring room-side surface temperatures during one of the cold cycles of AAMA 501.5 *Test Method for Thermal Cycling of Exterior Walls*. The 'Temperature Index' method is unique to the Canadian window industry with fixed indoor ambient air temperature of +20 +/- 1°C (68 +/- 2°F, approximately) and an outdoor ambient air temperature of -30 +/- 1°C (-22 +/- 2°F, approximately). Results are not directly comparable to methods for measuring condensation resistance in the USA, such as NFRC 500 *Procedure for Determining Fenestration Product Condensation Resistance Values*. Therefore, results for condensation tests for Canadian window wall systems should be reviewed carefully to ensure they are applicable for projects in the USA.
- Air Leakage, Article 5.9.3.4: reference is made to Section 5.4. for generic requirements that apply to all building envelope materials, components and assemblies (Sentence 5.9.3.4.(1). A specific requirement is made for testing to ASTM E 283 *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen* with specified maximum allowable air leakage rates (Sentence 5.9.3.4.(2)). For fixed glazed and opaque portions the maximum allowable air leakage rate is 0.2 l/s/m² (0.039 cfm/ft²) at a pressure difference of 75 Pa (1.57 psf) which is consistent with requirements in the Canadian Supplement to NAFS (CSA-A440S1 *Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/A440, NAFS – North American Fenestration Standard/Specification for windows, doors, and skylights*) for fixed windows but more restrictive than the performance levels used in the USA (1.5 l/s/m² (0.30 cfm/ft²)), for R, LC and CW performance classes). The NBC 2015 performance level is also less than the maximum recommended in AAMA 501 (0.30 l/s.m² at 75 Pa (0.06 cfm/ft²) at 1.57 psf)). For operable portions the maximum allowable air leakage rate is 1.5 l/s/m² (0.30 cfm/ft²) at 75 Pa (1.57 psf) which is the same as required in Canada and the USA under NAFS for R, LC and CW performance classes. There is no requirement in the NBC 2015 for testing at a 300 Pa (6.27 psf) air pressure differential as required by NAFS for the AW performance class or under AAMA 501 in buildings in which greater control of indoor air quality and/or humidity is required. However, the authors are aware of Canadian window wall manufacturers who test their products to such levels. Care should be taken by USA designers, builders and developers to ensure that a Canadian window wall under consideration has been tested to suitable performance levels for air leakage control.
- Water Penetration, Article 5.9.3.5: reference is made to Section 5.6. for generic requirements applicable to all envelope systems of buildings. Lab testing is also required to ASTM E 331 *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference* as in the USA for fenestration systems, or to ASTM E 547 *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference* which is required in Canada for 'punch' window systems. Regardless of the test method, the test pressure is determined in accordance with CSA-A440S1, the Canadian Supplement to NAFS, using the Driving Rain Wind Pressure (DRWP). Water penetration resistance of windows in Canada is not based on a fraction of the wind load (Design Pressure) as in the USA but instead on wind pressures measured during rainfall at specific locations across Canada (typically airports), for a 1/10 return period probability, modified for terrain condition (open or rough) and building height. This can result in the test pressure for water penetration resistance being lower or higher than required by NAFS for locations in the USA. Consequently, water penetration test performance levels need to be checked carefully for systems imported to the USA. The authors have worked with Canadian window wall manufacturers who have tested systems similar to curtain wall systems, to AAMA 501 at 300 Pa and 600 Pa (6.24 psf and 720 psf) pressure differentials so such systems are available.
- Appendix A also identifies AAMA 501.1 *Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure* as a test method that can be used to evaluate the performance of 'other fenestration assemblies'. The reference to AAMA 501.1 is significant because it recognizes that Canadian window walls systems are similar in some respects to unitized curtain wall systems, often installed at similar building heights (50 stories or more) and therefore, subjected to dynamic wind forces. Typically, in the past Canadian window walls were tested to static cyclic pressure differentials only (ASTM E 331 and E 547) which may not adequately duplicate service conditions when installed on very tall buildings. The authors have worked with several manufacturers of Canadian window wall systems who have tested to AAMA 501.1.

These new requirements and recommendations in the NBC 2015 will be used as a basis to highlight some critical differences between current Canadian and USA window wall assembly and installation details. The differences described following should be taken into account when considering importing a Canadian window wall system for a residential high-rise apartment building construction in the USA.

STRUCTURE AND ANCHORAGE

Attachment methods for Canadian window wall systems evolved from methods originally used for 'punch' windows set into two-wythe face brick on concrete block mass walls. In mass walls, windows were often secured with mounting flanges around the perimeter of the frame let into the collar joint between the face brick and back up concrete block. Where windows were set against concrete structural floor slabs, strap anchors were used to secure the window head to the underside of the slabs. Mounting flanges have long since disappeared (as have the surrounding brick on block mass walls) but strap anchors continue to be used by some manufacturers to secure floor-to-ceiling window wall panels to the concrete structure, precast concrete panel cladding or wind load bearing steel stud frame. Strap anchors generally consist of aluminum flat stock cut into narrow strips and screw fastened to the window head or extruded aluminum strips formed with a T-head to interlock into a formed race in the frame. Strap anchors were originally anchored to the concrete structure and the inner wythe of concrete block masonry with powder actuated fasteners and later, with pre-drilled concrete screws. In more recent buildings with wind-bearing steel stud framed walls behind the cladding, self-drilling, self-tapping screws or pre-drilled tapping screws would be used to fasten strap anchors to the stud frame or to wood buck liners on the steel frame.

Strap anchors are still favoured by many Canadian window wall manufacturers because of their flexibility, allowing installers to adjust to site conditions rapidly by bending the strap to suit variations in head to floor slab gap or easily repositioning the strap (if secured via interlock into the head rail) if fastener installation be frustrated by hard aggregate or embedded reinforcing steel or some other conflict. The length of strap anchors is usually kept short to minimize interference with interior finishes. These benefits can also be a liability. Strap anchors may not be long enough to extend across larger than expected window head to slab gaps. Installers sometimes stitch together two or more straps to reach the slab, providing dubious structural attachment and interfering with interior finishes. Repositioning straps to where frame to structure gaps are narrower or to avoid some type of interference may compromise needed anchorage for the window wall frame to resist lateral loads (wind, soft body impact/guard loads, etc.). Forethought is required to avoid conflict and adapt to construction tolerance errors (Fig. 3).



Figure 3: Examples of strap anchors at the head rail of a window wall. Left, straps secured with concrete screws to the underside of the floor slab with one component polyurethane foam air sealant foam in the rough opening gap as an air seal. Right, rough opening gap exceeds the length of the strap so straps are extended by stitching end-to-end. A gunned sealant was applied over the foam to ensure continuity of the air barrier. Encapsulating the perimeter of the straps may be needed if access behind the strap for sealant application is restricted.

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Strap anchors at the head have flexibility for vertical movement but little for lateral movement, such as might be caused by seismic activity. In seismically active regions, some manufacturers have adopted USA style head receivers and in some cases, jamb receivers also. Receivers may also have benefits in allowing easier relocation of fasteners from design locations to avoid hard aggregate, embedded reinforcing steel, damaged concrete, etc. The use of head and jamb receivers is not universal and should not be assumed to be provided.

At the floor slab, it has become common to secure window wall systems with a continuous extruded aluminum angle (back angle) along the room-side face of the window panels, fastened to the sill rails and bottoms of mullions with self-drilling, self-tapping screws and to the floor slab with concrete screws. Such connections are rigid. Movement capability for interstory drift and seismic activity can occur only at the head and jambs. Extruded aluminum sub frames/sill pans for structural anchorage and air and water leakage control, typical in USA window wall systems, are not common in Canadian window wall systems. The continuous back angle provides similar functions but is not as robust, and typically is not shimmed to adjust for slab irregularities and variations in floor to floor height. Variations in floor-to-floor height thus is typically accommodated at the head only which may lead to the problems with strap anchors being too short, as discussed. Floor to floor variations can also affect the overlap of head expanders on the window wall panel head so just as with strap anchors but it is easier to correct by shimming down the head receiver.

Window wall panels are often manufactured in widths similar to unitized curtain wall panels, 1220 to 1524 mm (48 – 60 in.) wide, typically the width of one fixed-glazed insulating glass unit or operable window. Panel width is limited by rail strength to support the dead load of insulating glass units within allowable deflection amounts, overall panel weight that can be moved manually and by hoist, overall panel size that can be accommodated by shipping services, etc. Adjacent panels are joined together by some form of mechanical interlock between the jamb mullions. Methods vary by manufacturer. Common approaches are to nest the open-back mullions with one mullion being slightly deeper than the mating mullion on the adjacent panel, and using connector plates H-shaped in cross-section (H-bar connectors) that slip over the exterior and interior faces of the open back mullions, tongue and groove style. These joining methods typically increase the depth of the mullions beyond the exterior and interior faces of the rails which can cause some difficulties when installing air and water seals and head and sill, as will be described later.

Where window walls pass in front of columns and shear walls there may be conflicts with the installation of strap anchors, head receivers and back angles. It may be possible to offset strap anchors laterally but head receivers and back angles must be continuous not only for structural anchorage but also to maintain air and water tightness of the wall/window interface. Columns and shear walls should be recessed behind the slab edge sufficiently for the anticipated width of the anchor system plus working room to install fasteners and also for air and water leakage control membranes, sealants, etc. This requires careful forethought during architectural and structural design. Unfortunately, the window wall manufacturer may not be selected early enough in the construction process to provide necessary design input so modifications may need to be made on site. Any modifications affecting the structure of wall panels should be reviewed and approved by a licensed design professional (Fig. 4).



Figure 4: Examples of interference/lack of coordination between structure, mechanical services and window wall systems.

Left and centre: column not recessed to allow the window wall frame to pass in front. The installer's solution was to cut away horizontal components including rails, and head receiver.

Right: kitchen and bathroom exhaust duct bulkhead installed before head rail/underside of floor slab joint air seal was complete (compare to Fig. 3, right).

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As noted, a defining feature of Canadian window wall is the slab by-pass. Typically, the sill extrusion inboard of the thermal break is anchored to the upper surface of the slab with a continuous back angle and mullion extrusions and sill extrusion outboard of the thermal break are extended down to the head rail of the window panel below, concealing the slab edge. In early window wall systems the by-pass was face sealed with composite panels consisting of metal skins sandwiching a rigid extruded or expanded polystyrene core glazed into the frame from the exterior. Such systems often had poor water leakage

resistance. Today, most Canadian window wall systems employ rainscreen design principles, including at the by-pass. The spandrel infill is a cladding that needs to resist gust wind loads. Air leakage and water penetration control are provided by waterproofing membranes and sealants behind. These functions will be discussed in more detail later (Fig. 5).



Figure 5: Examples of continuous sill angle with self-adhesive membrane waterproofing at exterior.

Left, continuous angle installed at the edge of the floor slab. Right: membrane installed at a curb at a balcony with the self-adhesive membrane overlapping the thermofusible waterproofing membrane for the balcony. All Photographs © Morrison Hershfield, 2106.

AIR LEAKAGE AND WATER PENETRATION CONTROL

As surrounding wall systems have changed from mass masonry construction to rain screen systems, window design and assembly and installation detailing has also changed. Today, most Canadian window wall systems are designed and installed according to the rainscreen principle. This consists of designing the systems so that exterior surfaces and sealants present a deterrent to precipitation ingress with barrier air and water seals located inboard, protected from direct wetting, gust wind pressure, solar radiation, etc. which should ensure long service life. The interstitial space between the exterior surfaces and sealants and internal seals is typically vented to moderate wind pressures on the internal air seals and drained to remove moisture that may penetrate back to the exterior.

Generally, window wall panels are factory prefabricated including infill glazing, vents and spandrel panels. On-site fabrication is limited to connection details such as inside and outside corners and junctions to adjacent enclosure systems. Frame openings are individually sealed, drained and vented to the exterior. Cascading, internal drainage to a sub frame/sill pan that is wept to the exterior, as is common in the USA, is unusual in Canadian window wall systems. However, allowance for leakage through frame joinery and through interface joints between window wall systems and adjacent wall systems is provided at the sill. The interface joints are typically waterproofed with gunned, liquid-applied sealants (caulking, bead-applied polyurethane foam) and membranes (self-adhesive, field-applied adhesive and/or thermofusible). Window wall systems used on the Canadian west coast and bound for the USA are likely to incorporate head receivers and sometimes jamb receivers instead of gunned sealants and membranes.

Insulating glass units are typically laid-in glazed from the building interior side of the frame. Rain screen design at the perimeter of insulating glass units is accomplished with gunned, liquid applied sealants and/or preformed elastomeric rubber gaskets around the full perimeter of each unit to the surrounding frame mullions and rails. Each frame opening in a window wall assembly (both vision and opaque areas) is usually wept directly to the outside through openings in the horizontal rails below, similar to a rainscreen designed curtain wall. Opaque areas (spandrel panels) are constructed similar to Canadian style rainscreen curtain walls with a sheet metal back pan sealed to the surrounding mullions and rails, with insulation mechanically secured to the outside face of the back pan, and with a cladding at the exterior glazed into the surrounding frame. The interstitial space is drained and vented to the exterior.

Strap anchors projecting beyond the interior, building interior face of window wall systems breach the interior seal at head and often, at jambs also. To maintain air leakage and water penetration control, each strap must be carefully encapsulated which is tedious, time consuming and expensive work. It is difficult to apply sealants to the edge of open back frames because the frame edge is narrow, providing little bond area for the sealant to the frame. A more robust fillet bead application to the room-side face of the frame provides more certainty of adhesion and long-term performance. However,

such sealant application may interfere with interior finishes (refer to Fig. 3). An alternative is to use a head receiver with preformed elastomeric rubber seals to the frame head to permit interstory drift and seismic movements and gunned, liquid-applied sealants for the static connection between the head receiver and the structure. Head receivers are available from most manufacturers serving the Canadian west coast markets. Some manufacturers can also supply jamb receivers.

At the sill, air and water leakage control is typically provided by application of a membrane over the edge of the floor slab behind the slab by-pass, extending from a head flashing or head receiver above the panel on the floor below to the vertical upturn leg of the continuous back angle used to anchor the sill. The membrane upturn is sealed to the window wall sill rail with gunned, liquid-applied sealant. The quality of the back angle membrane/window wall sill rail seal can be affected by the joining method between adjacent window wall panels. As described previously, nested mullions or H-bar connected mullions are deeper than the rails. When the mullions are set against the back angle, gaps are created between the upturned membrane on the back angle and the rails. The gaps must be filled with sealant. A common installation technique is to apply sealant to the membrane upturn prior to moving the panels in place, relying on squeezing of the sealant to fill the joint. This 'smash glazing' approach may not completely fill the gaps. A similar problem occurs at the head when head receivers are used. Preformed elastomeric rubber gaskets typically provided between the receiver and the window wall panels must be sufficient flexibility to seal the narrow gaps at mullions and the wider gaps at rails. Installation techniques should be reviewed carefully during construction and the method adjusted if inadequate sealing is detected (Fig. 6).



Figure 6: Careful thought in 3D is required to ensure continuing of air and water leakage control.

Left, a head receiver butts against a self-adhesive air barrier and WRB returned into the rough opening from an adjacent envelope enclosure system. A gunned sealant was applied to ensure continuity. Right: at another junction condition, the continuous sill angle and self-adhesive waterproofing membrane are extended past the jamb mullion into the adjacent wall assembly. Continuity between envelope systems was not adequately considered during design and construction. All Photographs © Morrison Hershfield, 2106.

A weakness of using different methods to seal the interface joints between window wall perimeter and adjacent wall systems at sill, jamb and head is ensuring continuity at junctions. Architectural and window wall manufacturer shop drawing details are almost exclusively two dimensional so junctions between different sealant systems must be discerned through careful study. If not addressed in the drawing review stage the installer is left to figure out a solution on site. The knowledge, experience and skill of the installer greatly affect the quality of the solution which can range from simply applying more gunned sealant to bridge or fill gaps to well thought out and installed flexible membranes, brake-shaped aluminum closures, etc. In this regard the common approach in the USA of using head and jamb receivers and a sub frame or sill pan at the sill, designed as a system with similar components, is superior to the Canadian approach.(Fig. 7).



Figure 7: Careful thought in 3D is required to ensure continuing of air and water leakage control.

Left, a head receiver butts against a self-adhesive air barrier and WRB returned into the rough opening from an adjacent envelope enclosure system. A gunned sealant was applied to ensure continuity. Right: at another junction condition, the continuous sill angle and self-adhesive waterproofing membrane are extended past the jamb mullion into the adjacent wall assembly. Continuity between envelope systems was not adequately considered during design and construction. All Photographs © Morrison Hershfield, 2106.

To be fair, it should be noted that the success of window wall systems in the USA also rely to a great extent on gunned, liquid applied sealants to prevent air and water leakage. Both families of window wall systems need good design and diligent shop and site personnel to correctly assemble and install frames and infill. A good QA/QC program should identify issues of concern in the shop and on site to ensure successful performance of the window wall and the building envelope as a whole.

CONCLUSION

This paper attempts to outline the distinctive characteristics of Canadian window wall systems to an audience outside of Canada, and primarily from the USA, some of whom may be considering the use of imported Canadian window wall systems. Within the limited space available in this paper we have provided a historical overview of the development of Canadian window wall and incoming model National Building Code of Canada requirements to set the stage for a discussion of key aspects of design, construction and installation detailing. There are significant differences from USA window wall systems which need to be considered. Despite the identified issues, with careful architectural, structural and manufacturer design and drawing review, careful factory prefabrication and site installation, Canadian window wall systems can provide cost effective and durable enclosures for high-rise residential apartment buildings in Canada and in the USA.

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REFERENCES

- Kesik, Ted and Saleff, Ivan, *Tower Renewal Guidelines for the Comprehensive Retrofit of Multi-Unit Residential Buildings in Cold Climates*, University of Toronto, 2009.
- Hoffman, Stéphane P., *Adaptation of Rain-Screen Principles to Window-Wall Design*, Thermal Performance of the Exterior Envelopes of Whole Buildings VIII, 2001.