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WINDOW WALL AND CURTAIN WALL: AN OBJECTIVE REVIEW

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Abstract: The enclosure designs for modern tall buildings in Canada often incorporate highly glazed cladding systems such as the window wall and the curtain wall. Simply put, the main difference between the systems is that the window wall structurally sits between the suspended reinforced concrete slabs while the curtain wall is hung off the slab edges by anchors. However, there are many more intricacies that differentiate the systems. The aesthetically slick and more expensive curtain wall is most often used in commercial buildings, while the highly customizable and constructible window wall is mostly used in residential construction. Further, curtain walls are designed to be self-supporting structures and must be installed from the outside via crane or rig while window walls are supported by the existing structure and can be installed from inside. In this paper, a comprehensive comparison of the two systems is presented. Thermal performance, water penetration, air leakage and moisture control are used as the metrics for each system's overall performance. A comparison is also made for the two systems' constructability, cost, and maintainability. Recommendations are outlined for the best use of each system, and improvements to their standard builds are defined. Overall, the window wall and curtain wall are very similar systems that can both be improved significantly from their typical designs. Both systems have their strengths, and can prove to be useful alternatives to each other with careful design.

1 Introduction

Over the last 150 years, many important innovations have led the evolution of tall buildings. Technological advances such as elevators, tower and "kangaroo" cranes, air conditioning, and design methods for earthquake and wind forces have allowed buildings to reach taller and taller (Massarella, 2008). Most important, however, was the change in materials so that the building envelope no longer served as one of the main structural elements of the building. Moving away from stone and bricks as structural elements, the introduction of steel and concrete enabled buildings to reach higher and allowed them to have non-structural façades. Prominent early adaptors of this method like the Fuller Flat Iron building (1902) and the Empire State Building (1931) in New York were able to build tall with steel frames and stone façades. Tall buildings were reserved for commercial use at the time, but high-rise residential buildings soon followed. Early iterations of the façades used stone and brick, and later cast in place concrete and pre-cast concrete panels were used. Glass façades were famously introduced on a large scale with The Crystal Palace (1851) in London for the Great Exhibition, however, it is argued that the modern glass façade as we know it, also known as the glass and metal curtain wall, first appeared with the Hallidie Building in San Francisco in 1918 (Yeomans, 2001). As the technology developed, and window glass became a more accessible material, the curtain wall grew to be a favourite of modern architects and wealthy companies who wanted to design and construct state of the art buildings. While the aesthetic was the main driver in its popularity, glass curtain walls also provided great daylighting, visual connection to the outdoors, and could promote a transparent corporate culture. Further, glass is an extremely durable material and acts as the buildings rain screen, air barrier and vapour barrier. The glass building is now a defining feature of modern city skylines. Some of the most prominent buildings in the world have all-glass facades, such as the Burj Khalifa (2009) in Dubai and the One World Trade Centre (2013) in New York City.

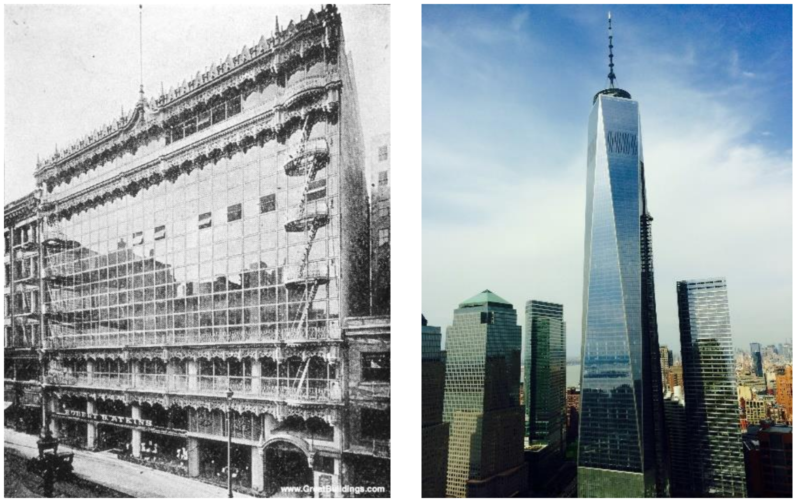

Figure 1: Evolution of the Glass Façade – left, Hallidie Building (1918), right, One World Trade Centre (2013)

Today, there are two main types of glass cladding systems: the window wall and the curtain wall. They are quite similar and the terminology can even be confusing. The window wall has been considered by some as a type of curtain wall (Frey, 2013) and perhaps even more blurring is that when the curtain wall technology was first being developed, it was referred to as a window wall (Yeomans, 2001). There is very little written in academia about the window wall, perhaps because it is lumped into articles that discuss curtain walls. In the Canadian construction industry, there is a clear difference between the systems. Simply put, the difference between the systems is that the window wall structurally sits between the slabs and the curtain wall is hung off the slabs (CMHC, 2004). However, there are many more intricacies that make these systems different.

First of all, the curtain wall is aesthetically slick, modern and desirable for many architects. It is used primarily for commercial buildings, and some unique residential projects. Curtain walls are structurally engineered and typically installed from the outside using a crane or a rig, which make them more expensive than their competitor and more rigorous to install. The window wall is generally less expensive and is installed from the building interior, but in early versions provided a break at every floor which detracted from its sleek continuity. They are almost exclusively used in residential buildings since they provide a practical and cost effective method to install highly glazed cladding, while still allowing balconies and operable windows. With modern window wall systems, it is possible to closely mimic the sleek aesthetic look of a curtain wall (United States Patent No. 0113891, 2015).

Commercial buildings have a variety of uses and are therefore constructed differently than residential buildings. For example, in residential construction there are usually many more enclosure penetrations needed for mechanical penetrations; here, a highly customizable window wall becomes very favorable. These penetrations are not as prevalent in commercial buildings which usually have centralized mechanical ventilation that services the entire building using vertical duct runs. Another difference that affects the façade is that commercial buildings do not typically have operable windows and balconies on every floor, thereby allowing the continuous cladding system found in curtain walls.

The two cladding systems are used in different situations, but a thorough performance comparison has yet to be made. This review paper offers an objective comparison of the two systems and recommends their best use and possible improvements. Caveat: the authors recognize details regarding both systems vary depending on location, manufacturer, and design. This paper's conclusions may not be applicable to all cladding systems.

2 The Curtain Wall

A curtain wall is an external, non-bearing wall that separates the exterior and interior environments (Carmody, 2004). The term "curtain wall" actually defines a broad spectrum of different wall types, but the everyday reference to the curtain wall refers to the glass and metal curtain wall (CMHC, 2004). Unlike windows placed into a wall also known as punched windows, curtain walls can comprise the entire outer skin of the building. They consist of vision glazing as well as opaque spandrel panels. Vision glazing simply means that the glass is transparent or translucent. A spandrel panel is an opaque, thermally insulated unit in the curtain wall. The exterior finish on the spandrel panel may be glass, forming a continuous exterior envelope made completely of glass and framing materials. Aluminium is used almost exclusively as the frame material in curtain walls. Some steel is used as well but it is often clad on the exterior with aluminium or stainless steel caps (Carmody, 2004).

There are two main types of curtain wall: stick and unitized. In the stick system, the curtain wall is installed piece by piece in the field. The framing components are one or two storey vertical mullions and horizontal rails equal in length to the glazing or opaque panels. Used primarily in low to mid-rise buildings, they are labour intensive and require a specialized crew to install it (CMHC, 2004). Most stick systems are standard, off-the-shelf products and therefore have relatively low material cost. An advantage of the stick system is the low expense of shipping and handling due to the ability to efficiently package and transport the separate components. In the unitized system, which is more common in high-rise buildings, large panels are preassembled in a factory and are shipped for installation on site. The unitized panels are faster to install and have better quality control at the joint seals because they are assembled in the controlled environment of the factory as opposed to onsite assembly (CMHC, 2004). Other types of curtain wall include cable net systems, point-supported glazing and glass fin walls (Frey, 2013).

The curtain wall is attached to the building with anchors that hold the dead and lateral loads of the wall. The anchors are either cast in place or drilled into the slab edge. If embedded in the concrete slab, the anchors must be installed long before the curtain wall is installed, and end up in the critical path of the construction (CMHC, 2004).

The curtain wall also has different methods for connecting the glazing to the frame. The basic method for designing the connection is to use pressure plates. The glass is held in place by a metal pressure plate on the outside which is attached to the metal framing members on the interior. Synthetic rubber profiles can also be used to hold glazing units in place. As a means of minimizing the exterior portion of the frame for aesthetic reasons, structural sealant glazing was developed. Silicone adhesives permit the glass to structurally adhere directly to the interior frame. The silicone carries some of the weight of the glass itself and transfers wind pressure to the frame. All that appears on the outside are the glazing panes with narrow, sealed joints in between.

3 The Window Wall

Sometimes referred to as a type of curtain wall, the window wall is an aluminium framed unitized cladding system used primarily on mid and high-rise residential construction. The distinctive feature of the window wall is that it spans between the floor slabs. At the base of the system on each floor, the window wall units are laterally fastened to an aluminium angle, which, in turn, is fastened to the floor slab. The floor slab directly supports the vertical load of the unit. The top of the unit is fastened with aluminium straps on the underside of the slab overhead. The window wall panels are typically installed from the building interior which improves logistics, simplifies installation and costs (YKK-AP, 2017).

Typically, the majority of the panels in a window wall system are vision glazing, however, at various locations such as shear wall and column covers, opaque panels are installed. The system is prefabricated in a factory and installed on site similarly to the unitized curtain wall system. The window wall requires substantially less infrastructure to facilitate installation. Since the curtain wall completely bypasses the slab edge, fire stopping and extra finishing are typically required, as opposed to the window wall. Early versions of the window wall left an exposed slab edge that caused problems which lead to innovations. Second generation window walls have a slab band cover spanning the depth of the slab that can be installed independently of the window wall system or as an extension of the window wall frame (Hoffman, 2001). Modern window wall systems can have the slab cover be part of the unitized panel as shown in Figure 2.

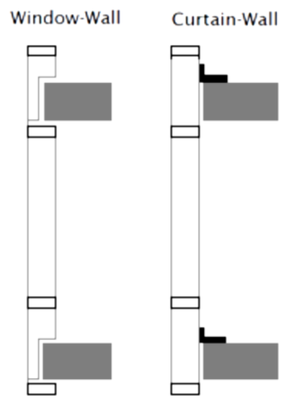

Figure 2: Simplified Window Wall and Curtain Wall

Unlike the unitized curtain wall, which typically relies on rubber gaskets to provide air seals, water resistive barrier, and rainscreen, early versions of the window wall relied heavily on sealant (Hoffman, 2001). Sealant, typically silicone, is applied at the interior face junction of the mullions to provide an air tight and water resistive barrier. Therefore, the performance of the window system is heavily reliant on the quality of site workmanship. More modern window walls can use a combination of plant installed seals as well as site applied material. Often, as sealant application occurs near the end of the project, there is pressure to both install quickly, and to install in inclement weather, such as when it is too damp or too cold. The building envelope engineer must be willing to step in and prevent installation in conditions that may negatively affect the long-term performance of the cladding.

Window walls are very customizable and can easily incorporate operable windows, balcony doors, and other desired penetrations compared to the curtain wall. The window wall also compartmentalizes the units better than a curtain wall would since there is no gap between the slab edge and the cladding. Compartmentalization has become desired to reduce the stack effect and improve energy efficiency (RDH Building Engineering Ltd, 2013). Since window walls are installed between floors unlike the continuous curtain wall, sound, smoke and odour transmission between floors is reduced, which is desireable for multi-unit residential buildings.

4 Comparison

When comparing the two systems, a focus is placed on the unitized curtain wall, since it is the most similar to the window wall. The metrics of thermal resistance, water, air and moisture control and cost are used to compare the systems. It is important to note that window-to-wall ratio (WWR) and insulated glazing unit (IGU) selection will have significant impacts on all metrics, but their impacts would be the same in both systems so they are not significant to this comparison.

4.1 Thermal Performance

Glazing systems have three significant heat flow paths: through the frames, through the edge-of-glass region and through the center-of-glass region (Straube, 2012). The IGU performance is the same for the window wall and curtain wall systems. What will change is the framing and the way the cladding connects to the structure. Typical framing is aluminum, which is more conductive than glass and creates a thermal bridge. Thermal bridges are localized areas of high heat flow through walls and other building envelope assemblies. Thermal bridging is caused by highly conductive elements that penetrate the thermal insulation. These paths allow heat flow to bypass the insulating layer and reduce the effectiveness of the insulation. Heat flow through thermal bridges can be significant and disproportionate to the overall enclosure area, which can cause a seemingly well-insulated building to underperform (Finch, 2014). Windows are targeted as obvious thermal bridges because of their relatively low thermal performance especially compared to surrounding walls, but exposed concrete slab edges and protruding balconies have nearly as much influence (Finch, 2014). Thermal barriers and/or breaks are needed to avoid major heat loss (Carmody, 2004). A thermal break is a non-conductive material that interrupts a conductive heat flow path.

There are 3 types of thermal transmittances: clear wall, linear, and point. Clear wall transmittance is the heat flow through uniformly distributed components, such as through a typical wall section. Linear transmittance is the heat flow through details that are linear such as slab edges, corners, and transitions between assemblies. Point transmittance is the heat flow caused by thermal bridges that occur at single infrequent locations. Typical curtain walls have point connections with the aluminium or steel anchors, which do not introduce nearly the same degree of thermal bridging as window walls that have linear connections at the top and bottom of each floor (Morrison Hershfield, 2016). Window walls with balconies or without slab edge covers also expose a critical thermal bridge through the concrete slab. Thermal bridges caused by uninsulated concrete slab edges and balconies can reduce the effective R-value of full height wall assemblies by over 60% (Finch, 2014).

Table 1: R-Values of Typical Sections (Morrison Hershfield, 2016)

R-Values for Typical Sections	Window Wall	Curtain Wall
Clear Wall (1.1.1 & 3.1.1)	3.2	3.8
Slab Intersection (1.2.1 & 3.2.1)	2.8	3.7
Improved Spandrel Bypass (1.2.2)	4.2	N/A

According to thermal modeling done in the Building Envelope Thermal Bridging Guide 1.1 (Morrison Hershfield, 2016), the curtain wall has overall better performance than the window wall (Table 1). Both at the clear wall and the slab intersection, the curtain wall has a stronger R-value than the window wall. However, with an improved spandrel bypass with interior sprayfoam insulation, the window wall can exceed the R-value of a typical curtain wall (Morrison Hershfield, 2016). If the window wall design combines improved spandrel bypass and thermal breaks in the balcony slabs to ensure a continuous thermal barrier, relatively strong thermal performance can be achieved.

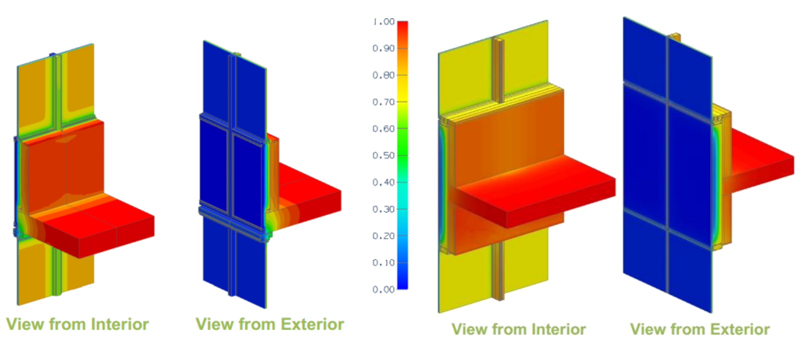

Figure 3: Thermal Gradients of Window Wall and Curtain Wall (Morrison Hershfield, 2016)

4.2 Water Penetration & Air Leakage

Water penetration is one of the most persistent problems in all wall types. Five forces are responsible for the migration of water through an exterior wall system: gravity, kinetic energy, air pressure difference, surface tension, and capillary action (Vigener, 2016). Unlike other wall types like masonry and stone that have the capacity to absorb water, most materials in curtain walls and window walls are impervious to moisture. This is one of the big advantages of glass cladding as it greatly reduces the risk of water penetration. However, this puts much more importance on the joints and seals.

There are 3 mains design concepts for controlling water penetration: exterior face seal, internal drainage, and pressure equalized rainscreen (PER). The exterior face seal was commonly used throughout the 1960s and relies on the integrity of the exterior sealant and gaskets to control water penetration. However, there were many problems as water still found a way to enter. Despite continuous industry improvement of sealant materials, excessive water leakage persisted due to poor workmanship and stress fatigue caused by wall joint movement (Ting, 2012). Designers started to assume that water will enter and provided a drainage path. The internal drainage system provides backup drainage to the exterior and was used through the 1960s and 70s in Canada and is still common in the USA. A downside of this system is that the intentional openings in the air barrier can lead to condensation (CMHC, 2004), especially in cold climates. The PER is the most common and contemporary design in Canada and has an intentional delineation of cavities.

Early window wall and curtain wall systems were commonly face-sealed systems and therefore susceptible to water infiltration (Hoffman, 2001). Chronic water infiltration problems were due primarily to deficiencies in the primary exterior seal, among other problems. In response, the pressure equalized rainscreen was adapted. The key to preventing water infiltration is redundancy within the system so there are many drainage paths for the water to take.

As curtain walls do not have exposed slab edges, the key factor for air and water tightness is the interface between the IGUs and the mullions and rails, which uses rubber gaskets to provide an air seal and water barrier. If the window wall has an exposed slab edge or penetrating balcony slab, there are extra interfaces that must be sealed. Even with flush slab edge covers, window walls have more interfaces, which increase the risk of water and air leakage (Ting, 2012). To ratify these leakage paths, a water drainage surface within the slab edge cover should be designed (Ting, 2012). Both systems have problems with connections between the system and other interfaces such as brick veneers, concrete panels and even window wall to curtain wall connections (Hoffman, 2001).

Water penetration and air leakage in curtain walls and window walls are closely interlinked (CMHC, 2004). Limiting air leakage through the building envelope is significant for controlling energy efficiency, moisture problems, noise transfer, smoke propagation, indoor air quality, and durability (Becker, 2010). Air leaks in a building envelope are also prone to water penetration. In the face sealed and rainscreen concepts, an impermeable plane is theoretically able to also provide an air barrier. In the case of curtain walls and window walls, most components are composed of airtight materials which are joined using contact or sliding joints, which therefore restrict the air flow to the contact areas. The air barrier system consists of the glass, frames, and gaskets and sealants that connect and join components together and at the interfaces to other assemblies (RDH Building Engineering Ltd, 2013). Window walls and curtain walls are tested to meet the requirements outlined in CSA A440, NFRC or ASTM standards. Therefore, the components tend to be very airtight (RDH Building Engineering Ltd, 2013). The largest variables in the airtightness are the quality of workmanship, design flaws or deformations caused by loads (thermal, gravitational and wind) (Becker, 2010).

Overall, since the curtain wall has less exposed parts and simpler connections to the structure, it has an inherent advantage over the window wall in terms of water penetration and air leakage. Further, operable windows and balcony doors are extra variables that are rarely present in curtain walls that would significantly raise the risk of leaks. However, if properly designed and installed, the window wall can outperform a typical curtain wall. In tall residential and commercial buildings, wind driven rain and strong winds will be major concerns and proper design of either curtain wall or window wall is needed to achieve strong performance.

4.3 Condensation

After water penetration, condensation is the most often reported performance issue (CMHC, 2004). The control of condensation is closely related to the thermal performance of the glazing system. Thermal bridging increases the chance of surface condensation in a fenestration system (Yan, 2014). Effective thermal breaks that retard heat flow from the warm interior to the cold exterior, or vice-versa, will help prevent condensation problems. Design for condensation resistance is effectively a process of minimizing the frequency and extent of condensation formation. It is not practical to expect that no condensation will ever occur as there will always be some extreme condition under which it can form. Instead, guidelines provide an allowable level of condensation under specific indoor and outdoor temperatures and indoor relative humidity at which the level is to be evaluated.

In both the curtain wall and window wall systems, the larger risk of condensation is within the spandrel panels. The typical construction of the spandrels uses a single exterior plate such as aluminum or single pane opaque glass with insulation behind it (Ting, 2012). In this case, the surface temperature on the back side of the exterior skin can be very low in the winter, presenting potential problems. Moisture on the interior of the spandrel panels can lead to the deterioration of the wet insulation, corrosion of steel parts, and in extreme cases, mold. These problems can be avoided with the careful detailing of insulation and air/vapor barriers (Vigener, 2016). Most systems include condensation drainage, which collects and drain water away from the spandrel to the exterior.

Curtain walls may have condensation problems with shadow boxes. A shadow box creates the appearance of depth in a spandrel panel by incorporating transparent glass a few inches away from the opaque layer. They are used to provide a more uniform appearance to the curtain wall. Detailing to allow venting of the space to prevent excessive heat build-up and thermally isolating the cavity from the interior can prevent condensation problems in the shadow boxes (Vigener, 2016).

Current window wall systems now add a cover to the exposed edges of the concrete slabs to make it aesthetically smoother, protect the concrete edge from environmental damages and prevent thermal bridging. However, in cold climates, there is a high potential for condensation in these cavities (Ting, 2012). The curtain wall does not have this problem as there is a separation between the slab edge and the spandrel cover. The condensation can be controlled with the help of an improved design known as air loop system. In the air loop system, the slab edge cover cavity is vented, allowing pressure equalization and easy drainage to the outside (Ting, 2012). If the slab cover is well designed, the window wall can achieve similar performance to the curtain wall in this respect. Note that certain provisions to improve the thermal performance like insulating the mullions or filling the window frame with expansion foam can lead to condensation in cold climates (McCowan, 2016).

Both the window wall and curtain wall have potential condensation problems that should be considered in their design. The window wall has the disadvantage of having a slab edge cover, but the air loop system can prevent damaging condensation problems.

4.4 Installation

Even a well-designed glazing system can be easily degraded by poor installation methods. Unitized curtain walls and window walls are both highly engineered and factory built with close tolerances. However, the placement of these precisely manufactured assemblies on a structure that was built to much greater dimensional tolerances can lead to issues with the overall façade, such as air and water leakage as well as unanticipated repairs.

Window walls are manually installed from the interior. An aluminum angle is fastened to the floor slab, and the prefabricated window wall panels are then fastened to the angle. The top of the unit is fastened with aluminum straps directly to the underside of the overhead slab. The most common installation errors are discontinuities in the sealant installation at the joints in the system and the perimeter where the window wall interfaces with the slabs and walls. Since window walls are installed from the interior, shear walls and columns can present problems if their location interferes with the window wall. One solution is to leave a gap between the slab edge and the column or shear wall to allow access, but this reduces useable space on the interior.

Curtain walls are typically installed from the outside, and the panels are lifted into place by a crane or a hoisting rig. If the anchors are not cast directly into the slab, field installation begins with the layout and installation of anchors on the slab edges. The panels are then fastened to the anchors. The curtain wall contractor will rely on the offset lines and elevation benchmarks set by the general contractor. Any error in setting these lines will impact the installation of the wall. All such marks should be set well in advance of the curtain wall installation to allow cross-checking and preparation by the curtain wall contractor.

For both systems, wind is a limiting factor during installation as the panels are heavy and have a large surface area that can be affected by wind and be difficult to place. Extreme cold and extreme heat are also problematic because these systems are designed to close tolerances, and the weather can impact both the worker and the materials being handled. As some window walls are sealed with caulking, installation during extreme temperatures can cause the caulking to take longer to cure (YKK-AP, 2017). The quality of installation can be affected by poor workmanship due to rushed installation, working in inclement weather, having multiple or untrained trades involved, and having complicated design details.

Installation issues are not always attributable to the façade/cladding installation. Variations in the tolerances of the building frame elements can be a significant quality issue when installing window walls and curtain walls. It is not uncommon to find floor slabs 50 mm above or below the specified elevation, slab edges out of alignment or columns out of plumb in existing buildings (CMHC, 2004). Curtain walls have an advantage for adapting to these variations than window walls since they are installed outside of the building and attach to the building at point anchors only. However, if the concrete slab edge is too far in or out from design position, the curtain wall installation can be affected if the position of the slab edge exceeds the adjustment tolerances of the anchor (CMHC, 2004). Alignment issues with the slabs and walls into which the window wall assemblies fit can be much more troublesome. Gaps, constrictions, and unlevel surfaces can make installation very challenging for all parts of the window wall system, including using the flush slab edge cover.

Exterior construction hoists are common to most multi-storey construction projects. The hoists and their supporting towers stay in place for a significant portion of the construction schedule, often for several months after the window wall or curtain wall is installed. As such, the cladding system cannot be installed in those areas. When the interior elevators are operational, the exterior hoists can be removed and the cladding is completed. The challenge is that as the units are designed to fit together at the mullions and the last unit cannot be fit to its neighbour as intended. The wall area must be specially detailed to allow installation after the rest of the wall is complete. Extra care must be taken to ensure that the air barrier is maintained. Depending on the time lapse between the first and final installations, the newly installed material may not initially match the already completed areas due to the weathering of the installed material. This is an issue for both systems.

Lab mock-ups are carried out for both systems so that constructability can be verified before the systems are manufactured (Lemieux, 2016). Field mock-ups should also be constructed on site to ensure that workers know how the systems are to be assembled, demonstrate that the system fits within the specified construction tolerances and enable testing of the system for water infiltration. Even though detailed 3D models can be made, they do not allow the trades an opportunity to practice the installation (Piertroforte, 2012).

4.5 Cost and Maintenance

Window walls are typically less expensive than curtain walls as shown by the cost estimates in Table 2 (Morrison Hershfield, 2014). Costs here include installation, material, and labour related to the assembly.

Table 2: Glazing System Assembly Costs (Morrison Hershfield, 2014)

Assembly Category	Detailed Description	Cost ($/ft^2)
Window Wall (§1.2.1)	Double glazed with insulated slab bypass	53.7
Unitized Curtain Wall (§3.2.1)	Double glazed with insulated metal backpan	104.9
Window Wall (§1.2.2)	Double glazed with insulated slab bypass and interior foam insulation	54.6

Construction costs vary widely in practice, but Table 2 gives an order of magnitude of the differences. A typical unitized curtain wall costs about double the costs of a typical window wall. Reasons for the lower cost of the window wall include fewer major hoisting equipment needed during installation, simpler components for manufacturing, and the lack of a requirement for it to be structurally engineered to be self-supported. Also noticeable is the relatively low increase in price for the addition of the interior foam insulation, which significantly increases its thermal resistance (Table 1).

Both curtain walls and window walls require maintenance to maximize their service life. Perimeter sealants, when properly designed and installed, have a typical service life of 10 to 15 years (Vigener, 2016). It is very important to keep the exterior seals in good condition. Exposed glazing seals and gaskets require inspection and maintenance to minimize water penetration, limit exposure of frame seals, and protect insulating glass seals from wetting (Vigener, 2016). Preformed tape and dry gasket are the most common form of the exterior seal on most modern curtain walls. In window walls, sealant is used but newer systems are converting to dry gaskets. Tapes and gaskets have a number of advantages over sealant but one notable disadvantage is the tendency for tapes and gaskets to shrink (CMHC, 2004). The application of sealant at the shrunken joint is the most cost-effective maintenance of these seals. For wall systems that use exposed exterior sealants, it is advisable to plan on localized inspection and maintenance to the sealants on a three to five-year cycle. Such maintenance work can be conducted in conjunction with regular cleaning of the wall.

In window walls, IGUs are installed from the interior with removable plastic stops and are therefore relatively easy to remove and replace and do not need an expensive exterior swing stage, as is needed to access the curtain wall. Replacement of curtain wall IGUs can also be more intrusive to tenants, as replacing larger panels can affect multiple floors; a compartmentalized window wall IGU replacements only affect one unit. However, maintenance for opaque panels in the window wall has access issues after installation. The exterior metal panels and metal back-pans are fastened with mechanical fasteners which are concealed within the mullions upon unit installation. Another limitation of window wall design is that the units are installed shingle fashion, with the mullions locked together through the entire height of the building. This makes the removal of a single or multiple units a very destructive process.

The design of both curtain walls and window walls should allow for easier replacement of defective components. The service life of even the most durable systems may be shorter than that of adjacent cladding such as stone or brick masonry veneer. Therefore, the design of the curtain wall and window wall interface with perimeter construction should permit removal and replacement without removing adjacent wall components.

5 Improvements

The thermal performance of both the curtain wall and window wall systems can be improved. Using high-quality IGUs such as low-e triple glazed units are one of the best ways to ensure better performance in both systems. Reducing window-to-wall ratio is also a proven way to improve thermal performance (Straube, 2012). New technologies such as electrochromic windows, vacuum evacuated windows and integrated photovoltaics can potentially all help with thermal performance (Carmody, 2004).

The most important factor that will lead to a successful enclosure is proper installation. Both systems can be expertly designed but if imperfectly installed, will not perform as designed. There must also be careful detailing. Holes in the cladding system, too much sealant that blocks drainage paths, and improper compression of the gaskets should all be avoided. Commissioning and regular cladding inspection can greatly improve the performance of these systems.

To improve thermal performance, thermal bridging cannot be ignored. Insulated slab edge covers are essential for reducing a key thermal bridge pathway with window wall units. Balconies should be avoided, but if necessary, thermal breaks in the balcony slab should be installed to reduce the energy losses and improve comfort for the occupant. Filling the window wall frames with low-expansion foam will maximize the thermal resistance of the frames (Straube, 2012). Aluminium frames are also very conductive, so frames with less conductive materials such as fiberglass or wood can help reduce thermal bridging. More attention needs to be spent on interface details. The interface connections between window walls, curtain walls, and other cladding types are not only thermally weak spots but present problems with water and air leakage as well.

When considering air tightness, the drawings of the construction details should be checked carefully including a virtual simulation of the sequence of construction activities to detect all 3D air paths that may develop due to the various dry joints (Vigener, 2016). Sealing these paths should be done carefully and with supervision. The façade design should start with the assumption that the external glazing seals, perimeter sealant joints, and sills will leak. The resulting water should be collected and drained to the exterior. Drainage holes should not be blocked when sealing. The drainage system should handle condensation as well as rain. In window walls, condensation at the insulated slab edge cover can be an issue, especially in colder climates. The condensation can be controlled with the help of an improved design known as the air loop system (Ting, 2012). The joint cavities will be well vented and pressure equalized and the infiltrated water is drained to the outside.

In curtain walls with pressure plate glazing, the glass and infill panels are installed from the exterior, typically against dry gaskets. The outer layer of gaskets is installed and the gaskets are compressed against the glass by the torque applied to fasteners securing a continuous pressure plate. The plate is later typically covered with a snap-on mullion cover. This system provides reasonable performance but is susceptible to leaks at corners or joints in dry gaskets. Four-sided gaskets can be fabricated at additional cost for improved performance (Vigener, 2016).

6 Conclusion

The two main glass cladding systems in Canada are the window wall and curtain wall. The defining difference between the systems is that the window wall structurally sits between the slabs and the curtain wall is hung off the slab edges. The window wall is used in residential construction as it allows a cost efficient way to compartmentalize the units, and allow units with operable windows and balconies. Typical curtain walls have an overall better performance than the typical window wall, but many improvements in new window wall designs allow it to outperform a typical curtain wall while still being less expensive. Curtain walls are more expensive, take longer to install and require specialized crew and equipment to install. Window walls can also take away some useable floor space and can be aesthetically less appealing, which can cause commercial constructors to prefer the curtain wall. Both systems’ performance relies heavily on appropriate design and installation. Many of the window wall’s perceived faults are attributed to its older iterations, such as the lack of slab covers. With the new technological advances, the window wall can be a good alternative to the more expensive curtain wall.

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