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# OVERCLADDING TO MEET THE NEEDS OF CONTEMPORARY HOUSING IN TORONTO

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## ABSTRACT

Studies of residential buildings in Toronto show poor energy use intensity in buildings constructed in the 1960s. This is often due to the obsolete heating and cooling systems, deteriorated condition of window assemblies, and poorly insulated building envelopes. To compete for environmentally aware tenants and profit from market rate rents, building owners face the challenge of meeting contemporary performance needs. Conscientious owners and institutions want to improve thermal comfort and meet the city's plan of 65% carbon footprint reduction by 2030 vs. the 1990 data.

Similar to other countries with booming post-war populations, the dynamic development of residential buildings in the 1960s and 1970s in Canada was focused on low and middle-income housing. Designers of many of these complexes attempted to follow Le Corbusier's Five Points of Architecture, but were required to work within economic restraints. Since a vast majority of mid-century modern buildings are not designated historic landmarks, maintaining their authenticity is not enforced through the Ontario Heritage Act. In the efforts to increase their performance, architects often turn to methods that will upgrade the building envelope, wrapping it in a "second skin" of over-cladding, as a middle ground between preservation, aesthetics, and cost efficiency.

Designs featuring a second skin range from simple sheet metal over-cladding to intricate glazed rainscreen systems. The paper will describe challenges faced in over-cladding design in modern residential buildings in Toronto. A range of options of detailing and lessons learned will be discussed through a review of the design process on case studies of modern buildings, where different types of over-cladding were used to improve the performance of the building envelope.

**KEYWORDS:** *overcladding, modernism, residential, Toronto*, *low-income*

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## INTRODUCTION

As many of the world's populations were recovering and growing again after World War II, their governments implemented plans to build large-scale, low-cost housing, typically following modernist design concepts. The goal to provide a large number of accessible and affordable homes at a low cost necessitated developing solutions that would help cut construction costs. This included many new inventions in the construction industry: prefabricated housing systems, such as Large Panel System buildings, peaking throughout Europe between the 1960s and 1980s, construction cranes, Chicago's first reinforced concrete high-rises in the 1960s. As a response to the high demand and thanks to these developments, new residential high-rises pop up across the globe like wildflowers.

Many post-war architects derived inspiration from studying Le Corbusier's architecture principles and Unite d'Habitation, which offered new exciting concepts and great economical solutions thanks to the high density of apartment units. In Toronto, the architectural expressions of residential buildings in the 1970s were broad and ranged from brutalist, cast-in-place concrete facades to combinations of brick veneer with exposed concrete slab edges featuring a variety of elaborate architectural concrete forms such as roof and entrance canopies, and embellishing formwork imprints, almost forming a bass-relief on facades.

As a type, reinforced concrete residential high-rise buildings flourished in Toronto in the 1960-80s thanks to the development of flying-form technology and increasingly widespread crane technology. This typology quickly became a means to respond to the increased demand for affordable housing in the city, partially caused by new post-war immigration. Often featuring wide city views, elaborate entrance canopies, and amenities such as swimming pools and open rooftops, several decades ago these buildings were the epitome of high-standard modern living (Saleff, 2007).

## PERFORMANCE CHALLENGES TODAY

The quality of architecture and workmanship varied greatly across the world and between buildings, with numerous performance challenges - such as inadequate insulation, explosions of obsolete gas pipes, inefficient mechanical (heating and cooling) systems or social issues in low-income housing complexes.

Half a century after the construction date of many residential towers, architects have begun to raise the question of whether preservation of these buildings should come along with the very needed performance upgrades. Preserving the original façade underneath a second skin allows keeping and protecting the façade from atmospheric factors and associated weathering, while reducing the cost of a comprehensive repair campaign, limiting it to necessary structural and safety repairs. In fact, overcladding provides designers with the opportunity to transform the aesthetics of the building, improve its thermal comfort, and employ advanced mechanical systems which additionally help protect the existing fabric.

A common issue faced by buildings of this era is poor energy intensity, which is believed to be caused by their age and associated service life of their systems. The heating and cooling loads of existing buildings are mainly defined by energy loss or gain through the building envelope and cooling and heating mechanical systems' efficiency. The building envelope performance depends on wall insulation, the condition of window assemblies - such as glazing, frames, and gaskets - and airtightness between components (Binkley, 2012).

According to United Nations' surveys (2017), heating buildings – currently dominated by fossil fuels – accounts for 30% of building-related $CO_2$ emissions worldwide (Global Status Report, 2017). Energy loss via thermal leaks and inadequate insulation is responsible for the majority of this greenhouse gas emission (Neuman, 2017).

To mitigate the effects of this phenomenon, local governments worldwide plan significant carbon footprint reductions – e.g. New York plans a 40%, while Toronto - a 65% carbon footprint reduction by 2030 vs. their 1990 levels. Both cities declare a target of becoming fully carbon neutral by 2050 the latest (City of Toronto, 2020 and NYC Mayor's Office of Sustainability, 2021). To achieve this, existing buildings require energy efficiency improvements.

**RETROFIT STRATEGIES**

Since buildings of the aforementioned vintage provide housing for millions of people worldwide, the most popular retrofit approaches, due to low associated costs, include the installation of supplemental insulation (thermo-modernization) and the replacement of individual mechanical and plumbing systems. While there are numerous innovative preservation technology solutions available in efforts to achieve the desired metrics, the purpose of this paper is to explore and evaluate over-cladding as a means to improve the performance and aesthetics of mid-century modern residential buildings. This retrofit strategy was deemed highly promising as it offered various system upgrades, including insulation, weatherproofing, soundproofing, ventilation, and more.

A common denominator between buildings of the mid-century modern period across the globe is their durability (Kesik, 2001). Since concrete was used not only in the structural walls, but also partitions and exterior aesthetic walls, many buildings of that era have a reserve load capacity that can currently accommodate overcladding, which is often very light thanks to modern technologies.

Different overcladding options reviewed in this paper will be illustrated with the following project case studies: Sherbourne Estates (historically: Centrepoint Towers) in Toronto, ON (Canada), St. Clair Birchmount buildings in Toronto, ON (Canada), AJ Celebrezze in Cleveland, OH (USA) and One Indiana Square, Indianapolis, IN (USA). See Figure 1.

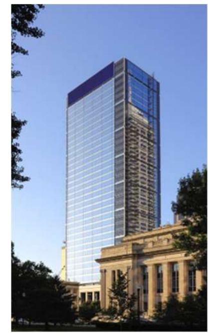
| **Photo** |  |  |  |  |
|---|---|---|---|---|
| **Project** | Sherbourne Estates[4] | St. Clair Birchmount[5] | AJ Celebrezze[6] | One Indiana Square[7] |
| **Location** | Toronto, ON | Toronto, ON | Cleveland, OH | Indianapolis, IN |
| **Type of overcladding** | hybrid solution | existing metal rainscreen / new EIFS | continuous curtain wall | continuous curtain wall |

**Figure 1: Case study projects presented in this paper.**

## BUILDING ENVELOPE THERMAL PERFORMANCE CONSIDERATIONS

The city of Toronto declares a goal that all existing buildings will have been retrofitted to achieve net zero emissions by 2050, and 100% of energy will be derived from renewable or low-carbon sources (City of Toronto, 2020). Conscientious owners and institutions want to improve thermal comfort and meet the city's plan of 65% carbon footprint reduction by 2030 vs. the 1990 data. Since a large part of energy losses occur through the building envelope, improving its thermal performance is a main driver of facade improvement projects.

Thermal performance evaluation may utilize several analytical tools from computing average thermal transmission values via a spreadsheet, to evaluating condensation potential with finite element THERM models[8], up to performing a whole building energy model.

In the Toronto climate zone, heating is the primary reason for energy consumption. Figure 2 demonstrates the analytically modeled load breakdown for an existing mid-century concrete commercial building in Chicago, IL, which has a similar climate to Toronto. In this case study, we found that improving the continuous wall insulation to at least R=14 could achieve a 20% reduction in total annual energy use.

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[4] Image courtesy of Zeidler Architects.
[5] Image courtesy of Thornton Tomasetti Canada, Inc.
[6] Image courtesy of US General Services Administration (GSA).
[7] Image courtesy of Thornton Tomasetti Canada, Inc.
[8] "THERM 2.0 is a state-of-the-art software program, available without cost, that uses the finite-element method to model steady-state, two-dimensional heat transfer problems" (Huizenga, 1999)

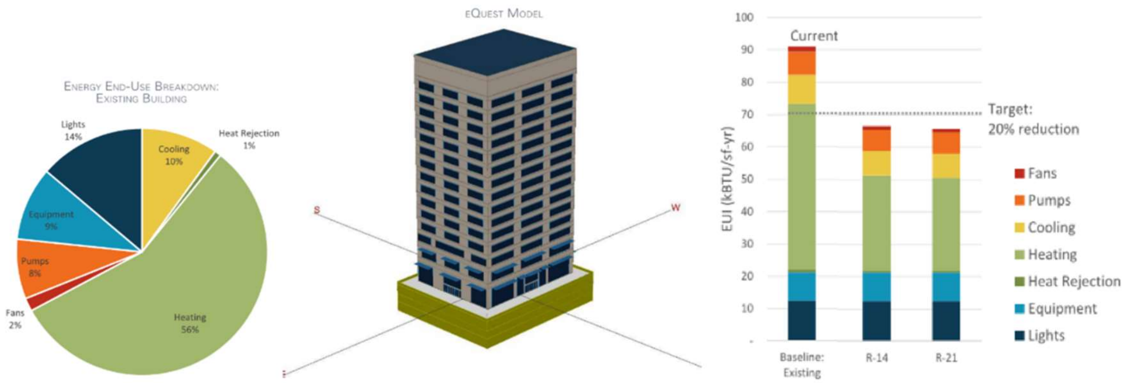


**Figure 2: 55 W Wacker, Chicago. EQuest energy model load assumptions and total energy use improvement with R=14 and R=21 envelope improvements. The model was developed in-house at Thornton Tomasetti.**

The local regulations for new residential construction (Climate Zone 6) now require walls to have R-20 continuous insulation. However, there is no code minimum requirement for undertaking insulation retrofits.

A common wall assembly from the mid-century era may comprise exterior face brick, backed by 4” (92mm) ungrouted block, 1” (25mm) EPS insulation, and plaster interior finish. This amounts to an approximate R=7 value, as shown in Figure 3.

| Layer | Description | Thickness inches | R H-ft$^2$-°F / BTU | U BTU/H-ft$^2$-°F |
|---|---|---|---|---|
| Outside Air Film Resistance | | | 0.17 | 5.88 |
| E1 | Face Brick | 4 | 0.44 | 2.27 |
| E2 | Block | 4 | 0.55 | 1.82 |
| E3 | Insulation | 1 | 5.00 | 0.20 |
| E4 | Gypsum | 1 | 0.50 | 1.00 |
| Inside Air Film Resistance | | | 0.68 | 1.47 |
| **Total** | | | 7.3 | 0.14 |

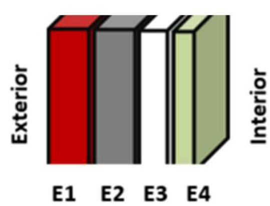


**Figure 3: St. Clair Birchmount II - Typical Wall Assembly Thermal Performance**

The original windows typically perform even worse with respect to new code requirements and expectations for design of efficient mechanical systems. At the St. Clair Birchmount property, although the windows comprise only 30% of the overall envelope area, we estimated that, by an area-weighted average of thermal transmittance (U-values), they would contribute to more than 55% of the total heat transfer through the facade. That assumption also generously considers the thermal contribution of a second single-pane, non-thermally broken window installed at some point in the building’s history, likely in an effort to improve performance.

Condensation due to thermal bridging is another consideration. Condensation is dependent on the relative humidity and the temperature of the interior space. At room temperature and an interior relative humidity of 50%, condensation may occur when the interior surface temperature of the envelope component drops below 11 C. Existing un-broken window frames present the greatest risk for thermal bridging, and moisture may condense on these surfaces.

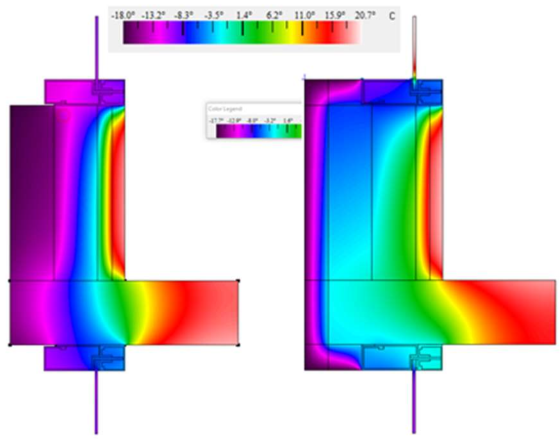

**Figure 4: St. Clair Birchmount - THERM Temperature profile of existing (left) vs. overclad knee wall (right).**

The THERM model in Figure 4 was developed to demonstrate the extent of thermal bridging from the continuous concrete slab extending beyond the building envelope without insulation. However, it also serves to show the role of the window sill in transmitting energy and the need for internal drainage in the extruded aluminum component. The yellow band at the interface of the slab and the interior wall represents a surface temperature potential just below 11°C. Assembly component of any temperature color below 11°C has a potential for experiencing condensation under typical interior humidity conditions.

With window performance in mind, it is rarely advisable to invest in wall overcladding without also replacing the existing windows. Installing new high-quality windows with thermally broken frames will reduce the thermal bridging. When properly sealed and installed with a weather barrier all around, they will also provide for internal drainage of condensate out away from the building substrates.

**BUILDING ENVELOPE HYGROTHERMAL PERFORMANCE CONSIDERATIONS**

Moisture may accumulate on substrates in wall assemblies depending on many hygrothermal parameters, including material vapour permeability, temperature and humidity differences between inside and out, ventilation, heat sources, etc. As described above, condensation may also occur on material surfaces due to thermal bridging – heat loss due to uninsulated materials extending through the building envelope.

The persistence of moisture at supporting conditions, can lead to microbial growth in some substrates. In the profiled buildings of the mid-century, the use of masonry and plaster materials in the building envelope do not typically provide the nutrients necessary for microbes. However present day interior renovations would likely include drywall sheathing. The backer paper in drywall could provide a suitable substrate for microbial growth, in conjunction with moisture from condensation or joint infiltration. This is another reason it may be advisable to minimize disruption to the original existing plaster interior walls.

Counter-intuitively, poorly sealed existing windows and inefficient heating units may actually provide an elevated level of ventilation and drying heat to prevent moisture accumulation within the existing wall construction. The introduction of the overcladding and a better-sealed and more thermally efficient window system would likely reduce the heating and airflow around the wall assembly, resulting in greater potential for moisture accumulation. This concern can be addressed through proper material selection and detailing.

In order to allow the evacuation of vapour from the existing wall assembly, any new weather barriers applied to the existing brick should be vapour permeable. Experience shows that a properly detailed overcladding system can achieve substantial thermal improvement without causing substrate damage. The new air and vapour barrier is often the problem point. We recommend that no new impermeable (less than 1 perm) vapour barriers should be installed, and any such barriers, if required, should be placed interior to the new insulation.

## STRUCTURAL PERFORMANCE CONSIDERATIONS

An overclad may increase or change the manner in which loads are applied to the base building structure.

### *Gravity Loads*

New gravity loads include the weight of the overclad and snow or ice loads on any new protruding surfaces. Concrete buildings from the 60s and 70s featured concrete not only in their structural walls, but also partitions and exterior aesthetic walls. This accounts for a reserve load capacity that can currently be used to accommodate the added loads from overcladding, which is also possible thanks to lightweight modern overclad technologies.

In most residential concrete towers of the typology described above the existing facade is supported on the slab edge, which sometimes includes a beam or curb. When it comes to floor slabs, slab thickness and rebar ratios are largely controlled by code minimums and practical construction considerations. Contemporary structural engineering offers methods such as finite element modeling to achieve more accurate evaluation. This allows engineers to understand the capacity margin of the existing structure that can be used to support the overcladding.

### *Lateral Loads*

Wind speeds can exceed 100 mph (160 km/hr) due to microburst wind events, even in areas far from hurricane regions (ASCE-7, 2017). Figure 4 illustrates wind effects on a highrise in Indianapolis, IN. Wind codes have developed substantially in the last half-century to better reflect climate patterns and pressures at different heights and locations around a building. The overcladding attachments must therefore be designed to meet the worst case condition or reflect regions of varying design pressure.

**Figure 5: One Indiana Square. Wind damage from microburst wind event.**

**Figure 6: One Indiana Square from the interior.**

**Figure 7:One Indiana Square, Indianapolis, IN. Overcladding installation performed from mast climbing scaffold.**

Rainscreen or EIFS overcladding systems often rely on attachment to the existing facade. With the exception of dramatic changes in the cladding profile, the local wind pressures are likely to remain the same after overcladding. However, overcladding often requires discrete connection points back to the existing substrate. Therefore suction on the overcladding may impart greater point loads on the existing backup. In the case of the St. Clair Birchmount II EIFS overcladding, we directed test probes to identify the existing wall ties between an exterior wythe of brick and CMU or concrete structural backup. We also commissioned pull-out tests for anchors into the face brick and substrate. We compared this field data with the fastener layout recommended by the EIFS manufacturer and ultimately proposed to install additional helical ties where the brick was not adequately restrained.

***Existing Condition***

Although concrete and masonry facades may be periodically maintained, long term exposure in an urban environment with many annual freeze-thaw cycles leads to concrete and masonry deterioration resulting in hazardous spalls and allowing ingress of moisture through the building envelope. Overcladding projects are typically preceded by comprehensive facade examination using binoculars and close-up observation from swing stages, lifts or pipe scaffolds. Artificial intelligence based apps, such as the Thornton Tomasetti Damage Detector (T2D2) can also be used as screening tools to identify and quantify distress of concrete and other facade materials.

T2D2 can be supported by the use of drones, phones and cameras, thus making rapid condition assessments possible, and in consequence saving time and money. A rapid evaluation of the condition of the building envelope prior to designing the overcladding is often a key component of the process.

Some overcladding systems offer the possibility of encapsulating deteriorating conditions without investing in full repair. Metal rainscreen overcladding, as described in Section “Rainscreen”, has been a common approach in the Toronto area.

At the Sherbourne Estates renewal project, we projected a savings of approximately $1,000,000 in brick masonry repair costs every five years by overcladding the existing brick knee walls and only repairing those in the most severe state of deterioration. The property management had been engaged in regular masonry repairs on the upper floors, wherein after about a decade the same units were again being repaired. Likely the sloping parapets with no drip edge and high exposure from the cantilevered structure contributed to this aggressive deterioration cycle. The new curtain wall overcladding panel will encapsulate and protect the existing brick. Often the slab edges are exposed and have deteriorated. While exposed structure permits ready access to accommodate attachment of new overcladding anchors, repairs may be necessary to achieve necessary anchor capacity.

## CONSTRUCTION CONSIDERATIONS

The choice to overclad versus re-clad is largely driven by the need to minimize disruption to existing tenants. When a building can be vacated, wholly or in stages, it may be more economical to demolish the existing facade elements from within the units and replace with a new cladding system. This affords contractors the opportunity to move material and work from the building interior according to the work procedures they would apply to a typical new build. However, most overcladding to occupied commercial and residential properties will seek to minimize tenant disruption. Therefore most work will need to be performed from the building exterior. This affects both the construction means and methods, and design choices.

## ENVELOPE IMPROVEMENT OPTIONS

Facade performance upgrades may take many forms, including: facade repairs (and resealing), adding interior insulation, replacing windows, overcladding, and re-cladding. Each building will have unique conditions that justify different interventions. In this paper, we focus on overcladding options. In our definition, building overcladding presumes that the existing facade material will remain. The type and condition of the existing facade is a key driver in the selection of overcladding type and the development of key interface details.

### *Rainscreen*

Metal rainscreen overcladding was a common means of addressing envelope performance in Toronto from the 1990s to the present. Options include metal panels, porcelain, or glass. Metal panel and porcelain rainscreens tend to be more resilient than the EIFS, which would still require maintenance over time. This approach covers potentially deteriorated masonry facade conditions from continued weathering and may include insulation to improve the overall thermal performance of the envelope. In the Toronto climate, placing insulation on the exterior face of the existing wall assembly is preferable to adding insulation on the inside from a hygrothermal standpoint. The masonry assembly is kept warmer and condensation is less likely within that assembly (Straube, J., 2011).

However, the challenge with the metal rainscreen approach is in the detailing of all the joints and interfaces with adjacent walls and windows. At St. Clair Birchmount, we observed loose trim pieces at the parapets and at joints between sheets. There was no weather barrier above the windows lapping the joint between the insulation and the metal flashing, giving potential for moisture to accumulate behind the assembly. The cladding may have held moisture within the assembly against the face of the existing porous masonry, potentially leading to ongoing, concealed deterioration.

The rainscreen is attached to the façade with mechanical anchors. At this project, field testing yielded low breakout capacities in the backup block. The number of anchorage points would need to double the typical spacing recommended for the metal panel and porcelain rainscreens. Elsewhere we were concerned about inconsistencies in the as-built placement of anchors, and had budgeted for installation of helical ties at such conditions.

Rainscreen assemblies often include insulation and a vapour barrier which is adhered to the substrate wall. The additional insulation helps achieve the desired U-value of the exterior walls thus improving the energy efficiency of the building envelope. Vapour barrier type can be selected based on hygrothermal performance requirements as determined by the building envelope consultant. Examples of rainscreen systems include Ceramitex Sintered Compact and Sobotec SurFlex panel systems.

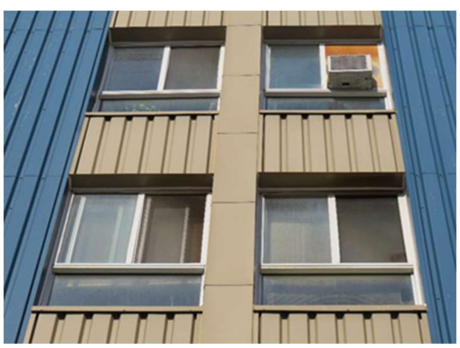

**Figure 6: St. Clair Birchmount I. Metal rainscreen assembly in front of existing brick veneer.**


**Figure 7: St. Clair Birchmount I. Probe in existing rainscreen overcladding revealed insulation added to increase the thermal performance of the building.**

Fire protection is another concern with such insulated rainscreen systems. The EPS/XPS insulation is flammable and typically unbroken in elements that span between floors. Care should be taken when specifying such systems that all local regulations are met, and even then to discuss the issue with building management and fire prevention consultants.

***Exterior Insulation Finishing Systems (EIFS)***
Buildings of this vintage in Toronto typically settle on a solution that features an EIFS[9] overclad, due to the cheaper cost and relatively high performance. EIFS is adhered with adhesive bond, though supplemental anchors are likely at higher levels of exposure and elevation. The adhesive system distributes wind suction pressures uniformly over the façade face, so there is little additional stress on the wall. The mechanical anchors concentrate the pull-out forces according to the fastener grid.

EIFS should be designed with a thought to allow for the vapour to escape the wall assembly without causing condensation and migrating to the interior. It is best practice for EIFS systems to include a vented air cavity between the insulation and water-resistive barrier. This allows vapour caused by heating of absorbed moisture to flee the system instead of migrating into the interior. Systems like Dryvit Outsulation® MD accommodate the drainage plane with grooved patterns in the adhesive and on the insulation board.

With respect to fire prevention, EIFS systems provide a cementitious layer that offers some preventative cover. However, during construction a continuous extent of exposed insulation will be present. In most overcladding scenarios the building will remain occupied through construction, so fire protection may still be at issue. There are non-combustible EIFS systems, such as Dryvit Exsulation ®, which utilize non-combustible mineral wool insulation instead of polymer-based products.

***Curtain Wall***
Continuous curtain wall overcladding presents several design and performance opportunities:

1. Complete aesthetic change. As in the case of One Indiana Square and the AJ Celebrezze Building, all areas of the original facade were covered to fully reposition the building aesthetic. The cladding may be placed outboard of minor changes in the wall profile.
2. Exterior installation. New probe openings for access to connect to the existing structure will likely be required. New structural outrigger framing, ledgers, or clips may be installed prior as support for the aluminum mullions. Installing the majority of the facade from the exterior avoids disruption to the tenants. After the new curtain wall is installed, original facade may be removed to expand the usable floor space (typically in conjunction with changes to the mechanical system from a perimeter system to overhead).

At One Indiana Square the original facade was ultimately removed, providing an extension of the usable space within the building envelope. This option was considered at the Sherbourne Estates

[9] EIFS - Exterior Insulation and Finish Systems

as well, but ultimately abandoned as the increased area may have triggered a zoning review which could have delayed the project.

At the AJ Celebrezze building in Cleveland, OH the original facade and perimeter fan coil unit was retained. The resulting double-skin cavity was vented and controlled to more efficiently insulate the building. Although the perimeter mechanical unit remained, the interior conditioning was replaced by a new HVAC system with ceiling diffuser. Since the cavity is not fully conditioned as the interior space, it was likely that the exterior outriggers could undergo thermal movement with respect to the columns and walls to which they are attached. This consideration affected the connection detailing and sizing of the outriggers.

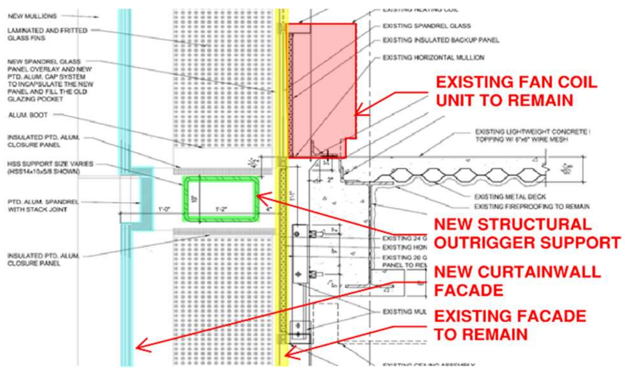


**Figure 8:AJ Celebrezze. Section through curtain wall facade assembly at floor level.**

**Figure 9: Sherbourne Estates at 201 Sherbourne Street.**

***Hybrid solutions***

The overcladding design process at the Sherbourne Estates began with a thorough survey of the existing conditions and removal of hazardous shards from spalling concrete. Various design options were reviewed. The EIFS option was quickly abandoned as it was revealed that the knee wall brick masonry required immediate attention and an onerous repair program. It became evident that the final overclad design should span over the brick, protecting it without imparting any new loading.

The buildings required developing a strategy that would both improve their thermal efficiency and protect their concrete façades from further deterioration, but without incurring the cost of complete facade replacement. The final building envelope improvement plan included over-cladding the brick knee walls and associated exposed concrete slab edges, replacing all of the windows and patio doors, and repairing the exposed concrete shear walls, and coating them with a high-performance protective coating.

A full curtain wall system placed in front of the existing slab edge was deemed too disruptive, as it would require demolition of the knee wall. This option would change the architectural expression of the building and raised concerns of creating additional gross floor area from the authority having jurisdiction. Additionally, the curtain wall system did not provide the flexibility needed for a building of this age where wall tolerances slab deflection up to 2 ½” (63mm) was observed.

**Figure 10: Overcladding mock-up at the Sherbourne Estates.**

The hybrid curtain wall type assembly facing the brick was a key point of innovation in the design (Figure 10). This solution accommodated several concerns, ultimately allowing the project to proceed in budget and achieving the design objectives. The installation of the overcladding panels was made possible exclusively from the exterior swing stage. Attentive detailing of the waterproofed and sealed interface joints allows accommodating the tolerances between the unit and the existing substrate. Additionally, the aluminum extrusions within the assembly provided adequate strength and stiffness to avoid loading the poorly constructed knee wall, without additional independent structural framing.

## CONCLUSIONS

Balancing cost and efficiency in the approaches to retrofit buildings from the 60s-80s can be made possible with the design of overcladding. Multiple design options are available to designers, including rainscreen, EIFS, curtain wall and hybrid options. The construction type and design objectives must be considered prior to the selection of the overclad system. Since overcladding follows the idea of installing a “second skin” over the existing envelope, it offers the possibility to improve the thermal, hygrothermal, protective and aesthetic aspects of the existing building.

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