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ON THE COVER:

Changing architectural needs and the technologies meeting those needs help to redefine the building envelope. Increasingly, exterior cladding offers aesthetic value, both for the public realm and for building users. There is growing use of tech references and imageries—think pixels, barcodes, QR codes and punch cards. These iconic tech images are finding their way onto glass, stone, metal and ceramic cladding, not only in Canada but internationally.

Ryerson University’s Student Learning Centre in Toronto is just one example. The centre opened this past spring and represents the future. The volume hovers like a sculpted ice block. The missing corners create a simple and important gesture, lifting the mass up from the street and the stepped plaza entry. The use of a strong blue on the powder-coated aluminum soffit reinforces the reference to ice.

Flip to page 24 to find out how architects around the world are incorporating technology into building design.

Cover photo by Lorne Bridgman.
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A wide breadth of quality building insulation products, world-class building science expertise and dedicated service. That's the Johns Manville promise and that's what makes JM one of the most preferred insulation brands in Canada today.
The greatest assets of an organization like OBEC are the volunteers who work on the board, lead our discussion groups, provide tours and make presentations. I recently read a short article that spoke volumes to me in *Hardsurfaces*, the Terrazzo, Tile and Marble Association of Canada’s (TTMAC) biannual magazine on the benefits of volunteerism for not-for-profit organizations.

The article said that a person’s professional and personal life today is filled with competing demands and pressures. Those individuals who excel are effective and maintain a balanced profession and personal life. They are a great resource to their companies and often receive more responsibilities and therefore less free time. This makes it more challenging for not-for-profit organizations like TTMAC and OBEC to attract and maintain volunteers.

Seven years ago, I was successful in being elected to the volunteer OBEC board. I volunteered in order to give back to the building envelope/building science community for which I have earned a living for the last 28 years.

Continued on page 13

Although I had been an OBEC member for many years, it was not until I joined the board that I found the true benefits of being an active OBEC member.
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Authored by: John Straube, Ph.D., P.Eng. Building Science Corporation

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Continued from page 11

Although I had been an OBEC member for many years, it was not until I joined the board that I found the true benefits of being an active OBEC member. You become responsible and your experience and strengths are stretched to get what needs doing done—from learning to read a financial statement to polishing skills as a public speaker (my greatest fear).

If you are up for a challenge, I strongly recommend you become active with an organization, one that will give you the opportunity to stretch your capabilities. OBEC is such a place for me and can be for you too. The experience you gain will far outweigh the investment in your time and energy.

My time as the OBEC president will end this fall and this is a good opportunity to thank all those volunteers who have provided their time and energy to OBEC. You have made my term as president very rewarding. Thank you.

On June 17, OBEC members were treated to extensive tour and seminar in IKO’s facilities in Brampton. The late afternoon event started with a tour of IKO’s polyisocyanurate insulation and membrane plants. IKO then entertained our members at its new technology centre with a well-received building envelope seminar by Joe Innocente and an information update on the CSA A 123.21-14 wind uplift test standard by Dave Miller. Mike Bisson and Joe Innocente completed the event with hands-on demonstrations of air barrier and roof membrane applications. Our thanks to IKO and especially to Joe Innocente for organizing this great event!

Mark your calendar for November 17, 2015. OBEC has partnered with the Canadian Precast/Prestressed Concrete Institute for the High Performance Building Enclosure Seminar. This day-long seminar will feature Dr. John Straube a leading industry lecturer, professor of building science at the University of Waterloo and, yes, an OBEC past president. This event will include OBEC’s annual general meeting and a special luncheon presentation for OBEC’s annual awards: the Anthony A. Woods Award (The Beckie), Distinction for Design award and the Distinction for Materials award. I hope to see you all there!

This edition of Pushing the Envelope Canada provides readers with a number of articles on how to improve the performance of the building envelopes. Halsall’s article provides us with two case studies that demonstrate how to improve the thermal performance of older solid masonry walls without reducing the durability of the masonry.

The article from Building Science Labs will provide us with the results of a study to optimize the performance of hybrid wall systems. Morrison Hershfield’s article reviews a research project to determine if low-e coated glass can improve thermal comfort in an existing high rise apartment building in Ottawa. LDR Engineering Group of Burnaby BC investigates the interactions between various heating systems and window-wall systems to determine their effects on surface condensation. Sylvia O’Brien of Colour Theory discusses how technology affects aesthetic choices of the building envelope.

The OBEC board hopes you will enjoy this edition of Pushing the Envelope Canada and, as always, we welcome your comments and suggestions.

REFERENCES
REDUCING ENERGY COSTS THROUGH BUILDING ENVELOPE DESIGN

The complexity of today’s building envelopes demands outstanding engineering support to meet the high performance expectations of architects, owners and occupants.

HH Angus has been designing and engineering building systems to maximize the heating and cooling efficiency of the building envelope for almost a century.

One recent renovation project for a major Canadian Bank included the complete recladding of a 40 year old, 12-storey building. The key design challenge was to answer the client’s desire for greater access to natural light through the building’s exterior - without creating a major penalty in energy efficiency.

HH Angus modeled envelope options and recommended a solution based on efficiency and cost considerations. Highlighting the importance of a collaborative approach, Commercial Division Director Kevin O’Neill reports, “We worked with the architect to determine the appropriate curtain wall components to achieve the client’s goal. The design benefits included increased perimeter glazing and daylighting, and the solution decreased lighting density by 7 W/ft². Working with the architect to ensure the envelope and mechanical systems performed well together, the design team was able to deliver a 20% reduction in energy costs for the owner, without replacing chillers and boilers.”

At the University of Toronto’s Centre for Cellular and Biomolecular Research, the building’s high performance curtain wall features a double façade on the south face - two glazed walls separated by a distance of one metre. HH Angus worked with the architects to design the supporting mechanical systems. Project Principal and Mechanical Engineer Tom Halpenny notes “The double façade features exterior blinds and operable windows, allowing natural ventilation for occupants. This not only circulates air but also tempers the effect of hot weather and acts as an insulating layer in subzero conditions, considerably reducing the heating and cooling load on the mechanical systems. The curtain wall also acts as a noise barrier while it decreases heat loss.”

Double façade curtain walls are popular in Europe, with its milder temperatures, but are rare in Canada. A knowledgeable engineering consultant can help owners understand the payback and the advantages of the double façade over time when it’s being considered for use in our climate.

With a breadth of experience in both retrofits and new builds, HH Angus can examine proposed envelopes, make recommendations on shading factors, and calculate U values produced by various options. Involving the consulting engineer early in the schematic phase helps owners and the rest of the design team make informed decisions about the envelope and how it will impact the building’s mechanical systems.

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Like most things in life, change is coming to the Building Science Specialist of Ontario (BSSO) designation. The time is right for an update, given the BSSO was created just over a decade ago by the Ontario Building Envelope Council (OBEC) and since then has become the benchmark qualification of building science practitioners.

If you are considering applying for the prestigious BSSO accreditation (and why wouldn’t you be?), you should know that effective January 1, 2016, the eligibility requirements are evolving.

Come the new year, an OBEC member in good standing must have one of following three accomplishments under their belt in order to be eligible for the BSSO designation:

- An engineering or architectural undergraduate degree and at least 2,000 hours of practical experience directly related to the practice of building science;
- An engineering or architectural diploma from a recognized college or polytechnical institute and at least 5,000 hours of practical experience directly related to the practice of building science; and
- Ten years of related work experience, in the opinion of the advisory committee, in building design, construction or maintenance.

Along with one of the above, the candidate must have successfully completed the Building Science Certificate Program offered by the University of Toronto’s (U of T) School of Continuing Studies. The program includes six courses: Building Science (I and II), Building Envelope Materials, Wall Systems, HVAC Systems, the Building Envelope and Roof systems. Simply put, the program touches all bases related to physical building concerns.

OBEC knows the significant value its BSSO designation brings to the industry. It has set strict criteria in order to qualify for the esteemed moniker. However, it offers a degree of flexibility for those candidates with previous education and experience.
For example, if a candidate has already completed a university-level building science course, he or she may be eligible for an exemption from the Building Science I and II courses at the U of T. The approved equivalent courses are Ryerson University’s BL8100 Building Science Theory, the U of T’s CIV375/575 Building Science and the University of Waterloo’s CIVE07 Building Science and Technology.

Furthermore, in lieu of the Building Science Certificate requirement, an applicant must have more than 20 years of continuous experience in at least four of seven identified areas of practice, be nominated by two current BSSO holders in good standing with OBEC and have completed some formal education in the area, either an engineering or architectural undergraduate degree from a recognized university or a diploma from a recognized college or polytechnical institute.

Once obtained, the BSSO designation is not a life-long badge of honour. OBEC members must renew it annually by providing proof of 10 continuing education credits every year. New for 2016 is that the BSSO designee does not have to obtain any credits in the year that the accreditation is granted.

However, from the following year forward, BSSO holders must earn 10 credits every year. If they earn more than 10 in any given year, they may carry forward a maximum of 10 for use the following year. Any such requests must be submitted in writing and approved by OBEC.

BSSO designees take pride in their accomplishment. They agree to adhere to a strict code of ethics and standards of conduct. Among other things, they must regard their duty to public welfare as paramount and be devoted to high ideals of personal honour and integrity.

If the BSSO designation is a goal you strive for in order to enhance your stature and reputation in the industry, we encourage you to take the first step at www.obec.on.ca.

If you have any questions regarding the BSSO process please contact, Sherry Denesha, operations manager via telephone, 647-317-5754, or email, info@obec.on.ca.

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Working Toward a Limit States Design Approach for Insulating Solid Masonry Walls in a Cold Climate


Worldwide, there is a large stock of historic buildings. Although often visually appealing, these buildings were constructed at a time when fuel costs were low and the primary purpose for the building envelope was to provide shelter from the exterior elements. Concerns for energy consumption and occupant comfort were not front of mind. As such, these buildings are either under-utilized or a burden to owners and tenants, who occupy the space and struggle to find comfort.

Many cities have realized the cultural importance of historic structures and have implemented regulations restricting their tear-down, as well as restricting modifications or retrofits that would alter the building’s exterior appearance. While their intentions are good, these regulations limit the ability for owners and designers to improve the building’s thermal performance, as insulating the structure from the exterior is no longer permissible.

Insulating from the building interior is the only available option. In cold climates, design professionals have reservations about this approach as the insulation cuts off the interior heat source. The resulting environment the wall is exposed to is colder and wetter, increasing the risk for accelerated deterioration.

Test methods and rules of thumb have been utilized to assess whether interior insulation will pose a problem on a proposed retrofit project. However, at times, they may provide overly conservative or overly tolerant thresholds that do not give the design team much confidence.

This article looks at an approach to identify thresholds where deterioration is expected and how the retrofit can be designed to minimize the risk of reaching these thresholds.

UNDERSTANDING FREEZE-THAW DAMAGE

Colder, wetter walls are concerning as they increase the risk for freeze-thaw, or frost wedging, damage. It is common knowledge that water expands when frozen, and research has shown that porous building materials such as brick or stone can also expand after multiple wetting-freezing-thawing cycles. This sequence is presented in Figure 1.

The saturation level where cracking occurs at freezing is called the Critical Degree of Saturation ($S_{cr}$). It represents the saturation point when there is no room in the pore structure for expansion without damage. If a brittle, porous material is wetted beyond $S_{cr}$, every freeze-thaw cycle will cause irreversible, cumulative expansion. The ease whereby a material deteriorates is a function of its material properties, including strength, porosity and pore interconnectedness.

Understanding the principle of $S_{cr}$ and its likelihood to occur is beneficial in deciding whether it is feasible to insulate from the interior. This is the basis of the Limit States Approach to assessing freeze-thaw potential and the risks associated with interior insulation.

THE LIMIT STATES APPROACH

Limit States is a common approach in engineering design. In basic terms, the designer identifies what loads constitute failure and the designer selects a design that is capable of withstanding more than that limit state. This is the basis of the Limit States Approach to assessing freeze-thaw potential.

Figure 1: A common mechanism of frost failure. Cordon, W.A. (1966). Freezing and Thawing of Concrete – Mechanisms and Control. American Concrete Institute.
FEATURE

seems like a basic concept when evaluating masonry walls; know this critical saturation point, assess whether the applied moisture loads would reach it and design a retrofit to minimize risk of reaching that threshold.

Through use of weather stations, interior space condition monitors and interior climate control systems, measuring the anticipated moisture loads from exterior and interior sources is something that can be successfully done by building engineers. Building engineers also have a good knowledge base of what techniques are available to control these loads (such as membranes, coatings and ventilation/drying techniques). Evaluating a specific brick or stone’s capacity is the missing piece for many.

Computer programs like Wärme und Feuchte instationär (WUFI) can give us a sense of how a masonry unit will absorb moisture and what moisture content values could potentially be reached. Previous approaches include the use of this information, combined with rule-of-thumb thresholds to estimate if the brick moisture content did not surpass 70 per cent or 80 per cent (depending on how conservative a design professional may feel like being), then the wall would be considered low risk for damage.

However, knowing that freeze-thaw resistance is a function of not only absorptivity and pore volume, but also the interconnectedness of the pores, questions were raised as to whether or not these rule of thumb approaches were sufficiently accurate.

IDENTIFYING AND ASSESSING S_{CRIT}

A process known as frost dilatometry can be used to identify S_{cr}. Multiple slices from a masonry sample are wetted to varying moisture contents, up to its maximum saturation (S_{max}). At specific moisture, each sample’s content is measured, exposed to freezing and thawing cycles, and then measured again. A difference between the before and after measurements indicates that freezing expansion stresses within the sample caused fracturing. Samples tested at higher moisture contents than when expansion was first noted will expand further. The moisture content of the sample, when expansion first occurred, is considered the critical degree of saturation (Figure 2).

In natural environments, porous materials will absorb water until they are saturated, or what is referred to as free water saturation (W_f). Free water saturation does not assume that the pore space within the material is 100 per cent saturated with water (i.e. S_{max}) as some pores trap air (dead-end pores) or are disconnected from the general pore space altogether (Figure 3). ASTMC-62 defines free water saturation as the maximum saturation coefficient when a sample is fully immersed in water for 24 hours.

W_f is less than the actual amount of water that can be held in the pore space if all the air were removed. In order to accurately measure a material’s total pore space and maximum saturation, trapped gas must be removed by a vacuum (S_{total/vacuum}). It can be safely assumed that a brick or stone in-situ will almost never be exposed to wetting above W_f, therefore a brick or stone unit is considered low-risk for freeze-thaw damage if S_{cr} is above W_f.

All this information can be plotted on a moisture storage function (Figure 4 on the next page).

RETROFIT EVALUATION

If S_{cr} is greater than W_f your wall is a good candidate for interior insulation. However if S_{cr} falls below W_f, a designer must predict whether the S_{cr} threshold is expected to be exceeded in service.

In these cases, hygrothermal modeling can be used to evaluate the change in risk of freeze-thaw damage between an existing ( uninsulated) and insulated wall assembly. To promote accurate results that represent the wall assembly, it is important that project specific material properties, such as porosity, water absorptivity (A-value) and the moisture storage function are inputs into such a model. These properties can be determined during frost dilatometry testing.

When comparing the model results for the existing wall to the insulated wall, the designer is looking for changes in the number of freeze cycles, as well as their duration. In addition, whether S_{cr} is reached

Figure 3: A masonry pore structure.
or surpassed at a location in the wall where the temperature is also below freezing. The amount of masonry expansion caused by a freeze-thaw cycle increases as moisture contents greater than $S_{sat}$ are realized. Judgment based on experience is required from the design professional to evaluate whether the increase in either the length of time, severity of freezing, or both, caused by insulating presents unacceptably high frost damage risks. If so, alternate approaches such as decreasing insulation thickness or whether to insulate at all should be considered.

**EMBEDDED METAL CORROSION AND WOOD ROT**

Historic masonry buildings are mass wall structures with elements such as wood or steel joists embedded directly into the wall. If the analysis finds interior insulation acceptable with respect to masonry performance, the impact of insulation on the other wall elements also needs to be considered.

As previously noted, adding interior insulation to an existing historic masonry wall will change its microclimate. The wall will become colder as it is cut off from the interior heat source. The wall will also become wetter as the wall’s drying potential towards the interior is removed (Figure 5). These changes increase relative humidity within the wall and can promote wood or steel deterioration.

To evaluate these risks, the design professional should start by selecting a threshold for relative humidity and temperature whereby wood rot or metal corrosion is expected. Typical limits for a metal corrosion threshold (termed “time of wetness”) is where the metal is exposed to conditions greater than 0°C and 80 per cent relative humidity.

Wood rot typically occurs at 28 per cent moisture by weight or around equilibrium with 95 per cent relative humidity. A combined threshold (i.e. time greater than 5°C and 85 per cent relative humidity) can be used.

**Figure 4: A sample moisture storage function.**

Continued on page 22
This threshold is acceptable as it is more conservative with respect to wood rot and corrosion rates are very slow around freezing. The same hygrothermal models used to evaluate the masonry can also be used to evaluate the conditions within the wall assembly where the embedded materials are located.

CASE STUDIES
Case study 1: Museum repurposing
A three-storey historic stone masonry building in northeastern Ontario is being renovated into a museum. The exterior facade of the building consists of squared, rough-faced Nepean Sandstone. Interior insulation (medium density closed cell spray foam) of the exterior walls was under consideration.

The structural system in a portion of the building consists of concrete floor slabs spanning between concrete-encased steel beams and girders that are supported by steel columns embedded within the exterior masonry walls. The masonry walls in this portion were not load bearing.

Frost dilatometry was used to determine if the proposed retrofit would increase the risk of freeze-thaw in the stone units and hygrothermal modeling was used to assess the risk of embedded metal corrosion. The test values for the $W_f$ and $S_{crit}$ for all types of stone used in the building facade demonstrated that $W_f$ was considerably less than $S_{crit}$, indicating that the stone is at almost no risk of freeze-thaw deterioration. This was consistent with the generally good stone condition observed.

The original structural steel elements have always been at risk of corroding as the walls are exposed to rain wetting. Hygrothermal modeling was used to estimate the increased risk for embedded metal corrosion from insulating the walls. The model predicted no change in risk for the outermost embedded metal.

Modeling indicated that insulating the walls would increase the risk for the inner portion of the steel (the model predicted elements would be above the corrosion threshold 30 per cent of the year). The corrosion rate of the inner steel was expected to more than double. However, upon further review, the existing steel was found to be in good condition, indicating that the corrosion rate experienced under the threshold conditions in service was actually quite slow.

Double a slow rate and you are still left with a slow rate. In this case, corrosion was not expected to become a concern in the short term. The client had a low tolerance for allowable deterioration and therefore the design team recommended that a cathodic protection system is considered.

Case study 2: Institutional building renewal
A two-storey historic masonry structure in southwestern Ontario was to be renovated into educational space that would house musical equipment, sensitive to relative humidity and temperature conditions, such as pianos. The new space would have increased relative humidity levels that were to be maintained year-round.

The exterior walls consist of load bearing brick masonry with an air cavity between three outer wythes and an inner wythe of masonry. Elements such as metal trusses and wood purlins were embedded in the masonry walls. Interior insulation was considered for the retrofit to help
maintain the space conditions and improve energy efficiency.

Frost dilatometry and hygrothermal modeling determined that the proposed retrofit would not increase the risk of freeze-thaw damage in the masonry. These findings were consistent with observations that the walls were in generally good condition where the existing walls were not heated and exposed to rain (i.e. parapets).

Hygrothermal analysis was then used to compare the insulated walls under the existing/original operating conditions to a) the original wall assembly with increased temperature and relative humidity, and b) an insulated wall with increased temperature and relative humidity. Modeling showed that the amount of time in a year that the embedded wood joists would be within the rot threshold had significantly increased with the desired temperature and relative humidity changes (close to 40 per cent of a typical year without insulation, over 75 per cent of a typical year if insulated). In the existing assembly, the wood rarely exceeded the threshold.

The wall evaluation was informative and beneficial, and the results had a considerable impact on the retrofit design moving forward. Various recommendations from the design team were made, including supplemental gravity and lateral support of the existing wood joists and/or joist end encapsulation with a thermal and vapour control layer.

**FINAL THOUGHTS**

The Limit States Approach presented here can be used to help designers assess risks and make informed decisions on whether to move forward with insulation in their retrofit. Although a step in the right direction, this approach requires further refinement to improve the ability to duplicate results between labs conducting the material testing. At this time, project budgets dictate how many masonry samples are collected and tested, but as each brick sample varies from another, it is best that a large sample size is tested. Guidelines for material sampling frequency and size, as well as hygrothermal modeling standards, should be established to improve results.

As these structures hold important historic and cultural value, in planning an interior insulation retrofit, it is important that the design community checks that the risk for building envelope deterioration is not high. The objective is to increase the occupant comfort and reduce energy consumption so this underutilized, but culturally important building stock can be used to its full potential for years to come.

Nastassja Pearson is a former employee of WSP. Her specialty is enclosure engineering and design.

David De Rose is a former employee of WSP (then Halsall Associates). De Rose applies the lessons learned in evaluating building enclosure performance in existing buildings to new building enclosures or building renewal to optimize building performance and durability.

**FOOTNOTE**

This article is based on presentation and article titled “Towards a Limit States Approach to Insulating Solid Masonry Walls in a Cold Climate” by David De Rose, M.A.Sc., P.Eng., Nastassja Pearson, M.A.Sc., P.Eng., Peter Mensinga, M.A.Sc., and Dr. John Straube, Ph.D., P.Eng., for the 14th Canadian Conference on Building Science and Technology.
Barcodes, QR Codes, Pixels & Punch Cards: What These Have to do with the Building Envelope

By Sylvia O’Brien, Architectural Colour Consultant

Changing architectural needs and the technologies meeting those needs help to redefine the building envelope. Increasingly, exterior cladding offers aesthetic value, both for the public realm and for building users. There is growing use of tech references and imagery—think pixels, barcodes, QR codes and punch cards. These iconic tech images are finding their way onto glass, stone, metal and ceramic cladding, not only in Canada but internationally. As is often the case, innovation in envelope design is coming out of Asia and Europe, but Canada is catching up.

One example is Oslo’s new waterfront development of 13 buildings known as the Barcode Project. The project is designed by a collaboration of architects. Three of the 13 are by Oslo’s own A-lab. Their latest building, called The Carve, is a 15-storey-mixed-purpose structure in which pixelation references become the form, rather than just an applied cladding.

A carved out communal patio section in the upper half of the structure lightens the mass and makes a very strong statement in the context of a rapidly changing urban landscape. The white marble cladding and the warm wood (ProdX HPL panels) used to clad the interior surfaces of the communal space, lend an opportunity for dichotomy, or double reading of the spatial experience, playing nature against technology or cold against warm.

But this trend is not only about new buildings. All over Europe, large, empty buildings are being repurposed. In France, Dutch architectural firm MVRDV used QR flashcode imagery to re-invent what once had been a mustard laboratory, and is now...
TeleTech International’s innovative call centre, education centre and project incubator.

Dealing with serious budget restraints, MVRDV came up with the solution of wrapping the existing cladding. This ingenious QR code-printed aluminum skin is actually functional and directs smartphone users to TeleTech’s website.

Closer to home in downtown Toronto, Ryerson University’s Student Learning Centre (SLC) on the corner of Yonge and Gould Street opened in spring of this year. Two prestigious architecture firms collaborated on this project—Snøhetta (Norway & New York) and Toronto’s Zeidler Partnership Architects.

“This building represents a clear image for Ryerson. It’s about the future. The lifted volume appears to float over the entrance supported on slender-angled columns. Chamfered corners lighten the mass and make it less boxy,” explains Mike Smith, senior partner with Zeidler and project architect for this building.

The volume hovers like a sculpted ice block. The missing corners create a simple and important gesture, lifting the mass up from the street and the stepped plaza entry. The use of a strong blue on the powder-coated aluminum soffit reinforces the reference to ice. The soffit, which carries into the building, is made up of a network of tetrahedra coated in a remarkable iridescent paint. Its effect comes from several layers of blue to create variation when viewed from different angles and in changing light conditions. The soffit’s aluminum sections are folded like origami, producing a texturally rich surface.

In addition, there are 20 different tessellated frit patterns using pixel imagery that are repeated on the high performance triple glazed skin. At 60 per cent coverage, the fritting allows the primarily glass structure to comply with ASHRAE 90.1 requirements.

“Aside from aesthetics, the fritting pattern is for solar performance. It reduces glare and cooling loads, making the interior space more comfortable,” Smith noted about the fritting.

This new multi-faceted building animates a very important street corner, giving Ryerson a strong new character and enriching the urban landscape.

Another Canadian example to be completed this year is the new Parliament Street Data Centre in downtown Toronto, designed by WZMH Architects. The data centre’s function dictates that there will be no windows, and with the exception of the southwest entry glass box, the rest of this structure is clad with black metal in contrast to clay coloured Tonality ceramic façade.

The strategic use of the black metal gives the illusion of windows where none exist, helping to modulate the solid wall surface. What is interesting about the style of cladding is that it references early computer punch cards. Remember those, anyone?

I spoke to Nicola Casciato, WZMH architect for this project, and asked what led him to this particular envelope material. “Aesthetically we wanted a pattern that recalled early data management systems and technically, this product allowed us to achieve our goal,” Casciato responded.

And what about colour choice? “Located next to the Distillery District, the building needed to blend with the existing context, which was primarily red brick.”

Both public and professional response to this innovative mixture of form and function has been very positive. Its proximity to Toronto’s financial district and its nod to technological history are very effective.

Forward-thinking architects and developers worldwide are incorporating tech imagery into cladding, such as Zaha Hadid with the Opus in Dubai and Esfera City in Mexico; Herzog & de Meuron Ltd. with the de Young Museum in San Francisco and the plan for the new Vancouver Art Gallery due in 2020; Aedas in Hong Kong with their Mongkok Residence; and an early example of Will Alsop’s Sharp Centre for Design for OCADU in Toronto. These buildings embrace innovative envelope design while also mirroring our rapidly changing world.

Sylvia O’Brien is the architectural colour consultant and owner of Colour Theory, a Toronto-based architectural colour and design firm specializing in colour co-ordination for the building envelope for both refurbished and new-build construction. She can be reached at 416-766-6789. Visit www.colourtheory.net/trade.htm for more information.
Nothing is More Disruptive or Possibly Fatal than Building Failures

Window Wall and Precast Concrete Panel Systems—Two Bodies Side-By-Side Have a Story to Tell about Their Connection


**FEATURE**

**PRECAST CONCRETE PANEL SYSTEM (PCPS)**

Precast cladding or curtain wall is the most common use of precast concrete for building envelopes. Precast concrete wall systems are available in a wide variety of shapes, colours, textures and finishes. Typically, each precast panel is independently supported to the building’s main structure using an assemblage of metal components and anchors.

**WINDOW WALL SYSTEM (WWS)**

Similar to PCPS, the window wall system is attached to the main concrete structure and in some cases, to the adjacent building elements such as PCP, concrete block walls, metal columns, structural studs and others.

Ideally, these building cladding systems (PCPS and WWS) are most often constructed as a curtain wall or veneer in which no building loads are supposed to be transferred to any of the systems.

Any uncalculated or additional imposed loads on either system may compromise both and may lead to undesirable results.

**QUALITY CONTROL**

Unfortunately, this is not the case for some buildings where site observations and investigations confirmed violation of the above rule.

Nothing is more disruptive, or possibly fatal, than a building failure. Building failures are usually the result of poor...
construction and co-ordination, which occurs when there is a lack of quality control during the construction phase. Details are either missing or overlooked, and the actual site conditions, tolerance for fabrication and erections are ignored or omitted. These factors can contribute to cracks, breakages and leakages resulting in building failures.

In some cases, the evidence shows that the window wall system gets attached to the surrounding building elements. This includes precast concrete panels, brick veneer and non-structural members without being designed for such support. This would sometimes be done without acknowledgement of the precast concrete design engineer.

It is crucial for the designer to review and consider the major variables that will affect the wall assembly performance...

It is crucial for the designer to review and consider the major variables that will affect the wall assembly performance including but not limited to the following:
- Durability and serviceability;
- Air/vapour barrier systems;
- Rain penetration control/management system;
- Load resistance; and
- Thermal expansion.

LOAD RESISTANCE

Consideration should be given to all the loads on the wall system.

In fact, each system must resist the lateral loads directly imparted on it independently, such as from wind and earthquakes, as well as vertical loads resulting from the self-weight (dead load) through the wall system. The design of any system should be in correlation with the wind study analysis calculated to project specific details.

THERMAL RESISTANCE/ EXPANSION

Another important factor is the thermal expansion of control and expansion joints. The thermal expansion of the window wall system is different from the precast concrete panel. Metal and concrete have two different characteristics that allow them to react and expand differently at various weather conditions. The thermal expansion coefficients vary for various materials. For instance, the coefficient of linear expansion (at 20°C) for aluminum is 23 (10-6/oC) whereas for concrete/steel is at 12 (10-6/oC).

Allowance must be made for the considerable expansion and contraction of the cladding, for it will be subjected to a full range of air temperatures plus the effect of solar radiation.

Therefore, these two bodies that are resting on the building structure cannot be anchored or attached to each other unless the system is designed for such connection to allow an adequate movement. If the design does not incorporate thermal or movement expansion joints and connection, the situation becomes complicated and any minor deviation from the original design may lead to potential problems.

This phenomenon could affect the performance of air and vapour barrier and may contribute to distress conditions, panel cracking, displacements and joint movement failure, which may eventually lead to deterioration or water penetration into the occupied areas. This could also present serious safety concerns that may cause steel components to rust, window system to bulge, glass to crack, window anchors to fail, concrete to spall at lateral support locations or structurally-reinforced concrete to be exposed to freezing and thawing conditions.

Every manufacturer is responsible for its own product and quality; however, in some cases the lack of co-ordination between different manufacturers, whose products are installed side by side, may create potential problems and serious consequences.

SOLVING AND AVOIDING FAILURES

The manufacturer designs the cladding for the specified erection loads, connection details and provides for the weatherproofing, performance and durability of the cladding itself. Based on drawings review and personal site investigation, it was noted that some manufacturers, such as window, railing and even vent box manufacturers, allow their products to be attached and secured to the adjacent concrete precast panel cladding without the consent of the precast panel engineer.

Under other circumstances, it was noted that window or railing shop drawings were shown to be attached to precast concrete panels without the approval or review of the precast designer.

The warranty of the precast panel may be voided once the manufacturer is aware that other building components are attached to their product without their consent, consult or calculation of certain factors. This is a fair judgment, since their system was not designed to take into consideration any additional loads and since the precast concrete system is not a part of the main supporting structure.

Consideration should be given to the following procedures and techniques that may minimize building failures and contribute to better building envelope performance:
1. Promoting sustainable design.
2. Allowing enough time for design development.
3. Analyzing various building cladding and evaluating system performance.
4. Adhering to standards, building codes and good engineering practices.
5. Maintaining co-ordination between architect, manufacturers and engineers.
6. Co-ordinating the shop-drawing reviews:
   a. Designing proper connections.
   b. Allowing for thermal expansion.
   c. Providing flexible joint movement.
7. Performing mock-ups for review and approval.
8. Endorsing a quality control program for site installation and reviews.

When the connection is co-ordinated, the story will have a happy ending.

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For high-performance walls, experience and demonstration projects have shown that systems made up of combinations of materials and approaches usually provide optimum performance. Combination or hybrid assemblies can also be quite cost-effective. This article describes research that evaluated the cost as well as the thermal, hygrothermal and structural properties of a series of hybrid wall assemblies.

WALL ASSEMBLIES TESTED
A number of hybrid-insulated wall systems were compared to a standard advanced-framed wall with oriented strand board (OSB) sheathing and an advanced-framed wall with exterior insulation. The hybrid walls used a combination of exterior insulation, diagonal metal strapping and spray polyurethane foam, plus additional insulation material in the cavity. In these hybrid systems, housewrap as a drainage plane is not used because the taped exterior insulation is expected to act as the drainage plane.

Similarly, structural sheathing (such as OSB) is not used because the high-density spray polyurethane foam in combination with the insulating sheathing and diagonal metal strapping is expected to provide adequate structural shear resistance.

The exterior insulating sheathing products used were one-and-a-half inches (38 mm) extruded polystyrene (XPS) and one-and-a-half inches (38 mm) and three inches (76 mm) foil-faced polyisocyanurate (PIC). Cellulose and fiberglass fibrous insulations were used to fill the stud space remaining after the
installation of a layer of closed-cell spray polyurethane foam (ccSPF).

The thickness of the ccSPF was chosen as one and a half inches (38 mm) because it was determined that this is likely the thinnest that can be reliably installed in a single pass to both create an air barrier and transfer the structural loads from the wood frame to the insulating sheathing. A complete list of wall components is available in Table 1.

RESULTS AND ANALYSIS

The analysis included an evaluation of incremental costs associated with each assembly, as well as a comparison of the thermal, hygrothermal and structural properties of the assemblies.

COST ANALYSIS

The hybrid wall systems were each assigned a cost relative to standard construction and were analyzed for cost-effectiveness. Assigned costs were determined by consulting with builders and verified using Reed Construction Data. RSMeans CostWorks was used to find the incremental labour and material costs of each test wall when compared to a standard two-by-six-framed wall with OSB sheathing and interior R-21 fibreglass batt insulation.

As shown in Table 1, the initial step to one-inch XPS exterior insulating sheathing is $1.66 per square foot (ft²). The most significant increase in cost is for Hybrid Wall 5 at $5.17/ft², because of the additional insulating sheathing, but also because this assembly cost includes longer fasteners, window box-outs and vertical wood strapping for cladding attachment through the three-inch-thick exterior insulation. The hybrid wall with the least incremental cost is Hybrid Wall 3 at $2.20/ft².

When considering costs, it is important to note that more expensive walls (as specified in this project) will be more energy efficient, and this energy cost savings must be taken into account over time. Research has shown that walls exceeding an R-value of 35 in an Ontario climate can financially pay back during the life of the initial mortgage through energy savings while reducing greenhouse gas emissions (Grin, 2008).

THERMAL & HYGROTHERMAL MODELING

Thermal and hygrothermal properties were determined by modeling, using Therm5 for thermal properties and Wärme und Feuchte instationär (WUFI) for hygrothermal properties.

For the thermal analysis, installed and Clear Wall R-values were calculated (see Table 2). The Clear Wall R-value provides
a more accurate value for comparison than installed R-value, because it accounts for thermal bridging and the location of insulation. Specifically, Clear Wall refers to the R-value of an assembly containing only insulation and the minimum necessary framing materials at a clear section with no windows, corners, columns or architectural details, and no intersections with roofs, foundations or other walls.

Hybrid Wall 1 has an apparent installed R-value that exceeds the Standard Wall by R-8.6, but performs R-9.2 better as a clear system primarily because of the reduction in thermal bridging. The hybrid walls thermally perform incrementally better topping out at Hybrid Wall 5 which performs the best with a clear system R-value of 39.3.

Hygrothermal modeling was conducted using WUFI, with outdoor climatic data for New Orleans and Minneapolis. Minneapolis has a similar climate to Toronto. The indoor temperature ranged from 20°C (68°F) in the winter to 24°C (75°F) in the summer and the relative humidity (RH) ranged from 30 per cent to 60 per cent. Durability comparisons were made using the total number of hours of air leakage condensation potential on surfaces within the wall. Each wall has a potential condensation plane (where any condensation will form, and may, accumulate).

The total hours of condensation potential is calculated by adding up all of the hours when the temperature of the condensation plane is below the dew
point of the interior air and compared to the 8,760 hours in one year. During these times, any moist air that leaks into the wall has the possibility to condense.

In cold climates, exterior insulation keeps the inboard wall components warmer, potentially preventing their temperature from going below the dew point. As a result, walls with an appropriate amount of insulation outboard of the condensation plane can prevent air leakage condensation. For the test walls modeled, the proposed hybrid walls reduced condensation risk from air leakage in cold climates by between 95 per cent and 100 per cent compared to a standard two-by-six framed wall with OSB sheathing.

The condensation plane of the hybrid walls is also a moisture tolerant ccSPF while the standard wall is moisture susceptible OSB. The hygrothermal analysis for New Orleans (i.e. a warmer climate) did not show any significant air leakage condensation risks for any of the test walls.

**STRUCTURAL TESTING**

To determine what shear resistance the hybrid walls provide, ASTM E72 structural testing was completed. Using a series of measurements, the ASTM E72 test calculates the displacement of the top plate of the wall in relation to the bottom plate, during a set of imposed loadings in plane with the sheathing. The lowest loading is 790 lbs (360 kg), and the highest is 30,000 lbs (13,636 kg) or whatever load causes four inches (102 mm) of deflection.

Three variations of the hybrid wall were compared to the standard wall.

<table>
<thead>
<tr>
<th>INSTALLED R-VALUE (RSI)</th>
<th>STANDARD WALL</th>
<th>EXTERIOR INSULATED WALL</th>
<th>HYBRID WALL 1</th>
<th>HYBRID WALL 2</th>
<th>HYBRID WALL 3</th>
<th>HYBRID WALL 4</th>
<th>HYBRID WALL 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 (3.7)</td>
<td>26 (4.6)</td>
<td>30 (5.3)</td>
<td>31 (5.5)</td>
<td>34 (6.0)</td>
<td>35 (6.2)</td>
<td>43 (7.6)</td>
<td></td>
</tr>
</tbody>
</table>

| CLEAR SYSTEM MODELED R-VALUE (RSI) | 17.7 (3.1) | 24.8 (4.4) | 26.9 (4.7) | 27.6 (4.9) | 29.4 (5.2) | 30.1 (5.3) | 39.3 (6.9) |

Table 2: Installed and clear system R-values.

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Three samples of each test wall were built in order to increase the certainty of the findings. In order to ensure the testing closely related to real world construction, a wood spacer was attached to the base of the steel testing apparatus. The bottom plate of the wall was then affixed to the wood spacer. This ensured the bottom plate would be attached to wood as it would be in the field, rather than being bolted directly to steel.

Upon completion of the testing, cores were taken through the test specimens to verify that the average ccSPF thickness was 1.5 in. (38 mm). The ccSPF thicknesses varied from one and a half inches (38 mm) to nearly two inches (51 mm), but the areas that were thick were small and localized.

The testing showed that each of the proposed hybrid walls exceeds the structural shear capacity of a standard advanced framed wall with OSB sheathing. Specifically, Hybrid Walls 3 and 4, which used thick-foil faced PIC exterior insulation and ccSPF, provide the highest ultimate strength while displacing the least and, more importantly, can be loaded and unloaded up to 2,360 lbs (1,073kg) without residual displacement.

**CONCLUSIONS**

The testing and analysis showed that hybrid insulated wall systems can cost-effectively provide robust thermal control, air control, moisture control and water barrier systems in one assembly, while also providing more shear resistance than a standard OSB sheathed wall.

Hybrid Wall 3 was shown to be the optimal wall when considering cost as
Pushing the Envelope Canada

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Joseph Lstiburek is the founding principal of Building Science Corporation, a building science consulting and full service architecture firm specializing in building technology consulting for all types of buildings including commercial, institutional and residential. Dr. Lstiburek’s work at BSC ranges widely, from providing building enclosure consulting to overseeing research and development projects, to writing for www.buildingscience.com.

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REFERENCES

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We are, increasingly, an urban nation. Census data for 2006 reveal that 80 per cent of the Canadian population lives in urban areas, over half (45 per cent) in Vancouver, Calgary, Edmonton, Toronto, Ottawa-Gatineau and Montreal. In the downtown core of these six major cities, between 23 per cent (Calgary) and 71 per cent (Montreal) live in apartment buildings.1 These proportions are likely to increase further in the coming years as planning departments seek to limit sprawl into surrounding valuable farmland and make more efficient use of the costly infrastructure of roads, potable water supply, sanitary and storm sewers, etc., that is needed to support urban dwellers.

I am one of those urban creatures. Growing up in apartment buildings, I experienced first-hand thermal discomfort from time to time (I remember well those hot, summer days) and throughout my career, working in the design, construction and rehabilitation of many apartment buildings, I’ve worked with building designers, owners, property managers, and residents to avoid or reduce thermal discomfort in many other buildings. There are many causes, including poor urban planning and building design, that do not consider the potentially beneficial effects of solar heat gain and the potential risks of excessive heat gain.

As with many things, what we ignore may become our peril. This article describes a study that was undertaken to determine if low emissivity (low-e) coated glass can be used as a retrofit strategy in existing buildings to alleviate fall, and especially spring “shoulder season” thermal discomfort.

UNDERSTANDING THE PROBLEM

Apartment buildings in Canada typically lack features to control solar gain such as exterior louvered shades or, as is common in many European countries, vertical rolling shutters. Most apartment buildings have projecting balcony floor slabs which provide shading, but usually these occur only at living rooms and dining rooms so protection is limited. Building orientation and apartment floor plans do not respect solar exposure so regardless of orientation, the size and placement of windows and glazed doors is the same.

In Canada, our primary concern when designing for thermal comfort is to provide sufficient space heating in the depths of winter. Historically, apartment buildings have been built with simple hydronic or electric baseboard space heating systems; in newer buildings two-pipe hydronic fan-coil systems are common. It is common for all these systems to be single zoned and so without flexibility to respond to high solar gain on one elevation and shaded conditions on others.

Inside individual apartments, controls to adjust space heating output within apartments may be provided but they may not be sufficient to reduce output to balance solar gain.

Residents experiencing discomfort from high solar gain during cold weather when space heating is operating may seek relief by opening exterior windows and doors. This is wasteful of renewable solar energy (although the sun will not last forever) and non-renewable, terrestrial energy sources, such as fossil fuels...
used on site or in distant generating stations to power space heating systems.

Energy use in residential apartment buildings accounts for 16 per cent of total energy used by Canadians; of that, 51 per cent is used for space heating which represents about 14 per cent of greenhouse gas (GHG) emissions. No reasonable person today doubts the reality of global warming; better design of new buildings and retrofit of older buildings can address the big picture of global warming by reducing space heating energy demand, as well as local improvements in the day-to-day quality of life of apartment building residents.

THE LOW-E SOLUTION

In the absence of exterior features to control solar gain through windows and glazed doors, what can be done to control solar gain? Indoor shading devices such as blinds, curtains, shades and even aluminum foil taped to window glass provide some relief by reflecting solar radiation back to the outside. A drawback of these methods is that solar radiation has already entered the building, so not all of the thermal energy is returned to the outside.

All of these methods detract from the principle reason we include glazing in our exterior walls—they block views to the outside and prevent daylight from illuminating the inside. A compromise is to include a low-emissivity (low-e) coating on one or more surfaces of the glazing to reflect solar radiation back to the outdoors before it penetrates into the building interior.

Low-e coatings were originally developed following the Arab Oil Embargoes of the 1970s to improve the energy efficiency of windows and glazed doors and thus, reduce dependence on imported oil. Those early coatings were formulated to allow high-energy, short-wave solar energy to penetrate indoors to warm the interior during the day and reduce the emittance of heat energy in the form of long-wave radiation to the outdoors at night. Today, we often refer to these low emittance (low-e) coatings as high solar gain or HSG low-e.

HSG low-e coatings typically have high visual transparency, which architects quickly took advantage of to improve daylighting in commercial buildings. Unfortunately, high solar gains sometimes created uncomfortably warm indoor conditions and consequently, high space cooling loads and increased energy consumption. Low-e
manufacturers soon responded with low solar gain (LSG) low-e coatings, which reduced high-energy, short-wave solar energy transmission, while at the same time, still controlling radiant heat loss, and saving cooling costs in the summer and heating costs in the winter.

Could LSG low-e help to offset shoulder season overheating in apartment buildings?

THE EXPERIMENT

In order to determine the effects of LSG low-e on resident comfort and energy use, an experiment was conducted in an apartment building owned by Centretown Citizens Ottawa Corporation (CCOC) in Ottawa. Funding for the study was provided through the Canada Mortgage and Housing Corporation (CMHC) External Research Program and from Natural Resources Canada (NRCan).

Three southeast-facing, upper-level apartments were used for the study. The apartments were almost identical in layout, size and solar exposure (Figures 1 and 2 on pages 37 and 38). Each unit was occupied by one resident with occasional guests. In two of the apartments, windows and sliding doors were refitted with low-e coated glass—one with HSG and the other with LSG. In the third apartment, the existing, uncoated glazing was left as is to act as a control against which performance in the refitted apartments was compared.

Each of the apartments was fitted with equipment to measure the interior air temperature and relative humidity (RH), which can be used to objectively assess indoor thermal comfort. Incident solar radiation was monitored at the exterior of the building and transmitted solar energy was measured inside each unit directly behind control (uncoated), HSG and LSG low-e coated glass.

Residents were interviewed for their perceptions of thermal comfort. Operation of the apartments (position of window coverings, windows and doors open or closed, thermostat settings) was observed monthly when monitoring equipment was accessed for data download and maintenance to estimate effects on energy use (energy use could not be directly metered). The experiment was conducted...
over a 12-month period from early September 2010 to late September 2011.3

THE FINDINGS
In the fall, solar gain increased as outdoor temperatures decreased. The resident in the apartment refitted with the LSG low-e coated glass reported improved comfort compared to the year before. At the same time, the residents of the control apartment and the HSG low-e refitted apartment reported uncomfortably warm conditions from time to time, generally coinciding with sunny weather, which they relieved (or attempted to) by opening windows and doors (Figure 3 on page 38).

In the winter, solar gain reached yearly maximum values and outdoor temperatures attained lowest values. The LSG low-e apartment resident continued to report improved thermal comfort. Residents of all apartments set their thermostats higher. HSG and LSG low-e apartment residents set their thermostats higher than the control apartment. The HSG resident reported discomfort and used plug-in electric radiators and other heating devices to stay warm (Figure 5 on page 39).

In the spring, as solar gain and outdoor temperature increased, thermostat settings were reduced in all apartments. The resident of the LSG low-e apartment continued to report improved thermal comfort whereas from time to time, on warm sunny days, the residents in the control and HSG apartments reported discomfort, which they attempted to relieve by opening windows and doors. The HSG apartment resident continued to report cold indoor conditions until the weather became warmer (Figure 5 on page 39).

In the summer, solar gain dropped to the lowest values with little variation between the apartments. From time to time, all residents reported uncomfortably warm indoor conditions with no improvement compared to pre-experiment conditions. They attempted relief by opening windows and doors, running kitchen and bathroom exhaust fans, and using electric fans to blow air directly over themselves. Despite occasional discomfort, the HSG apartment resident was generally comfortable (Figure 6 on page 39).

Measured indoor relative humidity and air temperature were plotted on psychrometric charts on which the warm weather and cool weather comfort zones described in the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) standard 55 were outlined.4 The comfort zones represent 80 per cent occupant acceptability of the indoor thermal environment based on several measurable factors including indoor air temperature and relative humidity.

Air temperature and relative humidity shifted seasonally from the warm weather comfort zone in the fall to the cool weather zone in the winter and spring and back to the warm weather zone in the summer. At the times when discomfort was reported, the temperature and relative humidity conditions were outside the ASHRAE comfort zones. For the HSG apartment resident who preferred warmer indoor conditions, there was a noticeable shift to the warm side of the cool weather comfort zone in the winter when residents raised the indoor air temperature (Figures 7 through 10, on pages 39 and 41).
ASSESSMENT

The study revealed improved thermal comfort for the LSG low-e apartment resident, in fall, winter and spring. Compared to the control and HSG apartments, improved thermal comfort in the fall and spring was clearly related to reduction in solar gain while the building space heating system was operational. In the winter, improved thermal comfort compared to the control apartment indicated that reduced solar gain had to be compensated by increased space heating energy consumption.

The resident of the HSG low-e apartment was also expected to report increased thermal comfort in the fall, winter and spring but did not. Reduced heat loss during cold weather should have resulted in greater comfort than for the resident of the control apartment. As the project progressed, we learned the resident preferred warmer-than-usual conditions which also explained why in the summer, that resident was at times more comfortable than the others.

Although HSG low-e coated glass allows high levels of solar energy to penetrate through the window. Some solar energy is reflected, apparently enough, to cause discomfort to some residents. Therefore, when HSG or LSG low-e coated glass is used, additional compensating actions should be considered to address reduced solar gain and increased space heating needs, such as:

- Windows and doors with more thermally-efficient frames;
- Double- or triple-pane insulating glass units with warm-edge spacers and argon or krypton gas fill; and
- Smaller or fewer windows and glazed doors (reduced window/wall ratio).

As the project progressed, we learned the resident preferred warmer-than-usual conditions which also explained why in the summer, that resident was at times more comfortable than the others.
In the summer there appears to be little benefit to LSG and HSG low-e. Other means of reducing solar gain should be considered, such as exterior sun shades, rolling shades or perhaps dynamic glass (e.g. thermochromic or electrochromic glazing). Reducing the amount of vision glass would also be beneficial—after all, what benefit is vision glass behind a couch set against a floor to ceiling window? Smaller glazing areas would also help in reducing heat loss and related thermal discomfort.

Detailed hour-by-hour analysis of the position of the sun in the sky (altitude, the vertical angle of the sun above the horizon, and azimuth, the horizontal angle of the sun from south, which combine into angle of incidence) and the length of daylight exposure (duration) allow the results of this study to be applied to other building elevations.

For example, the study apartments faced southeast; southwest-facing apartments in the building would experience similar combinations of angle of incidence (less than about 60 degrees) and duration of exposure in the afternoon.
and so would benefit from LSG low-e glass also. The northeast and northwest elevations experience conditions, for which LSG low-e could be beneficial, but for shorter periods. Therefore, an HSG low-e that provides better control of heat loss would be a wiser choice (Figures 11 and 12 on page 42).

GOING FORWARD

The findings demonstrate that there is a benefit to using LSG low-e glazing to control fall and spring “shoulder season” thermal discomfort. However, HSG low-e may be more appropriate for some solar exposures.

The concept of tuning each building façade to suit solar exposure has long been advocated by proponents of passive solar heating design. The ability to do this now exists using modern HSG and low-LSG technology. Computer energy modeling software, such as EnergyPlus, allows the design team to quickly and efficiently determine the effect of LSG and HSG low-e on building energy consumption and indoor thermal conditions.

However, LSG and HSG low-e are not enough to deal with all incidences of thermal discomfort. We need to get better at the basics—building orientation and floor planning that reflect solar exposure, reduced window-wall ratio, including external shading, improving ventilation and space cooling—to achieve year-round improvements in resident thermal comfort, reduced energy consumption and use of non-renewable energy sources.

A version of this article previously appeared in the July 2015 issue of Construction Canada Magazine.

George Torok, CET, BSSO, is a building science specialist at Morrison Hershfield in Ottawa. He has 28 years of experience in building envelope design and construction, performance failure investigation and remediation, and specializes in design and construction of new glazing systems and in repair, upgrade, and replacement of existing glazing systems.

Torok is active in the development of Canadian Standards Association (CSA) standards governing design and installation of fenestration systems. He can be reached at gtorok@morrisonhershfield.com.

REFERENCES

3. Detailed information on experiment conditions, findings, conclusions and recommendations can be found in CMHC’s 2012 report “Selection of Low-e Coated Glass for Older Residential High-rise Apartment Buildings in Canada, Ottawa,” available online at www.cmhc.ca/odpub/pdf/67829.pdf.
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In northern coastal climates, surface condensation often occurs in fenestration systems during the winter. The most common contributors of this phenomenon are air leakage, thermal bridging and boundary conditions (i.e. local convection and radiation). Researchers and industry experts typically focus on improving designs of fenestration and developing different strategies to deal with air leakage, and simplify the effects of boundary conditions on windows condensation.

This project focuses on investigating the ways different heating systems interact with window-wall systems through convection and radiation heat exchanges, and their effects on surface condensation. The three most common heating systems for multi-unit residential building (MURB) are considered: electric baseboard, hydronic radiant floor and forced air system.

Each heating system provides vastly different indoor conditions due to differences in thermal stratification, room air distribution and location of the heat sources. These differences have direct impacts on window performance and potentially increase risk of condensation.
In this project, the following questions are investigated:
- How significant is the impact of room air flow on condensation risk in window wall systems?
- Are empirical film coefficients sufficient for predicting condensation risk of window wall units?
- What are the quantitative differences between each of the heating systems on condensation risk?

This project designed a methodology in an attempt to better understand and predict these physical phenomena and will hopefully guide further efforts to better characterize the effect of different heating systems in window condensation risk analysis.

**WHY CONDENSATION ON WINDOWS IS AN ISSUE**

Surface condensation often occurs on fenestration systems in buildings due to changes in indoor humidity or indoor or exterior temperature. It happens on a window when the temperature of part of a glazing unit drops below the dew point temperature. Dew point temperature depends on the surface relative

<table>
<thead>
<tr>
<th>Detail</th>
<th>Heating system</th>
<th>Source</th>
<th>$hc$</th>
<th>Reference temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab Edge/Bypass</td>
<td>Reference</td>
<td>ASHRAE (2009)</td>
<td>6.8 (Fixed)</td>
<td>Average room air temperature</td>
</tr>
<tr>
<td>Slab Edge/Bypass</td>
<td>Electric baseboard</td>
<td>Khalifa, et al (1990)</td>
<td>$hc = 8.07 \Delta T^{0.11}$</td>
<td>Average room air temperature</td>
</tr>
<tr>
<td>Slab Edge/Bypass</td>
<td>Radiant Floor</td>
<td>Khalifa, et al (1990)</td>
<td>$hc = 7.61 \Delta T^{0.06}$</td>
<td>Average room air temperature</td>
</tr>
<tr>
<td>Slab Edge/Bypass</td>
<td>Forced Air</td>
<td>Goldstein , et al (2010)</td>
<td>$hc = 0.103(V/L)^{0.8}$</td>
<td>Supply air temperature</td>
</tr>
</tbody>
</table>

*Table 1: A list of convective heat transfer coefficients used in THERM.*
humidity and temperature and is highly influenced by indoor and outdoor boundary conditions.

Surface condensation accelerates deterioration of different building elements around the window frame. It leads to durability issues, such as corrosion of metal elements and induction of mold growth in wooden frames. Furthermore, surface condensation in window panes is not aesthetically pleasing. This phenomenon is a significant issue under North American moderate coastal climate condition, where interior relative humidity is still high in winter and exterior temperature is moderately low.

Each heating system provides vastly different indoor conditions due to differences in thermal stratification, air distribution in the room and location of the heater. These differences have direct impacts on window performance and affect the risk of condensation.

**METHODOLOGY**

In order to investigate the effects of these heating systems, it is important to understand each of the heat transfer mechanisms involved, i.e. conduction, convection and radiation. While conduction and radiation can be modeled accurately via the use of heat transfer simulation software, it is not the case for convection because convective heat transfer is highly sensitive to buoyant and mechanically-induced air movements.

There are two available methods to model convection coefficients in building simulation: 1) empirical coefficients obtained from laboratory experiments and 2) computational fluid dynamics.
(CFD) simulation. In this project, the two methods were explored and were used to model the selected window wall details. The software, THERM and Autodesk Simulation CFD were selected to simulate the condensation risk of these typical glazing units with different heating systems.

THERM was used to model the two-dimensional (2-D) heat transfer through envelope details. THERM uses the finite element method (FEM) based on well-stirred (or well-mixed) room air assumption; boundary conditions such as convective and radiation heat transfer coefficients are used to model heat transfer between surfaces and the room air.

CFD was used to predict the air flow patterns induced by the heating systems. CFD uses fluid (air flow) and heat transfer finite control model based on room air flow model assumption; simulation allows prediction of local heat flow patterns, thermal stratification and air distribution.

This project designed a methodology as illustrated in Figure 1 on page 46. As a point of departure, the boundary conditions were investigated from the literature for the window detail (THERM) and the room air flow models (CFD). In parallel, relevant window-wall details were selected from the local industry. Finally, 2-D heat transfer models were built in THERM and room air flow models in CFD for the window details, with representative boundary conditions for each heating system. The steady state models were simulated under typical winter conditions of Vancouver.

Two common multi-unit residential building window wall details were selected for the project—window wall assembly with bypass spandrel glass panel and extended

Figure 3-1: The CFD electric baseboard model.

Figure 3-2: A radiant floor model.

Figure 4: A comparison between CFD and THERM models for bypass detail.
slab edge with window wall assembly. THERM models were built to determine the indoor surface temperatures at the critical window-wall details for condensation. The models implemented in THERM of the bypass window wall system and the extended slab systems were identified in Figure 3 on page 47.

In THERM models, indoor boundary conditions are described by heat transfer coefficients of window assembly surfaces and a constant value is typically used. The effect of each heating system was modeled using corresponding convective and radiation heat transfer coefficients. The convective heat transfer coefficients used in THERM were drawn from the literature, as illustrated in Table 1.

The radiation component was modeled through the use of a view-factor-based radiation model in THERM. The conductive components of the models are simulated via the use of heat sources. For electric baseboard models, a radiating surface with a set temperature was used. For the radiant floor model, floor pipes and surface with set temperatures were used. The input parameters are selected based on manufacturers’ product data sheet.

COMPUTATIONAL FLUID DYNAMICS MODELING

A total of eight computational fluid dynamics (CFD) models were built—one for electric baseboard and radiant floor, two for forced air system with variant on supply inlet location, and a set of these for each window wall details—bypass detail and extended slab edge detail. Two configurations for location of the supply inlet were implemented in
the forced air models, as the location of supply inlet had a huge impact on the performance of the heating system.

The conductive components were simulated via the use of heat sources similar to the THERM models based on set temperatures (Figure 3 on page 48). The convective and radiation components were generated by dynamic fluid flow simulation.

DATA COLLECTING

Surface temperatures data were generated at each reference and for each of the heating system models and then the data were plotted under one graph. To plot a graph of surface temperatures against locations on the glazing unit, an origin point was set at the location where the window glass and the frame met at the sill section, which is called the “sight line.”

Positive sight line distance values are for points on the window frame below the sight line and vice versa. The Y-axis represented surface temperature in degrees Celsius.

The dew point threshold of 21°C and both 50 per cent and 60 per cent relative humidity were plotted to assess condensation risk of each model. For instance, the graph for comparison between THERM and CFD models is included in Figure 4 on page 48.

The CFD models present graphical simulation results on the air distribution and thermal stratification of the window sill sections and the room for each heating system model. The colour differences reflect temperature differences. The arrows represent the direction of air flow and the size of arrow represents the speed.

ELECTRIC BASEBOARD MODELS

The window sill section shows that there was an upward convective heat flow due to the heat sources on the radiating surfaces, which simulated the effect of the baseboard heater (Figure 5). Overall, the electric baseboard heater was able to distribute heat evenly at the center of the room (Figure 6).

The window sill section shows a downdraft flow towards the windows sill (Figure 7). The room air shows that there is little thermal stratification (Figure 8). Overall, the radiant floor system...
was able to distribute heat more uniformly within the room, except for the cold corner at the window sill.

The window sill section shows an air flow carried by upward momentum traveling along the fenestration unit and towards the window (Figure 9). However, this air flow does not provide sufficient heat for the cold corners, as revealed by the temperature gradient. The room air show flow patterns that the forced air system creates multiple convective air loops within the room (Figure 10 on page 52).

The forced air system does not distribute air as evenly as the radiant floor system and recirculation zones appear at cold corners. There appears to be a cold corner at the end of the room with a small localized convective air loop.

Based on the simulation results and analysis, the following conclusions were made:

• Validated that electric baseboard system had the least problem with surface condensation;
• Radiant floor system was under condensation risk when indoor relative humidity was above 55 per cent;
• Forced air system was considerably more susceptible to condensation risk due to its typical location of supply inlet and uneven thermal stratification within the room;
• Validated that extended slab edge detail performed worse than bypass detail due to thermal bridging;
• THERM (FEM) models provided consistent trend as CFD models, however, these results varied by as much as 30 per cent. The more sophisticated CFD models likely depict a more realistic outlook of the simulation; and
• THERM analysis showed that constant convective coefficient method (reference model), did not sufficiently characterize realistic indoor boundary conditions in some cases.

CONCLUSION AND FURTHER WORK

The research findings confirmed the hypothesis that the window condensation risk is affected by the heating system. The major finding in this project is that the typical modeling method of using a fixed interior boundary coefficient is not sufficient for
describing a realistic indoor boundary condition, in which a heating system is present in a room condition under winter conditions in northern coastal climate.

Each heating system provides vastly different indoor conditions due to differences in thermal stratification, air distribution in the room and location of the heater. These differences have direct impacts on window performance and affect the risk of condensation. The research further confirms that thermal bridging in the studied detail increase the chance of surface condensation in a fenestration system.

Based on the research findings, it appears that an accurate implementation of indoor boundary conditions is required to accurately assess condensation risk of window wall assemblies with typical heating systems. In addition, CFD simulation provided meaningful insights into how air flow affects the condensation risk in window assemblies. Future work may include developing three dimensional (3-D) CFD models to evaluate the effects of 3-D supply forced-air flows at the room-window corners.

Other relevant factors to be considered are the presence of furniture and blinds in reducing convection and radiation heat transfer. More importantly, future work on this topic should seek to calibrate the models through monitoring and measurements in case studies and explore improve window-wall constructive solutions to minimize the risk of condensation.

Derek K.F. Yan is a building science consultant with LDR Engineering Group, a full service Building Science Consulting firm in the Lower Mainland.

Rodrigo Mora, Ph.D, P.Eng. (British Columbia), is a faculty in the Building Science Graduate Program at the British Columbia Institute of Technology (BCIT). Mora received his M.Eng. and PhD degrees in Building Engineering at Concordia University in Montreal, with a focus on building systems integration. He has a bachelor's degree in civil engineering at the Pontificia Universidad Javeriana in Bogota, Colombia, and seven years of industry experience in research, development and management of large multifamily building projects and hospitals.
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October 19, 2015 is your opportunity to change the world. I suppose by the time you read this, the federal election will be over and Canadians will have opted for one of the 16, (yep, 16) different leaders that have thrown their hat into the ring as of date of writing this article.

I would say 17 except the Marijuana Party has not nominated the leader. Sure, I, too, have thought of a few reasons why. Anyway, the majority of the candidates come from the Conservative Party, the New Democratic Party, the Liberal Party and the Green Party, representing about 83 per cent of the 1,400 or so candidates. They may not all survive the election process and, in fact, in 2011, only five parties actually got elected, including the four mentioned above and, of course, the Bloc Québécois, which held on for four seats.

As I am barred by statute from talking about my party preferences (yes that is right—as a part-time bureaucrat sitting on an Ontario commission, I am bound by the Public Service of Ontario Act, which blocks me from even so much as a lawn sign). So, I am not permitted to state how I feel about Toronto’s preferences for voting for left-wing candidates or expound on the fact that it is up to the rest of Canada to try to set some sort of balance. I am going to talk about how silly I think one particular policy set by the Ontario government is and I am going to give you an example. I know, I know. It’s a federal election this fall but, as they say, all politics are local so I paint the parties with the same brush, whether federal or provincial.

Most Ontario readers have heard about the Infrastructure Ontario (IO) pre-qualification of consultants and the apparent benefits of their roster format for selecting consultants. I am here to tell you that while it appears to be fair and equitable and make perfect sense on the face of it, in reality it is just dumb right out of the box. Here’s why.

A little while ago, my company was hired to undertake an extensive investigation of an IO building operated by a private project management company. The request for proposal (RFP) came out from the project manager (no names to protect the guilty and my liability insurance), expressing a need to examine the occupant comfort issues arising from problems inherent in the building envelope. We submitted a response to help them arrive at a solution.

Immediately upon being awarded the project, we were advised that the problem was really one of water leakage. The curtain wall and the sloped glazing had leaked for over 20 years and that was the problem they really needed to solve—but we also needed to check the occupancy conditions for comfort, as well, to satisfy the IO people that their concerns were being addressed.

So, our scope of work expanded; the investigation cost increased significantly; and after considerable destructive exploration work, we arrived at the nature of the problem and some (pretty innovative, if I don’t say so) solutions.

As a sidebar, we also pointed out that the podium leaking they had solved previously by replacing a roof was the wrong solution and that the leaking actually arose from curtainwall deficiencies. The project manager was not particularly happy with that answer as he had spent quite a bit fixing a problem that was not there.

Nonetheless, we submitted our report and gave a presentation of our findings to the project manager and IO; and we received very high marks for our work. After two years of silence, we got an RFP from two different architects who had been given our report.

Their RFPs wanted us to design the remedial work and provide all technical support during the remedial work—all for a fixed cost. Who were these architects? Why were they now in the picture? Why are we now being asked to be a sub-consultant? Where was our invitation to be the prime...
consultant for repairs we know more about than any other consultant that has been involved with the project for the last 20 years?

Well, here comes the policy problem. Apparently, having been selected from the first group of five consultants for the assessment phase of the work, we were no longer in line for the design/construction phase of the work. The selection process had moved down the list to the next five consultants. The only way we could continue to be involved in this project would be as a sub-consultant to one of the next five who would rely on us completely, take a mark-up on our fee and leaving us out of the loop for the client management so vital to projects like this, while dealing all the professional liability to us. We declined. It is not really sour grapes that made us decline. It is that I do not see why we should participate in a flawed process merely to continue our involvement in the project.

I have no doubt that the solutions that we came up with will be deemed to be overly complicated by whoever gets the job and a far simpler, safer “replacement” option will be selected and the budget for the remedial work will quadruple as a result. Ideally, the IO project manager would then realize that the system is broken and they will do what they can to straighten out the mess. But I am not particularly hopeful.

It is all too easy for people administering government programs to say, “The process requires us to do this.” It is all too easy for those of us providing expert services to say, “I will be a good person and try and help you as best I can even though I do not agree with what you are doing or how you are doing it.”

Every day we have solutions that are cost-effective, technically sound, and will make a meaningful change to the performance of buildings and the lives of the people that work and live in them.

I hope that little by little we will all begin to say, “No, I am not playing that game. What you are doing is wrong and I am going to make you know that it is wrong. I am going to let you know that it is wrong by not participating and when you asked me why, I will tell you. I am going to let you know that it is wrong by expressing my viewpoints at every opportunity. And I am going to let you know that it is wrong by voting against the political party that put your silly rules into place.”

Now, I am not suggesting that we all take the Howard Beale’s approach and start screaming out our windows about how you are mad as hell and you are not going to take it anymore. But if you want to stick your head out the window and scream out something, that gives you a scream, “Be my guest!”

Every day, we, who are the experts in this area, deal with building envelope
problems. Every day we have solutions that are cost-effective, technically sound, and will make a meaningful change to the performance of buildings and the lives of the people that work and live in them. Do not let some bureaucratic process control how you do that.

If you are the architect that got the RFP to design the repairs and you do not know how to do it, then decline the RFP and tell them to hire the guy who does know how. If you are the project manager who has the job of putting out the RFP to the next five people on the list, how about you make sure they know what they are doing for this particular type of assignment? If you are the bureaucrat that put this nutty process in place, how about you take the policy and put it through the shredder. Maybe, then, we can get some work done that will not cost taxpayers three or four times what it should and get it done by people who know what they are doing.

That’s it, folks. This is my final Gripe. If you have enjoyed this op-ed piece, perhaps you can ask the current board of directors to provide “Guest Gries” by people who have something to get off their chest related to our beloved building envelope. I think you have all heard enough for me. I am actually generally a happy person—really.

Gerald R. Genge, P.Eng. C.Eng., BDS, BSSO, C.Arb., Q.Med. is Past-President of the Ontario Building Envelope Council and has been active in standards development, education and consulting for over 35 years. He is a Principal of GRG Building Consultants Inc. and ArbiTECH ADR and can be reached at jgenge@grgbuilding.com.
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MBEC OFFERS DISCOUNT ON PASSIVE HOUSE DESIGN COURSE

The Manitoba Building Envelope Council Inc. offered members a discount on CanPHI’s Passive House Design and Construction course, which took place April 6 to 10, 2015. The course provided participants with knowledge about design and build-compliant Passive House buildings, meaning an 80 to 90 per cent reduction in annual heating and cooling energy, and reduced mechanical systems.

The course offered participants the first step in becoming a certified Passive House designer or consultant and enabled them to be actively involved in the design and construction of Passive House buildings.

BCBEC WORKSHOP LOOKS AT BASEMENTS AND PARKADES IN RESIDENTIAL BUILDINGS

This past February, the British Columbia Building Envelope Council held a half-day workshop focused on the design, construction, maintenance and remediation of basements and parkades in residential buildings. The workshop—also presented by the Homeowner Protection Office, a branch of BC Housing—gave industry leaders the chance to discuss code requirements, soil condition assessments, building systems, remediation strategies and depreciation reports.

BCBEC SEMINAR ON CONSERVING HERITAGE BUILDINGS

This past March, the British Columbia Building Envelope Council held a seminar titled “Considerations for the Conservation of Heritage Masonry and Wood Windows.” Presenter Kurtis Topping, BASc, EIT, RRO, a design engineer with Read Jones Christoffersen, examined two heritage conservation case studies and explored the different stages and influencing factors in developing an appropriate conservation strategy for heritage building envelope components.

He discussed primarily considerations for the conservation of heritage masonry and wood windows and touched on identification, assessment and failure mechanisms of heritage building envelope elements, as well as maintenance of heritage building materials for conservation projects.

ABEC PRESENTATION LOOKS AT CONDENSATION ISSUES IN VENTED FLAT ROOFING

This past February, the Alberta Building Envelope Council held a presentation that looked at resolving condensation issues in vented flat roofing.

Presenter Pierre-Michel Busque, P.Eng, BEP, examined the condensation issues of a two-storey cinder block warehouses converted into a mixed use building in Whistler. The building has a main floor bakery with residential units on the second floor. During winter conditions, residents in the second floor units reported moisture and organic growth on ceilings in the units. Deteriorated materials were replaced and roof vents and fans were added to the building to improve air circulation. Even so, the condition worsened.

The design team pressurized the roof to prevent air leakage. Working with the building owner, the roof system was monitored to determine the outcome of the design.

In his presentation, Busque detailed the design process and revealed whether or not it was a success.

BECOR HOLDS SEMINAR ON RELATIONSHIP BETWEEN ENVELOPE & HVAC

In late January, the Building Envelope Council Ottawa Region held a seminar about improving the building envelope and HVAC for sustainable housing.

The better a building envelope is designed to prevent heat, air, and moisture flow, the less work the HVAC has to do to condition the space. Similarly, forces on the building envelope are reduced when the control of supply and return air flows is improved and the stack effect is dealt with.

In this seminar, speaker George Torok, C.E.T, BSSO, stressed that HVAC and building envelope designers should be involved early in the design process so that the impact, positive or negative, of design decisions from one system or the other can be understood.

Problems such as inadequate indoor thermal comfort, roomside condensation and poor indoor air quality can be avoided in today’s new and retrofitted buildings.

Torok, a building science specialist with the Façade Engineering Group of Morrison Hershfield, gave examples of expected and real performance of buildings and the effect on comfort, maintenance and the user experience.
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Ontario Building Envelope Council

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Half Year Fee - Ending May 31st 2016 ½ YEAR

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<tr>
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<td>$85.00</td>
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<tr>
<td>□ Professional (BSSO Holder)</td>
<td>$125.00</td>
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<tr>
<td>□ Student</td>
<td>$15.00/school year</td>
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City: __________________ Province: _____________ Postal Code: _____________
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