Pushing the Envelope Canada

A publication of the Ontario Building Envelope Council

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HENRY HESS
CITY OF GUELPH
1 CARDEN ST
GUELPH, ON
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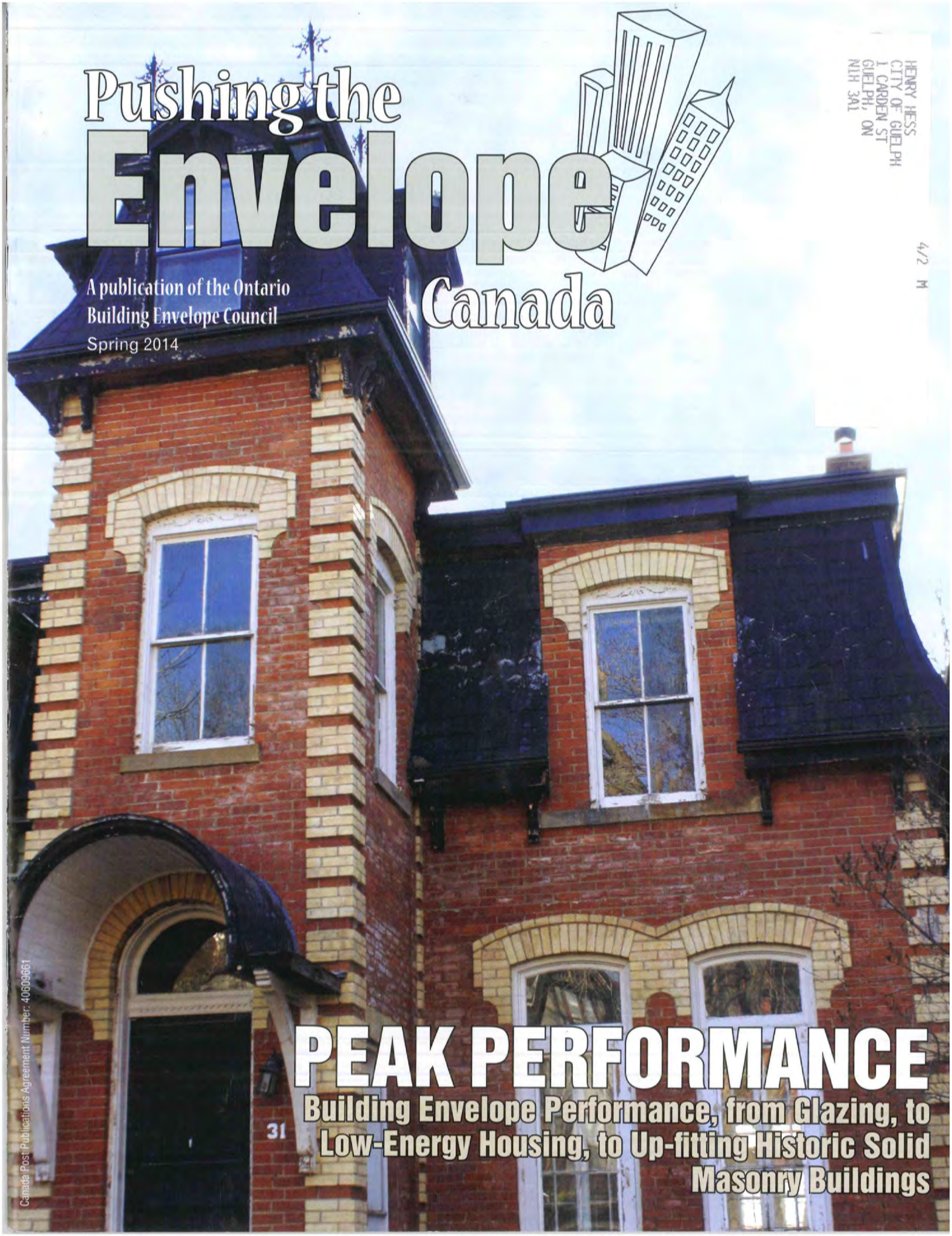

PEAK PERFORMANCE

Building Envelope Performance, from Glazing, to Low-Energy Housing, to Up-fitting Historic Solid Masonry Buildings

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From Research to Design and Construction:

Building the Low-Energy Gemini House

By Kim Pressnail, Ekaterina Tzekova, Marianne Touchie & Russell Richman

The Gemini House is a low-energy demonstration home located on the University of Toronto's St. George Campus. Using an innovative technique known as Nested Thermal Envelope Design™ (NTED™), the home has been retrofitted to show designers and constructors that it is possible to turn an historic 1879 Second Empire home into a low-energy and comfortable dwelling.

Back in 2010, the authors wrote an article for the spring edition of *Pushing the Envelope Canada* outlining the design approach. A lot has occurred since Professor Russell Richman of Ryerson University and Professor Kim Pressnail of the Department of Civil Engineering at the University of Toronto teamed up to apply the NTED™ approach to a listed historical property. Thanks to the significant funding support from the Ontario Power Authority's (OPA's) Technology Development Fund and the generous support of numerous project supporters, including designers and material suppliers, the project is now 98 per cent complete! Monitoring of the home began in December 2013 and will continue for at least one year.

WHAT IS NTED™?

The Gemini NTED™ involves constructing a "core" building within a "perimeter" building. Both of these building zones are designed to control the movement of heat, moisture and air independently. The perimeter envelope is designed the same way as a traditional low-energy envelope. The core envelope, since it is not exposed to the exterior weather elements, is constructed with interior finishes on both sides; however, beneath the finishes there are thermal, air and vapour control layers. Energy savings accrue because of the two efficient envelopes, and, more uniquely, because the occupant can choose to condition the perimeter space only when needed, unlike a conventional low-energy home.

DESIGN FEATURES

Implementing a low-energy design within an existing building is challenging. Doing so in an historic context with a façade and interior elements that must be preserved adds to the adventure. That's where Graeme Stewart of E.R.A. Architects Inc. stepped in. Experts in historical preservation, E.R.A. became the architects of record and partners in the design.

In order to make the Gemini concept work in an existing building, core and perimeter spaces had to be carefully created. Core spaces were located in the southern part of the building and included the kitchen, the dining room, the powder room and the stairway/hallway on the first floor. On the second floor, the master bedroom and the bathroom also became core spaces. The perimeter spaces were designed so that they could be intermittently heated to comfortable indoor temperatures; they include the ballroom on the first floor, the two second floor bedrooms on the north side of the house, and the basement.

The Gemini House is a low-energy demonstration home on the University of Toronto's St. George Campus. All photos in this article provided by Ekaterina Tzekova.

Once these zones were created, several distinctive design features were incorporated into the building, including:

- Existing single-glazed windows on the north-facing historical façade were restored and retained as vented storm windows. Inboard, sealed triple-glazed, low-emissivity, wood frame windows were added;
- South-facing windows were doubled up as core and perimeter windows were separated by a 150 mm vertical plenum for gathering solar heat;
- The solar heated plenum is part of the perimeter connecting the basement and second floor perimeter spaces by a dedicated passive flow duct system;
- The iconic tower is a solar chimney with an electrically-operable skylight for passive summer ventilation;
- An inter-zonal heat pump was added to move gathered solar heat from the perimeter to the core in the winter, or from the core to the vented perimeter in summer when cooling is required;
- Heating is provided by a zoned radiant floor system, while fresh air is supplied to the core and perimeter zones using separate energy recovery ventilators;
- Solar tubes direct light to illuminate core spaces that are furthest away from the southern windows;
- Interior doors between core and perimeter zones are insulated and include air-tight seals;
- Urethane foam insulation has been applied inboard of the exterior masonry walls. The spray foam has been coupled with a unique vented drying airspace that helps the double-wythe historic masonry continue to dry on both the inboard and exterior faces after insulation; and
- The ballroom, complete with an original hand-crafted plaster ceiling, has been restored to its original grandeur.

CONSTRUCTION CHALLENGES

Construction of the project proceeded using a slightly modified version of the traditional general contracting approach, which meant that all of the plans and specifications had to be in place before the project began. Given that this was a home renovation with an atypical interior building envelope, a construction management (CM) approach should have been used. If a CM approach had been used, the design could have proceeded as the construction began, thereby allowing design flexibility, shortening the project schedule, and, ultimately, reducing costs.

Although the design was straightforward and highly prescribed in an extensive set of contract documents that far exceeded the norm in residential construction, building two airtight envelopes is atypical. This meant that close supervision and collaboration with the general contractor were required in order to see that the design expectations were met.

In order to ensure that the required performance standard of two air barrier systems was met, a total of four fan depressurization tests were conducted throughout the project. The first test was carried out after the perimeter urethane foam air barrier had been put in place. The next two tests were conducted after the core foam was installed, and the final test was carried out to determine whether the previously noted deficiencies were completed. These tests were very helpful in identifying areas where more work was needed. Since these tests were carried out during construction, modifications and corrections could be made easily.

The windows used on the project were wood-framed windows with superior air and thermal ratings. Unfortunately, not enough lead time was allowed in the schedule for fabrication and delivery

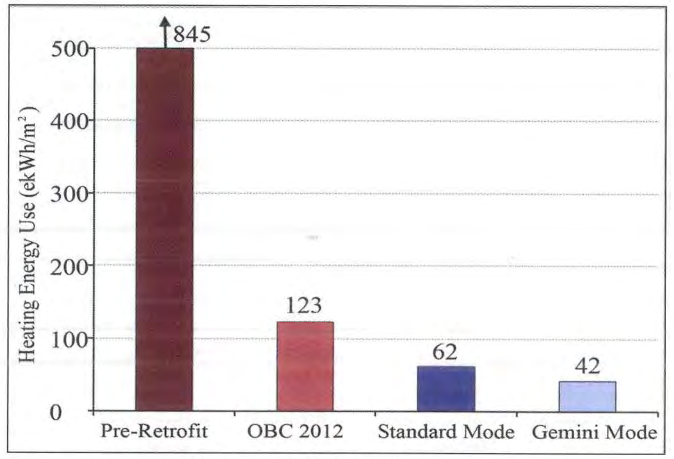
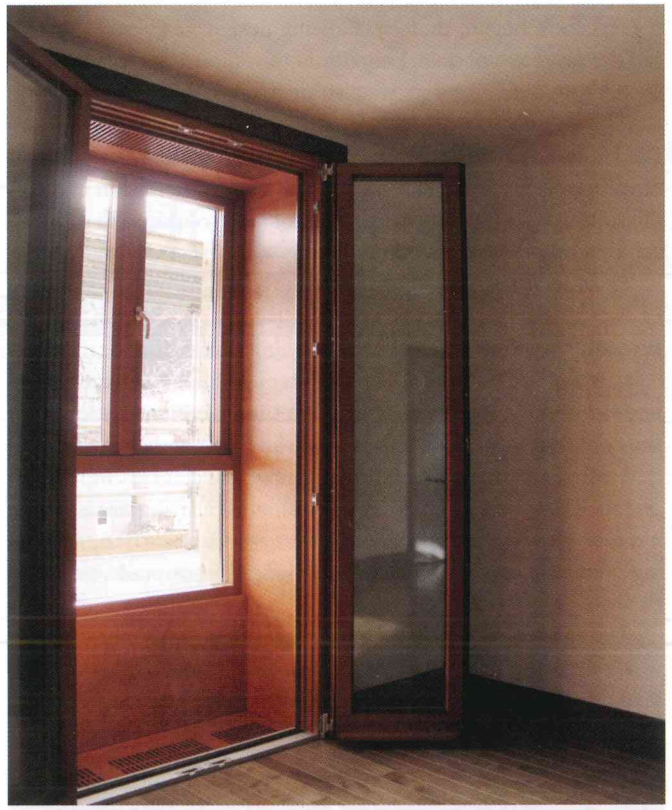
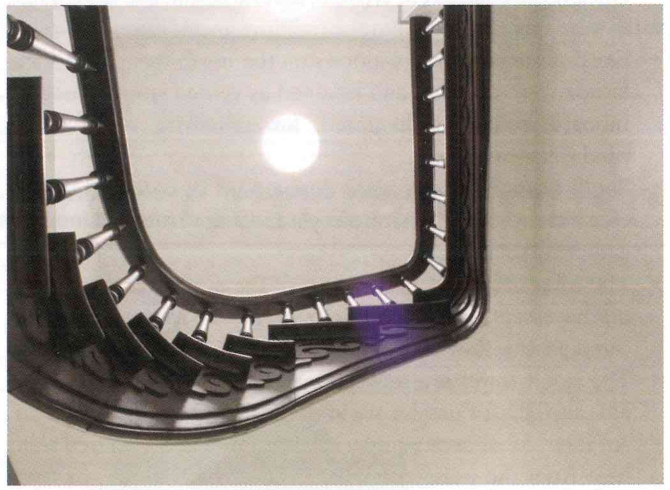


Figure 1: Gemini House modelled heating energy use.

Urethane foam insulation was applied inboard of the exterior masonry walls. The spray foam was coupled with a unique vented drying airspace that helps the double-wythe historic masonry dry on both the inboard and exterior faces after insulation.



South-facing windows were doubled up as core and perimeter windows were separated by a 150 mm vertical plenum for gathering solar heat.



Solar tubes direct light to illuminate core spaces that are furthest away from the southern windows.

of the windows, which ultimately led to a four-week delay in the construction schedule.

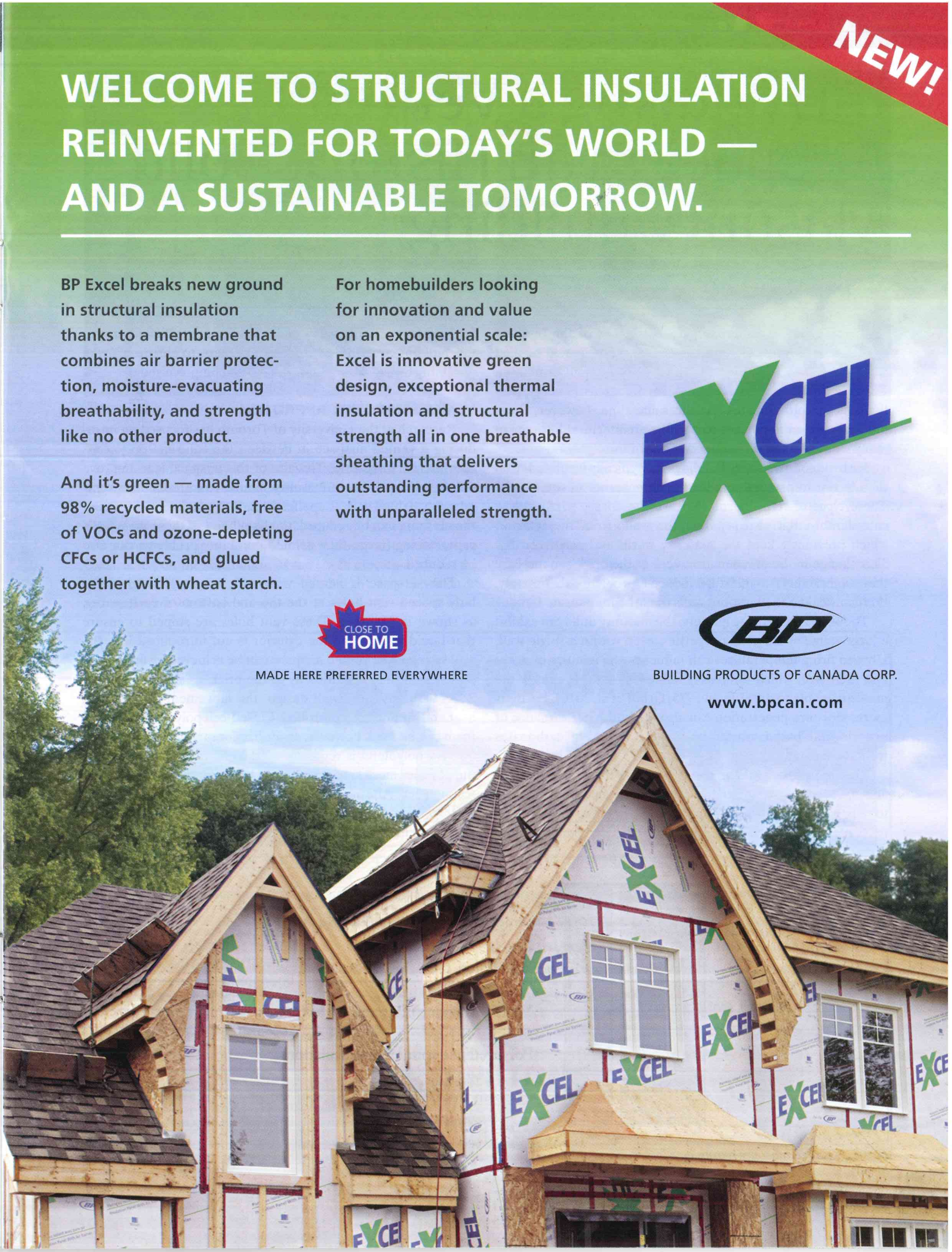
Even though the windows did not arrive as scheduled, construction still proceeded. The drywall was actually installed before the windows were put in place. This sent the design team scrambling, as maintaining the continuity of the air barrier around the windows became more challenging. This was a key time when product manufacturers were called on-site to discuss ways in which their products could be used to ensure the design objectives were met.

MONITORING BUILDING PERFORMANCE

Monitoring of the home began in December 2013. Ekaterina Tzekova, Donna Vakalis and Maria Rumeo, graduate students in the Department of Civil Engineering are all taking part in the monitoring. Ekaterina is living in the house for a year and operating the home in various modes. She will also be evaluating the hygrothermal performance of the vented masonry drying space. Donna will be studying the indoor air quality and will be looking at various contaminants including CO_2 and formaldehyde. Maria will be examining the energy performance of the building and comparing the actual energy performance to the modeled energy performance. Figure 1, on page 17, reveals modeling predictions using the as-built construction. Maria's work will reveal how well the Gemini house actually performs.

Since this home has been built as a demonstration project, we welcome individual or group site-visits. Tours can be arranged by appointment through Kim Pressnail (pressna@ecf.utoronto.ca). Stay tuned to learn more about our next steps. Plans are underway for modifying a 1950s bungalow using the NTED™ approach. Coming soon to a community near you? ■

Kim Pressnail is a Civil Engineering Professor at the University of Toronto. Ekaterina Tzekova and Marianne Touchie are PhD. Candidates in Civil Engineering at the University of Toronto. Russell Richman, PhD., is a Professor at Ryerson University and co-creator of the Build Better Now and Gemini House initiatives.



Introducing a Vented Airspace in an Historic Solid Masonry Building

By Ekaterina Tzekova & Marianne Touchie

As we improve the energy performance of the building stock through retrofits, special attention should be paid to historic buildings that often lack thermal insulation. These buildings tend to use significant amounts of energy, particularly in cold climates. At the same time, however, these buildings are an important part of the architectural heritage in many cities and should be preserved for future generations.

Historic solid masonry buildings are typically insulated from the interior to preserve the historic appearance of the façade. These types of retrofits can improve the energy performance considerably, but also separate the walls from the interior, which previously kept the masonry warm and relatively dry. This change in the microenvironment of the brick can increase the vulnerability to moisture-induced problems. Ultimately, this can weaken the masonry walls over the long-term.

To further complicate matters, the masonry units can exhibit a large range of material properties, even within a single wall. Uneven firing temperatures can influence the number of pores and their size, which ultimately influences to how quickly the masonry is able to dry (Litvan 1975, Groot et al. 2010). Furthermore, moisture penetration can also affect the performance of historic lime-based mortar by slowing removing carbonates from the mortar.

This moisture weakens the cohesion between the mortar and the brick, allowing progressively greater amounts of water to penetrate the walls. During the winter months, this can lead to freeze-thaw-related durability problems. Given the potential for long-term damage when undergoing energy efficiency retrofits, building practitioners should take steps to ensure that the durability of the historic masonry is not compromised.

VENTED MASONRY APPROACH

Research at the University of Toronto has focused on introducing a vented airspace in between the solid masonry walls and interior insulation. The aim of this airspace is to improve the drying capability of masonry, similar to introducing a vented cavity behind veneer applications. If the moisture content of the masonry can be reduced, the likelihood of these mass walls experiencing freeze-thaw-related durability problems can also be reduced.

This airspace is vented with exterior air through regularly spaced vent holes at the top and bottom of each storey, as shown in Figure 1. These vent holes are sloped to ensure that liquid water from the exterior is not introduced into the wall system. The vented airspace can be achieved by applying a polymer mesh system directly to the brick, as shown in Figure 2. As with any good wall design, the movement of moisture, heat and air must be controlled. Closed-cell polyurethane spray foam can be used, however, an air barrier material such as spun bonded polyolefin is recommended to be installed inboard of the polymer mesh system to ensure the foam does not seep into the airspace. Alternatively, a combination of glass fibre or mineral wool insulation could be used in conjunction with air and vapour membranes.

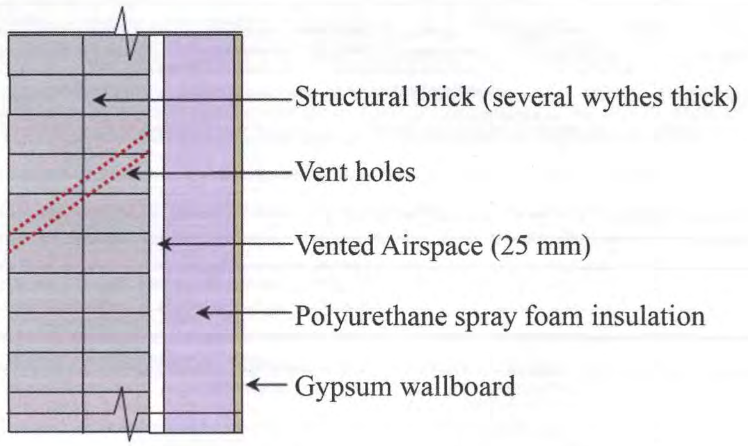


Figure 1: Vented masonry retrofit envelope configuration.

Figure 2: Application of the polymer mesh system (two layers).

MONITORING CASE STUDY

The vented masonry approach was tested in an historic solid masonry building in Toronto, ON. In 2004, the building underwent an industrial-to-commercial retrofit, where the existing solid masonry walls were insulated with medium density, closed-cell polyurethane spray foam. Vented masonry test cavities were constructed on the third floor, at the south elevation to test the effects of maximum solar exposure, and at the east elevation to test maximum wind-driven rain.

Temperature and relative humidity sensors were installed within the walls, as shown in Figure 3, and connected to dataloggers that took hourly readings. A weather station was also installed at the southeast corner of the roof to track local weather conditions. The monitoring period spanned from November 2011 to September 2013.

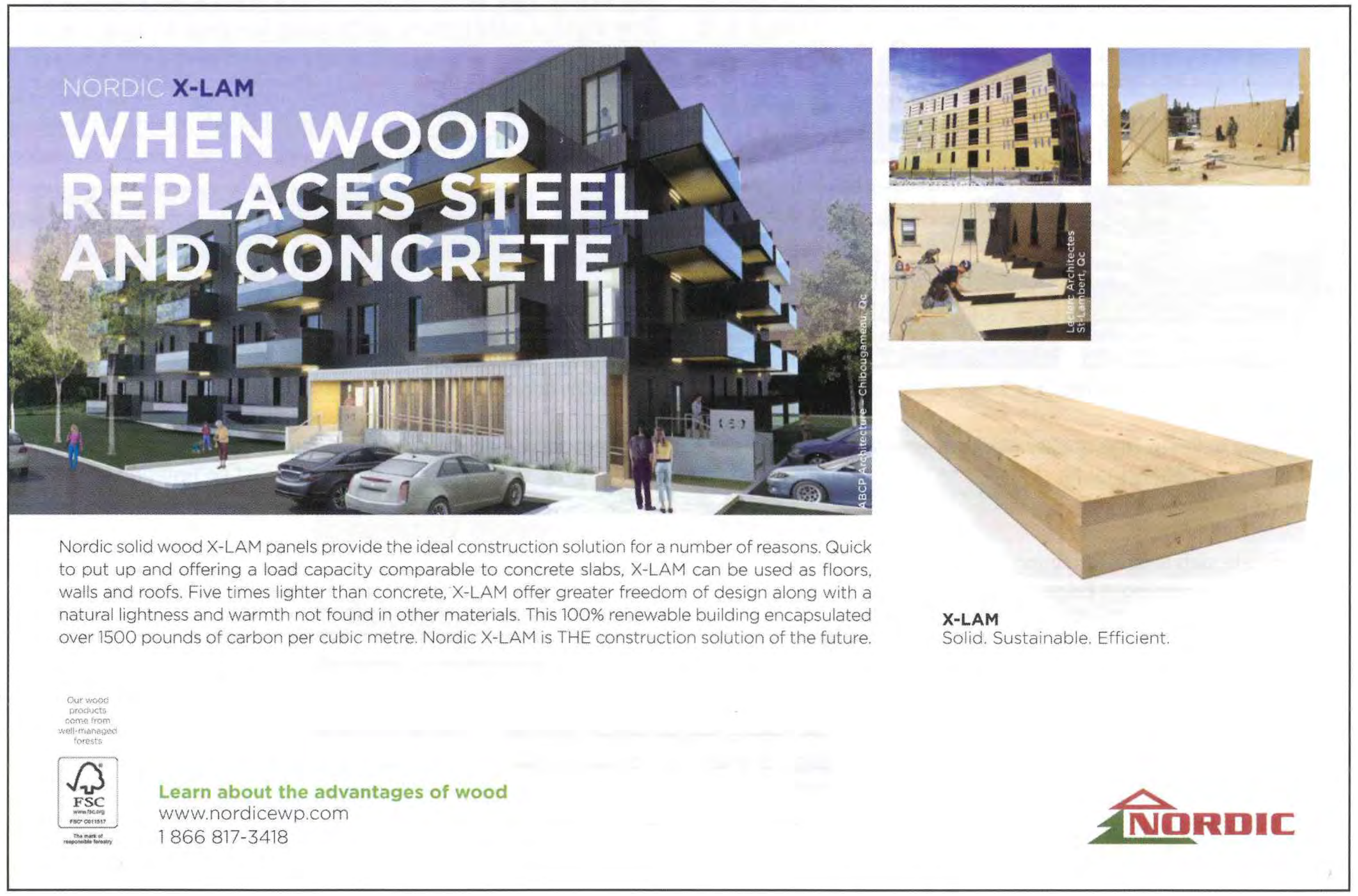
Using the monitored data and the vented cavity size, the air change and airflow rates were determined. The south wall exhibited a range of 0-102 air changes per hour (ACH), with an

Figure 3: Monitoring equipment at the top and bottom of the vented airspace cavity (prior to application of the polymer mesh system).

average of 52 ACH over the two-year monitoring period. The east wall showed a range between 0-69 ACH, with an average rate of 32 ACH. The ACH range exhibited by both walls is comparable with previous studies involving ventilation behind veneer applications (Burnett et al. 2004, Salonvarra et al., 2007). Generally, the east wall showed a slightly larger air flow cavity rate, an average of 1.23 L/s compared to the south wall at 0.81 L/s.

Next, the rate of moisture entering and leaving the cavity was determined on a monthly basis over the two-year monitoring period, as shown in Figure 4. This rate is normalized based on the cavity area. Positive moisture flow rates indicate that moisture is being removed from the masonry wall, promoting drying by natural stack action. Negative rates indicate that moisture is deposited within the vented airspace. Since the foam serves as the vapour and air barrier in this design, any moisture introduced by the vented airspace is likely deposited within the masonry.

Examining the south and east wall performance, it can be seen that the vented airspace is helping the masonry walls dry between September and April, when there is a risk of freeze-thaw damage. During the summer, relative humidity levels indicate that moisture introduced in the vented airspace is in vapour form. Given that the walls begin to dry well ahead of the colder months, any moisture introduced in the summer does not necessarily affect the durability of the walls. Overall, the vented airspace helped removed an average of 1.0kg/m² of moisture annually at the south and east test cavities.



CONCLUSIONS

Interior insulation retrofits in historic buildings largely reduce heat losses that once kept masonry walls warm and relatively dry. Insulating these buildings on the interior can potentially compromise the durability of the historic masonry. To help reduce the risk of moisture-related durability problems, building practitioners can incorporate a vented airspace located between the solid masonry wall and interior insulation. Monitoring a three-storey building over a two-year period in Toronto revealed that the vented airspace provides an effective means of increasing the drying potential of the historic envelope and reduces the likelihood of freeze-thaw damage. ■

Ekaterina Tzekova and Marianne Touchie are Ph.D. Candidates in civil engineering at the University of Toronto.

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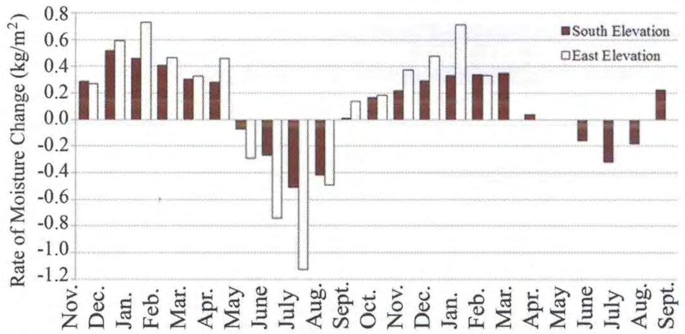

Figure 4: Change in moisture within the vented airspace.