AN INNOVATIVE BUILDING ENCLOSURE RETROFIT FOR AN EXISTING SOLID MASONRY DOUBLE WYTHE BRICK HOME IN A COLD CLIMATE

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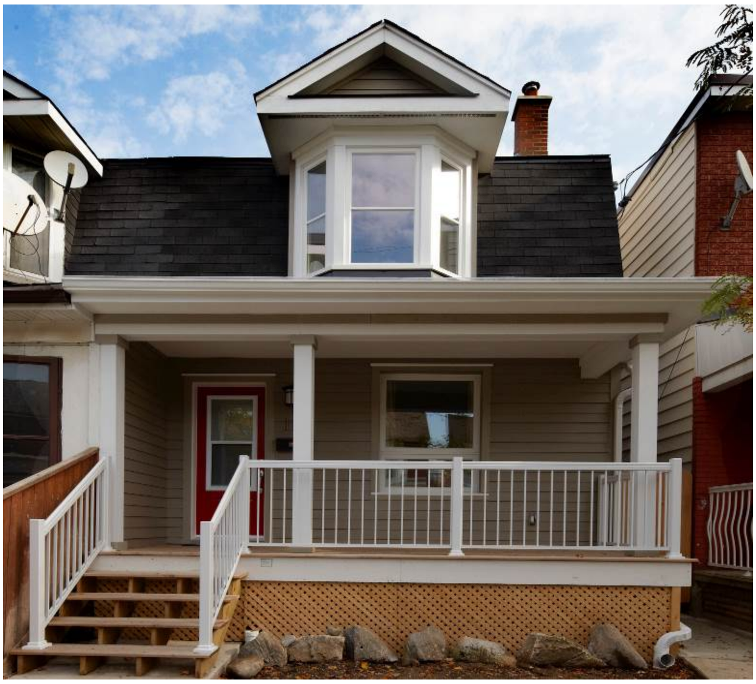

Fig 1: Completed Retrofit Project: 111 Russett Avenue

WHICH ARE YOUR ARCHITECTURAL (R)SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Research summary

Much of the housing stock of our larger cities consists of old buildings, many of which were built around the beginning of the 20th century and constitute our least energy efficient buildings. They are either totally un-insulated or poorly insulated, resulting in large volumes of air leakage. It is clear that increasing the energy efficiency of buildings is vital in ensuring energy security while minimizing environmental damage for future generations. 111 Russett Avenue is a double-wythe solid masonry brick building, a building type very common to Toronto and other North American cities. In partnership with MyHaven GreenVision Homes, the Russet Avenue Project focuses on the development of a new and innovative “green” re-cladding system that can be applied to old or “vintage” buildings. The following research questions will be answered; “What are the best technologies (materials and methods) for achieving energy efficiency within the constraints associated with vintage buildings?”, “What is the cost/benefit of retrofitting vintage building?” and “To what extent can the retrofit of vintage building and “green” co-exist?”

Keywords: Retrofit, Energy Efficiency, Building Enclosure, “Green” Recladding system, Revitalization

1. Introduction

According to the International Energy Agency, "Existing buildings are responsible for over 40% of the world's total primary energy consumption, and account for 24% of world CO_2 emissions." (IEA, 2008). Much of the housing stock of our larger cities consists of old buildings, many of which were built around the beginning of the 20th century and constitute our least energy efficient buildings. They are either totally un-insulated or poorly insulated at best, resulting in excessive levels of heat loss. It is clear that increasing the energy efficiency of buildings is vital in ensuring energy security while minimizing environmental damage for future generations.

Other issues of importance tied to energy efficiency are occupant comfort, and maintaining durability if retrofits are to be done. Through the careful design and installation of a retrofit system to an existing building, one can achieve all three objectives, providing a healthy comfortable building for generations to enjoy, while minimizing the impact on the environment.

2. Research objectives

ARGILE (Applied Research Green Innovation Lab Experience) is a research initiative by George Brown College to develop retrofit strategies to improve the energy efficiency, durability and occupant comfort of our aging housing stock. This research has been made possible with funding from the Ontario Government's Ministry of Research and Innovation.

The subject house, located at 111 Russett Avenue in downtown Toronto, is a double-wythe solid masonry brick building, a building type very common to Toronto and other North American cities. In partnership with MyHaven GreenVision Homes, the Russet Avenue Project focuses on the development of a new and innovative "green" re-cladding system that can be applied to old or "vintage" buildings.

The retrofit needed to improve the energy efficiency through increasing the overall thermal resistance of the exterior wall assemblies, as well as the air tightness of the walls to minimize uncontrolled air leakage. The assembly also needed to provide a very high degree of fire resistance due to the close proximity to the adjoining building. All this needed to be achieved using locally available building materials, with an assembly that was easily installed by non-specialized trades, and at a price competitive with the least expensive systems on the market, which was an Exterior Insulation Finishing System (EIFS).

Fig 2: 111 Russett Pre-Retrofit (left) and Post-Retrofit (Right)

Fig 3: Test walls in Natural Exposure Test Hut

3. Method OR Approach

This research was conducted in several stages, going from hygrothermal computer modelling, to a small-scale field mock-up. This was followed by the installation of a fully instrumented and monitored, small scale, pair of wall assemblies in a natural exposure test hut. These studies finally culminated in a full-scale application, instrumented and monitored, on a downtown Toronto home. The retrofit assembly was designed by the ARGILE research team in conjunction with MyHaven GreenVision Homes, a local and progressive renovation company in the Toronto area.

3.1 Hygrothermal Modelling

With a preliminary assembly in mind, hygrothermal modelling was performed using WUFI Pro 5.1 1-d to assess the durability. Five year simulations were run, and durability was assessed by examining two specific conditions. First by ensuring the exterior wythe of brick did not encounter freeze-thaw conducive conditions, and second, that the wood furring did not spend significant amounts of time in conditions conducive to rot or corrosion of the fasteners.

3.2 Small Scale Field Study

The constructability of the assembly was assessed with the first small-scale mock-up, which was installed on the corner of a vintage building. The assembly was also instrumented and monitored, to ensure durability.

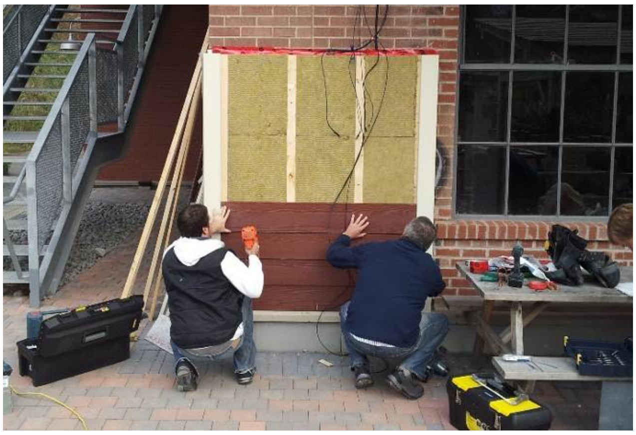

Fig 4: Small scale field test

3.3 Installation at Test Hut

After the first mock-up, a pair of 4’x8’ (1.2m x 2.4m) matching wall assemblies were installed in our natural exposure test facility (test hut). One wall had east exposure (the direction of the prevailing wind and thus maximum wind driven rain), and one west. These assemblies were part of a larger study with a total of 8 pairs of walls, all of which incorporated a solid masonry, double-wythe, reclaimed historic brick base wall with a lime based mortar, assembled by an expert bricklayer. The walls were instrumented with relative humidity and temperature sensors, embedded wood surrogate moisture content and temperature sensors (duff gauges), and moisture content pins driven into wood with temperature sensors, and monitored for a whole year. Data was logged via a Campbell Scientific data logger and multiplexer. The inside of the test hut was conditioned to a constant 20^{o}C and 40% relative humidity (RH), and the outside conditions were monitored with a weather station mounted on the test hut roof.

3.4 Full Scale Retrofit (111 Russett Avenue)

The final test phase was the full-scale retrofit of all the exterior walls of a semi-detached solid masonry home. Originally constructed in approximately 1925, the home was structurally sound but in need of a complete retrofit, from inside to out. The exterior wall retrofit work was all done by the MyHaven team, with direction as needed from the ARGILE team. Sensors for temperature, relative humidity and moisture content (duff gauges) were installed in the various layers of the assembly at one representative location with good exposure, at various construction stages. Data was logged by two Structure Monitoring Technologies (SMT) data loggers over the period of approximately two years.

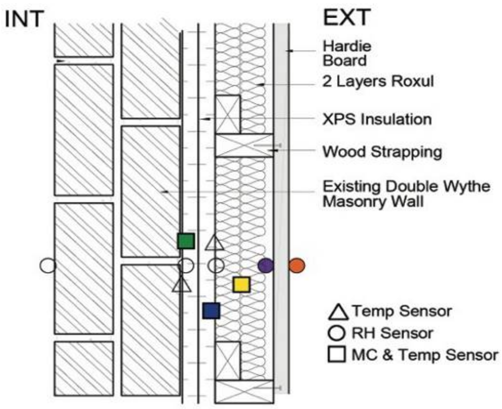

Fig 5: Sensors locations used in full scale retrofit at 111 Russett Avenue

4. Results and Design Potential

The Retrofit Assembly chosen based on the criteria outlined, was an exterior retrofit, over top of the existing solid masonry, double-wythe, brick wall consisting of (from inside to out):

- Two layers of 1” (25.4mm) extruded smooth skin Dow polystyrene (XPS), with staggered ship lapped joints and foam adhesive between the two layers
- Solid kiln dried 2x4 (38mm x 89mm) S-P-F (spruce or pine or fir) construction grade lumber strapping over top of the

XPS, spaced 2’ (610 mm) apart, fastened through the XPS into the brick with 5” (127 mm) Tapcon masonry screws

- Two layers of 1.5” (38.1mm) Roxul Comfortboard IS mineral wool insulation friction fit between the wood strapping
- ½” (12.7mm) air gap, vented top and bottom
- James Hardie “HardiePlank” fibre cement board lapped siding, nailed into the strapping

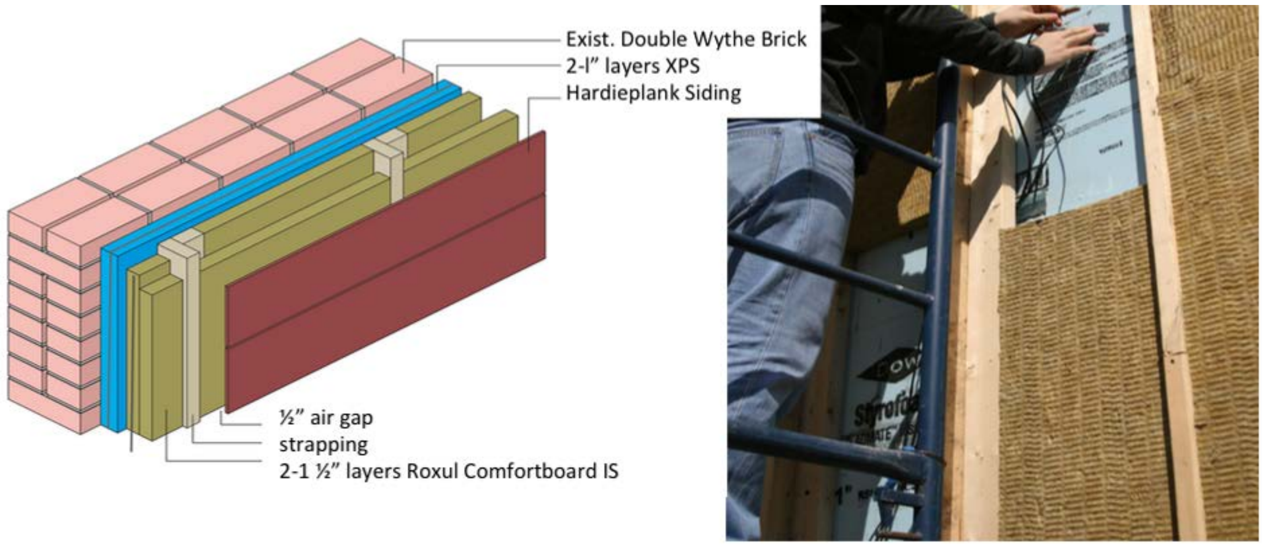

Fig 6: The image on the left indicates the exterior retrofit assembly chosen to be installed on the full scale field study with embedded sensors (right).

Installation of the exterior retrofit system proved to be relatively simple and straight forward, with all materials being readily available to the general public. The cost per unit area remained very competitive with any other exterior approaches, at approximately \$5 CAD/ft^2 (\$53.80 CAD/m^2) for materials (labour extra). The R-value was increased from about R-4 (RSI 0.7) to R-25 (RSI 4.4) effective.

In terms of durability the masonry, specifically the outer wythe of brick, remained both dry and warm, well out of the range of any danger for freeze-thaw issues. This was even true on the coldest days of winter (green line on graph below). The wood strapping and Tapcon fasteners also remained outside of any danger for wood or metal deterioration.

The occupants/ home owners reported that the home was much more comfortable after the retrofit, both in terms of winter and summer temperature stability. They opted not to install air conditioning, and even on the hottest summer days when the outdoor temperature reached the mid 30^{o}C range, said the indoor temperature remained comfortable.

With respect to energy efficiency, actual energy consumption data is not yet available, but the occupants did notice what they reported to be “significant” reductions in heating bills. Computer modelling using Hot2000 software predicts a change in

EnerGuide rating from 54 to 80, and a total annual energy savings of almost 116,000 MJ (Figure 7).

Component	Pre-Retrofit		Post-Retrofit	
Energuide Rating	54	EnerGuide	80	EnerGuide
Total Consumption	200,639	MJ	84,934	MJ
	2,636	$	1,683	$
Natural gas consumption	4,486	m^3	1,410	m^3
Natural gas savings	-		$662.93	
Electricity consumption	9,304	kWh	9,002	kWh
Electricity savings	-		$33	
Total annual savings	-		$696	

Fig 7: Resource consumption recordings both Pre and Post Retrofit

5. Future implementation

This exterior retrofit assembly uses easily accessible materials that can be used in retrofitting much of the aging housing stock found in our larger cities. Revitalizing older homes and buildings will help to reduce energy consumption, lower energy costs and mitigate some of the environmental damage associated with demolition and new construction. When done properly, it can ensure the survival of these buildings for many future generations. Although exterior retrofits are not suitable for all applications and elevations, "Retrofitting existing buildings on the exterior is the best possible technical solution: exterior insulation provides the highest level of durability, energy efficiency, and comfort with the least technical risk" (Straube, Ueno, & Schumacher, 2011).

Various municipalities have initiated home loan programs for residential homes, offering low-interest financing for residential building energy efficiency upgrades. If affordable solutions are offered to improve existing homes, with results comparable to new builds, homeowners would be more inclined to revitalize their existing structure instead of tearing it down. Solutions like the one herein described, work towards providing the renovation market with options that not only keep occupant health and comfort in mind, but the environment as well.

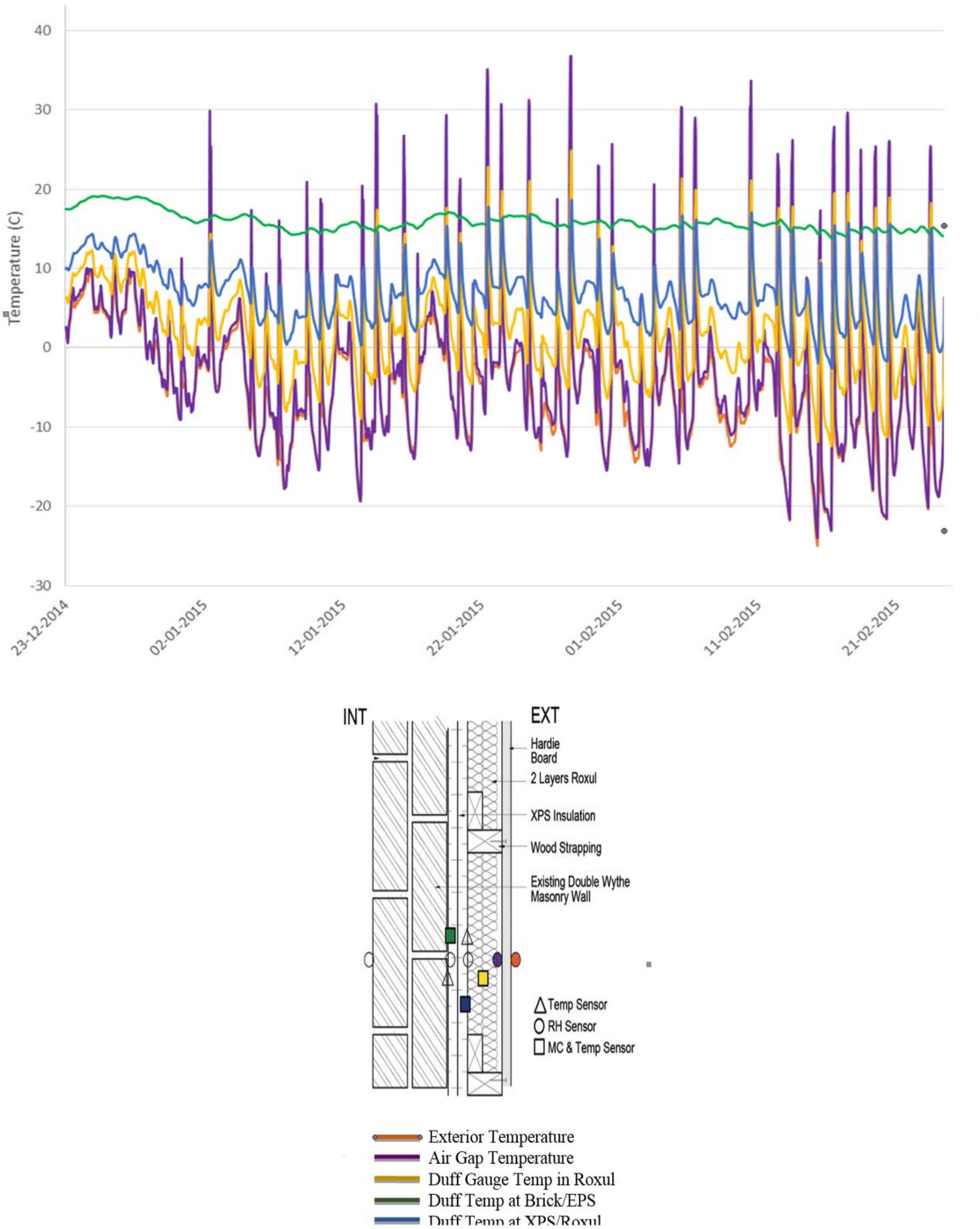

Fig 9: Plot of wall layer temperatures vs. time during cold two month winter period with legend below

6. Conclusions

Through the improvement of thermal resistance, air tightness, moisture control, and envelope durability, this retrofitted home provides savings on utilities to the homeowner, improves occupant health and comfort, and on a larger spectrum, reduces the energy consumption and environmental impact of this house.

By providing financial incentives to users through savings on utility bills and government grants, homeowners can be encouraged to fulfil a reduction in resource consumption that many countries and municipalities are being pressured to achieve. Solutions like the one described here, are just one of many affordable solutions that can help encourage people to preserve the existing housing stock in our cities without ignoring their lack of efficiency. With solutions such as these, the eventual expected result is to see an increasing trend of effective renovations of existing structures over new builds. Homeowners would be more inclined to maintain the heritage aesthetics of their older homes in place of reducing them to rubble. This is especially relevant in European cities where the era of initial construction far precedes that of North America. This method provides an example of the best technologies (materials and methods) for achieving energy efficiency within the constraints associated with vintage buildings and the cost/benefit of retrofitting vintage buildings.

7. Acknowledgments

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