THE TORONTO METHOD OF CONSTRUCTION:

RE-THINKING HOW WE INSULATE OUR HOMES

Abstract

The Toronto Method of Construction (METHOD.TO) is a practical re-imagination of residential construction. At SUSTAINABLE.TO Architecture + Building (STO), we challenged ourselves to develop a thin, super-efficient envelope that is suitable for Toronto's narrow, urban lots. An inch or two of exterior insulation has become commonplace, but the Toronto Method of building locates the majority of the insulation on the exterior of the structure with a single, continuous membrane control layer protected underneath the insulation.

This research was prompted by a dearth of information on super-efficient building envelopes using semi-permeable insulation as the primary thermal barrier. Our scientific approach began with a hypothetical design that fastens rigid rock wool insulation to a standard wood frame wall with long screws through wood strapping. A single, semi-permeable membrane on the sheathing, under the insulation, controls weather, air, and vapour.

We first tested the hypothesis by modeling variations in WUFI Pro. Exterior insulation thickness, stud cavity dimensions, and permeability of the membrane were manipulated to determine interdependencies and optimal configurations. Successful theoretical modeling prompted production of a full-scale mock-up in the form of a 2.4m x 2.4m test "shed" with 225mm (9 inches) of exterior rock wool. In-situ testing will quantify the physical, thermal, and hygrothermal mechanisms by measuring three-dimensional heat loss and moisture effects through a network of sensors. The structure currently sits at the Evergreen Brickworks where it is undergoing long-term testing by Ryerson University. This approach will quantify overall system performance as it performs in the field.

Keywords:

Toronto; rock wool; exterior insulation; rigid insulation; hygrothermal performance; energy efficiency; green building

1 Introduction

According to the International Energy Agency (IEA), buildings are responsible for about one third of all the primary energy consumed globally [1]. Furthermore, total global energy consumption is seeing a continual increase from year to year as the population continues to grow. Reducing the energy demand and thus the energy consumption of our buildings will have a significant impact on global energy use. Therefore, we must improve the efficiency of our buildings.

Over the past decade or so, the design and construction industry has begun to see the value in building 'green buildings'. Standards such as LEED, Living Building Challenge, Passive House and R2000 are pushing the envelope on building design and operation, and setting stringent targets for energy efficiency. An important component of efficient building design is a highly insulated building enclosure. Traditional wall assemblies in residential construction in Ontario and much of Canada consist of a wood frame stud wall with batt insulation between the studs. The studs cause heat to transfer more readily across the enclosure, a phenomenon known as thermal bridging, which can significantly reduce the overall thermal efficiency of the enclosure.

In order to improve the effective thermal performance of building enclosures, a preferred strategy is the use of continuous exterior insulation placed outside of the structure. Continuous exterior insulation provides various benefits when compared to insulation placed within the stud wall cavity, including:

- Reduced heat loss through thermal bridging
- Reduced risk of interstitial condensation
- Durability of structural elements

The exterior insulation must be a rigid board with sufficient compressive strength to support the cladding attachment system and cladding material beyond. Thicknesses up to 38 mm (1.5 inches) of exterior continuous insulation have been widely used in the construction industry. However, due to a lack of information available about the performance of assemblies with continuous exterior insulation, specifically those with mineral wool as the insulation material, there is a resistance from the industry to select wall assemblies with greater thickness of exterior insulation. Foam plastics such as extruded polystyrene (XPS), expanded polystyrene (EPS), and poly- isocyanurate (PIC) are used more readily as an exterior insulation product when greater thicknesses of exterior insulation are required because of their compressive strength. The compressive strength of foam ranges from about 15-25 psi, compared to about 1-5 psi for mineral wool [2]. However, several studies conducted over the last 5 years have shown that continuous exterior rigid mineral wool insulation is has sufficient compressive strength to support lightweight cladding materials (less than 5 kg (10 lb) per fastener) using wood strapping and long screws [3] [4] [5] [6]. Testing has been conducted for insulation thicknesses of up to 200 mm (8 inches). Further research is needed to determine the maximum thickness of rigid mineral wool that can support lightweight claddings.

Mineral wool insulation offers many benefits as an exterior insulating material when compare to foam-based products. Mineral wool, specifically rock wool, is made from waste slag from the steel industry and locally sourced quarry stone. The material does not burn and therefore has great fire-resistance properties. Rock wool insulation is also resistant to moisture, dries quickly, and is inert and therefore will not facilitate the growth of mold and mildew. However, the performance of mineral wool is less well understood than foam plastics as an exterior rigid insulation material, and the products practical limitations are to a large degree unknown.

Research was required for the METHOD.TO building enclosure system design due to a lack of information regarding the performance of mineral wool assemblies using thick layers of continuous exterior insulation. Figure 1 shows a comparison of METHOD.TO and a traditional Ontario residential wall. METHOD.TO employs 225 mm (9 inches) of rigid rock wool insulation outboard of a 38 mm by 89 mm wood frame wall. On the exterior of the sheathing, one single membrane that controls air, weather, and vapour is protected by the thick insulation later. Outboard of the insulation, 19 mm x 63 mm wood strapping is attached using long 300 mm steel screws that are screwed through the insulation into the wood stud backup wall. For the purposes of this investigation, 89 mm of rock wool batt insulation was placed into the wood stud cavity prior to installing the drywall.

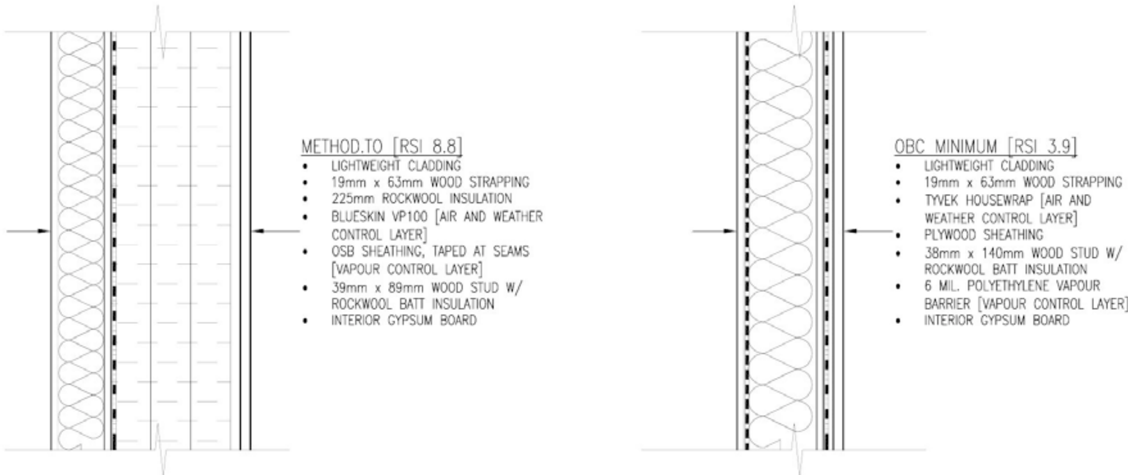

Fig.1. METHOD.TO Construction versus Standard Practice Ontario Code Minimum Construction.

The purpose of this research is to determine the effective performance of the METHOD.TO assembly by evaluating the system in several ways. First, a test structure was built utilizing the METHOD.TO construction method. This will be used to evaluate the in-situ performance of the enclosure using field measurements. Second, laboratory testing will be performed to evaluate the performance of the enclosure in a controlled environment against the performance of traditional Ontario code-minimum residential construction. Finally, the field and laboratory data will be used to calibrate a hygrothermal model in WUFI Pro. The calibrated model will be used to run a parametric investigation to determine the thresholds at which the wall assembly fails for particular external and internal hygrothermal loads.

The outcome of this research will determine the effective clear wall RSI value of the enclosure and determine the durability of the wall enclosure under varied hygrothermal stress conditions. This will determine the appropriateness for this wall under different thermal and hygrothermal loading situations.

2 methodology

In-Situ Testing

Data will be collected from the in-situ field testing over 5 months, from February to June, 2016, using a total of 54 sensors. The sensors, including temperature, relative humidity, and moisture content, have been placed at 12 locations in the field test structure. See Figure 2 for sensor placement. The data from the sensors will be used to drive the interior conditions in a WUFI Pro simulation and to calibrate the final model for parametric investigation of the METHOD.TO assembly.

Fig. 2. Sensor Installation; Fig. 3. Test Shed at Evergreen Brickworks with Weather Station.

Heat flux sensors have been placed on the north and south façade to evaluate the effective in-situ clear wall RSI value following the ASTM C1046 Standard (In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components). The heat flux sensors have been placed on the north and south facade to evaluate the in-situ clear wall effective RSI value. Heat flux (*q*) is measured across the envelope and using the temperature difference (ΔT) across the assembly, the effective RSI value is determined using the formula:

(1)

Indoor climate conditions have been set as 21° C and 50% relative humidity using an automated space heater and automated humidifier. Exterior climate conditions are monitored using a weather station placed atop the test structured. Exterior climate data collected includes;

- Air Temperature
- Relative Humidity
- Solar Radiation
- Wind Speed
- Wind Direction
- Rain accumulation

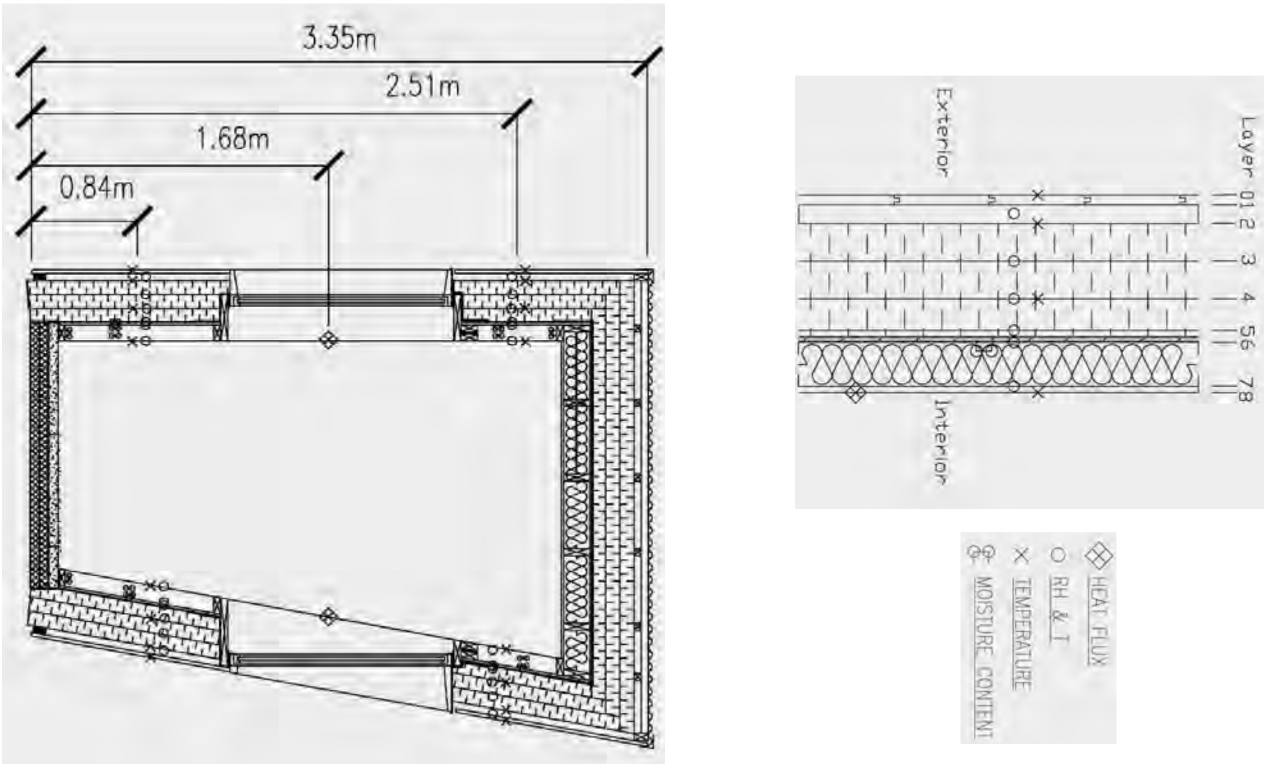

Fig. 4. Sensor Type and Placement Location in the Test Structure.

Laboratory Testing

Laboratory testing will be used to confirm and further thermal and hygrothermal results found during in-situ field testing. The experimental METHOD.TO wall and a standard to code built wall will be built within a climate simulator for testing and monitoring. The climate simulator is a large chamber in which interior and exterior climate conditions can be closely controlled. Data collection will be similar to the in-situ field collection in terms of sensor placement and type. Two testing conditions will occur and include:

i. Cold – Wetting Period (Inside: 21° C , 50%RH, Outside: -10°C, 75%RH)

ii. Warm – Drying Period (Inside: 21°C, 50% RH, Outside: 25°, 80% RH)

The data collected will be used to calibrate another WUFI file and to confirm the accuracy of the field test WUFI simulation.

The clear wall effective RSI-value of METHOD TO will also be measured during these testing conditions. To ensure testing accuracy the conductivity of the insulation used in the laboratory testing will be confirmed using a heat flux apparatus, following ASTM C518: Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. The effective RSI value of the wall will be further investigated by assessing the effect of the metal screw fasteners in the whole wall thermal performance using Heat3 computer simulation software.

Computer Modeling

Once the interior and exterior climate data files are entered into WUFI Pro the output values for the model will be compared against field and laboratory collected data. Input variables will be modified in the WUFI Pro model until there is close agreement between the datasets. This will be analyzed using Matlab and statistical analysis.

Using the calibrated WUFI file, hygrothermal parametric analysis will be performed by varying select loading conditions and applying them to the wall enclosure. Several conditions that will be explored are;

i. Changes in Environment and Climate (i.e. changing geographical location of the wall)

ii. Defects in Construction (i.e. Air leaks, built in moisture, etc.)

iii. Changes in Construction (i.e. Changes in interior and exterior control layers, changes in insulation amounts)

3 PRELIMINARY results

In-Situ Testing

The nominal RSI value of the METHOD.TO assembly with 225 mm (9 inches) of exterior rigid rock wool insulation and 89 mm (3.5 inches) of rock wool batt insulation is RSI 8.8 m^2•K/W (R-59.6 h•ft^2•°F/Btu). Preliminary field test results of the heat flux across the enclosure were used to evaluate the effective clear wall RSI value of the wall assembly in-situ. Figure 5 shows the preliminary results based on the heat flux and temperate difference field measurements taken between February 12 and April 22, 2016.

Fig. 5: In-Situ Effective Clear Wall RSI Value on the North (Loc1) and South (Loc2) Facades.

Based on these results, the wall assembly on the North facade (Loc1) has an effective RSI of 10.5 m^2•K/W on average. This represents a RSI 1.7 m^2•K/W (19%) improvement from the expected nominal RSI value of 8.8 m^2•K/W. The effective RSI value on the South facade (Loc2) is on average 7 m^2•K/W. This represents a RSI 1.8 m^2•K/W (20%) reduction from the expected nominal RSI value of 8.8 m^2•K/W. Data collection is ongoing and a full analysis of the data will be performed once testing is complete in June, 2016. It is hypothesized that the trend will remain constant over the next few months based on preliminary results. Further research will be conducted to identify possible causes of the decrease in RSI on the South facade from what is expected.

Further work

The remaining research and analysis outlined in the methodology section of this paper will be performed over the next four months into August of 2016. This work includes laboratory testing of the mineral wool insulation material and the METHOD.TO assembly in a controlled setting. Also, the WUFI Pro model of the wall enclosure will be calibrated using field and laboratory test data. The WUFI Pro Model will be used to perform a parametric analysis of the wall enclosure under several different loading conditions (i.e. different lactations, and different interior loadings) and the results will be used to indicate failure thresholds of the METHOD.TO system.

4 CASE STUDY

A variation of the METHOD.TO building enclosure is being used to construct a single family home in North York, Toronto, Ontario as part of an overall sustainable building design strategy. The wall assembly employs 150 mm (6 inches) of the exterior rigid rock wool insulation rather than the 225 mm (9 inches) in METHOD.TO. The building structure is a 39 mm x 140 mm (2 x 6) wood frame with 89 mm of rock wool batt inter-stud insulation. The remaining 50mm (2 inches) of space in the interior of the stud cavity can be used to run services without compromising the thermal insulation. As with METHOD.TO, one single membrane on the exterior of the sheathing controls air, weather and vapour. Figure 6 shows a section of the wall assembly as constructed. Whole building simulation was conducted in REM/Rate software to determine the expected energy performance of the home.

Fig. 6: Wall Assembly Construction for the North York Case Study.

Results show that the expected heating energy consumption of the building, using an air tightness value of 1.6 air changes per house (ACH), is 8,323 kWh. With a conditioned area of 358m^2, the expected space heating Energy Use Intensity (EUI) is 23.2 kWh/m^{2}a, with a heating load of 15.6 W/m^2. The energy model results show that the home is relatively close to achieving the Passive House requirements for heating, which set a space heating load maximum of 15 kWh/m^{2}a and a maximum heating load of 10 W/m^2. The overall site energy EUI is expected to be 71 kWh/m^{2}a, or a 75% reduction in energy use from a typical Ontario home. Air tightness testing will be performed on the house once the air barrier is complete at the end of May 2016, and again once the construction of the home is complete. The results will be input into a final energy model depicting the expected energy performance of the home. These results will be compared with energy usage data after one year of occupancy.

5 DISCUSSION

The Toronto Method of Construction (METHOD.TO) is undergoing continuous investigation to assess the performance and limitations of exterior-insulated assemblies using rock wool insulation, to validate this method for widespread uptake in cold climates such as Toronto. Over the next four months leading up to the SBE2016, in-situ and laboratory testing as well as computer simulation modeling will be performed and analyzed and the results will be presented at the conference. The results of the air tightness testing on the North York home will be integrated into a full as-built energy model of the home to determine the expected and validated energy performance of the home as constructed. Over the following year, the energy use of the home will be monitored to find the actual energy use intensity. This case study will be used to drive the marketing of METHOD.TO as a viable building envelope construction method to be used in residential construction in Ontario. As energy rates continue to increase over the coming years, investing in green building practices such as higher RSI value, exterior insulated building enclosures will only become more viable. As well, designing and constructing more environmentally sensitive and energy efficient buildings will not only serve to improve the durability, health and comfort of our building, but also to reduce the cost of operating these buildings over their lifetime.

6 References

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