CONDENSATION IN WALL ASSEMBLIES: MAINTAINING LOW LEVELS OF RISK THROUGH NON-TRADITIONAL INSULATION PACKAGES

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ABSTRACT

In 2016, we published the findings of a study involving hygrothermal simulations for exterior wall assemblies. Different levels of permeance were used for water resistive barrier (WRB) materials used in these assemblies. The study concluded that WRB permeance had less impact on the drying performance of the wall assemblies than other parameters such as type of cladding and the use of continuous insulation, but also that increasing WRB permeance above 20 US Perm can increase the risk of moisture-related problems in the assemblies.

As a follow-up to this study, additional simulations have been performed in different types of exterior wall assemblies in order to evaluate higher risk scenarios. Again, simulations were performed for cities in climate zones 4C, 5, 6, and 7. Assemblies commonly seen in Canada for non-residential construction were evaluated for moisture content and risk of biological growth. Non-traditional wall assemblies were also subjected to the same evaluation to determine their potential of success in the market.

In the current study, the impact of continuous insulation (its presence and its level of vapour permeance) was addressed specifically, considering the recent or imminent adoption of the 2015 NECB in various regions of Canada. When coupled with experimental testing under ASTM C1363 standard, simulations allowed the determination of assemblies with optimal thermal efficiency and moisture management.

Interestingly, some non-traditional wall assemblies using a combination of two or more different technologies for the thermal control layer (rigid polyisocyanurate continuous exterior insulation coupled with a dual-composition cavity insulation mixture) have shown promising performance levels.

BACKGROUND

In a previous study (Côté, 2016), we were able to demonstrate that the use of continuous insulation in exterior wall assemblies had significant impact on moisture management and drying/wetting potential of these assemblies. Claddings that could provide conditions for inward vapour drive were also identified as major contributors, in a more important fashion than the permeance level of the water resistive barrier (WRB) or permeable air barrier. In fact, evidence was made that increasing WRB permeance above 20 US Perm can increase the risk of moisture-related problems in the assemblies.

This previous study covered assemblies with R-19 batt insulation in the stud cavity, with and without continuous insulation (CI). When CI was used, vapour-permeable and vapour-impermeable insulation materials were evaluated at levels of R-6.5 and R-18. Many of these assemblies would not be compliant with the thermal performance requirements for one or more of the Canadian climate zones. Consequently, the present study was undertaken to predict the required amount of insulation (both cavity and CI) in climate zones 4 to 8 for specific wall assemblies. These assemblies were then verified for moisture management based on hygrothermal simulations.

THERMAL SIMULATIONS

Description of the Assemblies

In the current study, a total of 14 types of exterior wall assemblies were modeled for thermal performance by Morrison Hershfield following the same guidelines and principles that led to the BETB Guide (BC Hydro, 2016). Steel-stud assemblies (2"X6" dimension, 16" o.c. spacing) will be presented here as they represent the worst case scenario in terms of thermal efficiency. In order to evaluate the influence of the method for cladding attachment to the overall performance of the assembly, three types of cladding attachment were evaluated: standard vertical z-girts (poor), vertical aluminum rails and thermally insulated clips at 24" o.c. vertical spacing (good), and standard face mounted steel brick ties (better).

A conventional cavity insulation solution, R-20 fiberglass batt insulation, was also compared to a slightly lower performing solution provided by a single 50-mm pass of spray polyurethane foam (SPF, R-13), and to a more performing, innovative combination of materials very similar to the one referred to as "Hybrid Wall 3" (Grin and Lstiburek, 2014), realized with a single 50-mm pass of SPF and filling the remainder of the cavity with blown cellulose insulation (R-25). This combination was chosen as Grin and Lstiburek depicted it as "… the optimal in terms of cost, thermal, hygrothermal, and structural analysis".

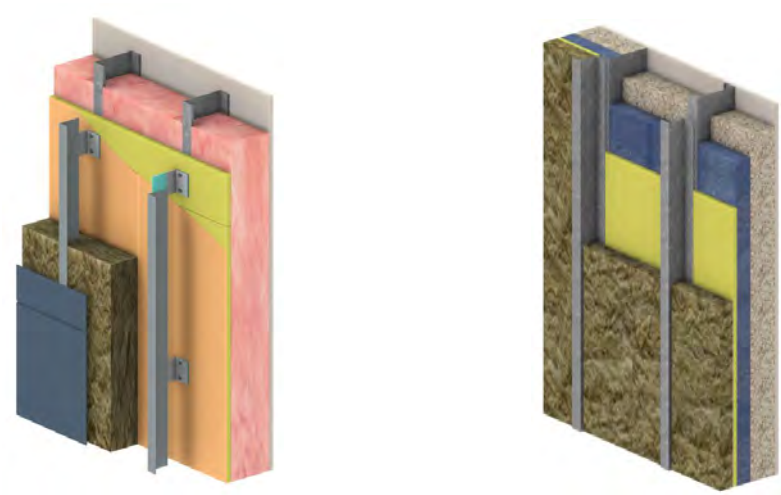

Figure 1: Sample drawings for split-insulated assemblies using vertical aluminum rails and thermally insulated clips (left) and an innovative combination of SPF and cellulose cavity insulation (right).

Combinations evaluated are described in more detail in Table 1 below. The overall thermal performance

of each type of assembly was determined by considering all structural components, cavity insulation and air films. The amount (thickness) of CI required on the exterior side of each assembly was then calculated from the difference with the prescriptive U-Value requirements found in the National Energy Code for Buildings (NRCC, 2015) for each climate zone.

Thermal Modeling Results

Table 1 summarizes the composition of the tested assemblies along with the required CI contribution for climate zones 4 to 8.

Table 1: Assemblies subjected to thermal modeling in the current study

Assembly	**A**	**B1**	**B2**	**B3**	**C**
Cavity Insulation	50-mm SPF (R-13)	Fiberglass batt (R-20)	Fiberglass batt (R-20)	Fiberglass batt (R-20)	50-mm SPF + 100-mm cellulose (R-25)
Cladding Attachment	Vertical z-girts (16" o.c.)	Vertical z-girts (16" o.c.)	Insulated clips & vertical rails	Face-mounted steel brick ties	Vertical z-girts (16" o.c.)
Required CI for climate zones 4 to 8	All zones > R-30	Z4: R-22 Other zones > R-30	Z4: R-8.4 Z5: R-12.5 Z6: R-17.4 Z7: R-25.9 Z8: > R-30	Z4: R-7.1 Z5: R-10.7 Z6: R-14.7 Z7: R-21.2 Z8: R-27.8	Z4: R-18.6 Other zones > R-30

From the results obtained with these steel-stud assemblies, it is noticeable that assemblies A, B1 and C are largely penalized by their cladding attachment, regardless of the amount of cavity insulation present. Large amounts of CI are required to compensate and meet minimum code requirements. If any type of foam plastic is used as CI, its thickness would be such that it would be vapour-impermeable. If a vapour-permeable WRB was used, its permeance level would not provide any benefit. Consequently, more risks of moisture-related damage are present in these. Nevertheless, type C is, as expected, the best performing of the three, with a 15% reduction in required R-value for CI. It is however less performing than the B series of assemblies as the cladding attachment method represents a big thermal penalty.

Between B1, B2, and B3, all insulated with fiberglass in cavity, the improvement of thermal performance is directly linked to the reduction of thermal bridges in the cladding attachment. Moving away from the z-girts brings a significant reduction of required CI (more than 50% in Zone 4), then around 15% additional reduction is brought by replacing the rails and clips by brick ties. Cladding attachment has therefore much more impact on the global thermal performance of the assemblies than the amount of cavity insulation.

Furthermore, assuming that the CI is the lowest permeance material of the assembly (therefore that CI will dictate the wetting and drying behaviour of the assembly), Figure 2 shows the steady-state yearly evolution of the moisture content of the sheathing behind CI for the B3 assembly. Relative humidity

never reaches above 90% in both scenarios, along with low moisture content of exterior sheathing, confirming a low risk of moisture accumulation. We also note that, although these simulations are realized in two different climate zones, the presence of an appropriate amount of CI maintains temperature at the exterior side of batt insulation approximately at the same level in both scenarios.

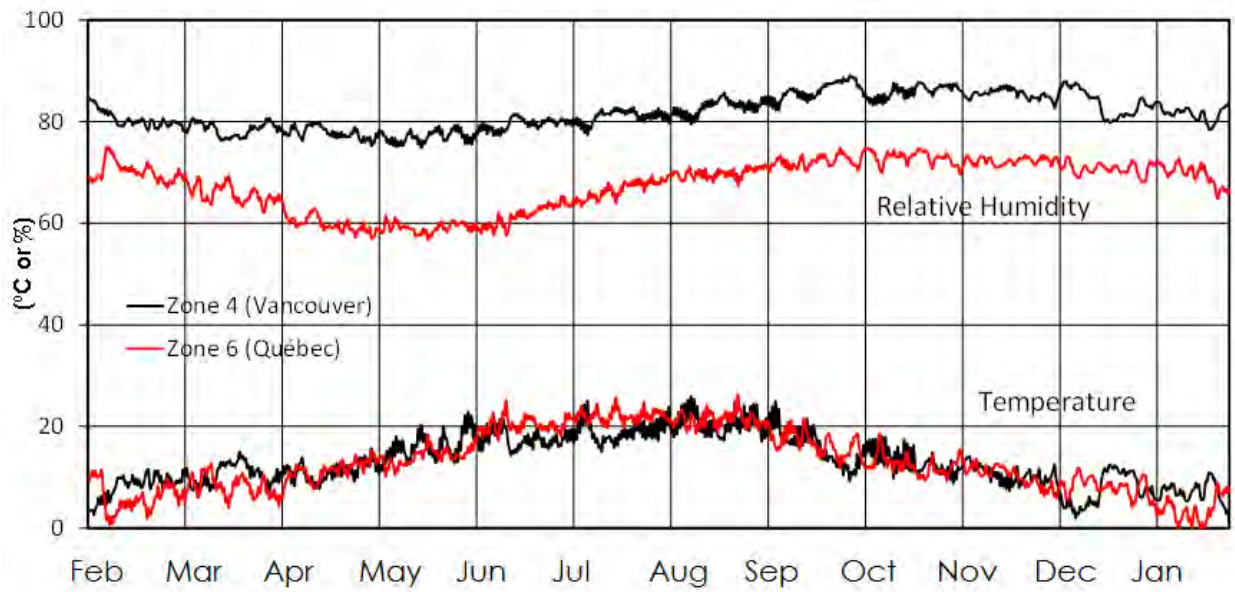

Figure 2: Yearly evolution of temperature and relative humidity at the exterior side of batt insulation in assembly B3.

If the hybrid assembly C was constructed with a cladding attachment having a better thermal performance, such as a system with only discrete contact points (brick ties), it would only require 25 mm of polyisocyanurate insulation to meet the requirements of NECB as the required R-Value would drop below R-6.

CONCLUSION

Innovative (hybrid) split-insulated wall assemblies have shown to provide improvements in thermal performance. However, the impact of the use of a combination of cellulose and SPF in the cavity with polyisocyanurate as CI cannot compensate for the use of a poor performing cladding attachment method (caused by major levels of thermal bridging). Moisture management in such systems can easily be managed as long as the understanding of the dynamics of wetting and drying of these assemblies (through all materials of these assemblies – not only the air barrier or water resistive barrier) is taken into consideration.

REFERENCES

Côté J.-F. 2016. *Condensation in Wall Assemblies: Can Vapor Diffusion Through Highly Permeable Air Barriers Increase the Risk?* RCI Inc. 31st International Convention & Trade Show.

BC Hydro. 2016. *Building Envelope Thermal Bridging Guide, Version 1.1*. Available online at

http://www.bchydro.com/construction.

Grin A. and Lstiburek J. 2014. *Structural and Hygrothermal Analysis of Hybrid Wall Systems*, Proceedings of the 14th Canadian Conference on Building Science and Technology, pp. 267-275.