7 May 2014

Team Montreal SD Envelope Team- Research Summary

Envelope Team Co-Representatives

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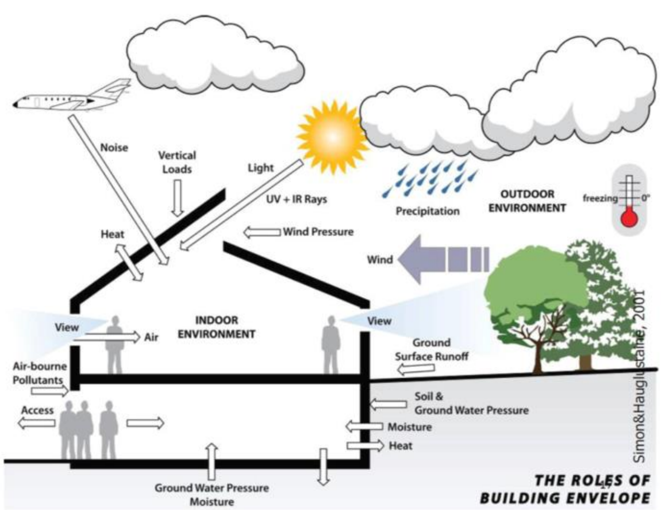
1.0 Introduction

N.B. Hutcheon states that the exterior walls and roof of a building protects the occupants from the following:

1. Cold
2. Heat
3. Rain Penetration
4. Solar Radiation
5. Outside Noise
6. Pollution
7. Smoke
8. Fire-spreading

The envelope must also be:

9. Structurally sound
10. Durable
11. Aesthetically pleasing
12. economical



The goal of this report is not to give detailed information about different envelope materials, but to address the important considerations and process for designing a high performing envelope. Once these considerations are made aware, material selection and analysis will be much easier.

This report highlights the common components of an envelope, work completed so far (Holcim application and alternative designs), software available for envelope analysis and future work to be completed.

2.0 Technical Background

2.2 Components & Considerations

The most important principle for energy efficient construction is a continuous insulating envelope all around the building (yellow thick line), which minimises heat losses. In addition to the insulating envelope there should also be an airtight layer (red line) as most insulation materials are not airtight.

Preventing thermal bridges (circles) is essential – here an individual planning method has to be developed, according to the construction and used materials, in order to achieve thermal bridge free design. Independently of the construction, materials or building technology, one rule is always applicable: both insulation and airtight layers need to be continuous.

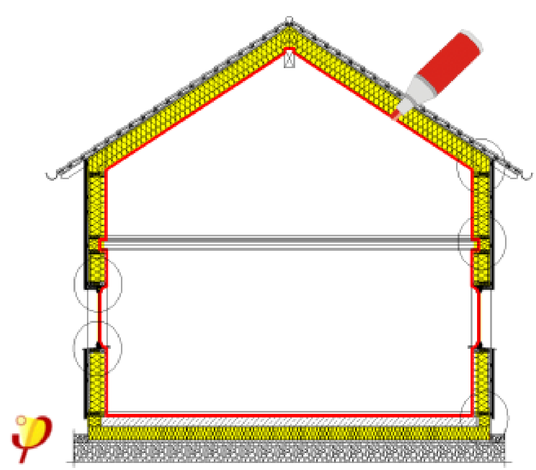


Figure 1: Continuous Thermal & Air Barriers

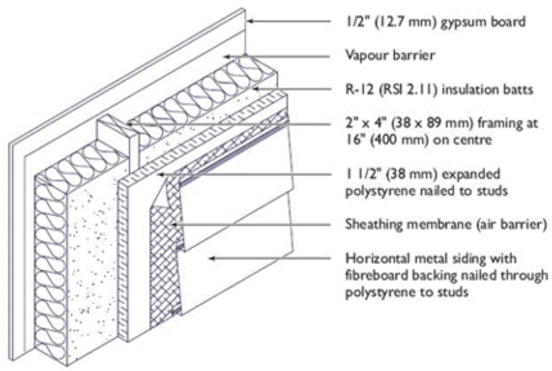


Figure 2: Typical Wall Section

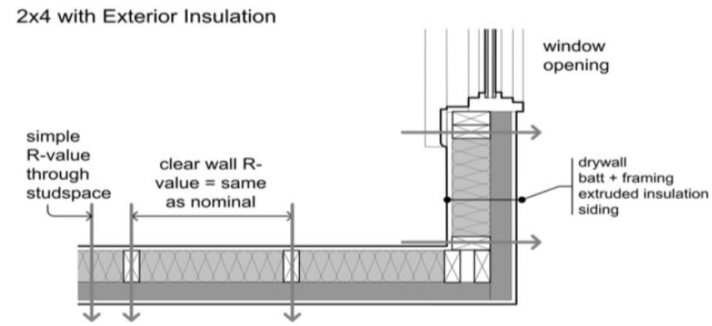


Figure 3: Thermal Bridging

The following is a list of components that make up the envelope of a building that we will need to research, design, or analyse:

1. **Insulation**
 The Thermal Barrier should be continuous throughout the entire envelope. There are many materials suitable for insulation of a building.
2. **Vapor Barrier – The Moisture Barrier**
Rule of thumb: located on the warm side of the insulation layer. The vapor barrier is very import and its location within the section needs to be designed mindfully so as to avoid condensation within the wall.
3. **Air Barrier**
Air Barrier needs to be continuous. Location within section isn't as important.
4. **Weather Barrier (rain penetration)**
Stop the penetration of rain etc. Into the building
5. **Windows**
What type of window (double glaze vs triple glaze)? What type of gas (air, krypton, argon)? What should the window-to-wall ratio be on each wall (north, south, east, and west)?
6. **Doors**
Choose an efficient and affordable door
7. **Skylights**
Will our design incorporate skylights of light tubes?
8. **Modularity for transport in shipping containers**
The house needs to be modular to easily build and deconstruct for cross continental shipping in standard size shipping containers.
9. **Thermal Comfort**
Occupants of the home should be comfortable in the indoor environment (Air temperature stratification, drafts, radiant temperature asymmetry, humidity)
10. **Shading**
Shading design for optimal sun energy capture and utilization for daylighting and heating.
11. **Thermal Bridging effects**
Thermal bridging effects need to be minimized as much as possible

3.0 Work Completed

3.1 Holcim Award Application

The design teams have been working on an application for the Holcim Awards which is due on March 31, 2014. We have proposed a "row house" design for urban Montreal with an envelope of minimum R50 wall and roof insulation. For the envelope the design team decided to use natural, VOC free materials such as cellulose. Minimizing thermal bridging in the envelope will be the greatest challenge, as well as proper design for moisture transport without resulting in condensation. Wall and roof sections have been proposed for the Holcim award, but no details regarding joint design or wall/roof and wall/foundation connections have been investigated. Also, windows and doors need to be investigated. The design decided for the Holcim application is not necessarily the design we will carry forward for the final design of our Solar Decathlon House. As we move forward from Holcim, there is lots of room for changes and improvements to the floor plan, envelope design and location of the house.

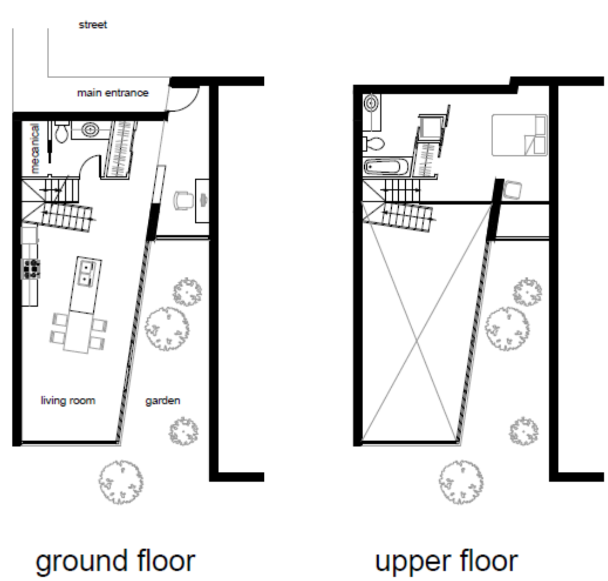


Figure 4: Floor Plan - Holcim Award Application

In order to obtain R50 in the wall with natural materials, the wall needs to be a minimum thickness of 40cm and be double 2x6 stud (can be staggered stud). The wall section contains the following insulation materials:

- Wood fibre insulation (60mm thick)
- Cellulose Insulation (140mm thick)
- Rockwool insulation (140mm thick)

Wall

Layer (outer to inner)	t (mm)	thermal conductivity (W/mK)	Thermal Resistance (m2K/W)
exterior film			0.03
Cladding w sheathing	12.70		0.11
Airgap	19.00	0.280	0.18
Air barrier			0.00
Wood Fibre insulation	60.00	0.038	1.58
MDF board	12.70	0.070	0.18
wood frame (for cellulose)	140.00	0.120	1.17
Celulose Insulation	140.00	0.036	3.88
OSB	12.70		0.12
wood frame (for rock wool)	140.00	0.120	1.17
Rockwool Insulation	140.00		4.00
gypsum	12.70	0.160	0.08
interior film			0.12
TOTAL THICKNESS	397.10		
		R_{stud}	4.73
		R_{ins}	10.28
		R_{total}	**9.17**
		U	0.11
		R-Value =	52.07204608

Figure 5: Holcim Envelope Layers

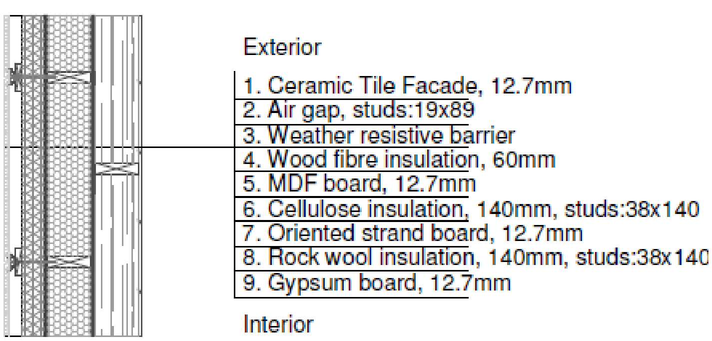


Figure 6: Holcim Envelope Section

The thickness of insulation required to reduce energy consumption results in a steep temperature gradient, across the wall section, and requires control of thermal bridging, moisture and air movement to avoid condensation and mould growth.

The underlying concept of this envelope design is to have a "breathable" construction. Instead of having one layer, such as polyethylene, as the vapour barrier, the idea is to choose a layer which acts as a vapour check near the inside face, and increase the vapour transmission step by step [to about a factor of 5] by introducing other insulation materials progressively in layers toward the outside. Breathable construction does not mean promoting air flow. Breathable construction is a vapour open construction which allows water in the form of humid vapour to defuse from high saturation into lower saturation without hitting the dew point.

3.2 Issues with Holcim Design

This design results to a very thick wall section, which may be inappropriate considering the overall dimensions. The useful area loss form the original design with an average 30cm thick wall is about 8.5m2.

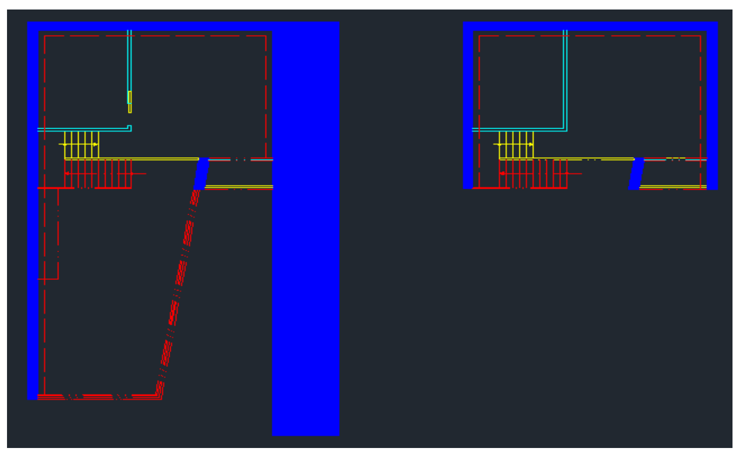


Figure 7: Holcim floor plan with 40cm thick walls

The dashed line represents the inside border of the chosen wall section.

A couple of things to be taken into account for possible redesign:

1. A thick wall section for the northern part might not influence the interior as much as the side walls, which may create a narrow interior.

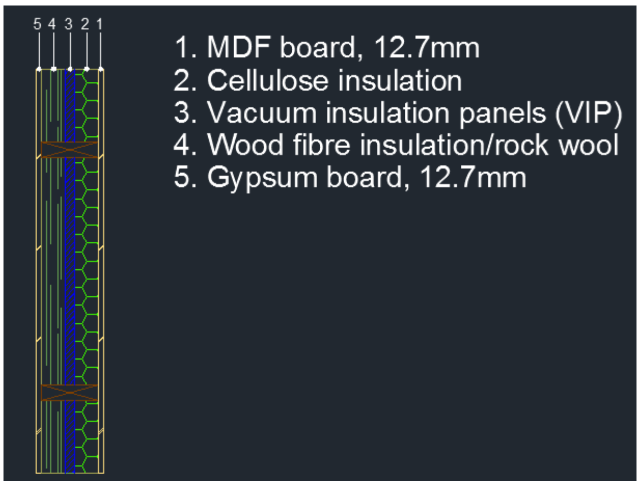
2. If there are adjacent buildings on the sides, the thermal performance of the wall required might be less than R-50.

However, issues of noise reduction should be taken into consideration.

3. Consideration of other possible high performance materials, such as Vacuum Insulation Panels (VIP).

3.3 Holcim Redesign with VIPs

VIPs could be used in combination with the initial materials, providing wall section solutions with reduced thickness, meanwhile achieving high thermal performance. One possible solution with the use of VIPs is the embedment of the panels within the framing:



For this case, conventional 2x6 framing is used, with the insulation materials being set among an MDF and a gypsum board. There is use of conventional 610mm spacing between the studs and the VIP is protected within the wall assembly and it may work as vapor barrier between the adjacent buildings.

On the downside, the framing dimensions are predetermined, and VIP will not be able to fit at places where additional bearing elements are needed.

There are of course other possible design options for use of VIP, not necessarily within the framing, but may produce thicker wall sections.

A more detailed thermal analysis should be completed, as well as an economic one, for this case, as VIP performs very well and should be taken into consideration.

3.4 Other General Ideas

Shipping Containers

3D Printing

4 Software & Calculations

We will be using several simulation software to better analyse our design options. Here is a list of standard programs commonly used in research and industry:

THERM

THERM is a computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators etc. A two dimensional model can be made to study the heat-transfer effects in building components. The two-dimensional conduction heat-transfer analysis is based on the finite-difference method, which can model the complicated geometries of building products. We will be using THERM to study window/wall connections, roof/wall connections and anywhere else where thermal bridging may be an issue.

THERM can be downloaded for free at: **http://windows.lbl.gov/software/therm/therm.html**

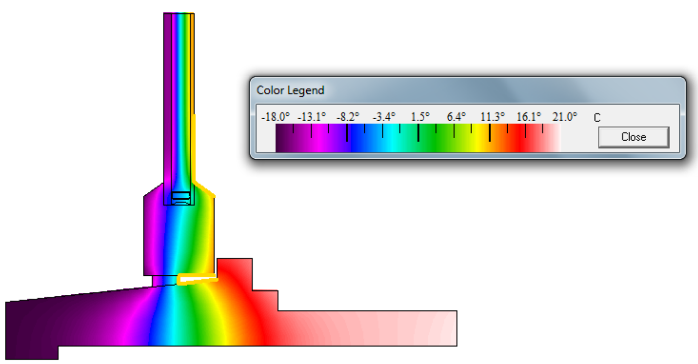


Figure 8: Example of Analysis of Window Assembly in THERM

WINDOW

WINDOW allows for the analysis of products made from any combination of glazing layers, gas layers, frames, spacers, and dividers under any environmental conditions and at any tilt.

WINDOW can be downloaded for free at: **http://windows.lbl.gov/software/window/window.html**

WUFI Pro

WUFI Pro is a software program which allows realistic calculations of the transient coupled one- and two-dimensional heat and moisture transport in multi-layer building components exposed to natural weather. It is based on the newest findings regarding vapour diffusion and liquid transport in building materials and has been validated by detailed comparison with measurements obtained in the laboratory and outdoor testing field.

WUFI Pro is not free but can be accessed in a few computer laboratories at Concordia University.

EXCEL

Excel (or similar) can be used to calculate effective R-Value of walls and roofs. It can also be used to carry out the Glaser Method as a condensation check in the walls and roofs. Excel condensation checks can be compared with more detailed simulations using WUFI Pro. For more information regarding the Glaser Method refer to ASHRAE Handbook of Fundamentals 2009.

AutoCAD

AutoCAD will be used to draw building cross sections such as:

1. Section through whole building envelope
2. Junction between wall and floor
3. Junction between window sill and wall
4. Junction between wall and roof

AutoCAD is free for three years for students: **http://www.autodesk.com/education/free-software**

5 Future Work

We have the tools in place to perform detailed analysis on different envelope options. The next steps will be to do more detailed research on different materials (windows, insulation, vapor barrier etc), decide on a few wall section concepts and perform detailed analyses of highly efficient envelopes. Working closely with the architecture and structural team we plan to develop solid envelope options for the Montreal SD team.