Designing and Testing for Airtight Construction:

Simplified details and mid construction testing are the keys to success

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OUTLINE

A. Defining envelope commissioning
   Why it's important

B. Brief History of Energy Saving Design
   Why we need to be careful as we tighten up buildings

C. Our experience in building tight envelopes
   One proven envelope design that is easy to test and fix

D. Testing techniques in conjunction with blower door

E. Air tightness measuring methods and targets
   Design and specifications that are likely to succeed in meeting your goals target

F. Importance of acknowledging the construction sequence and other realities

G. Summary

Commissioning: Ensuring that what was intended (and paid for) is actually installed and performing

Envelope commissioning: primary focus is on reducing air leaks, but water migration, moisture migration, condensation and mold avoidance are also involved. Hopefully, some education of the owner is also involved.

At our 25 person firm, we do all sorts of projects – large, small, wood and steel. Many of the achievements and our understanding of how envelopes work come from the smaller projects. The principals apply to all sizes.

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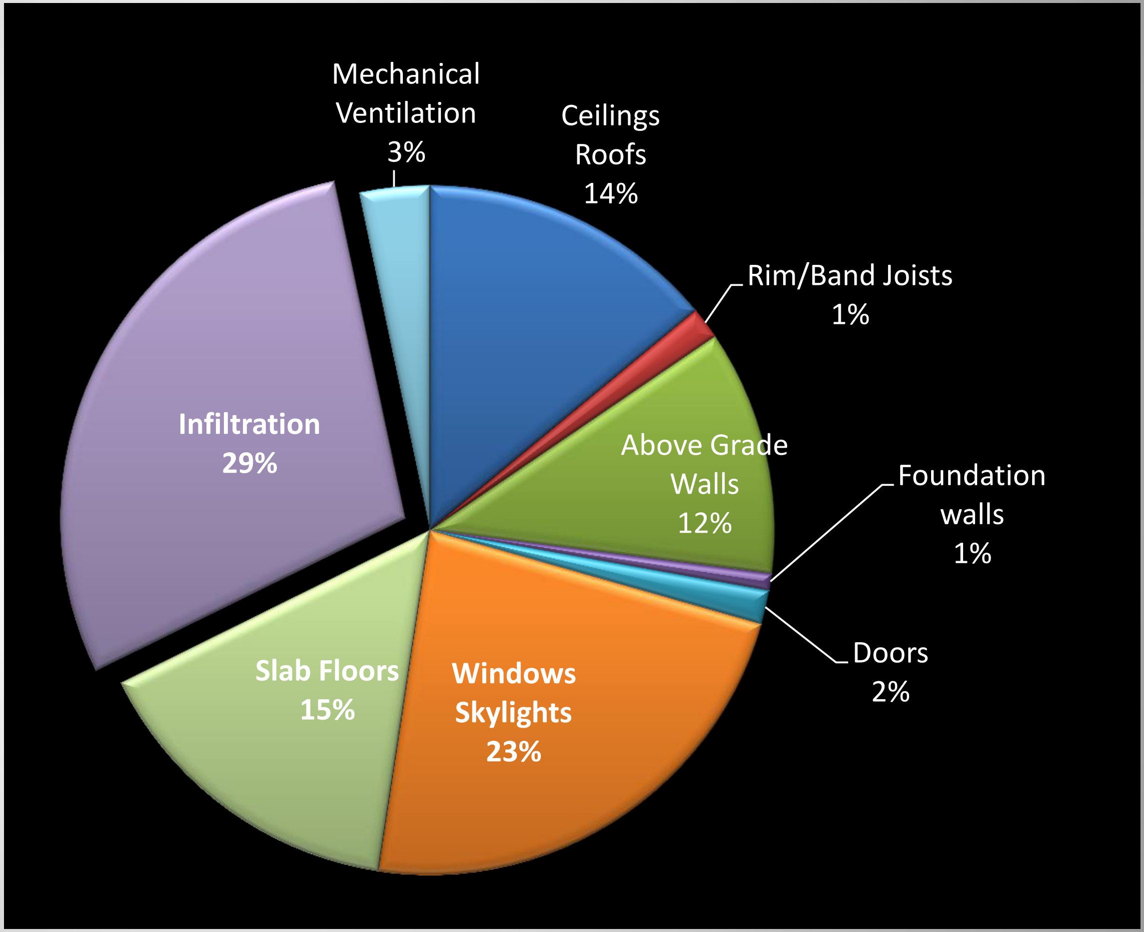
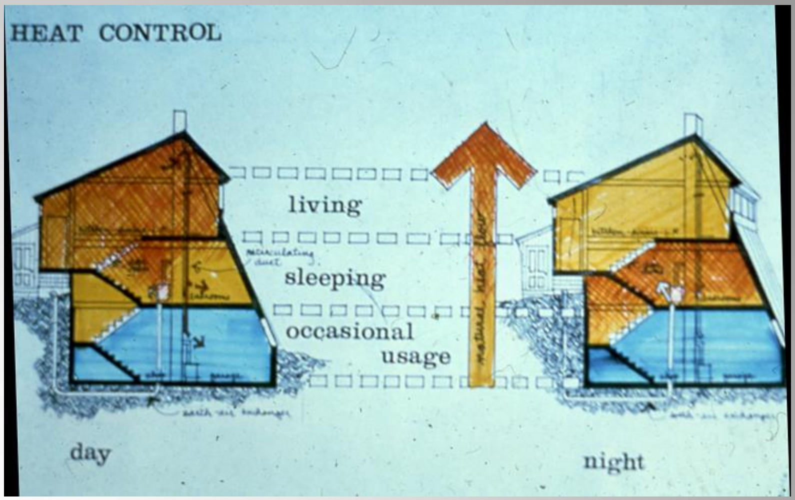
AIR LEAKAGE:
A SIGNIFICANT COMPONENT OF HEAT

Heating Season	MMBtu/yr	% of total
Ceilings/Roofs	10.5	14
Rim/Band Joists	1.1	1.5
Above Grade Walls	8.6	11.5
Foundation walls	0.6	0.8
Doors	1.2	1.6
Windows/Skylights	17.2	23
Frame Floors	0	0
Crawl Space/Unht Bsmt	0	0
Slab Floors	11.5	15.3
Infiltration	22.1	29
Mechanical Ventilation	2.9	3.3
Ducts	0	0
Active Solar	0	0
Sunspace	0	0
Internal Gains	-16.3	0
Total	59.4	100
	+ 16.3	
	75.6	



Air infiltration is the low hanging fruit.
Airtightness is achievable.

THE 1970's BROUGHT FOCUS ON USING RENEWABLE ENERGY, NOT ON SAVING ENERGY



ACTIVE SOLAR!

- Green lumber
- 2x6 framing, fiberglass insulation
- No insulation around the foundation or under slab
- Full 8" of insulation between framing in roof

Cardboard Model

Green Lumber Framing

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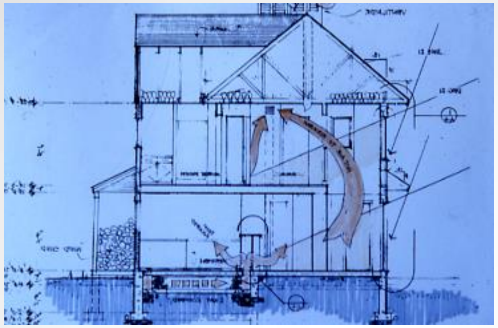
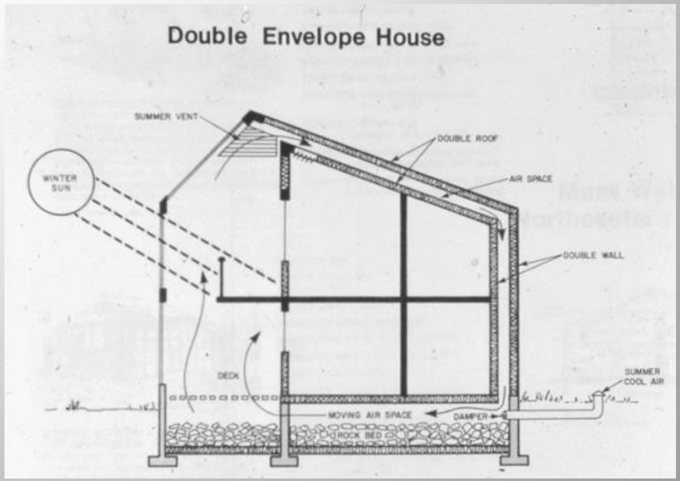
THINGS WENT THROUGH A COMPLICATED PHASE

- The double envelope house
- Passive venting through heat sinks
- Trombe walls



Rock Storage



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THE SUPER INSULATED RANCH THAT "POPPED OUR BUBBLE"

Gene Leger House
Pepperell, MA (1976)

- Thick walls, tight
- Approx. $38/year to heat

WHICH HOUSE WAS AHEAD OF IT'S TIME?

The greatest advancements in understanding how buildings perform has been in the envelope and in reducing heat loss, not in renewable energy and technological advances

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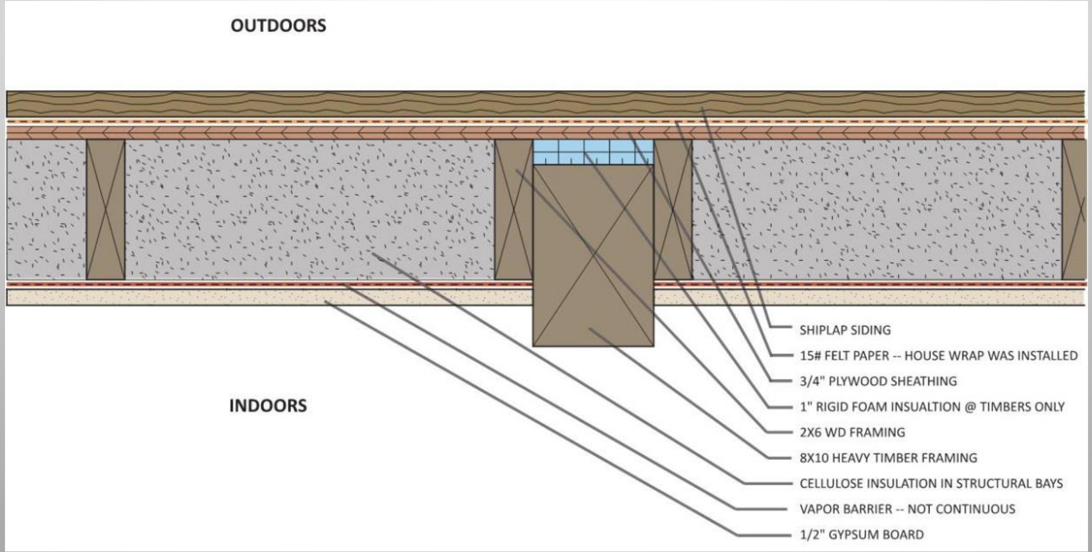
AVOIDING MOISTURE PROBLEMS AS WE REDUCE HEAT LOSS

1800's house – little insulation, no vapor barrier, good drying from inside and outside, porous walls

THE TIGHTER THE HOUSE, THE MORE VULNERABLE TO MOISTURE PROBLEMS



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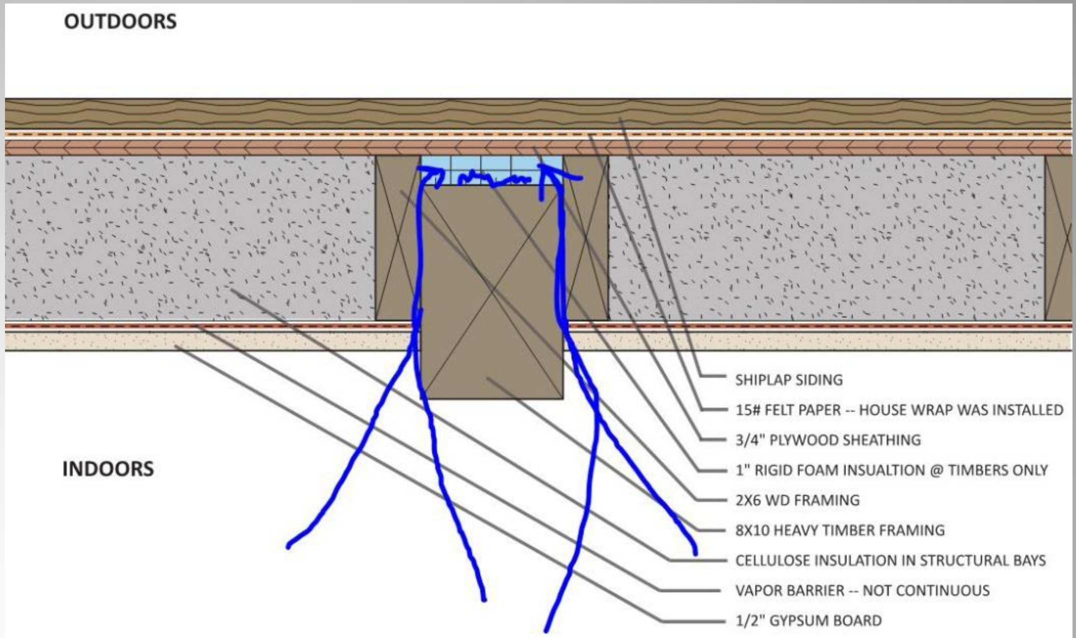
IN THIS CASE WE DID NOT NEED TO WAIT 10 YEARS TO SEE THE PROBLEMS



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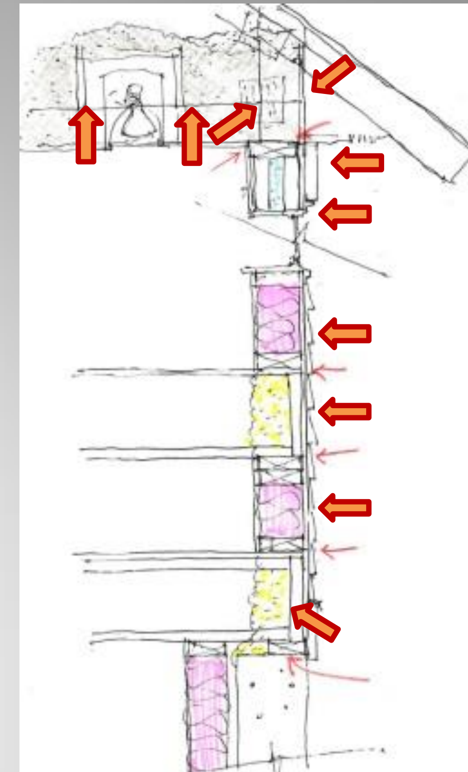
Traditional (unresilient) Wall



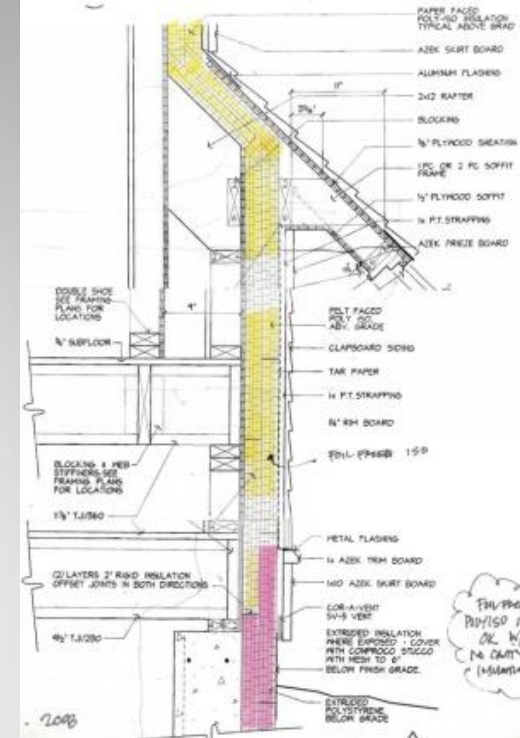
Perfect continuous vapor barrier to prevent condensation in wall

Mechanical ventilation included (and used)

Wall Success

Waterproof siding

Resilient Wall



Perfect continuous vapor barrier to prevent condensation in wall

No condensation. No vapor barrier needed. Allow to dry to the inside.

Optional

Mechanical ventilation

Only needed for healthy air quality.

Wall Success

Waterproof siding

<u>Assume it leaks.</u>
Allow to dry to the outside.

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OUR FIRST EXPERIMENT WITH CONTINUOUS EXTERNAL RIGID FOAM INSULATION: 1992

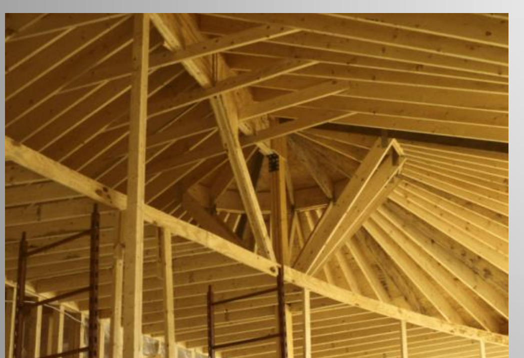
With insulation in the ceiling plane (cold attic) how are we going to prevent violations in thermal envelope?

Vapor barrier?

Ridge vent?

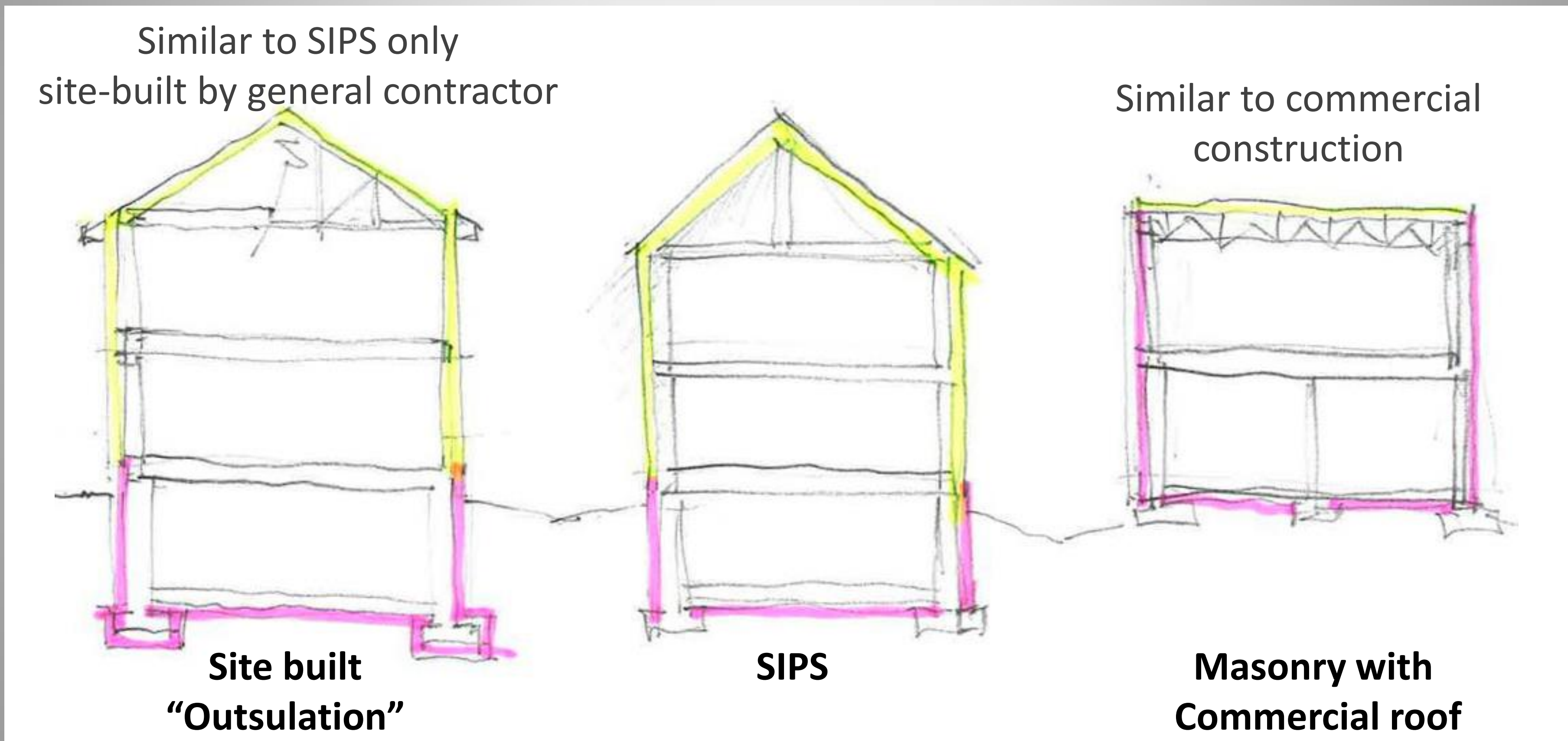
Eave vents?

How do we insulate the meditation room?



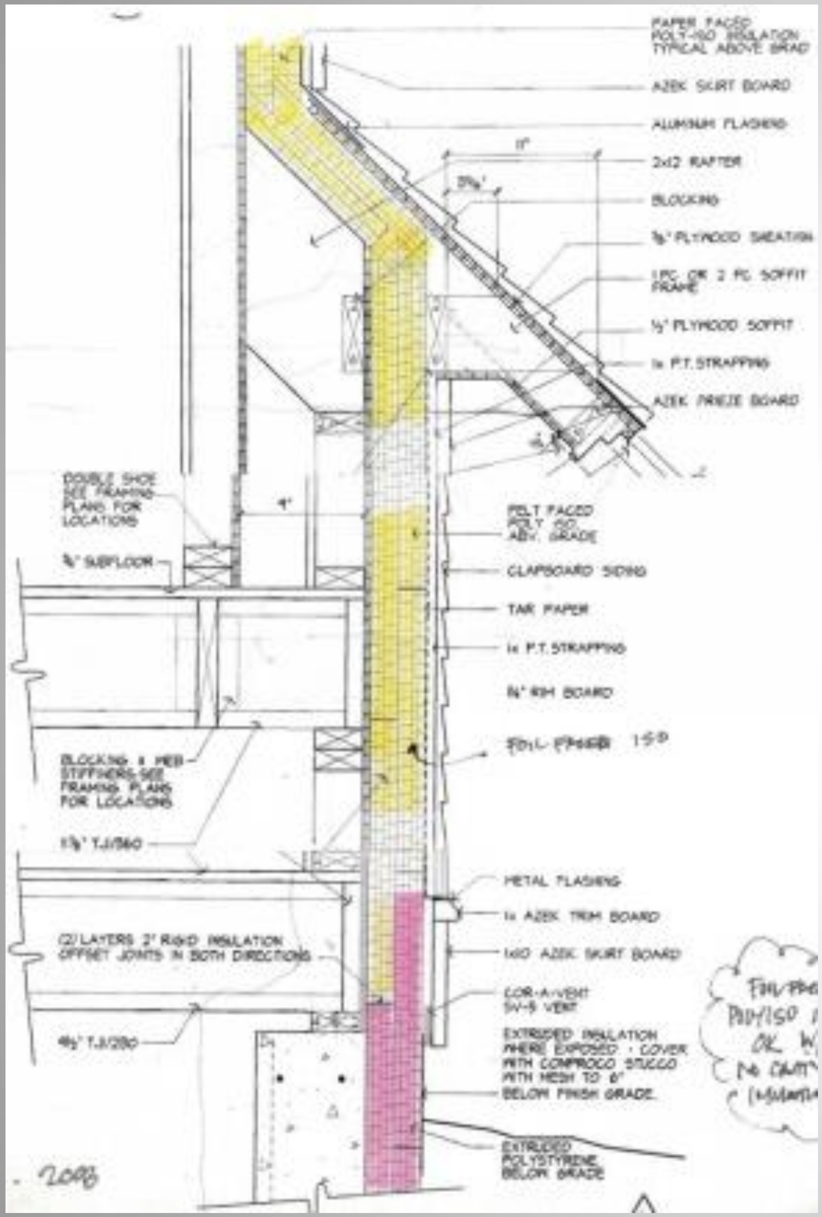
OUTSULATION: SITE BUILT EXTERIOR INSULATION

Building insulation system that wraps the building in rigid foam, continuously and with minimal thermal interruptions.

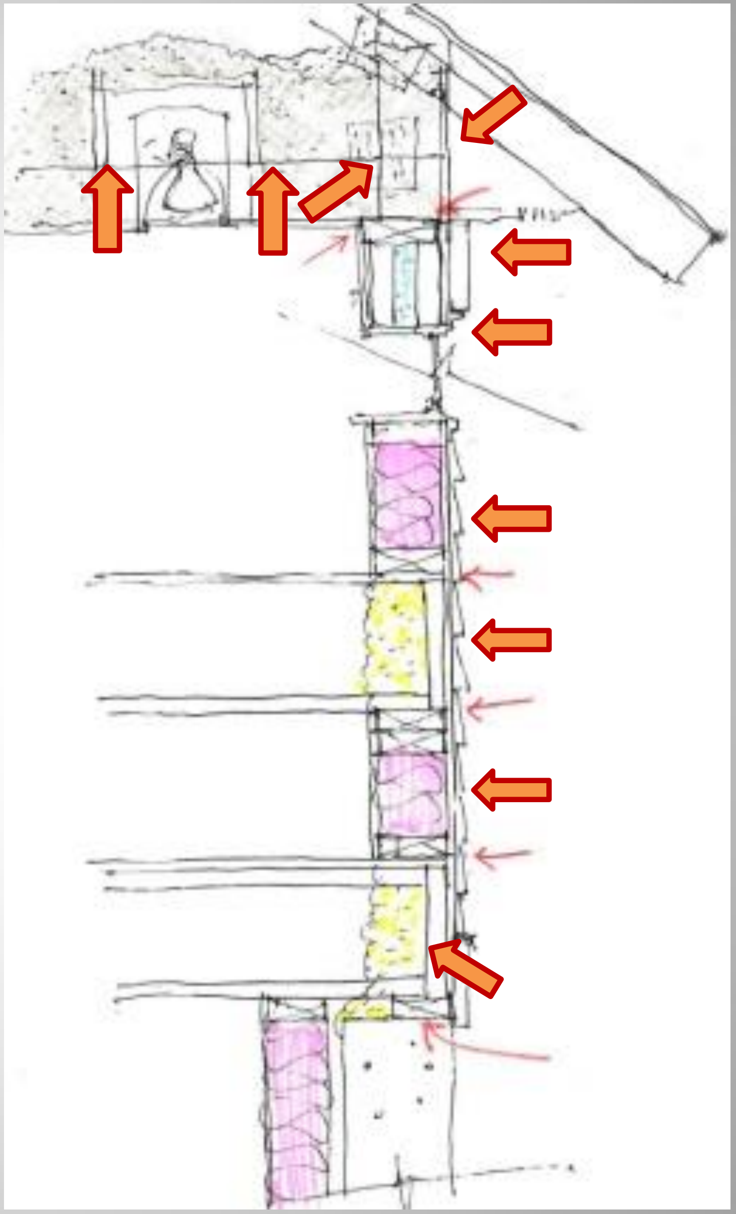


WHAT’S SO IMPORTANT ABOUT IT:

- Designed for continuity, practicality, durability
- Designed to prevent moisture damage



Outsulation



Conventional insulation

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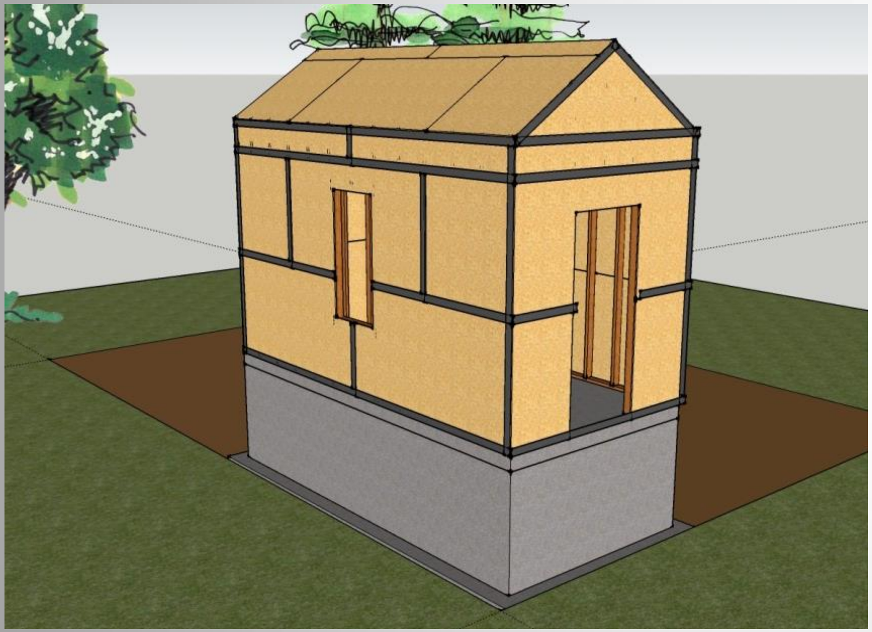
AIR BARRIER

Tape seams of plywood, or use zip wall (a good location for the air barrier)



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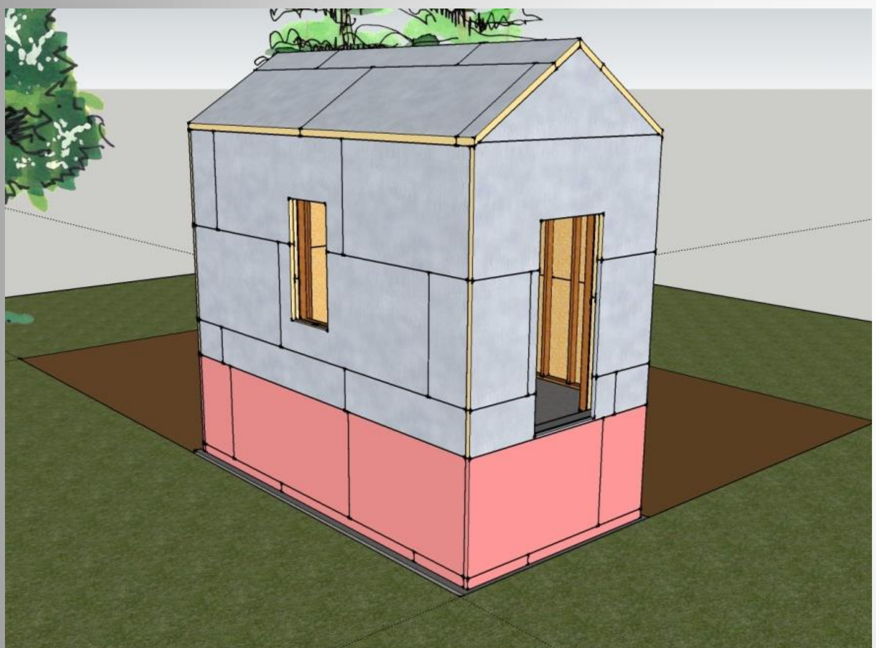
FIRST LAYER OF INSULATION

Second layer with strapping



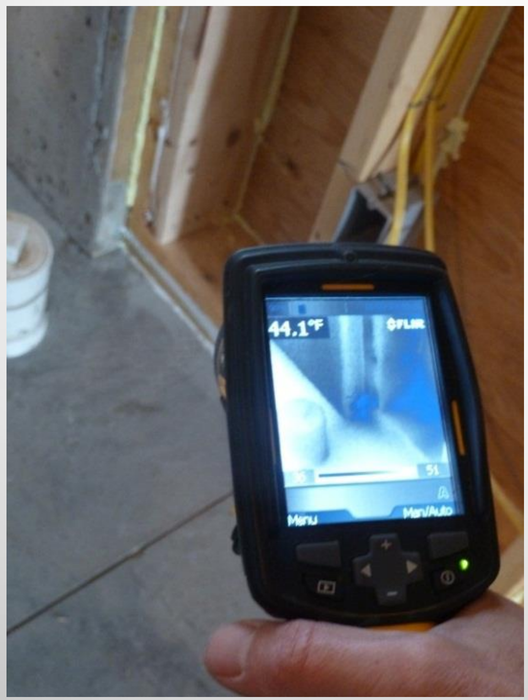
“Outsulation”

AIRTIGHTNESS IS ACHIEVABLE

Check the insulation/air sealing at a time when you can fix it – **what a concept!**

Blower door – test after insulation is in place, but before finishes are installed. This allows the building team to fix leaks <u>when you can still get to the air barrier.</u>

1 – Depressurizing the building



2a – Thermal scan

2b – Photo using thermal scan

3 – Fixing the leaks

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Other tools for testing

- Smoke sticks
- Fogging machine

We are early in the understanding of the "opportunity" to find and fix leaks.

The blower door person did not think it was important to bring a thermal scan. Improvement was limited to addressing the areas you could feel with your hand.

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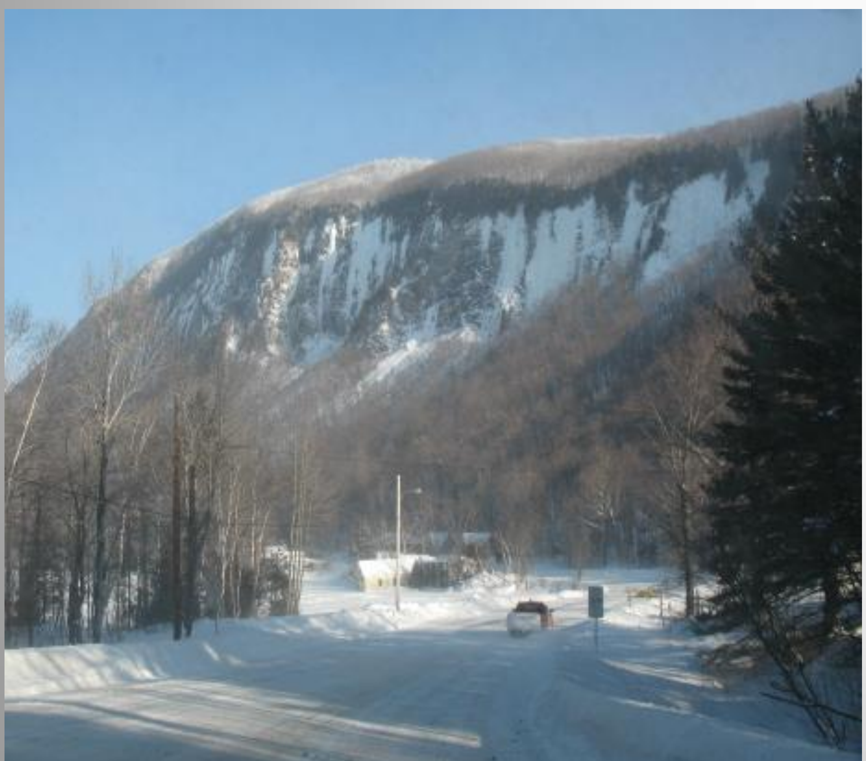
MISSED OPORTUNITY

"I can see this will meet code. I don't even need to test it," said the state energy official.



Air sealing was designed at the perimeter of the overhangs

Williamstown Youth Center (2013)

Perfect in concept, unrealistic to achieve.

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Living Building Challenge – Net Zero

Plywood – 1st blower door test

With Insulation – 2nd blower door test

AIRTIGHTNESS TARGETS

METRICS	TARGETS
A. Air changes per hour at 50 Pascal pressure (ACH50) = CFM50*60/building volume	0.6 ACH50: Passive House 5.0 ACH50: 2011 Vermont Residential Building Energy Code 4.0 ACH50: Energy Star Homes V3
B. Air changes per hour at 75 Pascal pressure (ACH50) = CFM50*60/building volume	
C. "Natural" air changes per hour (ACHnat) = ACH50/LBL factor	0.5 ACHnat: 2001 Energy Star Homes
D. CFM50 per square foot of above-grade surface area = Minneapolis Leakage Ratio	0.5 CFM50/sf: 2011 Vermont CBES
E. CFM50 per square foot of 6-sided (total) surface area = ELR : envelope leakage ratio	
F. CFM75 per square foot of above-grade surface area	
G. CFM75 per square foot of 6-sided (total) surface area	0.25 CFM75/sf: US Army Corps of Engineers
H. Effective leak area (ELA)	

AIRTIGHTNESS METRICS

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If you don't know, how do you expect your contractor to know what these numbers mean?

Design & Specifications that Are Likely to Succeed in Meeting Your Target Goal

SECTION 072705 - AIR SEALING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
1. Air sealing of the building envelope
2. Blower door testing
3. Basis of Design Document (BOD)

B. Related Requirements:
1. Section 061600 Sheathing: for exterior sheathing as an air barrier
2. Section 072100 Thermal insulation: for board foam insulation as an air barrier
3. Section 072500 Weather barriers:
4. Section 079200 Joint sealants
5. Sections in Division 08-Openings

1.2 SYSTEM PERFORMANCE REQUIREMENTS

Air sealing of this building represents the best opportunity to save the most heat loss for the least effort. As such, air sealing and planning for air sealing during the construction process will be very important.

A. The purpose of airsealing tests 1,2, and 3 is to create a specific continuous plane that can be sealed, and then checked at a time when it is possible to correct any leaks that are found. This sequence allows the contractor to meet an aggressive but very achievable air leakage target, and beyond this, to make the envelope as tight as possible. This is why the air seal testing has to be done when the airseal plane is exposed and available for sealing. In this project, the Airsealing Plane is the initial layer of plywood on both the existing building the new portion, and the connections of other components to these layers (windows, doors, chimneys, and other penetrations.)

B. Blower Door Testing: Contractor to coordinate construction sequence to allow for blower door tests and shall coordinate the date of the test with the commissioning agent hired by the owner.
1. Test #1 – finding sealing leaks – When the airsealing plane (plywood sheathing) is complete, and sealed, on the entire exterior, but before it is covered up by other construction. (Penetrations for doors and windows can be temporarily sealed as we are not seeking a specific level of airtightness at this time.)
2. Test #2 – Building can be divided up if desired by contractor. Temporary sealing is required to separate area to be tested. Preliminary numbers will indicate progress toward final goal.
3. Test #3 – Window, door and other penetration testing. Identifying leaks and sealing them, prior to installation of trim.
4. Test #4 – Final airtight quantitative test. This test should be conducted as soon as the penetrations are sealed (windows, doors, etc.) but ideally before trim is installed, in case there is an opportunity to fix a leak at this test.

C. At the time of testing, contractor shall provide tradesman in sufficient numbers and armed with the proper (and LBC approved) sealants to seal any leaks found during testing to allow for testing personnel to move through the entire building envelope until all leaks are sealed to the satisfaction of the weatherization consultant. (On past jobs, we have been able to achieve the desired results in less than a day.)

D. Airsealing Target: Ultimately, the airsealing target is air change Min 1.5 ACH 50 or better. This translates to a min. airtightness rate of 0.08 CFM per 6 sided shell at 50 pascals differentiated.

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Importance of Acknowledging the Construction Sequence & Other Realities

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SUMMARY

- Airtightness is achievable, but requires:
  - Design that enables testing and <u>fixing</u>
  - Contractor involvement
  - Testing agencies “on-board”

- Even though the “devil” is in the details, when it comes to addressing airtight construction, there are tools available today that enable everyone to build an energy efficient moisture resistant and durable envelope.

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The lessons apply to all types of buildings

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