Kohta Ueno

Basement Insulation: What to Do & What Not to Do

March 29, 2012

Building Science Corporation

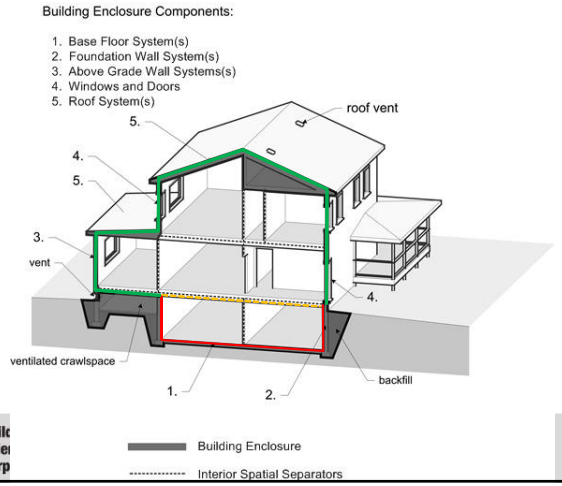
ACI NATIONAL HOME PERFORMANCE conference
March 26-30, 2012
Baltimore Convention Center

Background-Basement Thermal Behavior

Basement/Foundation Energy Use

- Basement ~¼ of energy consumption in a typical house case
- Often left unaddressed in insulation retrofits
- Basements ~80% of houses in Northeast and Midwest
- Code requirement for insulation in DOE Climate Zone 3 and higher
- Uninsulated concrete wall very low R value (R-0.4 to R-0.8)

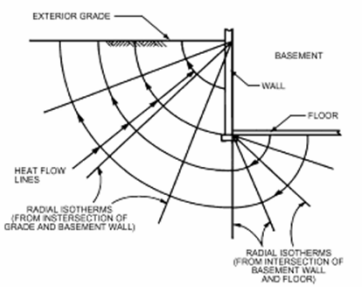
Basement Insulation Location

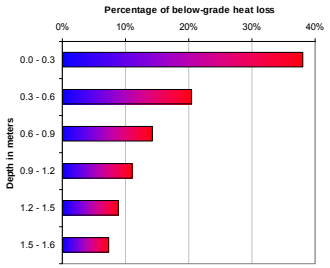


Basement Insulation Location

- 4.6 ACH50; 2129 CFM 50 total; 1100 CFM 50 through floor
- 8.5 ACH50; 3590 CFM 50 total; 1740 CFM 50 through floor

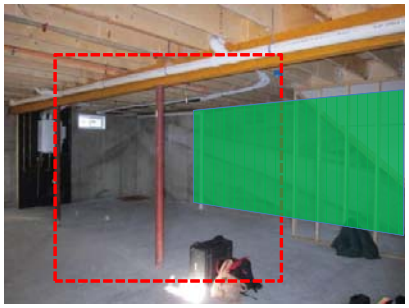
Heat Loss from Basements

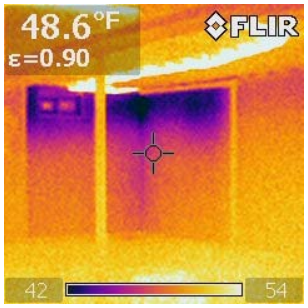




- Greatest heat loss from top of wall
- Basement slab insulation—little energy benefit (but some moisture benefits)

Heat Loss from Basements





- Full height insulation anyway—cold surface condensation, easier to build?

Background-Basement Moisture Behavior

Basement Moisture Behavior

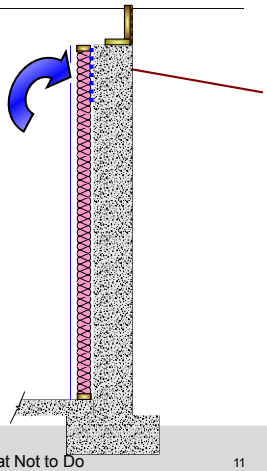
- Historically, many moisture problems with basement insulation—builder callbacks, etc.
- "Building a hole in the ground…"
- Recommended assemblies with reduced moisture risk

Foundations w. bulk water issues

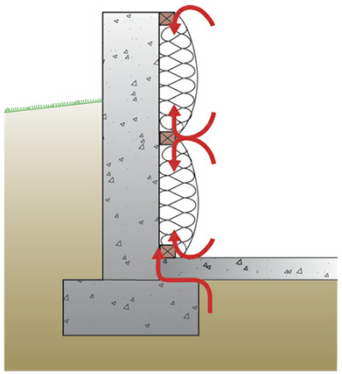
- Severe and rapid damage to interior insulation and finishes due to bulk water intrusion

Basement Insulation Problems

- Wintertime interior moisture condensation (like above-grade walls)

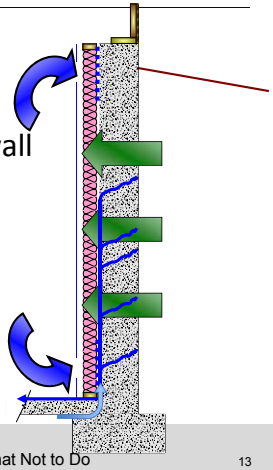


Cold Weather Condensation Issues



Basement Insulation Problems

- Wintertime interior moisture condensation (like above-grade walls)
- Condensation at bottom of wall (thermal lag of soil)
- Lack of drying of assembly (moisture from concrete and soil); soil is at 100% RH
- Soil gas condensation
- Liquid water through wall

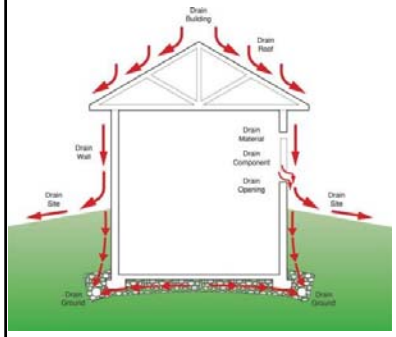


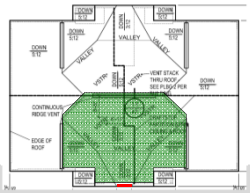
Priorities for Dealing with Water

- Damage Functions (In Order of Importance)
- Liquid Water
  - Control from exterior—drainage, grading
  - Will address in more detail
- Capillary Water ("wicking")
- Air-Transported Moisture
- Vapor Diffusion
- General rules; can vary on case-to-case basis

Dealing With Bulk Water

Drain Water Away From Foundation



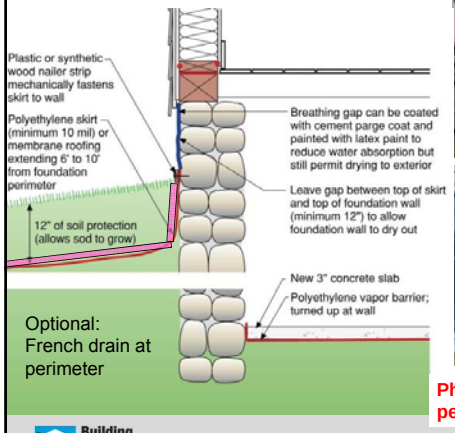


- Also address water concentrations

Control Liquid Water (drainage mat)

See Building Science Insight 057: Hockey Pucks and Hydrostatic Pressure

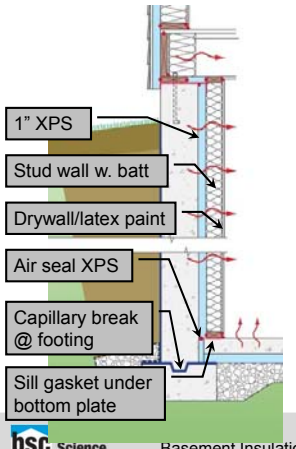
Ground "Skirt" Detail



Photos via Petersen Engineering
petersenengineering.blogspot.com

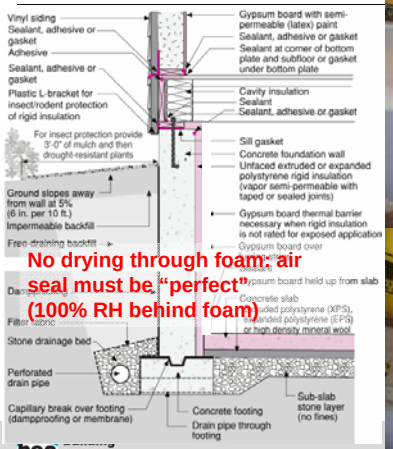
Recommended Assemblies

Recommended Wall (XPS/Frame)



- Wintertime condensation controlled
- Summertime (bottom of wall) condensation controlled
- Concrete can dry through XPS at a safe rate
- XPS is moisture tolerant

Recommended Wall (Foil-faced Polyiso)

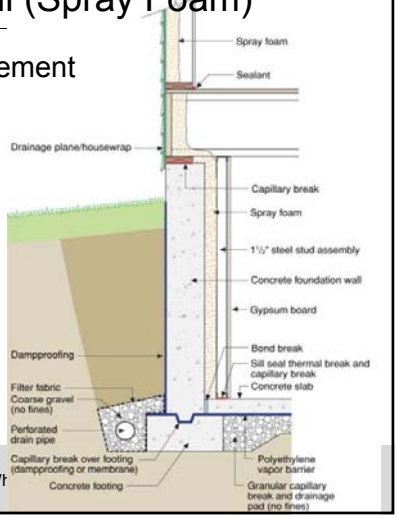


No drying through foam: air seal must be "perfect" (100% RH behind foam)

Photos via Marc Rosenbaum drivingonlowcarbon.typepad.com

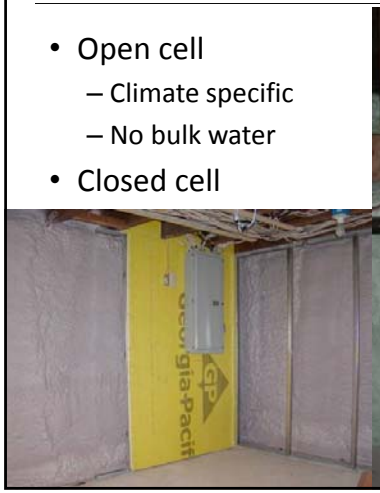
Recommended Wall (Spray Foam)

- "Substantially dry" basement
- Judgment call
- Steel studs clear of spray foam



Spray foam basement insulation

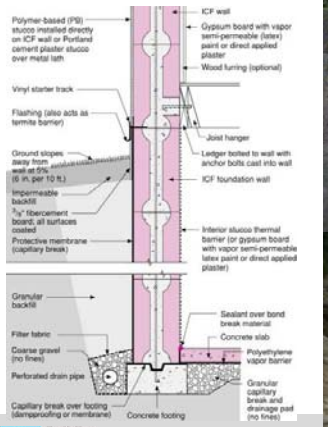
- Open cell
  - Climate specific
  - No bulk water
- Closed cell



Other Good Basement Walls

- Adhered membrane (backup water control)
- XPS foam (insulation)
- Drainage mat to footing drain (primary water control)
- Protection of insulation above grade?

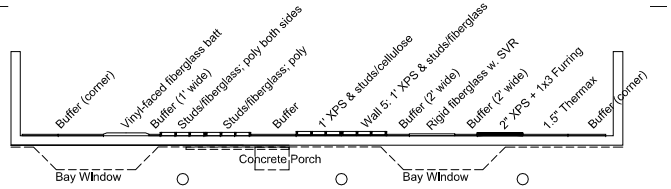
Other Good Basement Walls



Other Good Basement Walls

Non-Recommended Assemblies

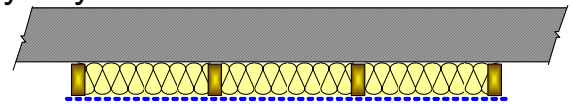
Test House Setup (Chicago)



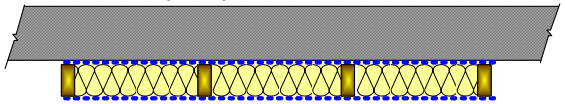
Test House Setup (Kitchener)

Test Walls (Kitchener)

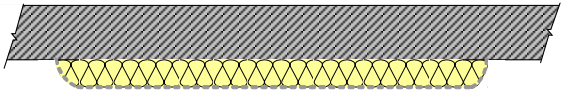
Polyethylene & Stud Frame Walls



- Stud frame, polyethylene one side



- Stud frame, polyethylene both sides (“moist. barr.”)



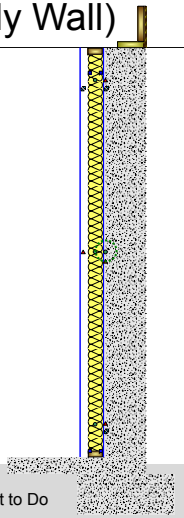
- Polyethylene “roll blanket”

So What Did We Find?

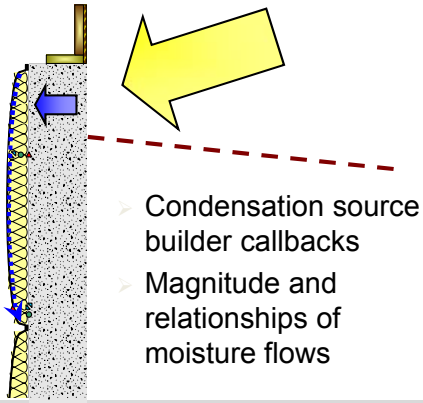
- All the walls essentially worked—no substantial failures
- If no liquid water, and dry interior conditions (wintertime RH)—failure prone assemblies OK
- Examine monitoring results—relative risks
- Air leakage important
- Many other conclusions…

Moisture buildup (Double Poly Wall)

- Stud frame wall with polyethylene on both sides
- RH sensor behind exterior poly "moisture barrier"
- RH rose to ~100% and remained at this level
- Basement had dried for 3+ years before installation
- Lack of drying of assembly



Inward Vapor Drive



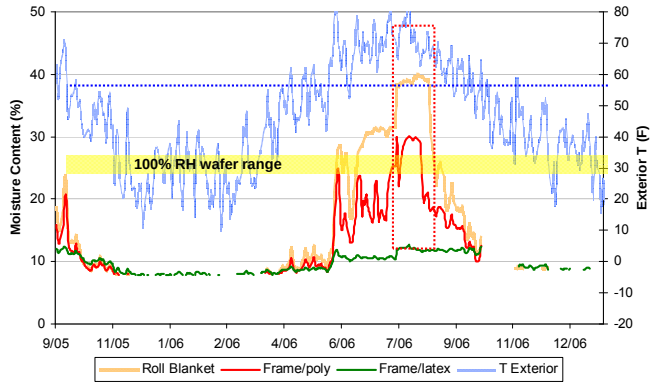
- Condensation source of builder callbacks
- Magnitude and relationships of moisture flows

Inward Vapor Drive to Poly

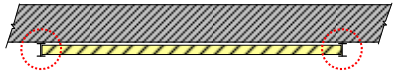
"Wafer" sensor roughly at grade

Sensor shows difference between 100% RH and liquid water condensation

Inward Vapor Drive to Poly



Air Leakage



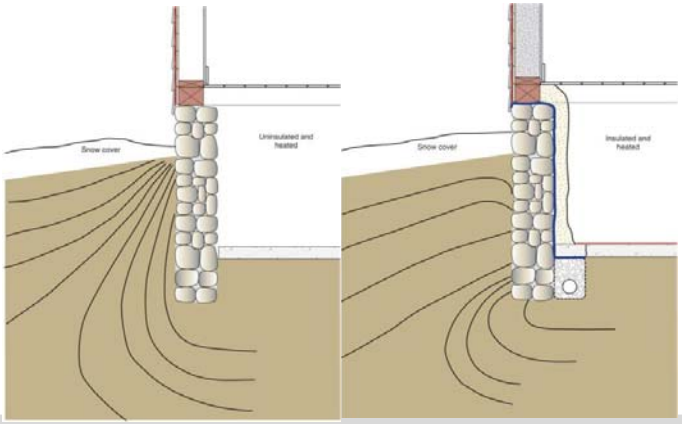
- Foil-faced polyisocyanurate in plastic tee tracks
- Dewpoint of air behind insulation identical to interior
- Evidence for air leakage in many walls
- In most cases, allowed drying of concrete wall

Frost and Freezing Issues

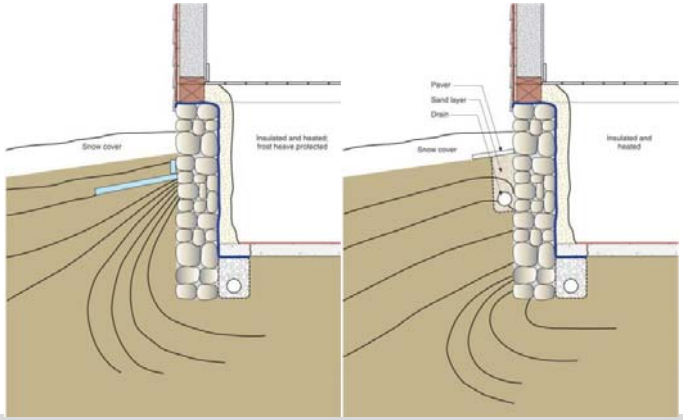
Freezing/Frost Heave Issues

- Interior insulation reduces heat flux → colder ground temperatures/deeper frost penetration
- Frost damage unlikely <60" extreme frost depth
- Inward frost heave impossible → directional heave
- Adfreezing similar: can occur on unheated structures. Heated → heat flux still outwards (although reduced)
- Canadian BETT study (1980s)

Freezing/Frost Heave Issues



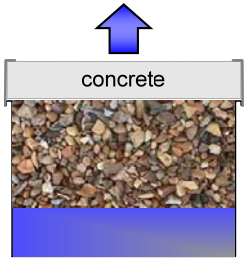
Freezing/Frost Heave Issues



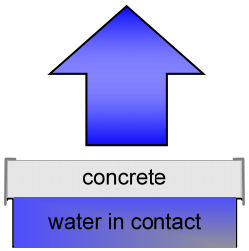
Footing Capillary Breaks

Vapor Diffusion vs. Capillarity

Capillarity ~10 × the moisture movement rate of vapor diffusion alone

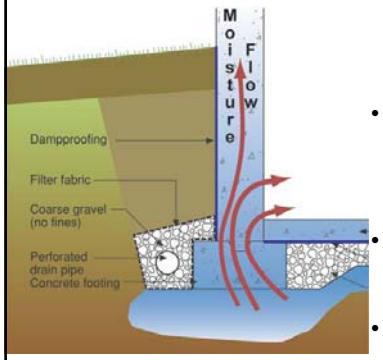


Vapor diffusion



Capillarity

Controlling Capillary Water



- Polyethylene under floor slab (w. free-draining fill)
- Capillary break between soil & basement wall
- Measures already in building codes
- Capillary break at footing-wall connection

Footing Capillary Breaks

Footing Capillary Breaks

Footing Capillary Breaks

Material Choices

- Asphalt-based (standard dampproofings)
- Cementitious coatings (cement-based waterproofing, polymer modified)
- Can add acrylic polymer admixture if desired (greater durability?)
- Latex paint based waterproofing coatings
- Silanes & siloxanes

Membrane Material

Building Science Corporation Basement Insulation: What to Do & What Not to Do 49

Membrane Material

Building Science Corporation Basement Insulation: What to Do & What Not to Do 50

Membrane Material

Building Science Corporation Basement Insulation: What to Do & What Not to Do 51

Membrane Material

Building Science Corporation Basement Insulation: What to Do & What Not

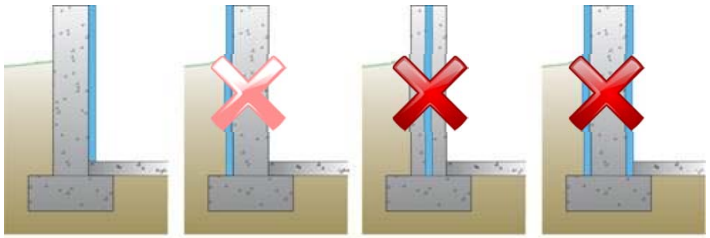
Spray Foam Bulk Water Control Retrofits

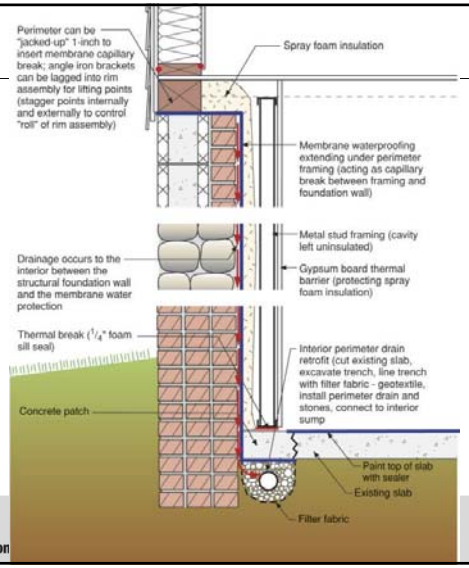
Background

- Basement with persistent bulk water (leakage) issues
- Retrofits of existing foundations
  - Especially uneven wall (rubble stone) foundations
- "Hybrid" insulation and bulk water control assemblies

Retrofit Insulation Location Choices

- Retrofits: interior insulation is often the only available option





Interior Rubble Retrofit

Building Science Corporation Basement Insulation: What to Do & What Not to Do 57

Interior Rubble Retrofit

Building Science Corporation Basement Insulation: What to Do & What Not to Do 58

Interior Rubble Retrofit

Building Science Corporation Basement Insulation: What to Do & What Not to Do 59

Interior Rubble Retrofit

Building Science Corporation Basement Insulation: What to Do & What Not to Do 60

Interior Rubble Retrofit

Air Gap Membrane Variant

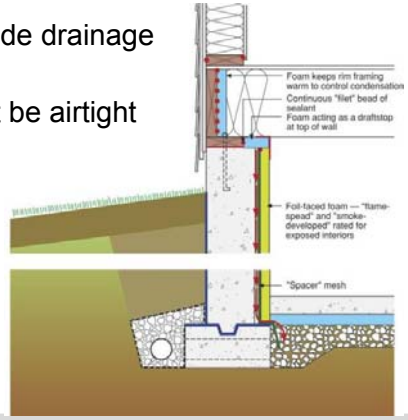
- Spray foam sufficiently stiff at typ. thickness (2" +)
- XPS basement slab perimeter insulation
- Spray foam forms concrete slab thermal break

Beam pocket detail (air seal)

- Beam pocket detail (air seal away from sub-slab)

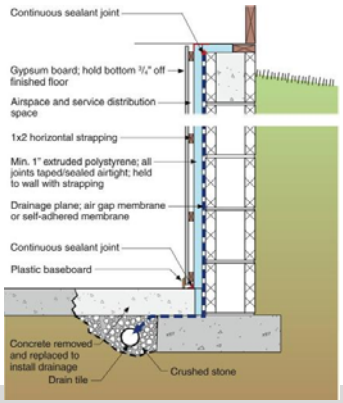
Flat Surface Walls

- Spacer mesh to provide drainage behind foam
- Drainage space must be airtight



Flat Surface Walls

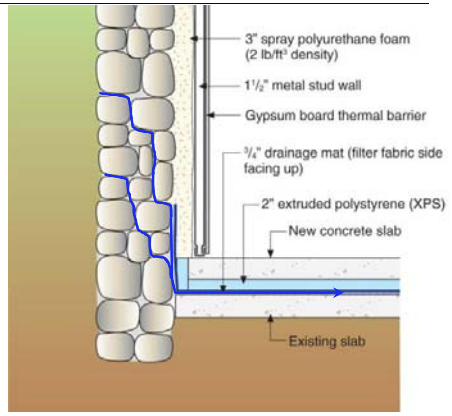
- Alternate version: air gap membrane layer
- Drainage space must be airtight
- Another option: XPS with channels and filter fabric



Building Science Corporation Basement Insulation: What to Do & What Not to Do 65

Partial Drainage Detail

- Insulated slab on top of existing slab
- No membrane up wall surface
- Light gauge steel framing interior wall
- Wet vs. dry basement?



Building Science Corporation Basement Insulation: What to Do & What Not to Do 66

Partial Drainage Detail

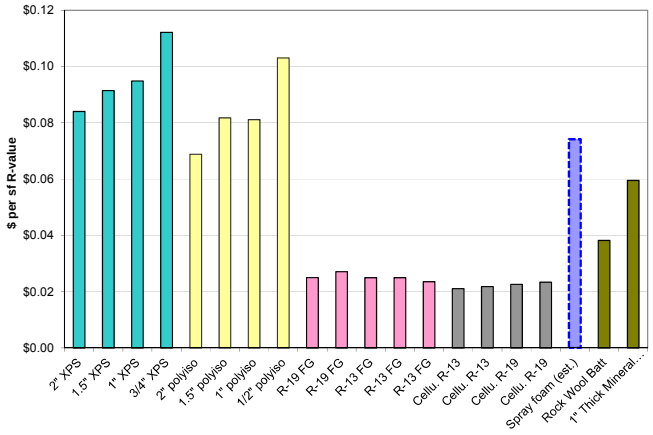
- Sump must be connected to drainage mesh
- Air leakage around drainage space termination (interior chimney)

Building Science Corporation Basement Insulation: What to Do & What Not to Do 67

Spray Foam "Bathtub"

Building Science Corporation Basement Insulation: What to Do & What Not to Do 68

Insulation Normalized Costs



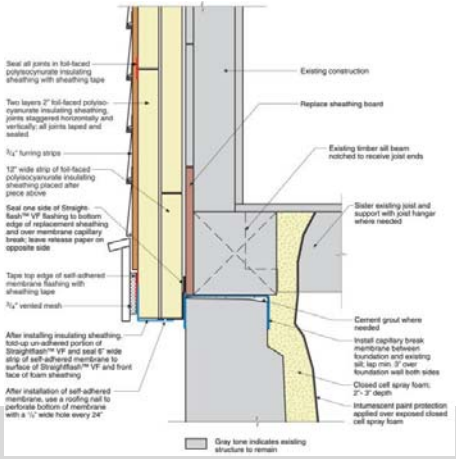
Installed Costs

- Full retrofit $5-$7/sf basement wall area (R-20)
- With stud wall $10-$11/sf basement wall area
- Spray foam (installed) $1.00-$1.50/board foot
- Perimeter drains ~$20-40/lineal foot
- Rat slab (2” thick) ~$3.25-$4.00/sf floor area
- Insulation system + water management
  - Cost comparisons should be to insulation + drainage
- Has to be compared to what actually works!

Additional Research: Sill Beam Durability

Sill Beam Moisture Durability

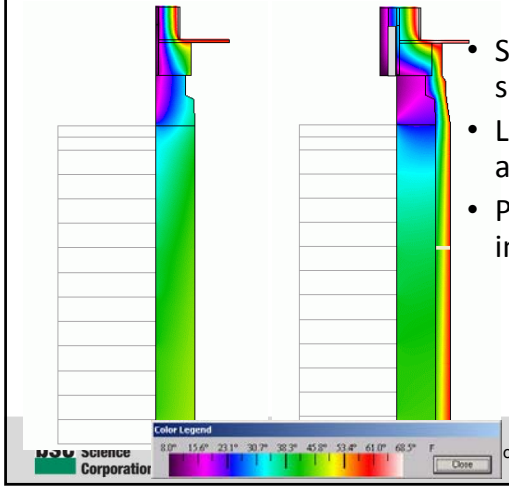
Sill Beam Moisture Durability



Sill Beam Moisture Durability

"This building has been around for the last 100 years…"

Sill Beam Moisture Durability



- Sill-to-foundation surface colder
- Less drying available
- Permeable insulation detail?

Permeable Sill Insulation Detail

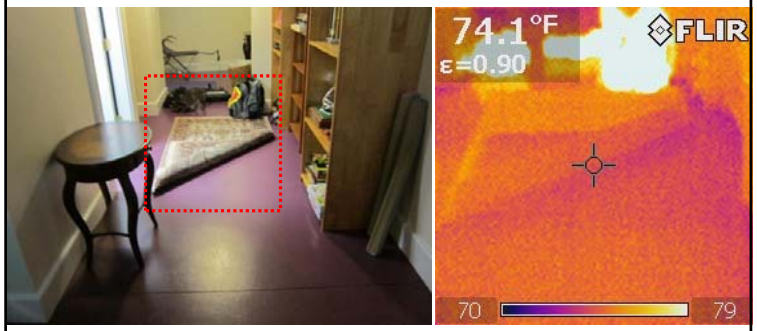
- Foil-faced polyisocyanurate overclad on most of house
- High-density mineral fiber (permeable) at sill

Sill Beam Moisture Risk Factors

- Exterior water control features
- Capillary activity of foundation
- Magnitude of splashback
- Height of sill beam/rim joist above grade
- Drainage plane location
- Permeability of exterior

- Westford Barn retrofit sill beam example

Field Survey Work



- Sub slab insulation reduces risk of moisture issues (carpets on slabs; cardboard boxes)

Questions?

Kohta Ueno
kohta@buildingscience.com

This presentation is based research covered in
BSC TO2 7.7 Hybrid Foundation Insulation

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America U.S. Department of Energy

Resources

- Building Science Digest 103: Understanding Basements
  http://www.buildingscience.com/documents/digests/bsd-103-understanding-basements
- Building Science Insight 041: Rubble Foundations
  http://www.buildingscience.com/documents/insights/bsi-041-rubble-foundations/
- Building Science Insight 045: Double Rubble Toil and Trouble
  http://www.buildingscience.com/documents/insights/bsi-045-double-rubble-toil-trouble/
- Building Science Insight 057: Hockey Pucks and Hydrostatic Pressure
  http://www.buildingscience.com/documents/insights/bsi-057-hockey-pucks-and-hydrostatic-pressure/
- RR-1108: Hybrid Foundation Insulation Retrofits: Measure Guideline
  http://www.buildingscience.com/documents/reports/rr-1108-hybrid-foundations-retrofits-measure-guideline/
- RR-1003: Building America Special Research Project—High-R Foundations Case Study Analysis
  http://www.buildingscience.com/documents/reports/rr-1003-building-america-high-r-foundations-case-study-analysis/
- RR-??: Bulk Water Control Methods for Foundations
- RR-0309: Renovating Your Basement
  http://www.buildingscience.com/documents/reports/rr-0309-renovating-your-basment/
- Information Sheet 511: Basement Insulation
  http://www.buildingscience.com/documents/information-sheets/basement-insulation/
- Hygrothermal Behavior of Interior Basement Insulation (Kohta Ueno MASc Thesis)
  http://uwspace.uwaterloo.ca/handle/10012/3242
- Info-408: Critical Seal (Spray Foam at Rim Joist)
  http://www.buildingscience.com/documents/information-sheets/critical-seal-spray-foam-at-rim-joist