

Kohta Ueno

Basement Insulation: What to Do & What Not to Do

March 29, 2012



Background-Basement Thermal Behavior



Basement Insulation: What to Do & What Not to Do

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Basement/Foundation Energy Use

- Basement $\sim\frac{1}{4}$ of energy consumption in a typical house case
- Often left unaddressed in insulation retrofits
- Basements $\sim 80\%$ 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)



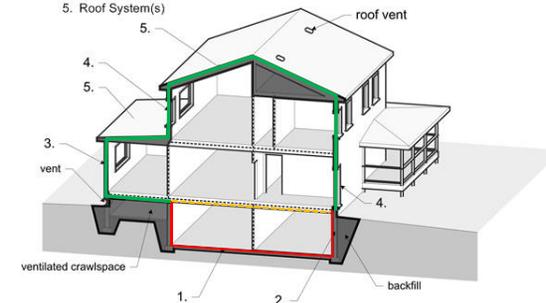
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Basement Insulation Location

Building Enclosure Components:

1. Base Floor System(s)
2. Foundation Wall System(s)
3. Above Grade Wall System(s)
4. Windows and Doors
5. Roof System(s)



— Building Enclosure

----- Interior Spatial Separators



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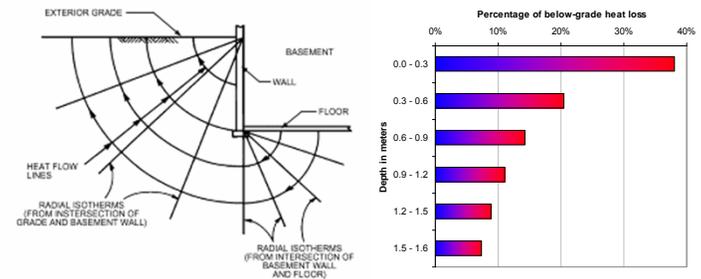
Basement Insulation Location



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



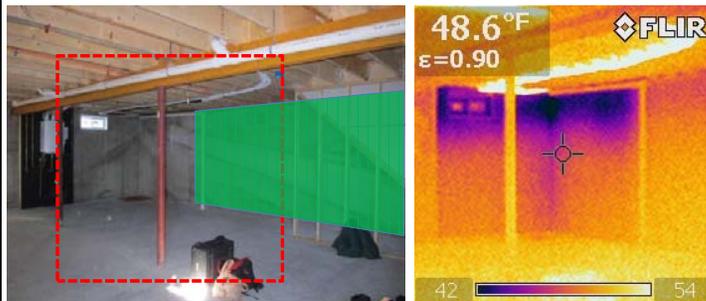
Heat Loss from Basements



- 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

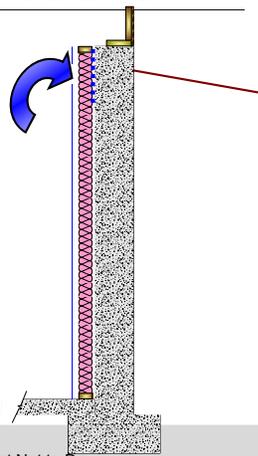


- Severe and rapid damage to interior insulation and finishes due to bulk water intrusion

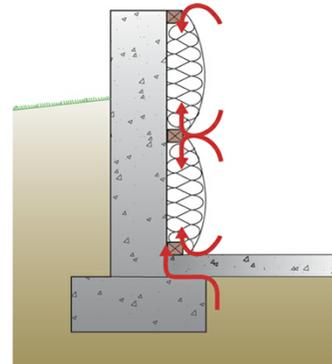


Basement Insulation Problems

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

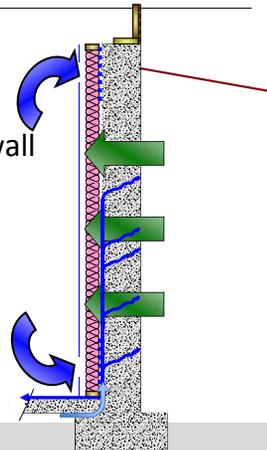


Cold Weather Condensation Issues



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

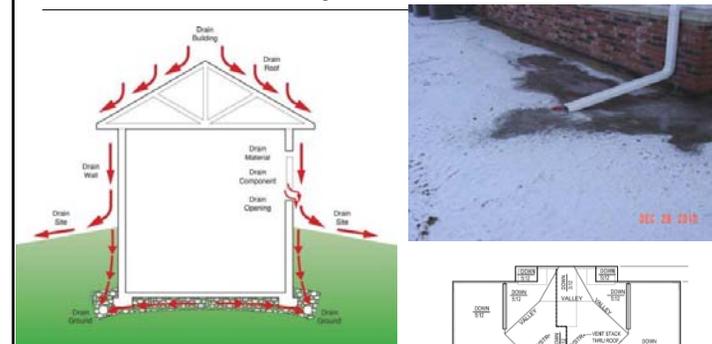
- Damage Functions (In Order of Importance)
- Liquid Water
 - Control from exterior—drainage, grading
 - Will address in more detail
- Capillary Water (“wicking”)
- Air-Transported Moisture
- Vapor Diffusion
- General rules; can vary on case-to-case basis



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 at www.greatsource.com

Ground "Skirt" Detail

Plastic or synthetic wood nailer strip mechanically fastens skirt to wall

Polyethylene skirt (minimum 10 mil) or membrane roofing extending 6" to 10" from foundation perimeter

Breathing gap can be coated with cement parge coat and painted with latex paint to reduce water absorption but still permit drying to exterior

12" of soil protection (allows sod to grow)

Optional: French drain at perimeter

Leave gap between top of skirt and top of foundation wall (minimum 12") to allow foundation wall to dry out

New 3" concrete slab

Polyethylene vapor barrier; turned up at wall

Photos via Petersen Engineering petersenengineering.blogspot.com

Recommended Assemblies

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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

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Recommended Wall (Foil-faced Polyiso)

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

Photos via Marc Rosenbaum
livingonlowcarbon.typepad.com

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Recommended Wall (Spray Foam)

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

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Spray foam basement insulation

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

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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?

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Other Good Basement Walls

Labels in diagram include: Polymer-based (PB) slucco installed directly on KCF wall or Portland cement plaster slucco over metal lath; Vinyl starter track; Flashing (also acts as termite barrier); Ground slopes away from wall at 1% (1/8 in. per 10 ft.); Impervious backfill; 3/4" fiber cement board, all surfaces coated; Protective membrane (capillary break); Granular backfill; Filter fabric; Coarse gravel (no fines); Perforated drain pipe; Capillary break over footing (dimpled roofing or membrane); Concrete footing; KCF wall; Gypsum board with vapor semi-permeable (latex) paint or direct applied plaster; Wood furring (optional); Joint hanger; Ledger bolted to wall with anchor bolts cast into wall; KCF foundation wall; Interior slucco thermal barrier (or gypsum board with vapor semi-permeable latex paint or direct applied plaster); Sealant over bond break material; Concrete slab; Polyethylene vapor barrier; Granular capillary break and drainage pad (no fines).

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Other Good Basement Walls

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Non-Recommended Assemblies

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Test House Setup (Chicago)

Labels in diagram include: Buffer (corner); Vinyl-faced fiberglass batt; Buffer (1" wide); Stud/fiberglass; poly both sides; Stud/fiberglass; poly; Buffer; 1" XPS & studs/cellulose; Wall 5: 1" XPS & studs/fiberglass; Buffer (2" wide); Rigid fiberglass w. SVR; Buffer (2" wide); 2" XPS + 1x3 Furring; 1.5" Thermax; Buffer (corner); Bay Window; Concrete Porch; Bay Window.

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Test House Setup (Kitchener)

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Test Walls (Kitchener)

- Stud frame w. fiberglass & polyethylene; painted gypsum board
- Stud frame w. fiberglass & no polyethylene; painted gypsum board
- 2" extruded polystyrene
- polyethylene roll blanket

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Polyethylene & Stud Frame Walls

- Stud frame, polyethylene one side
- Stud frame, polyethylene both sides ("moist. barr.")
- Polyethylene "roll blanket"

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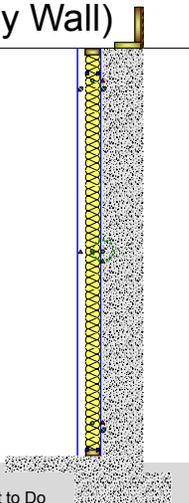
So What Did We Find?

- 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...

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Moisture buildup (Double Poly Wall)

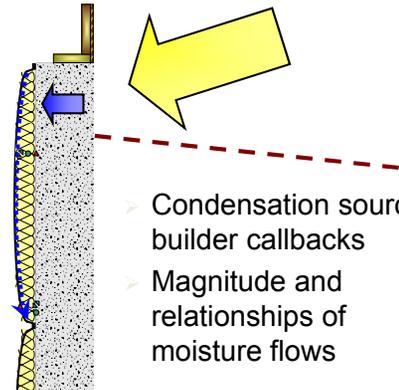
- Stud frame wall with polyethylene on both sides
- RH sensor behind exterior poly “moisture barrier”
- RH rose to ~100% and remained at this level
- Basement had dried for 3+ years before installation
- Lack of drying of assembly



The diagram shows a vertical cross-section of a wall assembly. From left to right: a stud frame wall, a layer of polyethylene (yellow zig-zag), a layer of insulation (grey stippled), another layer of polyethylene (yellow zig-zag), and a concrete foundation. A red dashed line indicates a moisture barrier. A blue arrow points to a sensor location behind the exterior polyethylene.

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Inward Vapor Drive



The diagram shows a vertical cross-section of a wall assembly. A large yellow arrow points from the right towards the wall, indicating the direction of vapor drive. A blue arrow points from the interior towards the exterior, indicating the direction of moisture flow. A red dashed line indicates a moisture barrier. A blue arrow points to a sensor location behind the exterior polyethylene.

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

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Inward Vapor Drive to Poly



A photograph showing a yellow wafer sensor installed in a wall assembly. A red arrow points to the sensor with the text: “Wafer” sensor roughly at grade.

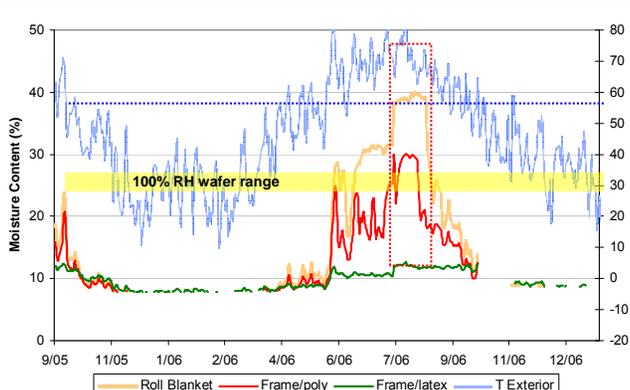


A close-up photograph of the yellow wafer sensor with a ruler for scale. The sensor is a small, rectangular, yellow device with a blue wire.

Sensor shows difference between 100% RH and liquid water condensation

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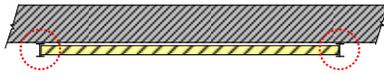
Inward Vapor Drive to Poly



The graph plots Moisture Content (%) on the left y-axis (0 to 50) and Exterior T (°F) on the right y-axis (-20 to 80) against time on the x-axis (9/05 to 12/06). The legend includes: Roll Blanket (orange), Frame/poly (red), Frame/latex (green), and T Exterior (blue). A yellow shaded region indicates the 100% RH wafer range. A red dashed box highlights a period of high moisture content and temperature fluctuations between June and September 2006.

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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

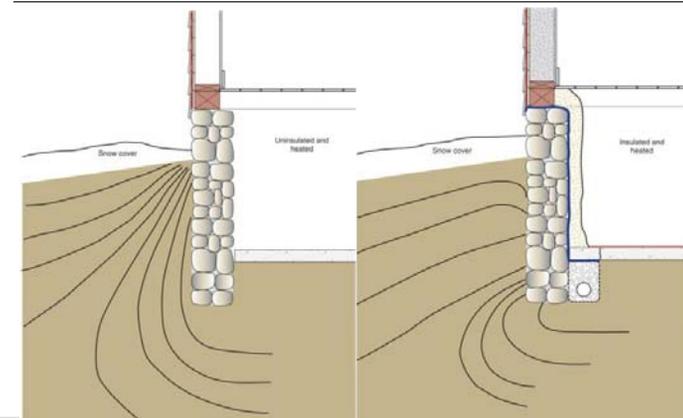


Freezing/Frost Heave Issues

- 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

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Footing Capillary Breaks

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Vapor Diffusion vs. Capillarity

Capillarity $\sim 10 \times$ the moisture movement rate of vapor diffusion alone

concrete

concrete

water in contact

Vapor diffusion

Capillarity

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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

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Footing Capillary Breaks



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Footing Capillary Breaks



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Footing Capillary Breaks



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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



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Membrane Material



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Membrane Material



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Membrane Material



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Membrane Material



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Spray Foam Bulk Water Control Retrofits



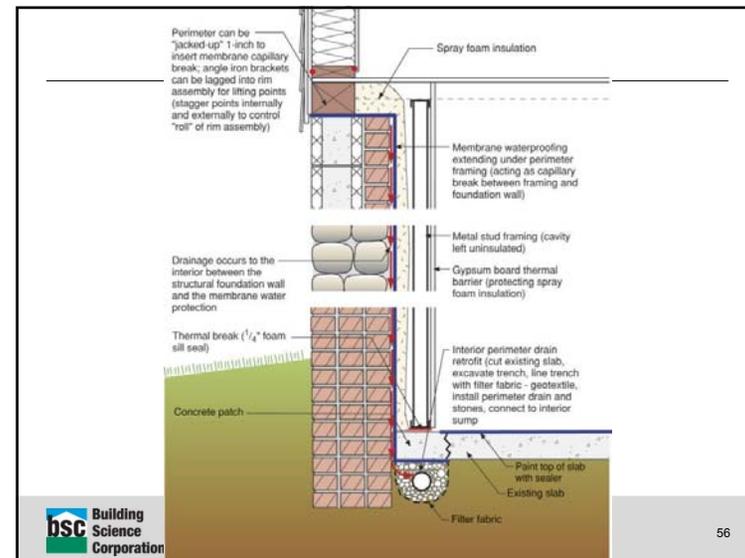
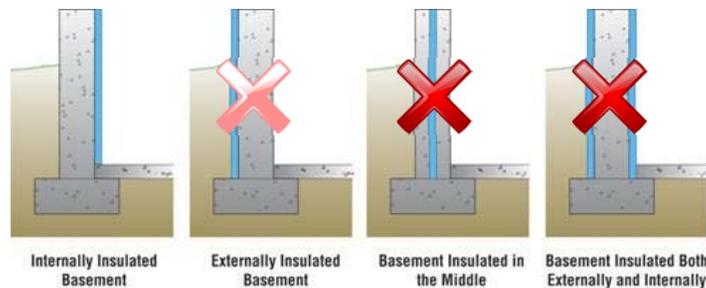
Background

- 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



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Interior Rubble Retrofit



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Interior Rubble Retrofit



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Interior Rubble Retrofit



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Interior Rubble Retrofit



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Air Gap Membrane Variant



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

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Beam pocket detail (air seal)



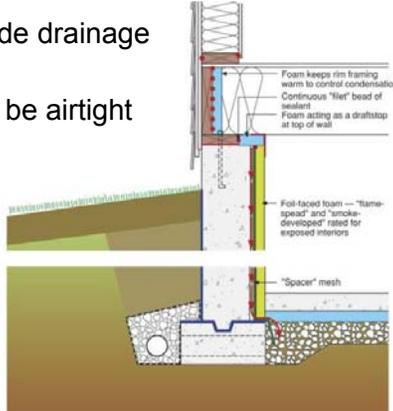
- Beam pocket detail (air seal away from sub-slab)

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Flat Surface Walls

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

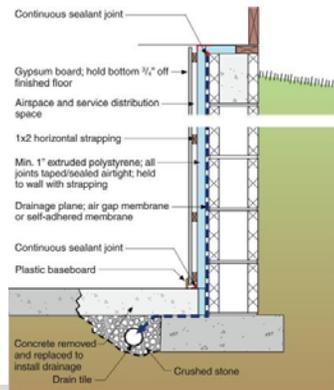


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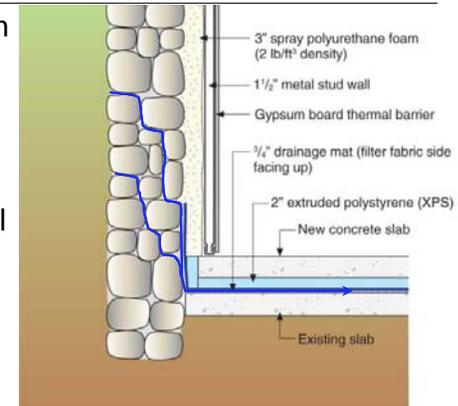
Flat Surface Walls

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



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?



Partial Drainage Detail



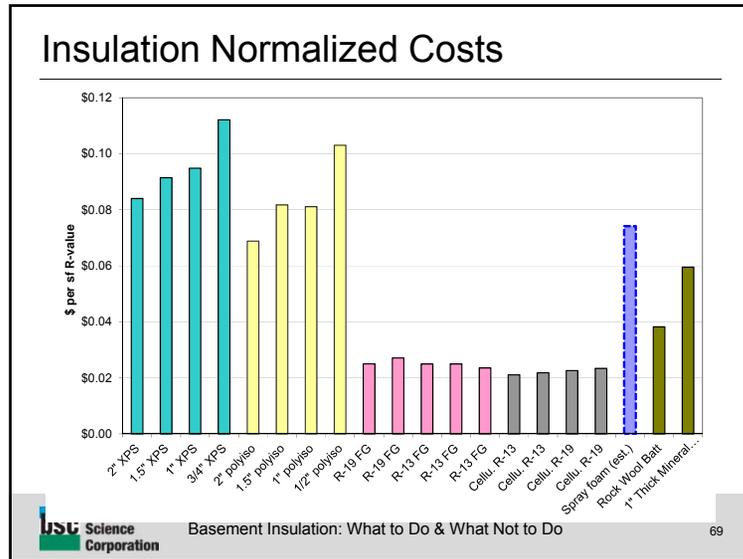
- Sump must be connected to drainage mesh
- Air leakage around drainage space termination (interior chimney)



Spray Foam “Bathtub”

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- ### 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!**
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Additional Research: Sill Beam Durability

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Sill Beam Moisture Durability

Seal all joints in foil-faced polyisocyanurate insulating sheathing with sheathing tape

Two layers 2" foil-faced polyisocyanurate insulating sheathing, joints staggered horizontally and vertically, all joints taped and sealed

1/4" furring strips

12" wide strip of foil-faced polyisocyanurate insulating sheathing placed after joints above

Seal one side of Straightedge™ VP flanking to bottom edge of replacement sheathing and over membrane capillary break, leave release paper on opposite side

Seal top edge of self-adhered membrane flanking with sheathing tape

1/4" vented mesh

After installing insulating sheathing, tack-up an adhered portion of Straightedge™ VP and seal 1/2" wide strip of self-adhered membrane to surface of Straightedge™ VP and front face of foam sheathing

After installation of self-adhered membrane, use a roofing nail to perforate bottom of membrane with a 1/2" wide hole every 24"

Existing construction

Replace sheathing board

Existing timber sill beam notched to receive post ends

Slab existing joist and support with joist hanger where needed

Correct gird where needed

Install capillary break membrane between foundation and existing sill, use one 2" open foundation wall both sides

Closed cell spray foam, 2"-3" depth

Impermeant paint protection applied over exposed closed cell spray foam

Gray line indicates existing structure to remain

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Sill Beam Moisture Durability

“This building has been around for the last 100 years...”

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Sill Beam Moisture Durability

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

Color Legend: 30.0°, 15.6°, 21.1°, 30.2°, 33.3°, 45.8°, 53.4°, 61.0°, 68.5° F

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Permeable Sill Insulation Detail

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

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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



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Field Survey Work



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



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Questions?

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



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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>



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