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**

- 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?
**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

Recommended Assemblies

Ground “Skirt” Detail

Optional: French drain at perimeter

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
https://thrivingonlowcarbon.typepad.com

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

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

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
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

- 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

Vapor Diffusion vs. Capillarity

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

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
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
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

Interior Rubble Retrofit

Interior Rubble Retrofit

Interior Rubble Retrofit
### Interior Rubble Retrofit

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

### 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

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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”**
**Insulation Normalized Costs**

- **Costs per sf R-value**
  - $0.00
  - $0.02
  - $0.04
  - $0.06
  - $0.08
  - $0.10
  - $0.12

**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-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)

Resources

- Building Science Digest 103: Understanding Basements
- Building Science Insight 041: Rubble Foundations
- Building Science Insight 045: Double Rubble Toli and Trouble
- Building Science Insight 057: Hockey Pucks and Hydrostatic Pressure
- RR-1108: Hybrid Foundation Insulation Retrofits: Measure Guideline
- RR-1003: Building America Special Research Project—High-R Foundations Case Study Analysis
- RR-????: Bulk Water Control Methods for Foundations
- RR-0309: Renovating Your Basement
- Information Sheet 511: 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)

Questions?

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