Hybrid Foundation Retrofits

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Hybrid Foundation Retrofits

Background
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- Space conditioning energy use for basements
- Known moisture-safe solutions (previous research)
- Persistent bulk water (leakage) issues
- Retrofits of existing foundations
  - Especially uneven wall (rubble stone) foundations
- “Hybrid” insulation and bulk water control assemblies
Foundations w. bulk water issues

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

• Retrofits: interior insulation is often the only available option

- Internally Insulated Basement
- Externally Insulated Basement
- Basement Insulated in the Middle
- Basement Insulated Both Externally and Internally
Hybrid Foundation Retrofits

**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
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
- Capillary Water ("wicking")
- Air-Transported Moisture
- Vapor Diffusion
- General rules; can vary on case-to-case basis
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
Previous Work

- Trade press: interior perimeter drainage
  - Drains slab and wall: no air barrier between sub-slab and interior
- AVID System (Air/Vapor/Insulation/Drainage)
  - Interior drainage; half-height insulation
  - Interior 0.5 PCF spray foam
  - Typically good performance/low moisture accumulation
- Zone 7 frosting on above-grade portion (insulation/foundation)
Closed Cell Spray Foam Characteristics

- Insulation value ~R-6/inch
- Air control layer: air impermeable material
- Vapor permeability: 0.8 perms at 2” thickness
- Water control: moisture tolerant/hydrophobic
- Code Requirements (ICC)
  - Separate from interior by “thermal barrier” (R316.4) ½” GWB or equivalent, intumescent paint
  - “Ignition barrier” permitted for some attic/crawl cases: (less stringent requirements; R316.5.4)
- Installed cost typically ~$1-$1.50/board ft. (1’x1’x1”)

Hybrid Foundation Retrofits
Insulation Normalized Costs

Hybrid Foundation Retrofits
Installed Costs

- AVID example ~$2/sf floor area for 4’ crawl, half height, polyethylene only on floor (~$4/sf wall)
- 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!
Recommended Designs & Variants
Hybrid Foundation Retrofits

Perimeter can be "jacked-up" 1-inch to insert membrane capillary break; angle iron brackets can be lagged into rim assembly for lifting points (stagger points internally and externally to control "roll" of rim assembly)

Spray foam insulation

Membrane waterproofing extending under perimeter framing (acting as capillary break between framing and foundation wall)

Metal stud framing (cavity left uninsulated)

Gypsum board thermal barrier (protecting spray foam insulation)

Drainage occurs to the interior between the structural foundation wall and the membrane water protection

Thermal break (1/4" foam sill seal)

Concrete patch

Interior perimeter drain retrofit (cut existing slab, excavate trench, line trench with filter fabric - geotextile, install perimeter drain and stones, connect to interior sump)

Paint top of slab with sealer

Existing slab

Filter fabric
Interior Rubble Retrofit
Interior Rubble Retrofit
Interior Rubble Retrofit
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 from subslab)
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
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?
• Sump must be connected to drainage mesh
• Air leakage around drainage space termination (interior chimney)
Non-Drained Detail

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

- Open cell
  - Climate specific
- Closed cell
Guidance Flowchart

- Rough guidelines
- User judgment required
Additional Research: Moisture Flow
Hygrothermal Simulations

- Moisture emissions before/after interior ccSPF
  - No drainage layer—spray foam only
  - kg/m²·year
  - Constant and variable interior T/RH

2.8 liters day uninsulated vs. 0.3 l/day insulated

Family 4 = 10-15 l/day

Slows down capillary mortar erosion?
Hygrothermal Simulations (Capillarity)

Lime mortar “eaten” away over time “sacrificing” itself to protect brick and masonry units.

Evaporation from thick lime-based mortar rendering.

Mortar “eaten” away as drying happens from within the mortar matrix.

Salts left behind on surface in the form of crystals (“efflorescence”).

Evaporation from surface film of water.

Capillary flow of salts in solution.
Additional Research: Sill Beam Durability
Sill Beam Moisture Durability
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.
- 3/4" furring strips.
- 12" wide strip of foil-faced polyisocyanurate insulating sheathing placed after piece above.
- Seal one side of Straightflash™ VF flashing to bottom edge of replacement sheathing and over membrane capillary break; leave release paper on opposite side.
- Tape top edge of self-adhered membrane flashing with sheathing tape.
- 3/4" vented mesh.
- After installing insulating sheathing, fold-up un-adhered portion of Straightflash™ VF and seal 6" wide strip of self-adhered membrane to surface of Straightflash™ VF and front face of foam sheathing.
- After installation of self-adhered membrane, use a roofing nail to perforate bottom of membrane with a 1/4" wide hole every 24".
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?
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
Field Survey Work

- Existing foundation 1996 to 2009, Zone 5A
- Variety of interior ccSPF foundation insulation
- Temperatures and RHs
  - Basement/crawl space dewpoint vs. above grade
  - Behind foam ~80-90% consistently (not 100%)
Field Survey Work

- Disassembly: no damage seen

- Rubble stone walls are not air barriers!
Field Survey Work

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

- Moisture contents uniformly in 8-13% range
- Limited survey
Additional Research: Foundation Surface Ts
Concrete Surface Temperature

- Well insulated foundation (R-25)
- Above grade wall ~R-40
- Outdoor temperature -8 F (AM) to +23 F (PM)
- More than R value, solar exposure, thermal mass
Concrete Surface Temperature

Sensor Key:
- Temperature
- Relative humidity/temperature
- Moisture content/temperature
- Moisture content block
- Soil sensors MC/gypsum/temp

6” soil temperature never fell below 32° F
Two-dimensional thermal effects
Concrete Surface Temperature

Wintertime temperature moderated by soil coupling
Further Work

• Mature technology; extensive track record
• Frost damage to foundations in very cold (DOE Zones 6 & 7)—“Where is the edge?”
• Decision to use drainage layer—“historically dry” basement, etc.
• Efflorescence/mortar erosion—sufficiently slowed by reduced evaporation?
• Sill beam drying in interior retrofits; capillary break requirement guidelines?
Questions?

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