How Do We Retrofit Tough Buildings?
Foundation Insulation for Existing Homes

Building America Technical Update
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Patrick H. Huelman
Cold Climate Housing Coordinator
University of Minnesota Extension
Foundation Insulation for Existing Homes

• Context
  – Focused on basements and crawlspaces.
  – Aimed at cold climates (Climate Zones 6 & 7).
  – Generally aimed at liquid active walls.

• Approach
  – Managing risks
  – Current solutions & best practices
  – Evaluating new approaches
Primary focus is to reduce energy use by 30 to 50% with emphasis on existing homes.

Promote building science solutions using a systems engineering and integrated design approach.

“Do no harm” => must ensure that safety, health, and durability are maintained or improved.

Intended to accelerate the adoption of high-performance technologies.
Foundation Insulation for Existing Homes

• Should we insulate basement walls of existing homes?
  – Comfort => certainly
  – Energy => yes
  – Moisture => probably
  – Indoor Air Quality => with caution

• How should we insulate existing basement walls?
  – It’s a system.
  – It depends!
Basement Insulation: Opportunities

• Foundation heat loss can be significant in existing buildings.

• While below grade temperature differences might be smaller,
  – the surface area can be fairly large
  – the above grade portion can be large, especially in older homes.

• There are a lot of uninsulated foundations in cold climates.
Basement Insulation: Obstacles

- Most existing foundations lack
  - waterproofing and/or
  - capillary break.
- In cold climates,
  - the top of the foundation is very cold in the winter,
  - the bottom of the foundation can be below the dewpoint in summer.
- Foundations get wet from all four sides by all four moisture transport mechanisms
  - bulk water, capillarity, diffusion, and air flow,
- The foundation wall must dry inward; interior insulation generally limits this drying potential.
Foundation Insulation for Existing Homes

- Challenges of adding insulation to existing foundation walls, especially on the interior ...
  - We have limited experimental data sets.
  - Existing modeling tools are crude and poorly validated.
  - Existing material properties and boundary conditions are highly variable and unknown, so we must focus on ...
    - developing a liquid water management approach,
    - balancing R-value and vapor diffusion characteristics,
    - evaluating safe moisture storage,
    - identifying risk and risk tolerance.
Perception of Risk

• Which surfaces or layers can be:
  – Saturated?
  – Frozen?
  – Moldy?
Foundation Insulation Solution Sets

• Option 1: Customized Approach
  – Based on a holistic assessment of:
    • site conditions,
    • basement conditions,
    • foundation construction details, and
    • interior conditions.

• Option 2: Universal Approach
  – Do we have one-size fits all designs?
Foundation Insulation Solution Sets

• Universal Approaches
  – Existing wall is likely liquid water active
    • No exterior water proofing or capillary break
    • Signs of water staining and efflorescence
    • Most CMU

  – Existing wall is not liquid water active
    • Good waterproofing and capillary break
    • Very dry soil and site conditions
Foundation Insulation Solutions
Walls That Are Liquid Water Active

• Exterior options
  – Most will work very well
  – Rarely will increase risks
  – Can mitigate bulk water issues

• Interior options
  – Generally more risky
  – Will likely require a water separation plane
Foundation Insulation Solutions (water active; exterior)

Source: Oak Ridge National Laboratory
Foundation Insulation Solutions
(water active; interior)

Source: Building Science Corporation
Foundation Insulation Solutions
(water active; interior)

Source: Building Science Corporation
Foundation Insulation Solutions
Walls That Are Not Liquid Water Active

• Exterior options are pretty much wide open
  – Partial insulation-only options are viable

• Interior options improve
  – Generally requires a semi-impermeable insulation
  – but must be airtight and limit exterior wetting
Foundation Insulation Solutions
(not water active; interior)
Foundation Insulation Solutions
(not water active; interior)

Source: Building Science Corporation
Foundation Insulation Caution

• Basement Renovation Touches It All
  – Combustion safety
  – Foundation moisture
  – Radon (& other soil gases)
  – Biologicals (mold, dust mites, etc.)
  – Garage gases (if attached)
• And front and center are uncontrolled...
  – negative pressures in basements
  – below grade moisture transport
Foundation Insulation Caution

• If a Basement Floods ... 
  – Floor coverings must be removed to facilitate clean-up and improve drying.
  – Interior insulation systems must be fully removed because they are contaminated and retard drying.
  – From field experience, exterior foam plastic insulation systems appear to recover with little deterioration in performance.
Building America: 2011-12 Project
Innovative Exterior Retrofit Options

• Exploration of methods to insulate the exterior of existing homes.
  – Identify novel approaches that could be used
  – Investigate means and methods
  – Determine how many homes would be conducive to each approach
The Ins and Outs of the Outside Approach

- Exterior foundation insulation confers multiple hygrothermal benefits
- Missing moisture control can be added, or importance is diminished, because the wall is warm and can dry readily to interior.
- Typical exterior approaches are costly, destructive, and disruptive.
- A cost-competitive, minimally-invasive technique is needed!
Technical Approach

• To find an “excavationless” exterior foundation insulation upgrade that is ...
  – cost-competitive with current methods and
  – has minimal impact to existing site/landscape features.

• Identify potential technologies, costs, and savings
  – Identify promising means and materials.
  – Interviews with industry representatives to establish suitability, along with cost estimates.
  – Analysis of base costs for traditional insulation upgrades.
  – BEOpt analysis to establish energy savings potential.
Recommended Guidance

- Cut a narrow slot trench using air/hydro-vac
- Backfill with one of three potential materials:
  - 4” pourable polyurethane (R-26)
  - 6” cellular concrete (R-9 to R-11)
  - 6” perlite aggregate concrete (R-9 to R-11)
- Above-grade foundation and insulation
  - application of rigid insulation is one possibility
- Potential for moisture mitigation
  - add waterproofing membranes prior to installation
  - using “hygrophobic” admixtures for cementitious or foam materials.
Cost Comparison Table *

<table>
<thead>
<tr>
<th>Product</th>
<th>Insulation Type</th>
<th>Total R-value (h ft² °F/Btu)</th>
<th>Material Cost</th>
<th>Labor Cost</th>
<th>Excavation Technology</th>
<th>Excavation Cost</th>
<th>Total Cost</th>
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</thead>
<tbody>
<tr>
<td>Rigid mineral wool</td>
<td>Rigid board</td>
<td>10 (2.38” thick)</td>
<td>$689</td>
<td>$3198</td>
<td>Traditional power shovel</td>
<td>$2920</td>
<td>$6807</td>
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<tr>
<td>Extruded polystyrene</td>
<td>Rigid board</td>
<td>10 (2” thick)</td>
<td>$630</td>
<td>$3198</td>
<td>Traditional power shovel</td>
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<td>$6748</td>
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<tr>
<td>Expanded polystyrene</td>
<td>Rigid board</td>
<td>8 (2” thick)</td>
<td>$336</td>
<td>$3198</td>
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<tr>
<td>Cellular concrete</td>
<td>Cast in place</td>
<td>9 (6” thick)</td>
<td>$3000</td>
<td>included</td>
<td>Hydro-vac</td>
<td>$2600</td>
<td>$5600</td>
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<tr>
<td>Perlite Concrete</td>
<td>Cast in place</td>
<td>11 (6” thick)</td>
<td>$3529</td>
<td>included</td>
<td>Hydro-vac</td>
<td>$2600</td>
<td>$6129</td>
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<tr>
<td>Polyurethane foam</td>
<td>Cast in place</td>
<td>26 (4” thick)</td>
<td>$3360</td>
<td>included</td>
<td>Hydro-vac</td>
<td>$2000</td>
<td>$5360</td>
</tr>
</tbody>
</table>

* Cost does not include landscaping remediation, which will likely be higher for “traditional” methods
“Excavationless” Pros

- Exterior insulation can be forgiving of existing defects.
- Vacuum excavation methods reduce landscape impact.
- Many landscape features (walks, stoops, decks, etc.) can remain in place with vacuum excavation.
- Process can be quick (2 to 3 days for a simple home).
- Pourable insulation materials can be made relatively waterproof, potentially reducing bulk water intrusion.
- Cost competitive with, and likely cheaper than, current methods of exterior insulation upgrades.
“Excavationless” Cons

• Method does not address moisture loading from sources such as capillarity from the footing or through the slab.

• More expensive than typical interior insulation methods – though most of these increase risk of moisture problems.

• Long-term thermal properties of materials are unknown – potential for moisture accumulation within pore spaces may cause thermal degradation.

• Large obstructions (patio slabs, sidewalks) may need to be sawcut to the trench width or removed and replaced.

• Extent of waterproofing ability, and durability of that solution are not well-characterized.
Market Potential

- Survey selected neighborhoods to evaluate constructability issues
  - House constraints
    - steps, stoops & porches
    - attached garage
    - sidewalks & landscaping
    - cantilevers
  - Access issues
    - equipment limitations
Market Potential
Market Potential
“Excavationless” Summary

• Foundation insulation has a significant energy impact
  – and perhaps more importantly large comfort benefits.
• Exterior insulation confers many hygrothermal benefits
  – compared to typical interior approaches.
• Homeowners who understand these benefits currently choose exterior insulation upgrades
  – despite the inconvenience, cost, and landscape damage.
• Technologies evaluated are in current use in other sectors.
• Estimates indicate the method is cost competitive
  – with current exterior insulation upgrade methods and
  – replacement of landscape features was not included.
Building America: 2013-14 Project
Innovative Exterior Retrofit Options

• Further investigation of means and methods
  – Comparison of available equipment/techniques
  – Continue material down selection and optimization

• Field demonstration and proof of concept
  – Address common accessibility issues
  – Identify critical process steps
  – Improve cost estimates
Building America: 2012-13 Project
Innovative Retrofit Options for CMU

• Exploration of novel methods to insulate hollow concrete masonry block foundations.
  – Using existing models
  – To determine energy/hygrothermal benefits
  – Investigate means and methods to insulate cores
  – Estimate cost factors
Innovative Retrofit Options for CMU

- CMU is prevalent in this market
  - Especially for older homes
  - Frequently shows moisture activity
  - Open core top is common

- Convective looping contributes to
  - Increased energy loss,
  - Reduced interior surface temperature, and
  - Hygric redistribution.
Innovative Retrofit Options for CMU

- Focus on core fill (or partial core fill)
  - Identify hygrophobic insulating material (or material with potential for safe storage)
    - pourable
    - sprayable
  - Determine potential installation processes

- Compatibility with other techniques
Innovative Retrofit Options for CMU

• Core Fill Benefits
  – Improved comfort
  – Condensation control
  – Energy savings
  – Reduced latent load

• Enable future add-ons
  – Exterior top of wall only
  – Interior whole or partial wall
Building America Resources

• Excavationless Exterior Foundation Insulation

• Hybrid Foundation Insulation Retrofit

• High R-Value Foundations

• Basement Insulation Guide
World Class Research…

… at Your Fingertips

Building America
Solution Center

JUST RELEASED!

http://basc.pnnl.gov
Foundation Insulation for Existing Homes

• Questions?

• Contact Information
  – Patrick H. Huelman
  – 203 Kaufert Lab; 2004 Folwell Ave.
  – St. Paul, MN 55108
  – 612-624-1286
  – phuelman@umn.edu