Innovative Foundation Wall Exterior Insulation Retrofit – “Excavationless”
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Rolf Jacobson, LEED AP
Skandia Design & Consulting
University of Minnesota, NorthernSTAR
Excavationless Research Team –
Tom Schirber, U of M
Garrett Mosiman, U of M
Cindy Ojczyk, Simply Green Design

Industry Partners –
Cocoon
BASF
American Environmental
Urban Homeworx
Outline

1) Building science background – moisture & foundation walls
2) Standard insulation retrofit approaches
3) The “excavationless” approach
Building Science Background

Look familiar?
Building Science Background

1) The outside soil is wet
2) Concrete is hygroscopic, therefore concrete is typically wet
3) Basement air is typically drier
Building Science Background

1) The outside soil is wet
2) Concrete is hygroscopic, therefore concrete is typically wet
3) Basement air is typically drier

Historical solution – “dry to the inside”

And – don’t live in the basement!
Building Science Background

Is it advisable to insulate and/or occupy a basement like this?
Building Science Background

Should we insulate basement and crawlspace walls of existing homes?

- Energy => yes (and necessary for Passive House retrofit)
- Comfort => certainly
- Moisture => maybe – depends on many things
- Indoor Air Quality => with caution
- Cost savings => in some cases
Building Science Background

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Probably necessary to understand more about the building science and options available before this question can be answered.
Building Science Background

1) Groundwater
2) Moisture of construction
3) Capillary rise
4) Condensation
5) Diffusion

Disregard insulation layer in diagrams
Building Science Background

1) Groundwater
2) Moisture of construction
3) Capillary rise
4) Condensation
5) Diffusion

Each one of these pathways can be affected by placement of insulation.
Building Science Background

Diffusion – it’s complicated!

Moisture drive varies with season. Far below grade, moisture drive is always inward. Above grade and slightly below grade, moisture drive flops back and forth depending on temp and RH conditions.
Diffusion – it’s complicated!

Moisture drive varies with season. Far below grade, moisture drive is always inward. Above grade and slightly below grade, moisture drive flops back and forth depending on temp and RH conditions.

Where does the vapor retarder go?

![Diagram showing moisture movement in different seasons](Image from Building Science Corp)
Building Science Background

Basement Wall Insulation Retrofit Challenges:

• Foundations get wet from all four sides by all four moisture transport mechanisms: bulk water, capillarity, diffusion, and air flow
• Most existing foundations lack such basics as:
  1) intact waterproofing
  2) capillary break between footing and foundation wall
• In cold climates:
  1) top of the foundation wall is very cold in the winter with outward vapor drive, but simultaneously...
  2) bottom of the wall is relatively warm with an inward vapor drive
• Stack effect means basement wall and floor slab are under negative pressure. Air leakage at cracks becomes a source of radon gas.
Building Science Background

Basement Wall Insulation Retrofit Options:

- Exterior
- Interior
- Within (T-mass)
- Interior + exterior (ICF)
Building Science Background

Basement Wall Insulation Retrofit Options:

- **exterior**
- **interior**

**a**

**b**

NA for retrofit within (T-mass)

**c**

**d**

NA for retrofit

interior + exterior (ICF)
No insulation:
• Interior wall surface is cold (approx 55°F) and may be wet, but can dry freely to the inside.
• Interior air in contact with the wall primarily dries the wall, rarely leads to condensation, but that depends on interior RH.
Building Science Background

Interior insulation retrofit:
• Interior wall surface is warmed (approx 70°F) but concrete wall is chilled.
• Interior air that comes in contact with the concrete often leads to condensation.
• Reduced heat leads to wetter concrete, which can no longer dry freely to the interior.
• If an interior vapor retarder is installed, drying is further limited.
• Exterior drainage and possible water leakage paths are not addressed.
Building Science Background

Exterior insulation retrofit:
- Entire concrete wall is warmed (approx 70°F).
- Interior air that comes in contact with the concrete does not lead to condensation.
- Wall can dry freely to the interior, and increased heat aids drying.
- Exterior drainage and possible water leakage paths can be addressed.
- Saturated soil (100% RH) is kept out of direct contact with hygroscopic concrete.
- Wetting pathways not addressed (such as capillary rise) are less damaging.
<table>
<thead>
<tr>
<th>Interior insulation retrofit</th>
<th>Exterior insulation retrofit</th>
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<tbody>
<tr>
<td>• Energy =&gt; improved</td>
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<td>• Comfort =&gt; improved</td>
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<td>• IAQ =&gt; increased risk</td>
<td>• IAQ =&gt; likely decreased risk</td>
</tr>
<tr>
<td>• Cost payback =&gt; in many cases</td>
<td>• Cost payback =&gt; no payback due to high initial cost</td>
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In addition, for passive house cases, basement floor space considerably reduced

In addition, exterior insulation disrupts landscaping and could require considerable reconstruction for attached structures such as porches and garages
Insulation Retrofit Approaches

What if we could get the energy, comfort, and hygrothermal benefits provided by exterior insulation, with very minimal disruption to the exterior AND significantly reduce the cost of an exterior insulation retrofit?
The Excavationless Approach

“Excavationless” is a combination of two existing, mature technologies:

1) Hydrovac excavation – developed by utilities
2) below grade polyurethane foam – available from BASF, NCFI, others
NorthernSTAR and team partners have completed 2 excavationless projects to date, with 4 more scheduled for the remainder of the year.

A Building America field study report based on the first project has passed peer review at the DOE and is days away from publishing. Search “NorthernSTAR excavationless” for more info.

The following pictures are from the first field test, performed by Cocoon and American Environmental at a Minneapolis single family home rehab project owned by Urban Homeworks, a low income housing developer.
Rehab test house owned by Urban Homeworks
Vacuum excavator truck, American Environmental, 12 yard capacity
Truck has a pivoting, telescoping boom and can suck debris through 400’ long, 8” diameter hose – eliminates need to drive on the site.
Excavators work in pairs – high pressure washer pushes slurry towards vacuum

High pressure washer (3000 psi) rented from Home Depot provides same pressure but uses 1/5 the water (3 gallons/minute) expands tank capacity of truck.
Incision next to the foundation can be made as narrow as 4”, or as wide as desired to achieve proper foam thickness for desired R-value.
High pressure washer easily excavates around pipes without damaging them.
Rocks as large as 6” can be removed through the vacuum, larger ones can be lifted out using suction from the hose.
Cave-ins are the biggest problem, but are simply excavated wider. (Winter excavation with frozen soil would actually work better by limiting cave-ins.)
In many cases, attached porches or other structures can be “tunneled” under, although there is a maximum tunnel length of about 12 feet.
The entire foundation of this house was excavated in one day.
Below grade, trench wall and foundation act as the formwork for the liquid polyurethane. (Liquid application was achieved simply by turning off the compressor that typically supplies high pressure for the spray foam applicator.)
Foam is a hydrophobic, closed cell polyurethane developed by BASF specifically for below grade applications and ground contact. R-5/inch
At cave-ins, a sheet of plywood covered with poly is placed to provide formwork. Poly acts as a slip sheet so plywood can be removed after foam sets.
Transition at grade is handled using rigid foam. The rigid provides formwork and finish surface for stucco parge coat.
Gap between rigid foam and rim joist is then filled with the same pourable foam.
Foam expands to create a continuous air, water, and vapor seal from the footing to the top of the rim joist.
Some bowing occurred with 2x2s at 16” on center and 1.5” XPS. Thicker rigid insulation, closer spacing, or additional support such as a temporary plywood sheet is recommended.
Above grade detail

- Sheathing
- House wrap WRB
- Exterior insulation
- Flashing or peel & stick membrane
- 2x2 furring
- Peel & stick membrane
- Rigid foam
- Stucco parging coat or protection board
Benefit for Passive House construction:

Continuous exterior insulation layers on foundation wall and above grade wall are aligned ->

Reduced thermal bridging at rim joist.
Finished look following stucco parge coat and metal flashing.

The above and below grade insulation and formwork was completed on the 2\textsuperscript{nd} day of the retrofit.
## The Excavationless Approach - Value

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<th>Retrofit Approach</th>
<th>Insulation Type</th>
<th>Nominal Wall R Value</th>
<th>Material Cost</th>
<th>Labor cost</th>
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<td>3&quot; XPS (full depth)</td>
<td>R-15</td>
<td>$960 for XPS ($0.42/bd ft.) + $833 for water barrier</td>
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<td>2) Full depth &quot;Excavationless&quot; with cast in place foam and XPS above grade (AG) for formwork</td>
<td>4” cast-in-place foam (full depth) + 1.5” XPS above grade</td>
<td>R-20 (avg)</td>
<td>$4,224 BG ($1.50/bd ft.) + $698 for XPS and cast-in-place foam AG included</td>
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* Cost does not include landscaping remediation, which will likely be higher for “traditional” methods

(model is 36’ X 28’ foundation, 2’ exposed above grade, plus rim)
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Actual cost reduction: 14%

Potential cost reduction: 50%

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The Excavationless Approach

Advantages

1) Seals the exterior foundation wall against water and air penetration.
2) Creates vapor retarder in proper location to control inward vapor drive at wall bottom, variable vapor drive at wall top
3) Exterior insulation warms the concrete wall, adding drying capacity, eliminating interior condensation, and improving occupant comfort.
4) Exterior insulation aligns with above grade wall exterior insulation to minimize thermal bridging at the rim joist.
5) Minimizes disruption to landscape and demolition of attached structures often necessary with other means of excavation.
6) Potential to reduce cost of an exterior insulation retrofit by 50%.
The Excavationless Approach

Disadvantages

1) Capillary moisture rising from footing is not addressed.
2) Large attached obstructions greater than 12’ still need to be removed or saw cut.
3) Costs are still higher than interior insulation approaches (although IAQ and durability benefits of exterior insulation are probably worth it).
The Excavationless Approach

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1) Capillary moisture rising from footing is not addressed.
2) Large attached obstructions greater than 12’ still need to be removed or saw cut.
3) Costs are still higher than interior insulation approaches (although IAQ and durability benefits of exterior insulation are probably worth it).
4) Greatest unanswered question: long-term performance and durability of polyurethane foam below grade. Also, environmental impact of ccSPF.

Can it resist moisture and maintain enough structural integrity to act as an air and water barrier while retaining its R-value?

Some other options include cast-in-place cellular concrete, perlite concrete...