Upgrading Below Grade Spaces

Residential Energy Efficiency Stakeholder
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Patrick H. Huelman, Sam Breidenbach, Steve Schirber

NorthernSTAR Building America Partnership

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A Building America partner in research, innovation, and real home solutions.

- Act 1: Technical Challenges & Opportunities
  - Pat Huelman, University of Minnesota
- Act 2: Assessing Homeowner Priorities & Risks
  - Sam Breidenbach, TDS Custom Construction
- Act 3: An Industry Perspective
  - Steve Schirber, Cocoon

Act 1. Upgrade Below Grade

- Basement Remodeling: It Doesn't Get Any Riskier!
  - 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 (beyond stack)
  - below grade moisture transport (liquid & vapor)

Big, Bad, Boogie Men in the Basement

- Carpet on the slab
- Insulating the walls (from the interior)
- Egress windows
- Furnace change-out
- Ductwork changes
  - drywalling the ceiling
  - rim (or extended) joists to the garage
- Adding a hot tub or sauna

The Problem Isn't New

"Changes and new developments in building construction during the past few decades have brought about an increasing need for control of moisture which often migrates upward from the ground."

William A. Russell, Chief of Technical Standards

Housing and Home Finance Agency, 1954

Basement Moisture Challenge

- Foundations get wet from three sides by all four moisture transport mechanisms.
  - bulk water, capillarity, diffusion, and air flow
- Foundations can only dry to the inside.
  - generally by diffusion only
- That means you must keep it dry from all sides.
  - or come up with an approach that promotes inward drying better than outward wetting.

Challenges of Basement Insulation

- Arguably the most challenging component of the building enclosure!
  - The physics is simple, but demanding
    - It starts out damp and cold and goes downhill from there, especially with interior insulation.
  - A road less traveled
    - There is a serious lack of good and useful below-grade hygrothermal models and experimental data is limited.
  - Occupancy and expectations have changed
    - Basement use and finishing has increased dramatically.

Basement Insulation Background

What we want!

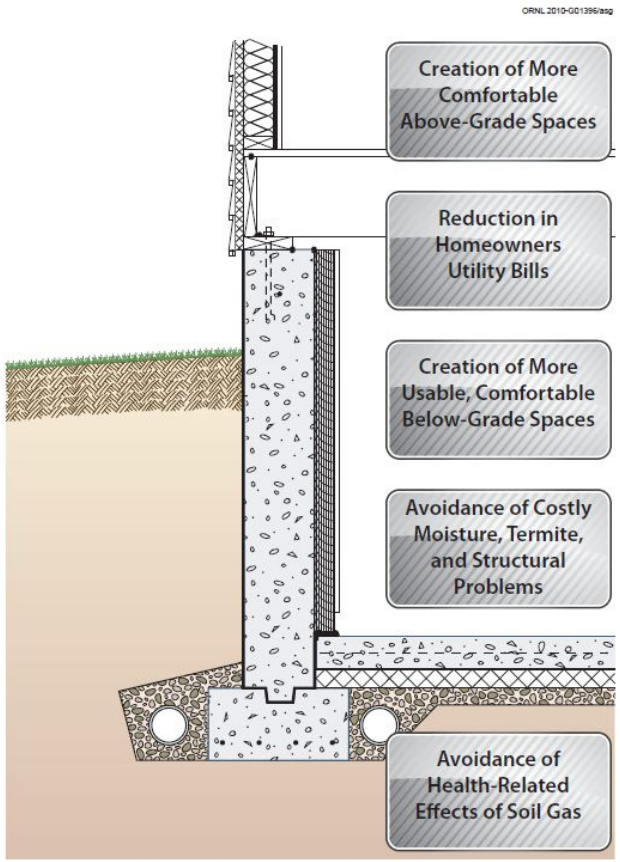


Figure 1-2: Benefits of Foundation Insulation and Other Design Improvements

Source: Oak Ridge National Laboratory

Basement Insulation Background

What we have – large 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 is quite significant, especially in older homes.
- There are a lot of uninsulated foundations in cold climates.

Basement Insulation Background

What we get – big obstacles!

- Most existing foundations do not have waterproofing and capillary break at the footing.
- When you insulate the interior
  - the top of the wall is extremely cold in the winter and
  - the bottom can be below the dew point in the summer.

- The foundation wall must dry inward; therefore interior insulation generally limits drying potential.

Basement Insulation Background

Heat Flow Fundamentals

- Below grade heat loss is always out.
  - winter heat loss is highest at the top and gets progressively less as depth increases
  - summer heat loss is higher at the bottom
    - colder soil conditions & footing connection
- However, the above grade portion has similar issues to other above grade construction.
  - but not identical, due to vertical coupling

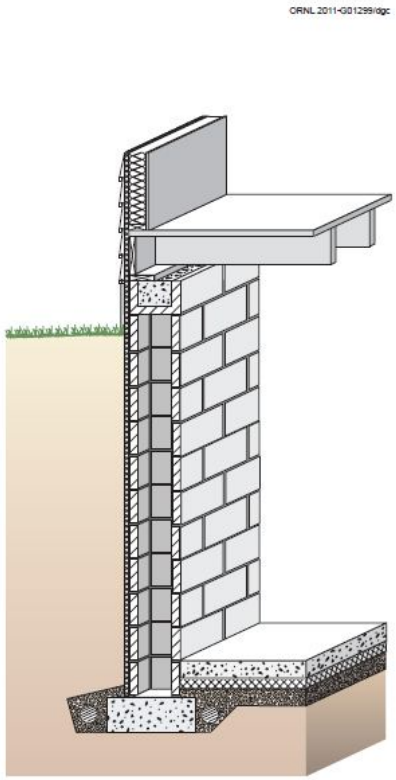


Figure 2-1: Concrete Masonry Basement Wall with Exterior Insulation

Source: Oak Ridge National Laboratory

Basement Insulation Background

Vapor Transport Fundamentals

- Below grade vapor flow is almost always inward.
  - will vary with soil temperature and interior conditions
- However, the above grade portion has similar issues to other above grade construction.
  - vertical coupling is huge, especially with concrete masonry blocks

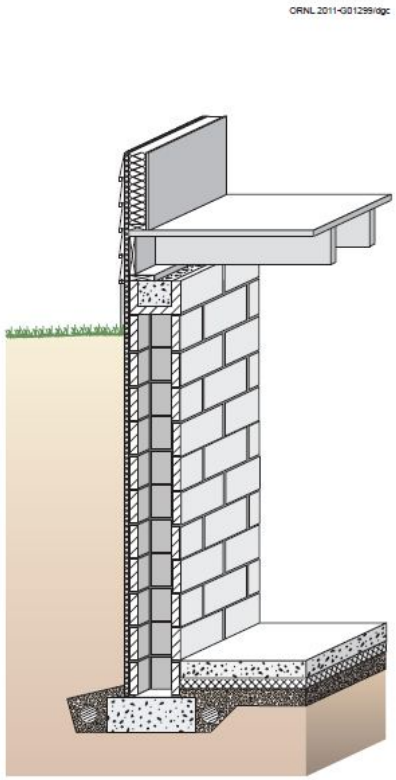


Figure 2-1: Concrete Masonry Basement Wall with Exterior Insulation

Source: Oak Ridge National Laboratory

Basement Insulation Background

Condensation Potential at Foundation Surface

- Without insulation
  - condensation is limited
- With exterior insulation
  - condensation is virtually nil
- With interior insulation …
  - condensation can occur at the top in the winter
  - condensation can occur at the bottom in the summer

Basement Insulation Background

Drying Potential of Foundation Wall

- Without insulation
  - heat and moisture move freely
- With exterior insulation
  - drying to the inside is strong
- With interior insulation
  - outward warming and interior drying is severely limited

A Reality Check

A Reality Check

A Reality Check

Foundation Insulation for Existing Homes

- Exterior insulation is almost always preferable
- If interior insulation is used
  - should have a very dry foundation
    - quality dampproofing in very dry, free-draining soils
    - waterproofing in moderate soils
    - waterproofing and drainage in tight, wet soils
  - should have a capillary break
  - should have an interior air barrier
  - should have basement dehumidification

Foundation Insulation for Existing Homes

- Challenges of adding interior insulation on existing foundation walls
  - Existing material properties and boundary conditions are highly variable and unknown, so we need to focus on …
    - development of an water separation plane
    - balancing R-value and vapor diffusion characteristics
    - evaluate safe moisture storage.

Foundation Insulation Alternatives

High Cost & Low Risk

- Add exterior waterproofing, drainage & insulation
  - ideally would go to footing
  - however, 3’ or 4’ below grade could work in some cases
- Lack of capillary break at footing may be tolerable
  - it can dry to the interior

Source: Oak Ridge National Laboratory

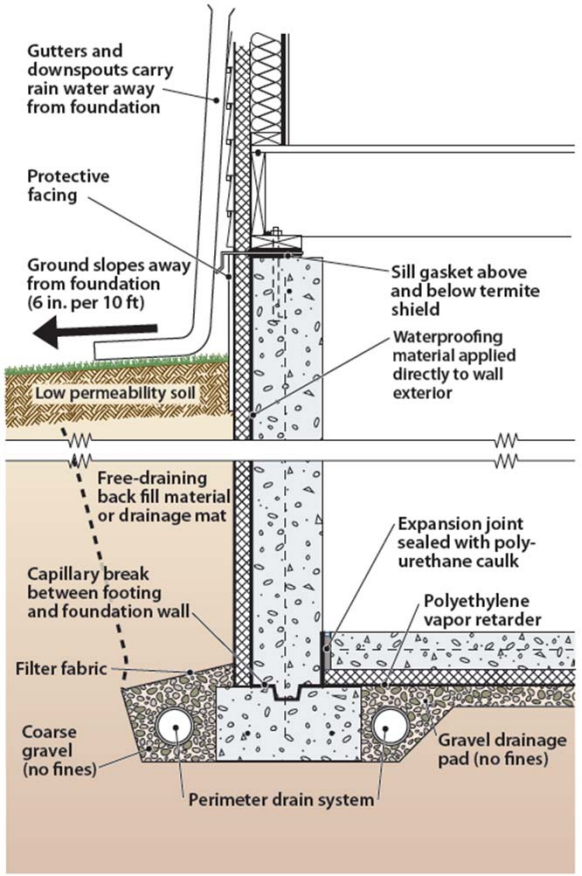


Figure 2-3: Components of Basement Drainage and Waterproofing System

Foundation Insulation Alternatives

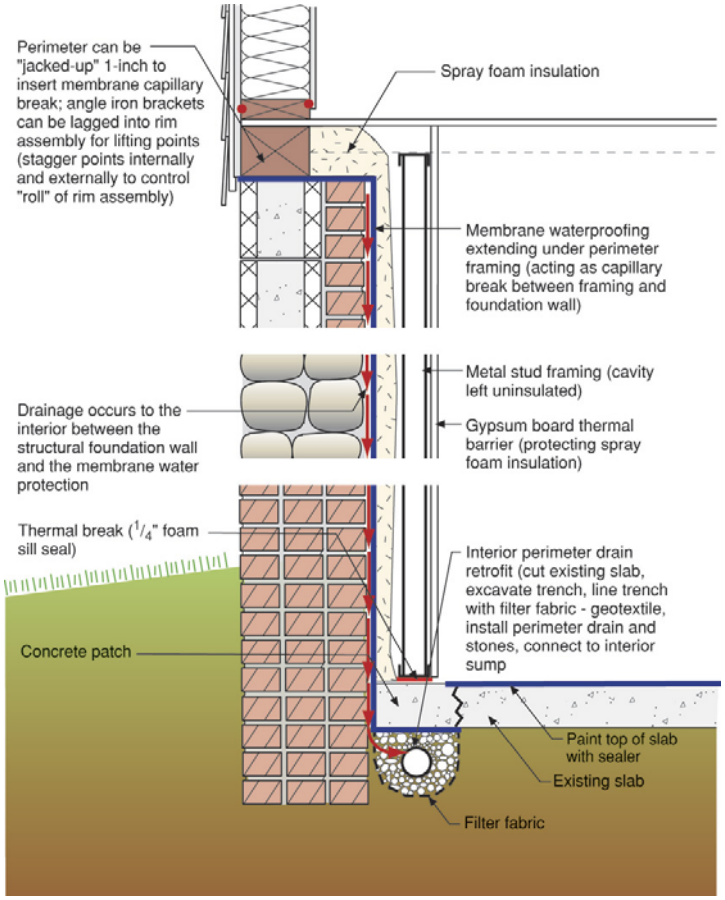
Low Cost & High Risk

- Frame wall with air permeable, vapor permeable insulation system
  - vapor retarder is probably needed on both sides
  - air barrier is critical
  - very limited drying potential
  - moisture accumulation on foundation wall is likely

Foundation Insulation Alternatives

High Cost & Low Risk

- Barrier system w/ interior finishes
  - sealed interior liner with concealed drainage
    - and possibly active drying
  - use semi-permeable continuous insulation and appropriate interior finishes



Source: Building Science Corporation

Foundation Insulation Alternatives

Moderate Cost & ??? Risk

- Air impermeable insulation with permeable finishes
  - low R-value, semi-permeable, airtight foam
  - aggressive interior humidity control may be desirable

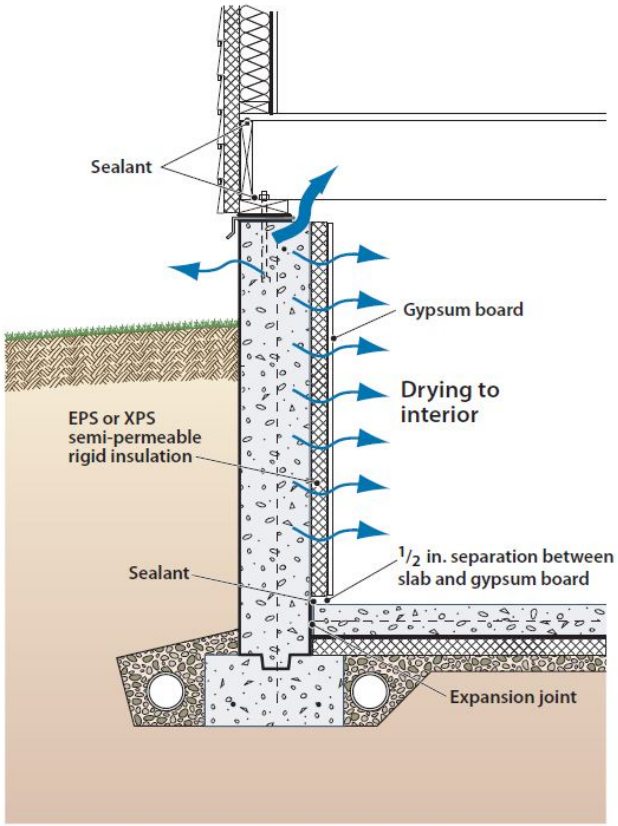


Figure 2-7: Basement Interior Insulation with EPS or XPS Semi-permeable Insulation on Inside Wall

Source: Oak Ridge National Laboratory

Foundation Insulation Alternatives

A Frequently Forgotten Risk

- For interior systems, if the 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

- Field experience suggests that exterior foam insulation systems appear to recover with little deterioration in performance

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Exterior Retrofit Options

- Largest impediment to an exterior approach appears to be the cost and hassle of excavation.

- In 2011, we launched an exploration of methods to insulate the exterior of existing homes
  - identify alternative approaches that could be used
  - investigate means, methods, and materials
  - determine how many homes would be conducive to each approach

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Exterior Retrofit Options – Possible Approaches

- Full depth insulation
  - with waterproofing & drainage
  - without waterproofing
- Partial depth
  - with waterproofing
  - without waterproofing
- Upper foundation
  - without waterproofing

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Exterior Retrofit Options – Means & Methods

- Equipment and techniques
  - narrow trenching
  - vibratory knife
  - air or water blade with vacuum
- Evaluate insulation formulations
  - installation
  - properties
  - durability

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Exterior Retrofit Options – Potential Market

- Survey of selected neighborhoods to evaluate constructability issues
- Evaluating constraints
  - steps, stoops & porches
  - attached garage
  - sidewalks & landscaping
  - cantilevers
- Addressing access issues
  - equipment limitations

Foundation Insulation Systems
Technical Gaps & Barriers

- Below grade heat transfer models are both crude and cumbersome, especially for deep basements.
  - U of MN w/ ORNL & NREL are working the problem
- The are currently no validated and user-friendly below grade hygrothermal models in the U.S.
  - ORNL will be doing work in this area for FY-2012
- Boundary conditions are not well characterized, especially for existing homes.

Foundation Insulation Systems
Market Gaps & Barriers

- Most homeowners and many contractors don't recognize the risks associated with basement remodeling, especially with interior insulation.
- Is uncontrolled dampness and mold growth behind interior insulation …
  - a building materials liability?
  - a building performance liability?
  - an indoor air quality liability?
  - a contractor liability?

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