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

Building America Technical Update
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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!

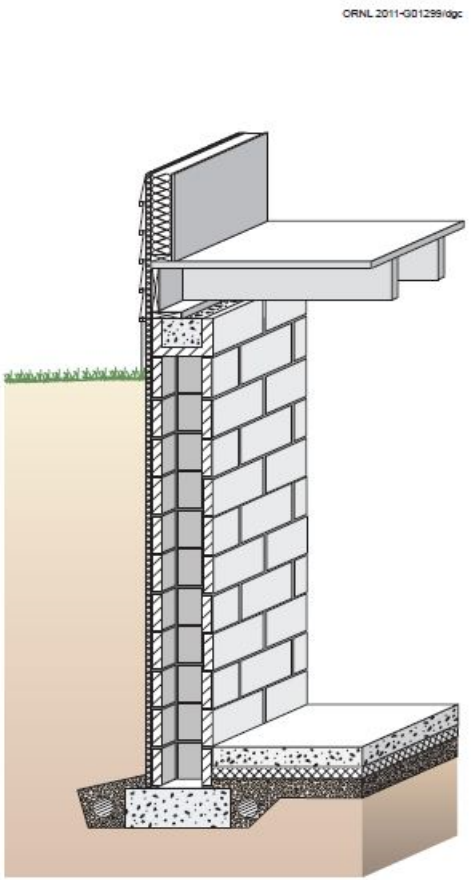
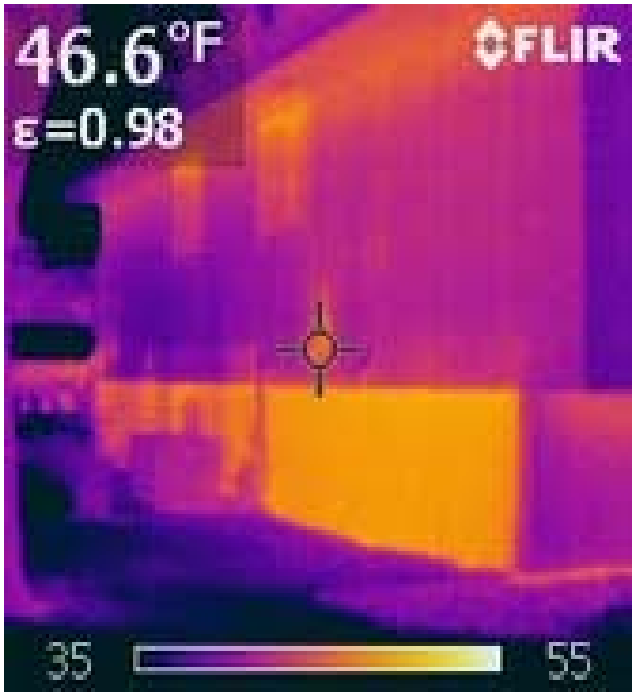


Figure 2-1: Concrete Masonry Basement Wall with Exterior Insulation

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.

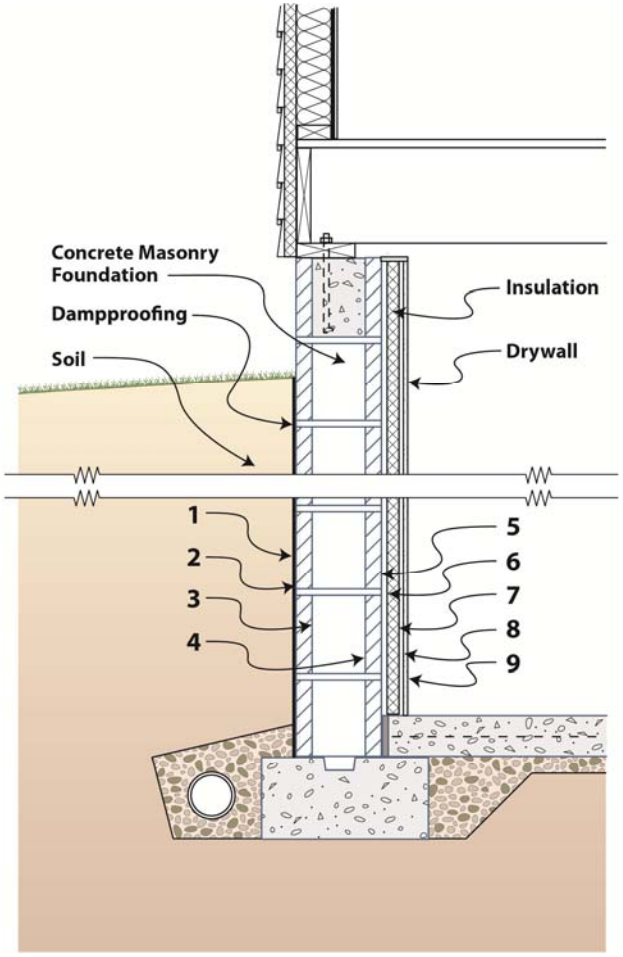
- Foundations get wet from all four sides by all four moisture transport mechanisms
  - bulk water, capillarity, diffusion, and air flow,
- The foundation wall must dry inward; interior insulation generally limits this drying potential.

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)

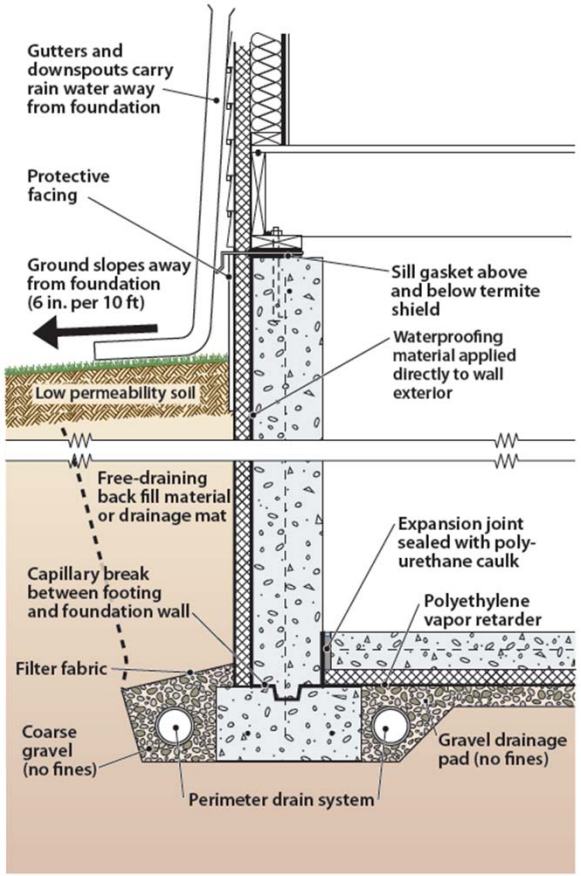
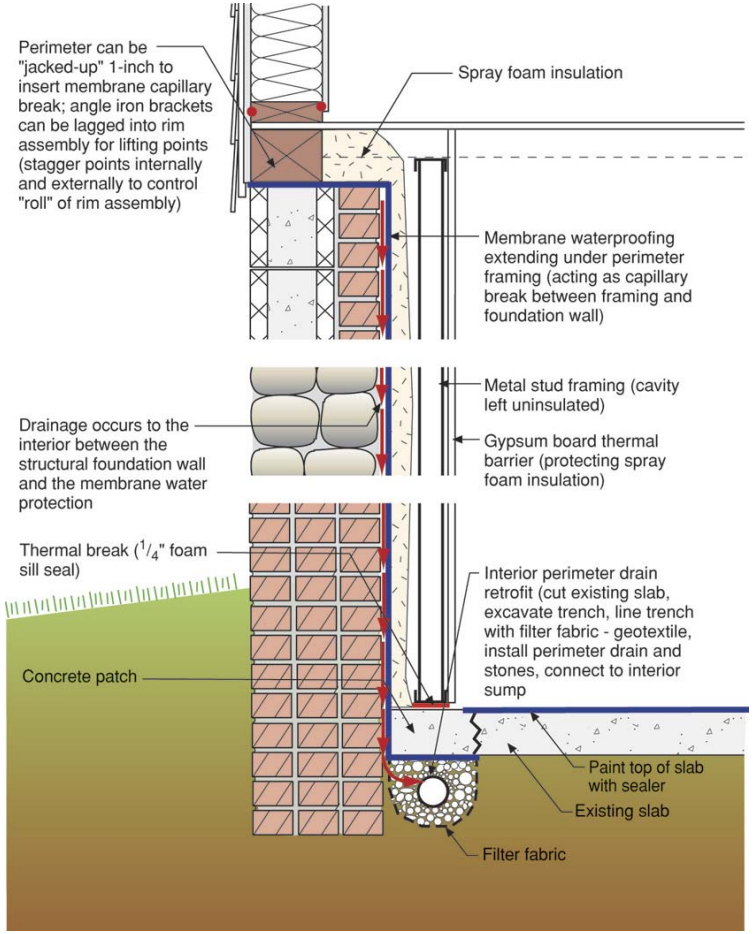


Figure 2-3: Components of Basement Drainage and Waterproofing System

Source: Oak Ridge National Laboratory

Foundation Insulation Solutions

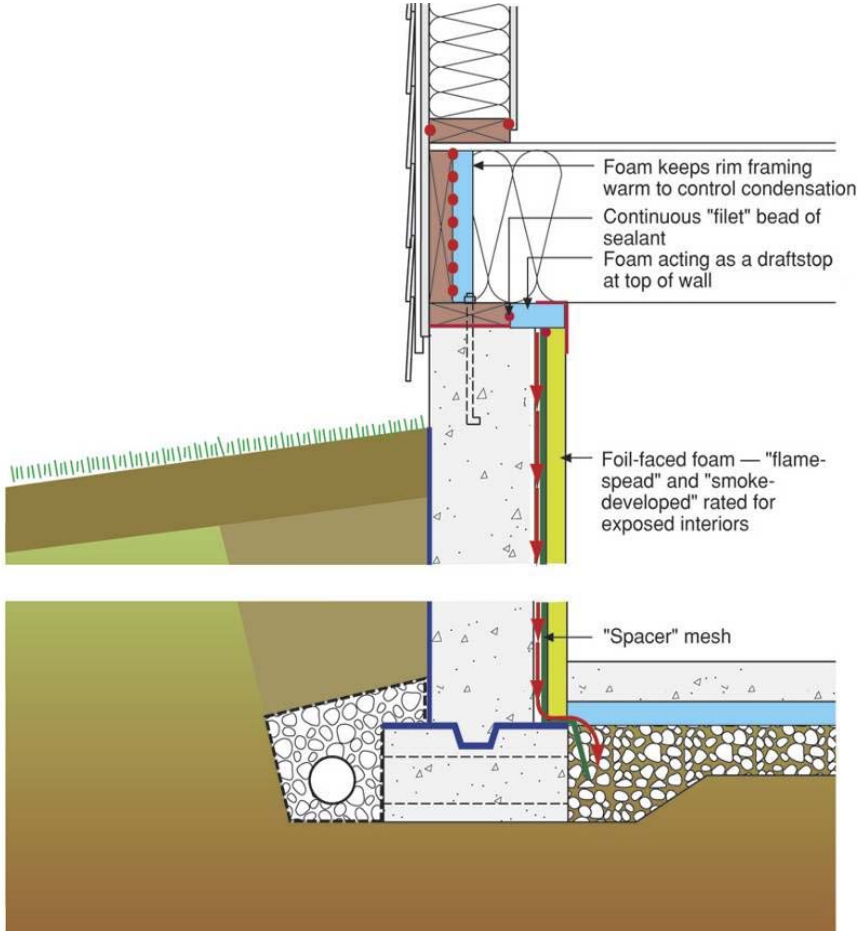
(water active; interior)



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)

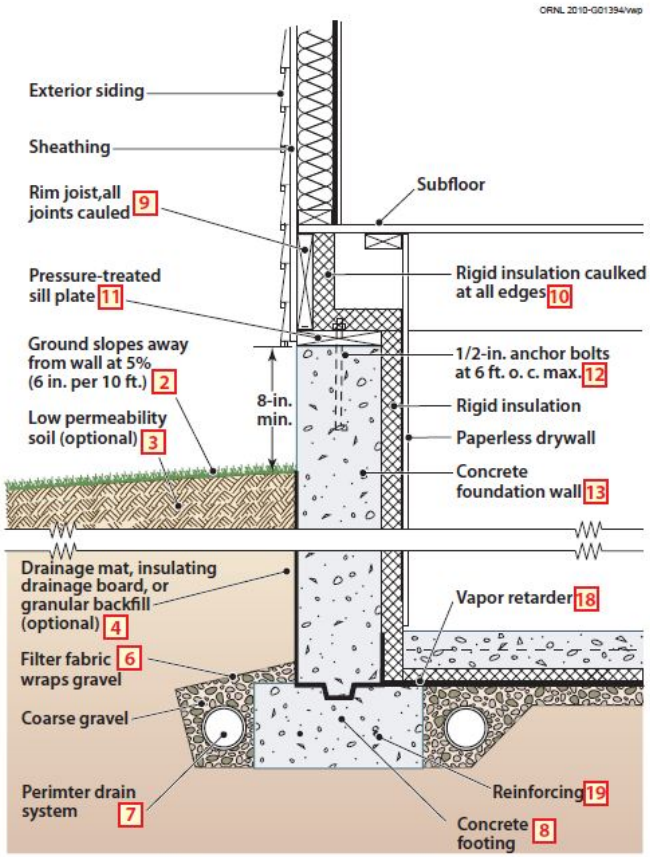
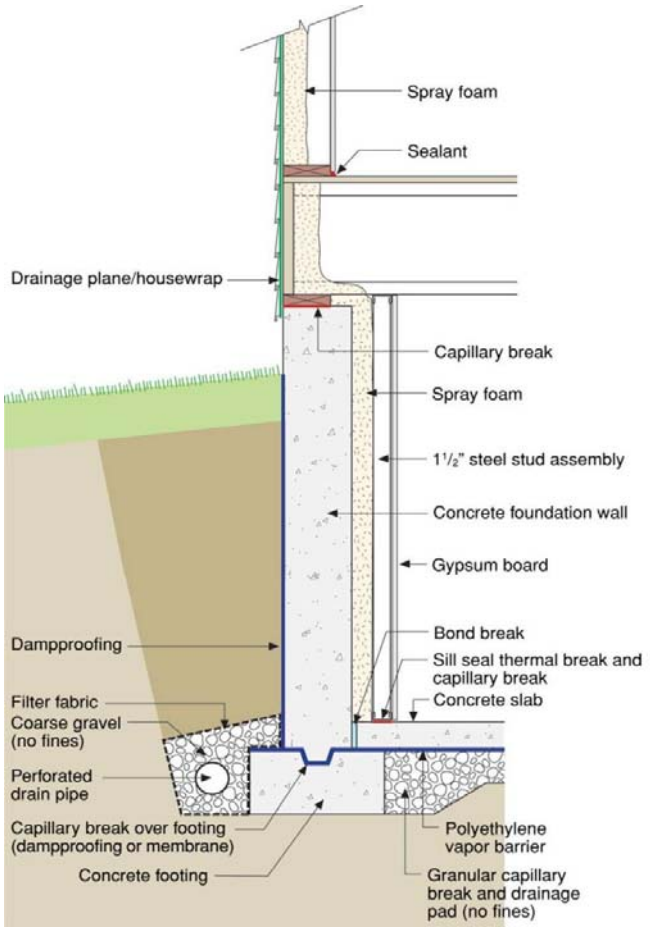


Figure 2-15: Basement Wall with Interior Insulation

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

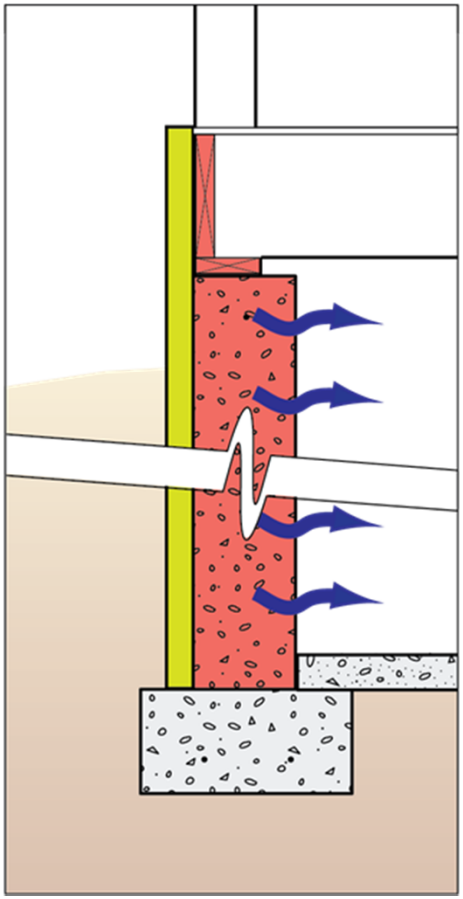
- If a Basement Floods …
  - Floor coverings must be removed to facilitate clean-up and improve drying.
  - Interior insulation systems must be fully removed because they are contaminated and retard drying.
  - From field experience, exterior foam plastic insulation systems appear to recover with little 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 *

Product	Insulation Type	Total R-value (h ft² °F/Btu)	Material cost	Labor cost	Excavation technology	Excavation cost	Total cost
Rigid mineral wool	Rigid board	10 (2.38" thick)	$689	$3198	Traditional power shovel	$2920	$6807
Extruded polystyrene	Rigid board	10 (2" thick)	$630	$3198	Traditional power shovel	$2920	$6748
Expanded polystyrene	Rigid board	8 (2" thick)	$336	$3198	Traditional power shovel	$2920	$6454
Cellular concrete	Cast in place	9 (6" thick)	$3000	included	Hydro-vac	$2600	$5600
Perlite Concrete	Cast in place	11 (6" thick)	$3529	included	Hydro-vac	$2600	$6129
Polyurethane foam	Cast in place	26 (4" thick)	$3360	included	Hydro-vac	$2000	$5360

* 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.

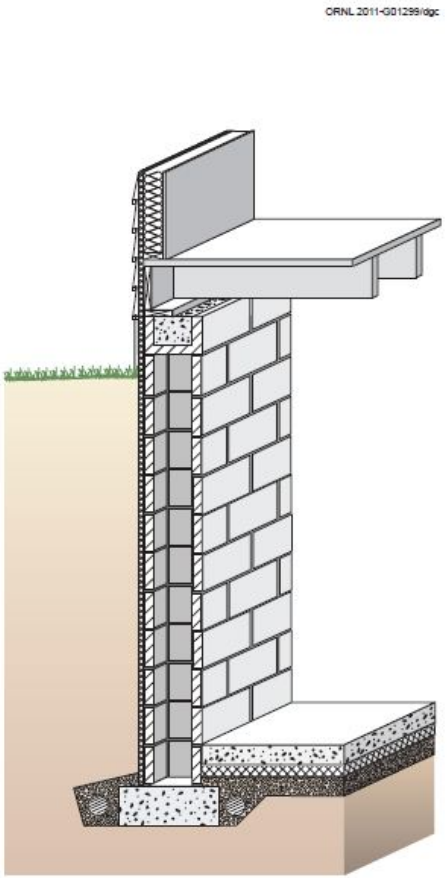


Figure 2-1: Concrete Masonry Basement Wall with Exterior Insulation

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
  - http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/excavationless_exterior_found.pdf
- Hybrid Foundation Insulation Retrofit
  - http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_hybrid_found.pdf
- High R-Value Foundations
  - http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/high-r_foundations_report.pdf
- Basement Insulation Guide
  - http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_basement_insul.pdf%20

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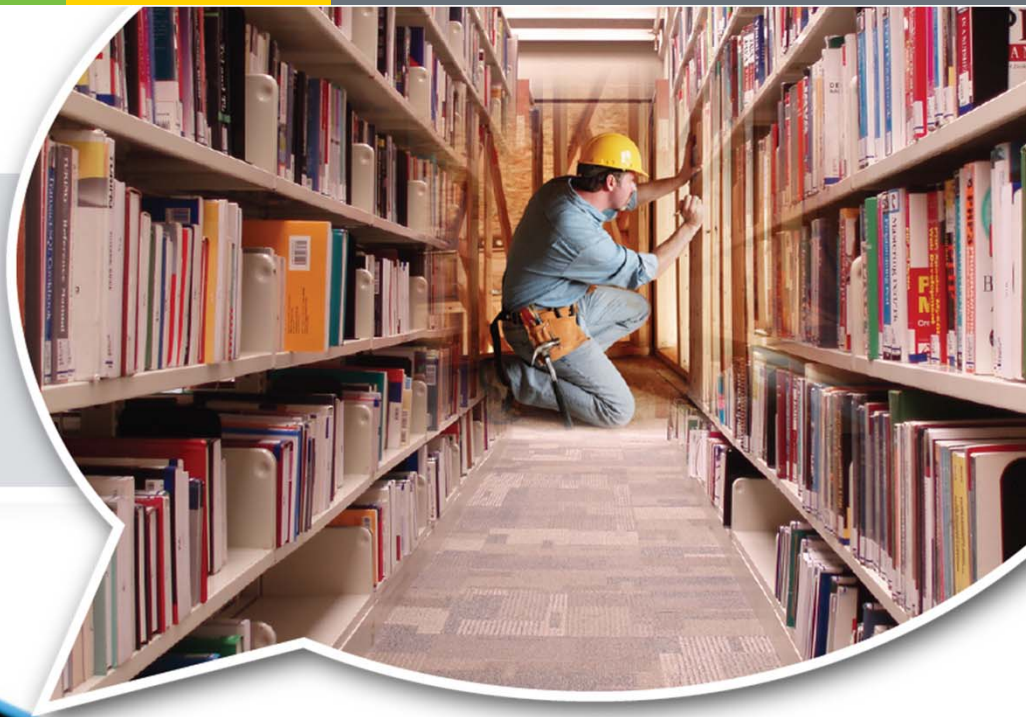

Building America Solution Center

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Foundation Insulation for Existing Homes

- Questions?

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