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Innovative Foundation Wall Exterior Insulation Retrofit – "Excavationless"

Steve Schirber, ThinkHouse
Rolf Jacobson, Skandia Design & Consulting
Building America NorthernSTAR Research Team, U of M

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Industry Research Teams

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Excavationless Research Team –

Tom Schirber, U of M

Garrett Mosiman, U of M

Cindy Ojczyk, Simply Green Design

Industry Partners –

Cocoon

BASF

American Environmental

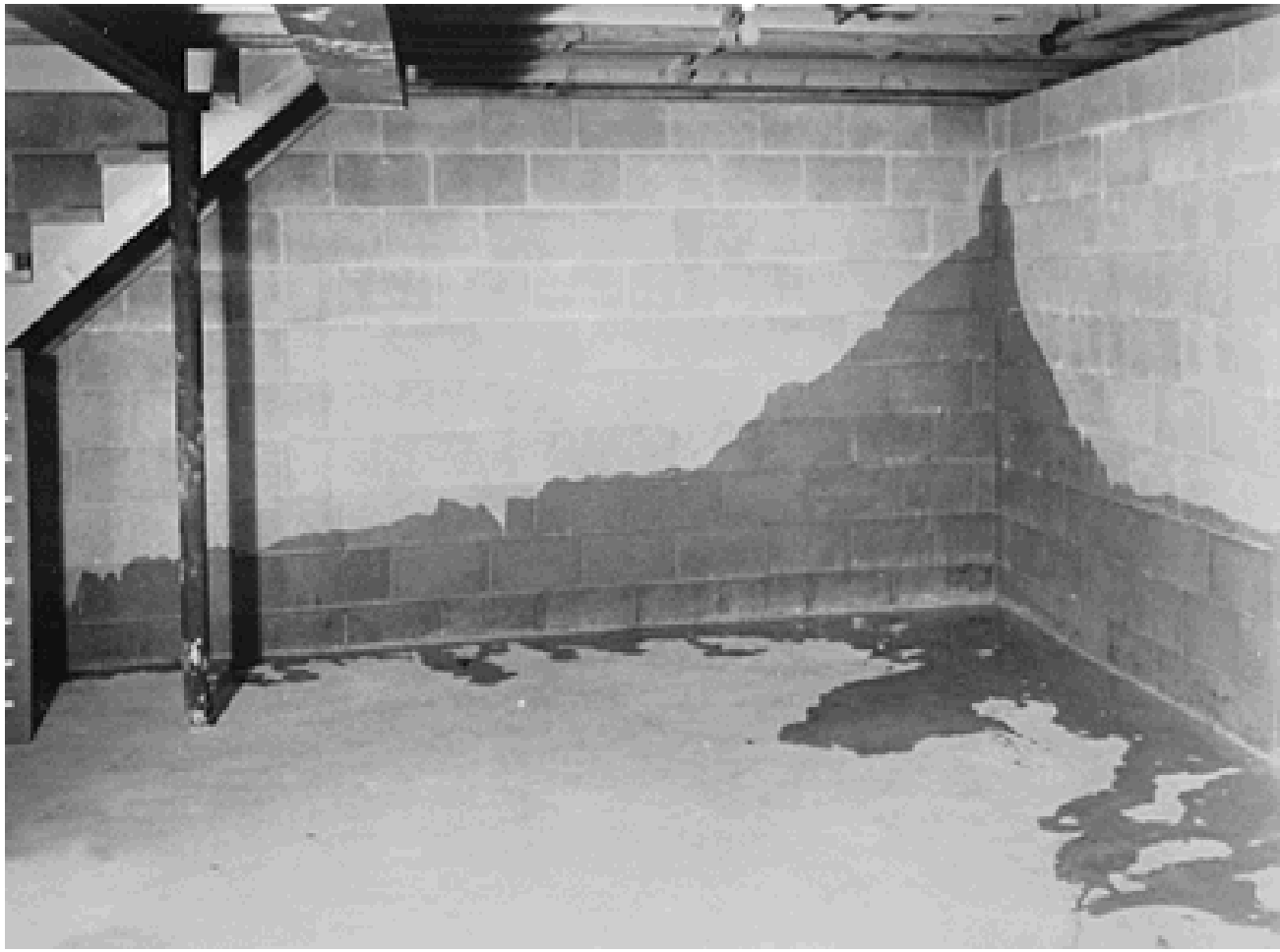
Urban Homeworks

Outline

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

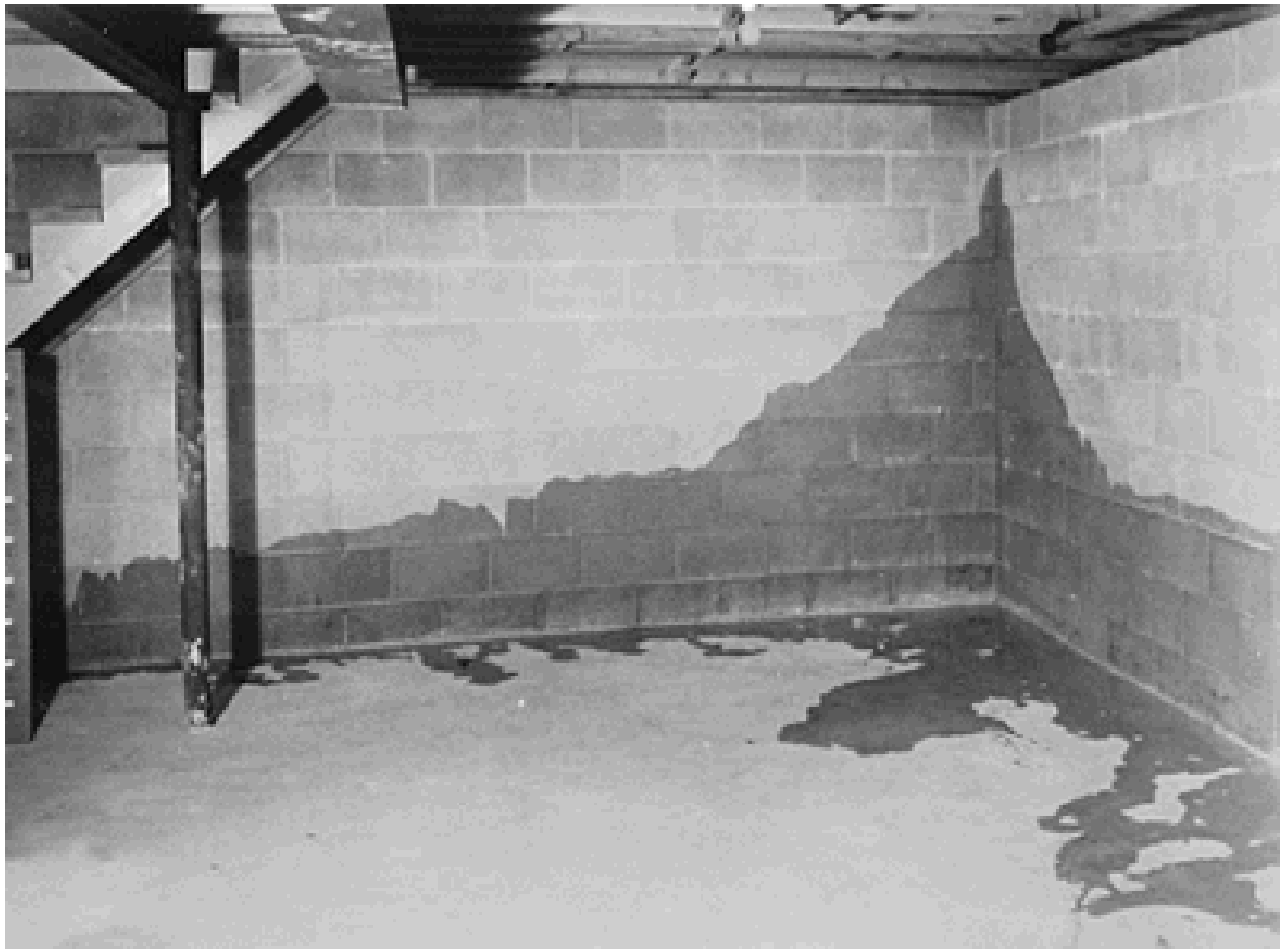
Building Science Background

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

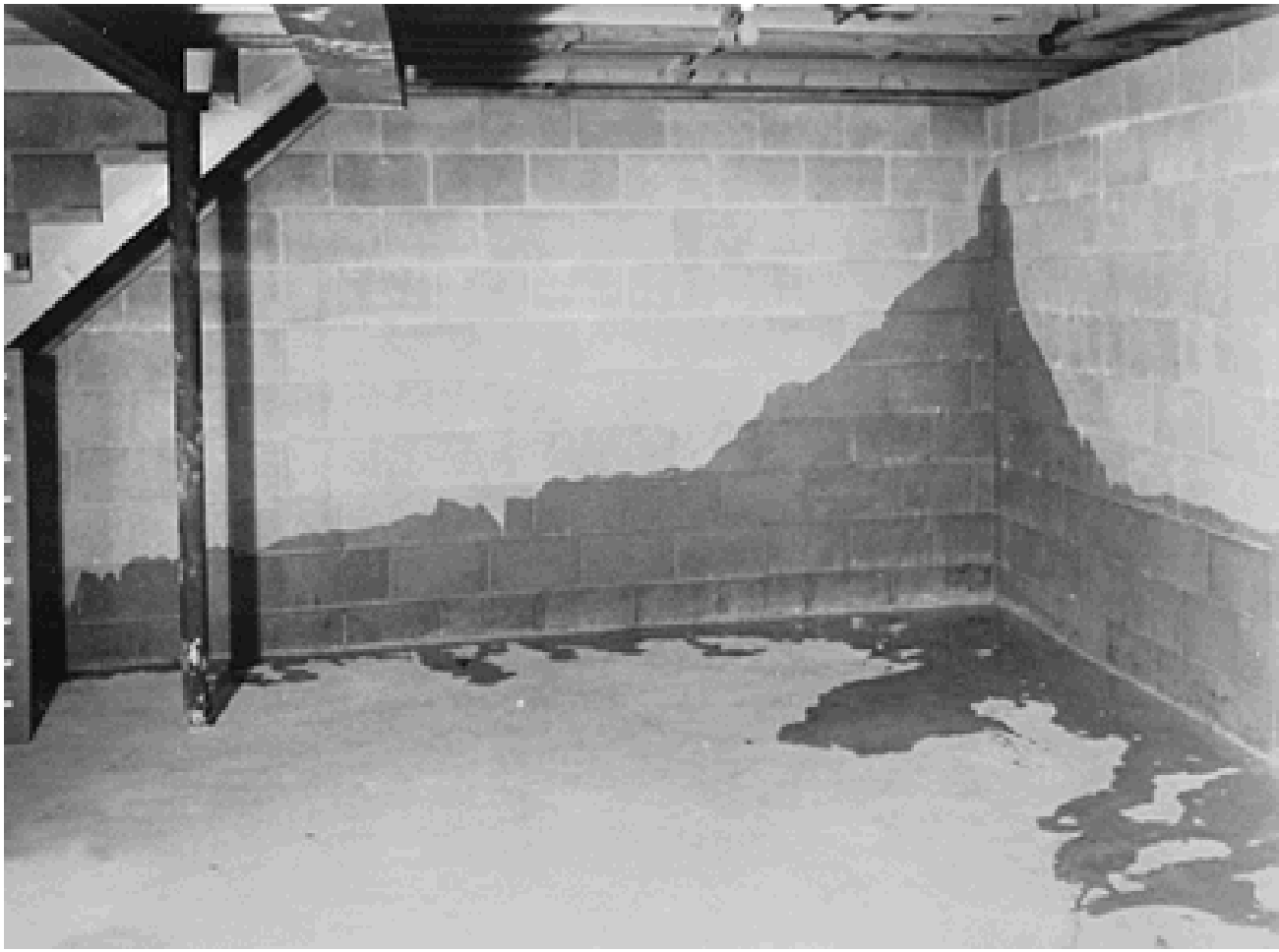


Building Science Background

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!



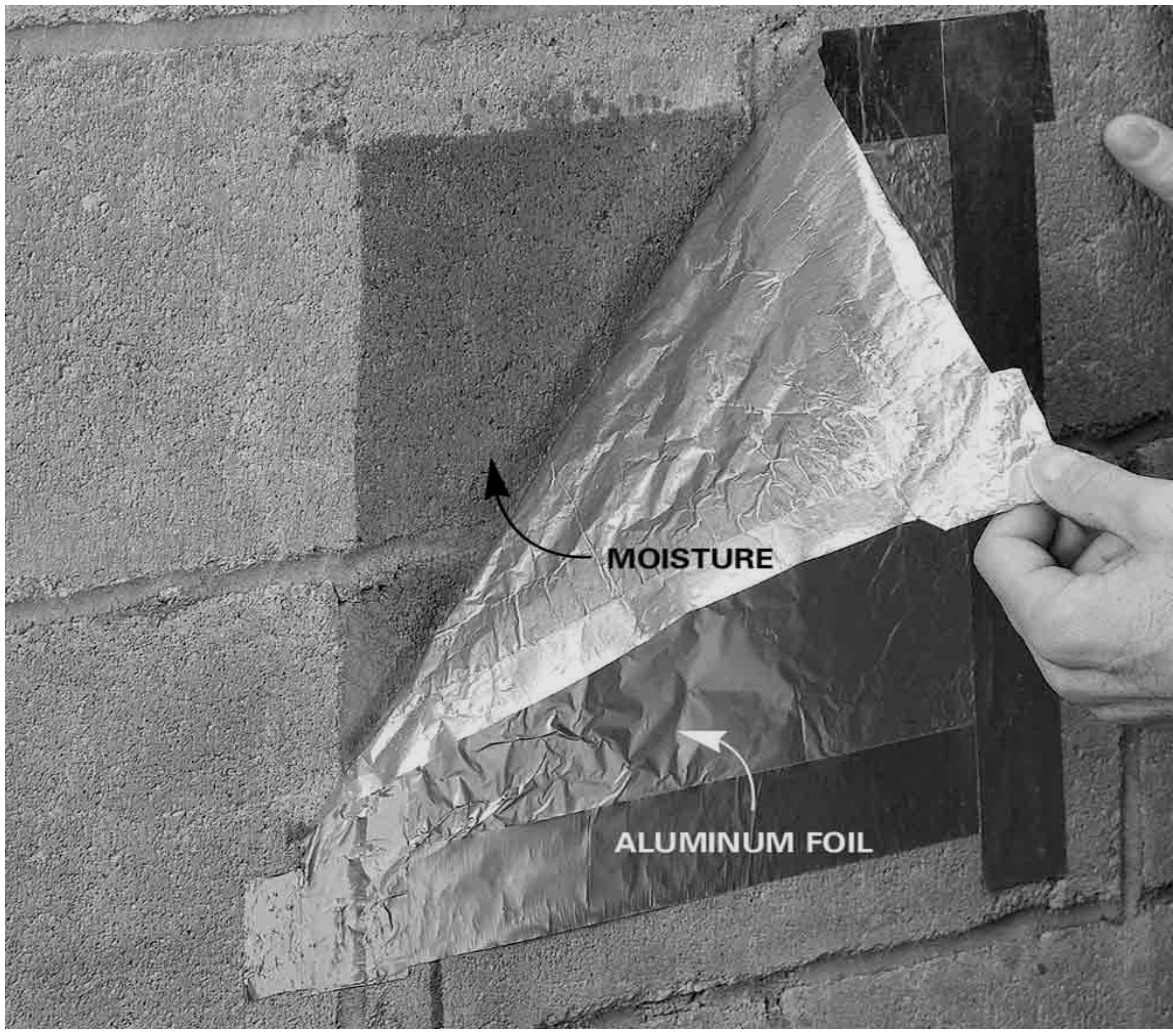
Building Science Background

Even a basement wall in good condition may only be “superficially dry”.

Building Science Background

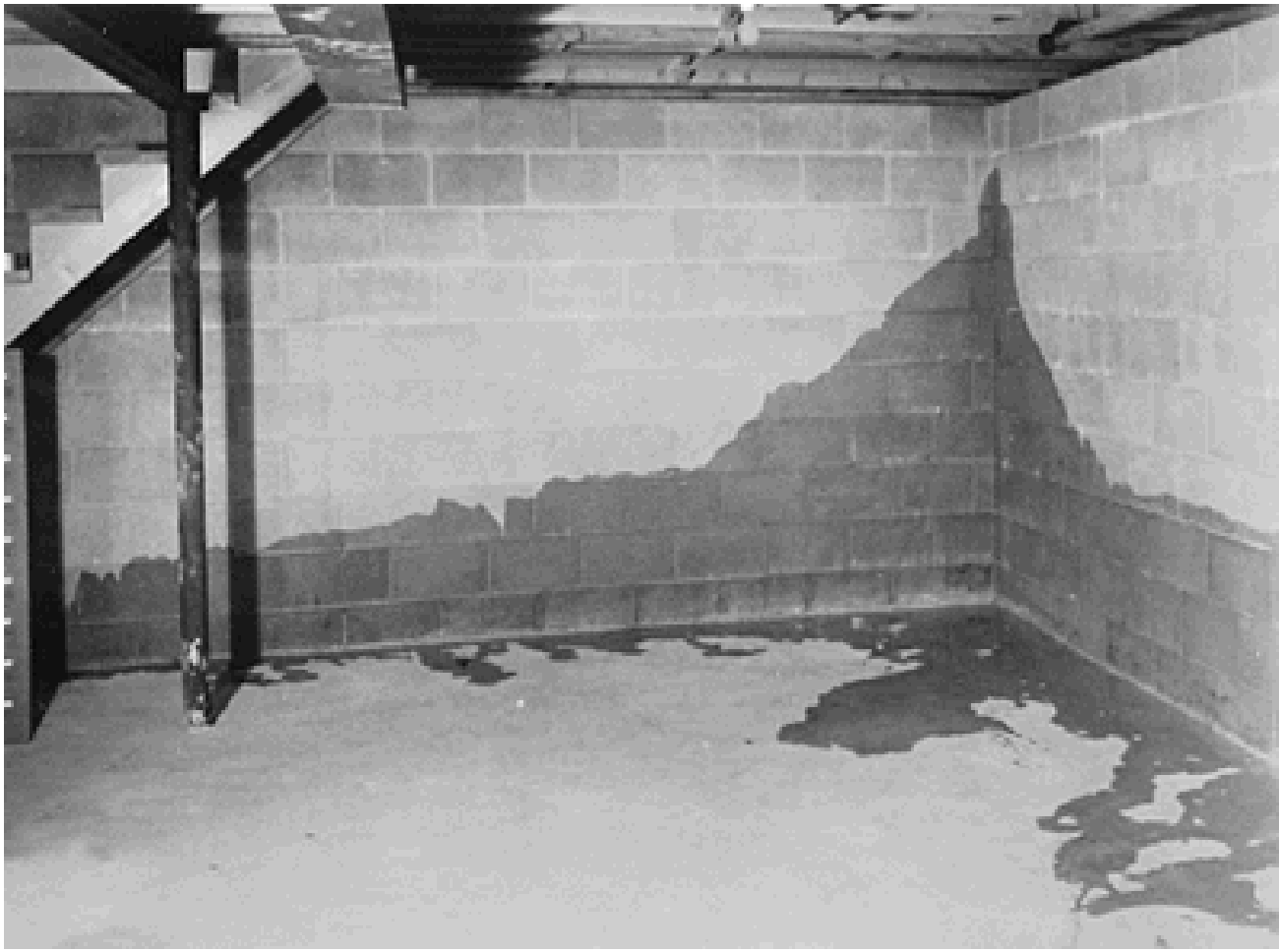
Even a basement wall in good condition may only be “superficially dry”.

It relies on constant exposure to warm temperatures and air flow to remain dry.



Building Science Background

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



Building Science Background

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

Or this?

Building Science Background

Should we insulate basement and crawlspace walls of existing homes?

- Energy => yes
- Comfort => certainly
- Moisture => maybe – depends on many things
- Indoor Air Quality => with caution
- Cost savings => in some cases

Building Science Background

Should we insulate basement and crawlspace walls of existing homes?

- Energy => yes
- Comfort => certainly
- Moisture => maybe – depends on many things
- Indoor Air Quality => with caution
- Cost savings => in some cases

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

Building Science Background

Should we insulate basement and crawlspace walls of existing homes?

- Energy => yes

  For an older home (R-9 walls, R-16 roof, R-2 windows),
  a complete R-10 foundation wall exterior insulation retrofit can reduce total home heat loss by 10 – 15%.

  That fraction increases as above grade envelope is improved.

  For a high performance house (R30-40 walls, R50-60 roof, R-4 windows) heat loss through an uninsulated basement accounts for more than 50% of total.

Building Science Background

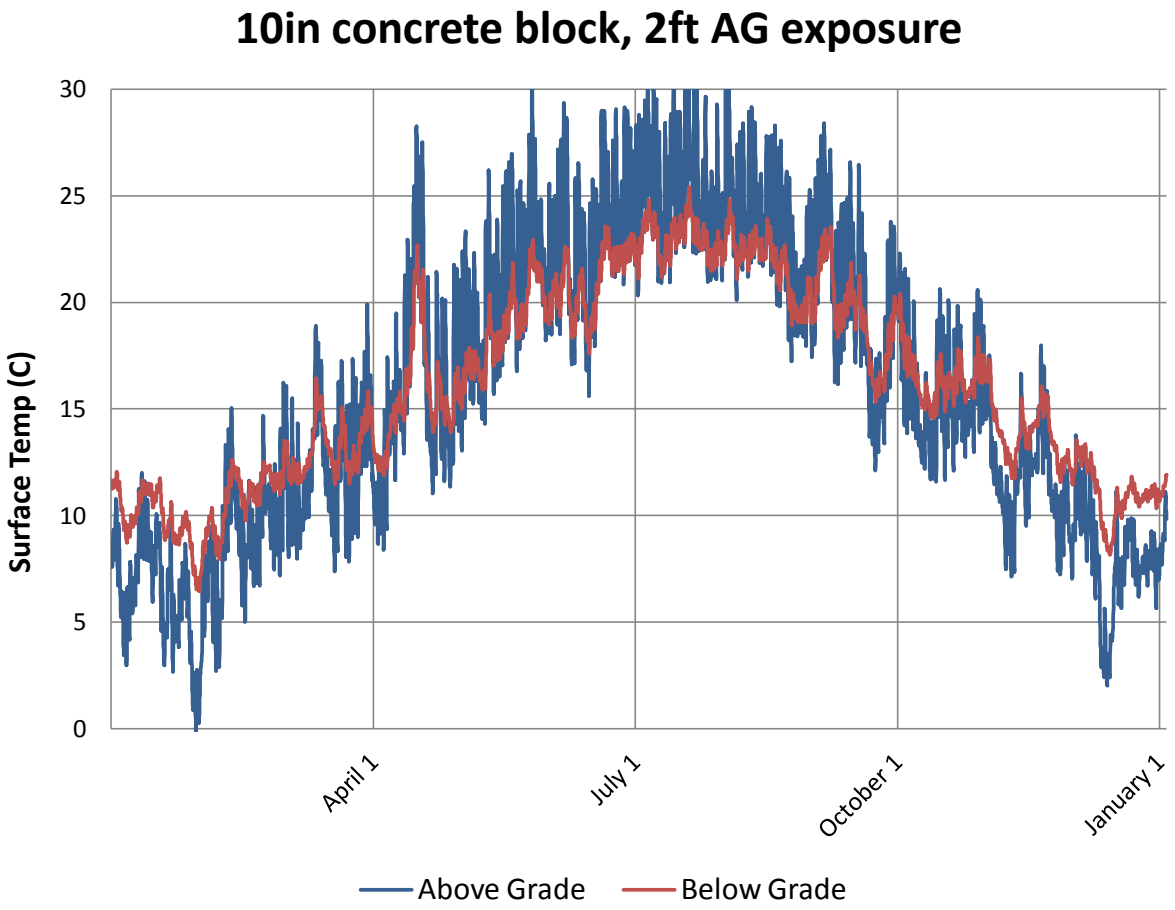
Should we insulate basement and crawlspace walls of existing homes?

- Comfort => Certainly

For a 10” concrete block basement wall with 2 foot above grade exposure:

Below grade interior surface temps average in low 50°s

Above grade interior surface temps average in upper 40°s (but occasionally drop to freezing!)



Building Science Background

Should we insulate basement and crawlspace walls of existing homes?

- Moisture => maybe

This is where things get complicated.

Building Science Background

1) Groundwater
2) Moisture of construction
3) Capillary rise
4) Condensation from interior air leakage
5) Diffusion

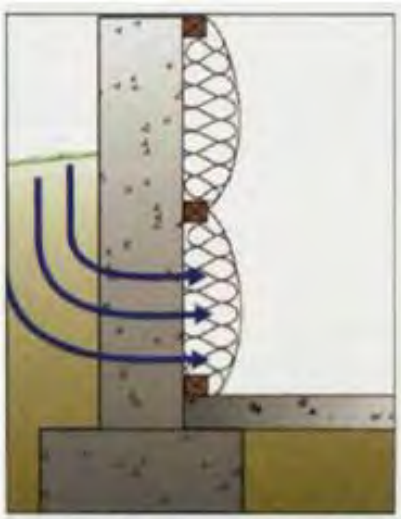


Figure 6: Groundwater entry:

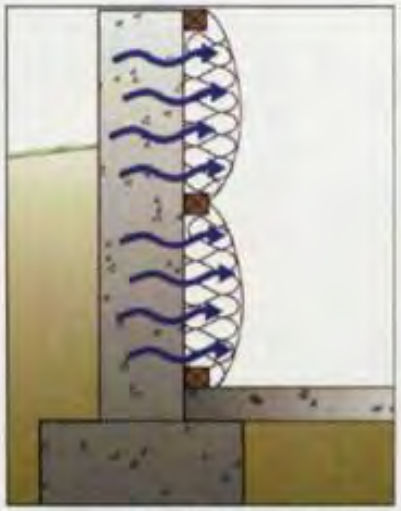


Figure 7: Moisture of construction:

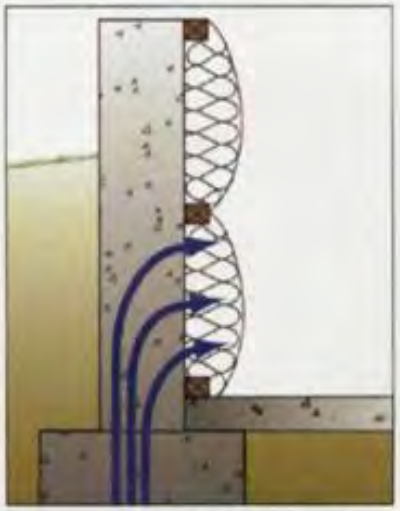


Figure 8: Capillary rise through footing:

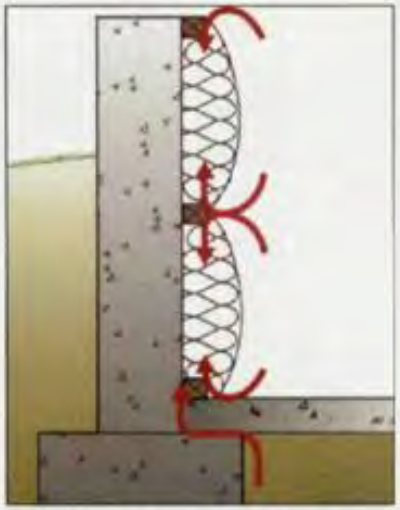


Figure 9: Condensation from interior air leakage:

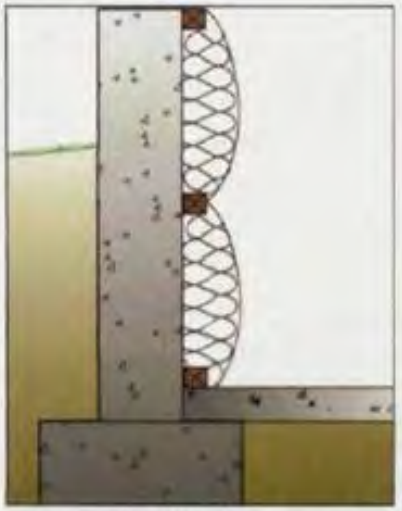


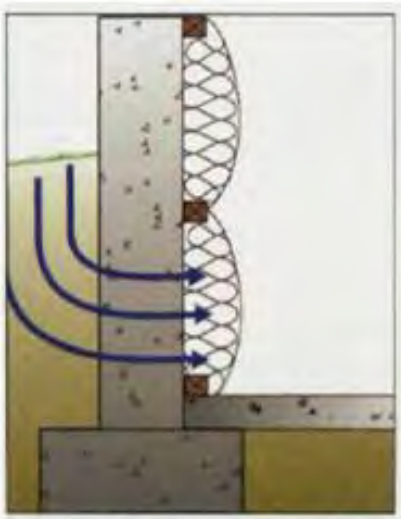
Figure 10: Diffusion

Image from Building Science Corp

Building Science Background

1) Groundwater
2) Moisture of construction
3) Capillary rise
4) Condensation from interior air leakage
5) Diffusion

Each one of these pathways can be affected by placement of insulation



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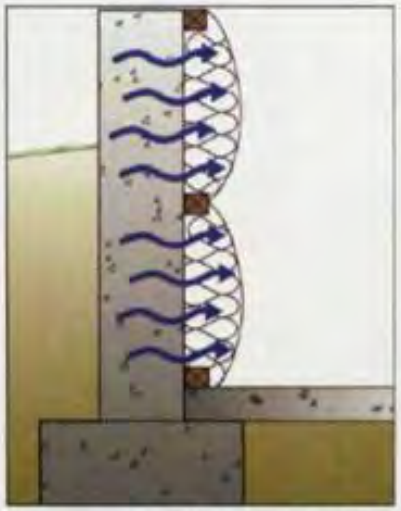

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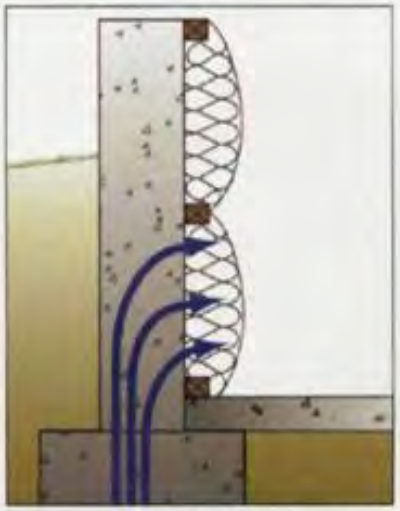

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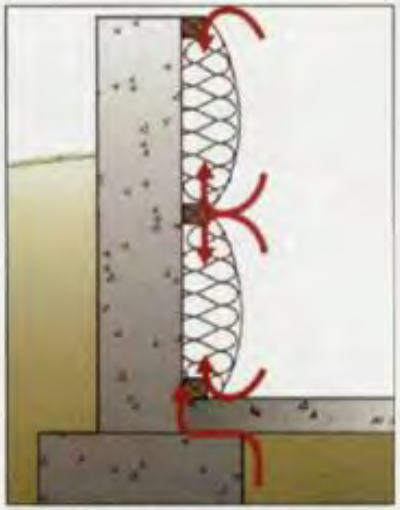

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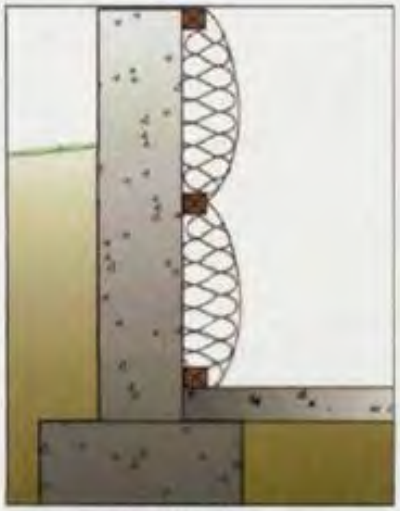


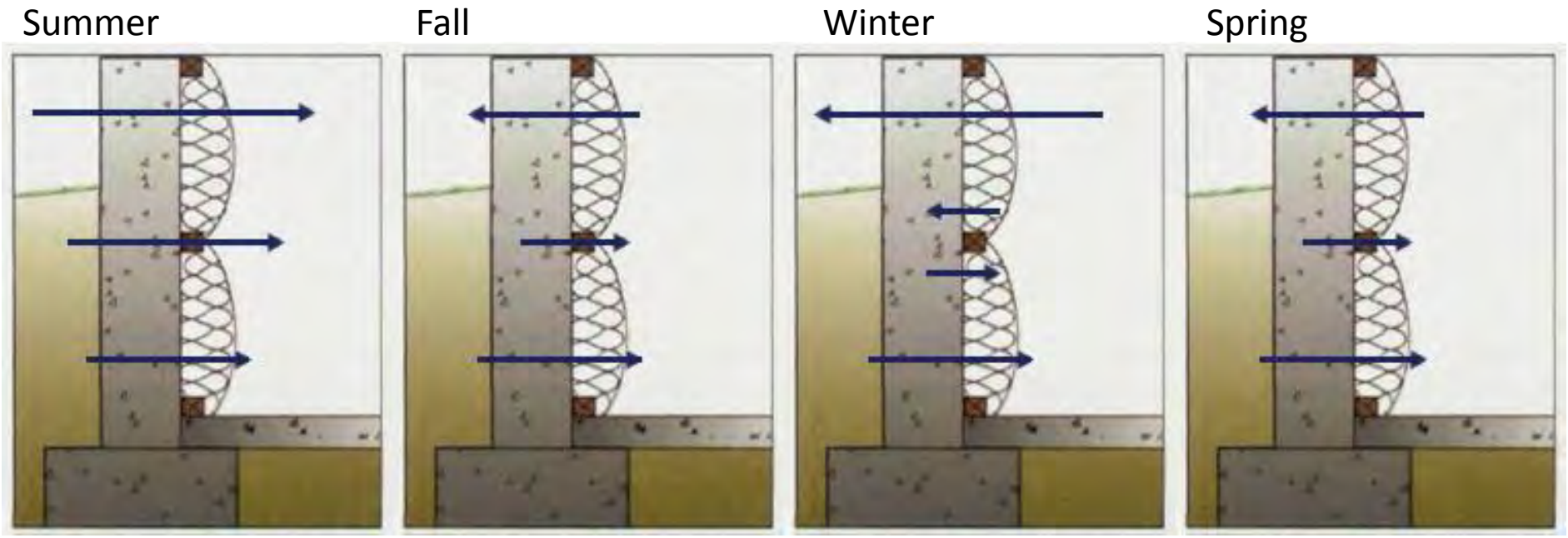
Figure 10: Diffusion

Image from Building Science Corp

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.



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Where does the vapor retarder go?

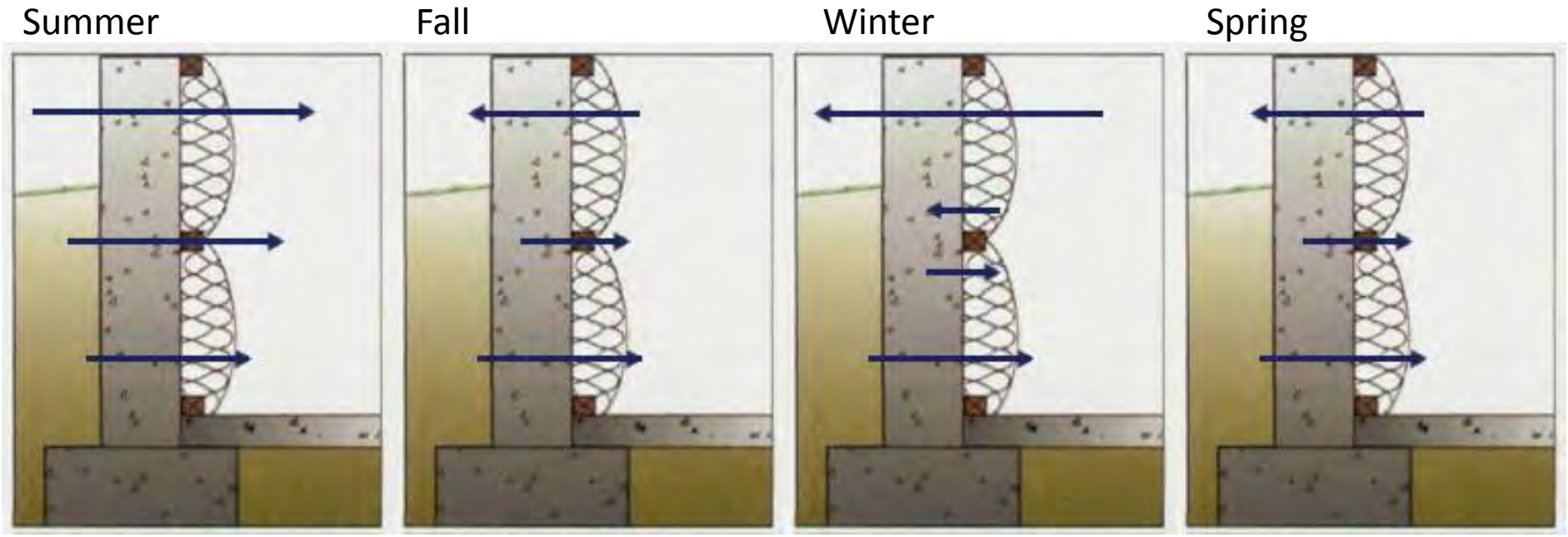

Image from Building Science Corp

Building Science Background

Where does the vapor retarder go?

Vapor retarder placed between insulation and concrete:

Effective against inward vapor drive (below grade) but…

- Outward vapor drive (above grade) is trapped on cold side of insulation.
- Inward migrating moisture and bulk water leaks cannot dry and will pool at bottom plate unless drainage is provided.

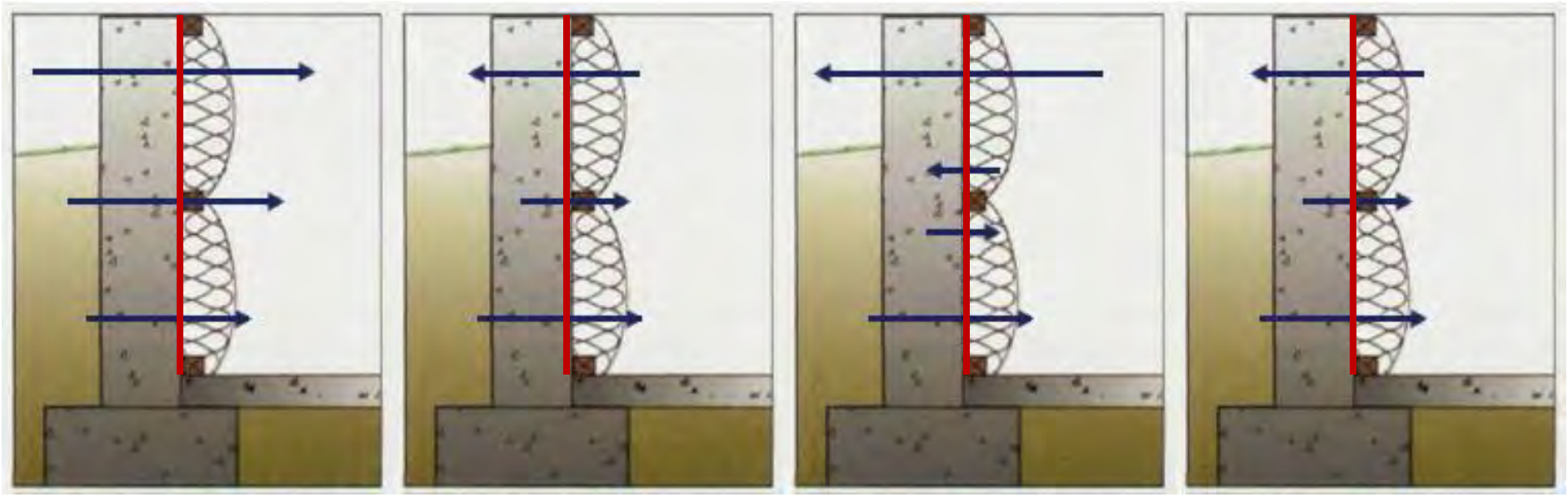

Image from Building Science Corp

Building Science Background

Where does the vapor retarder go?

Vapor retarder placed between insulation and concrete: Not Acceptable

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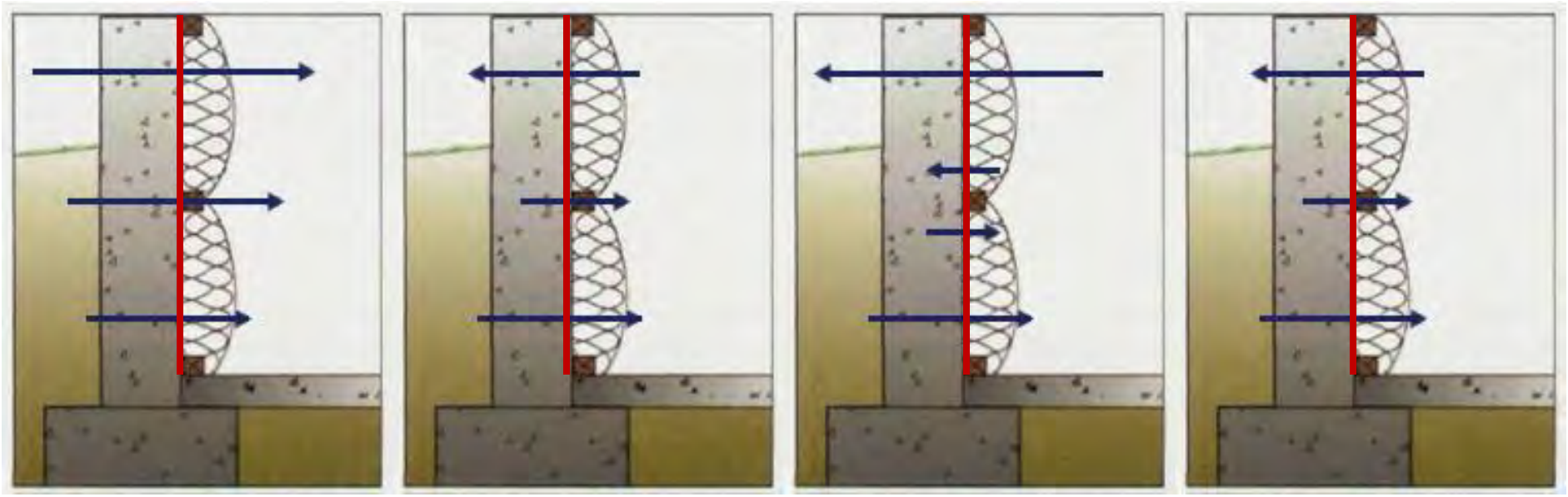


Image from Building Science Corp

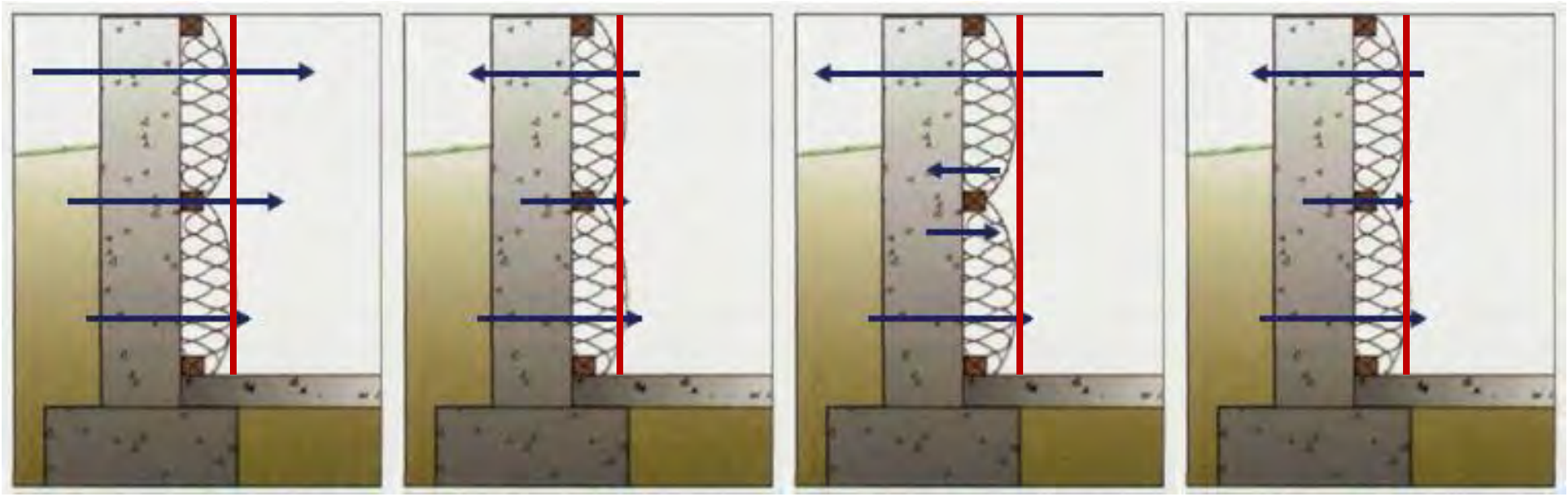
Building Science Background

Where does the vapor retarder go?

Vapor retarder placed between insulation and drywall:

Effective against outward vapor drive (above grade) but…

- Inward vapor drive (below grade) is trapped in insulation.
- Bulk water leaks cannot dry and will pool at bottom plate unless drainage is provided.



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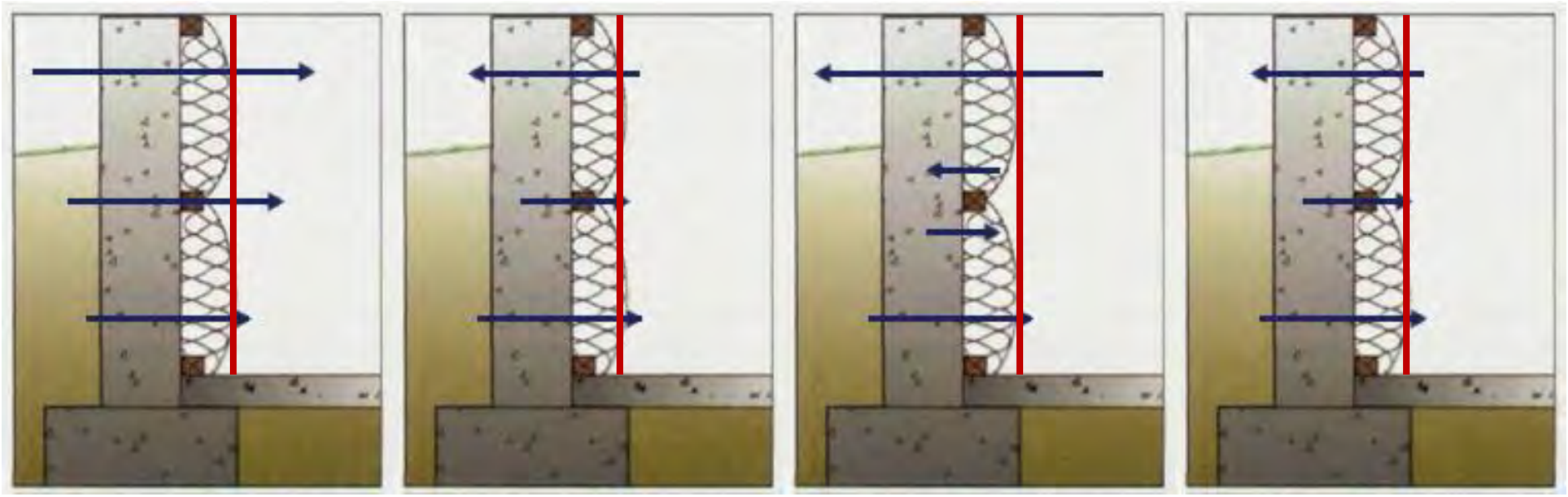


Image from Building Science Corp

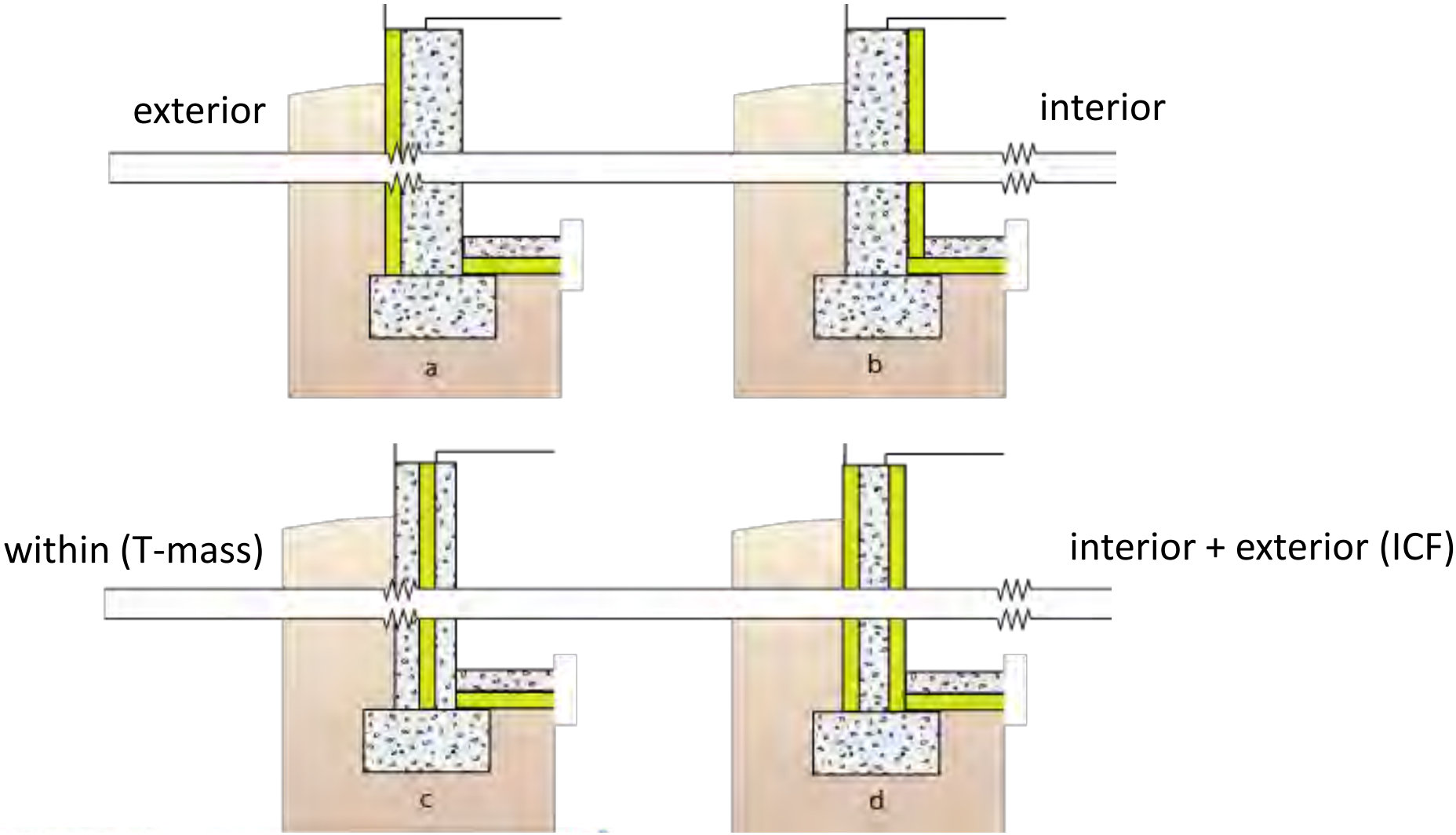
Building Science Background

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.

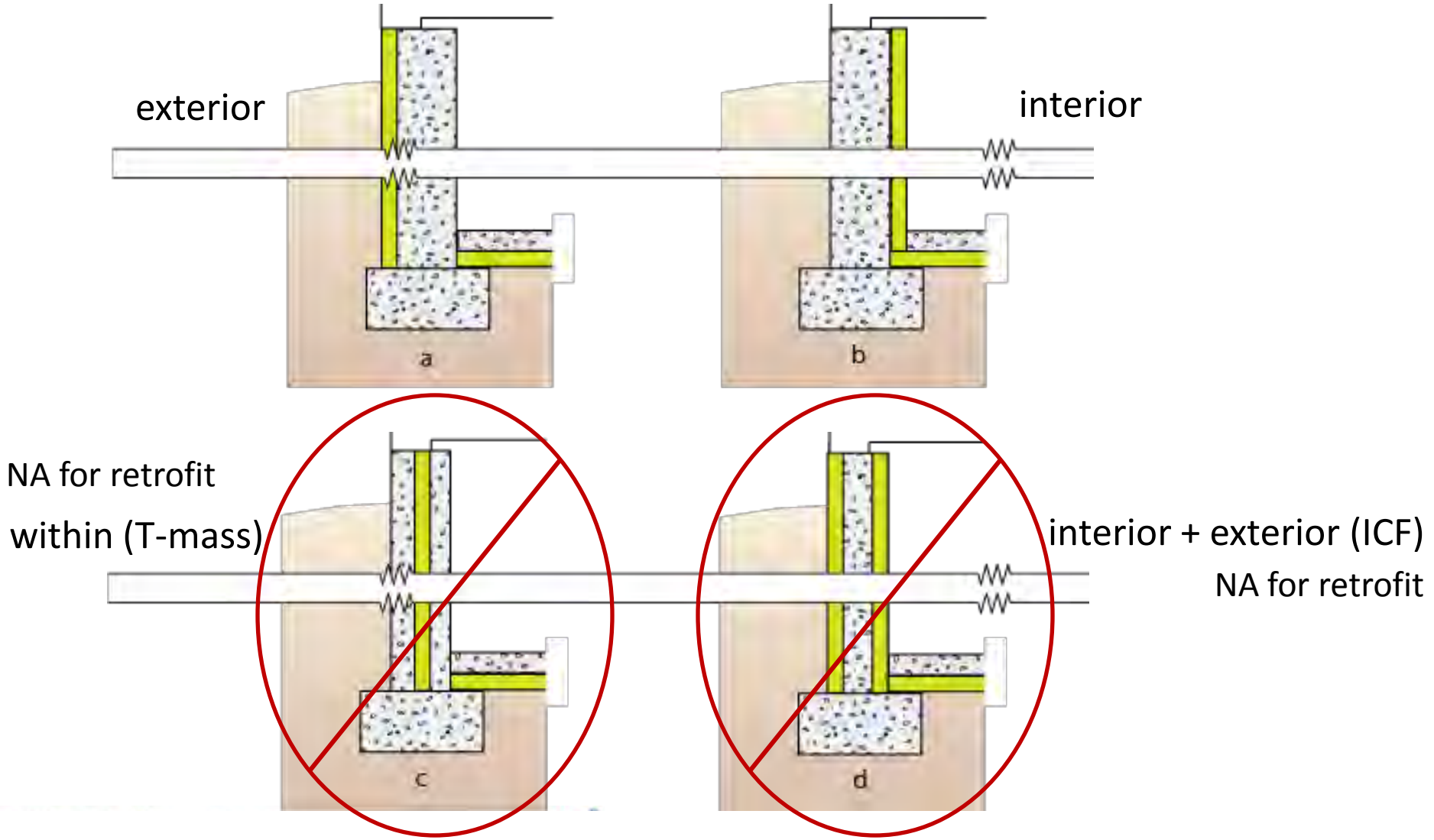
Building Science Background

Basement Wall Insulation Retrofit Options:



Building Science Background

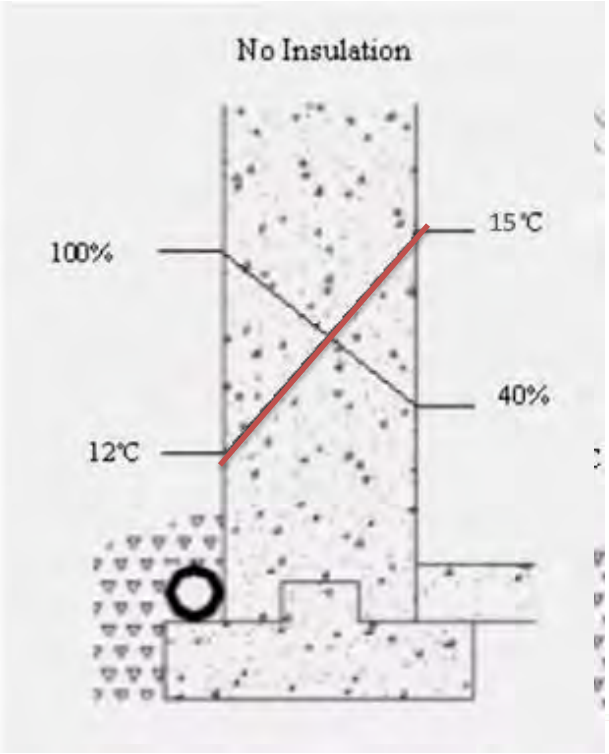
Basement Wall Insulation Retrofit Options:



Building Science Background

No insulation:

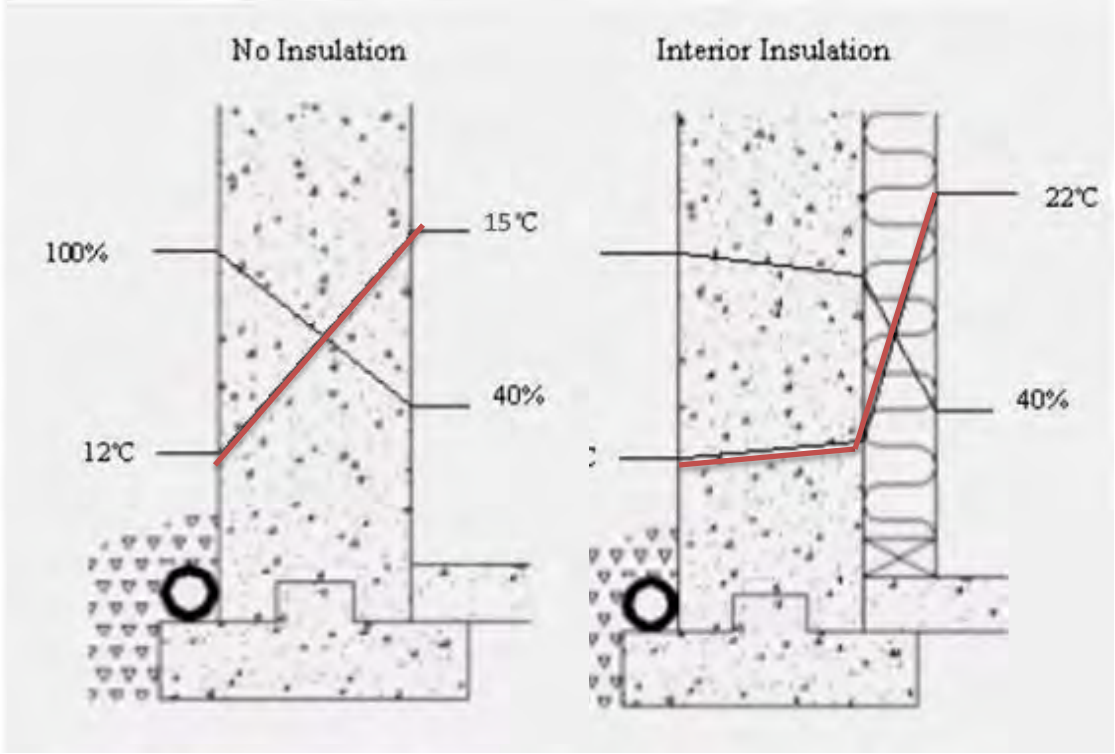
- Interior wall surface is cold (approx 55°F) and may be wet, but can dry freely to the inside.
- Interior air in contact with the wall primarily dries the wall, rarely leads to condensation, but that depends on interior RH.



Building Science Background

Interior insulation retrofit:

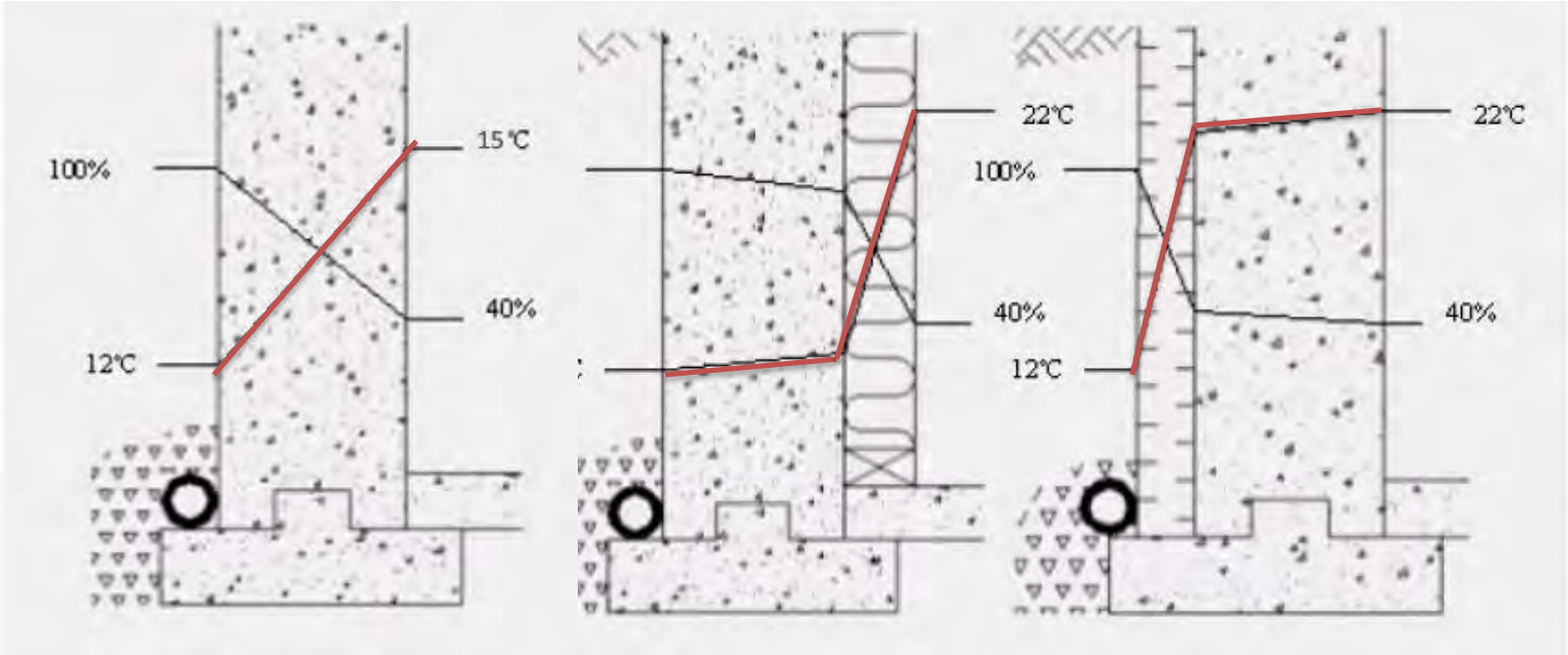
- Interior wall surface is warmed (approx 70°F) but concrete wall is chilled.
- Interior air that comes in contact with the concrete often leads to condensation.
- Reduced heat leads to wetter concrete, which can no longer dry freely to the interior.
- If an interior vapor retarder is installed, drying 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.



Insulation Retrofit Approaches

Interior insulation retrofit

- Energy => improved
- Comfort => improved
- Moisture => increased risk
- IAQ => increased risk
- Cost payback => in many cases

Exterior insulation retrofit

- Energy => improved
- Comfort => improved
- Moisture => decreased risk
- IAQ => likely decreased risk
- Cost payback = > no payback due to high initial cost

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

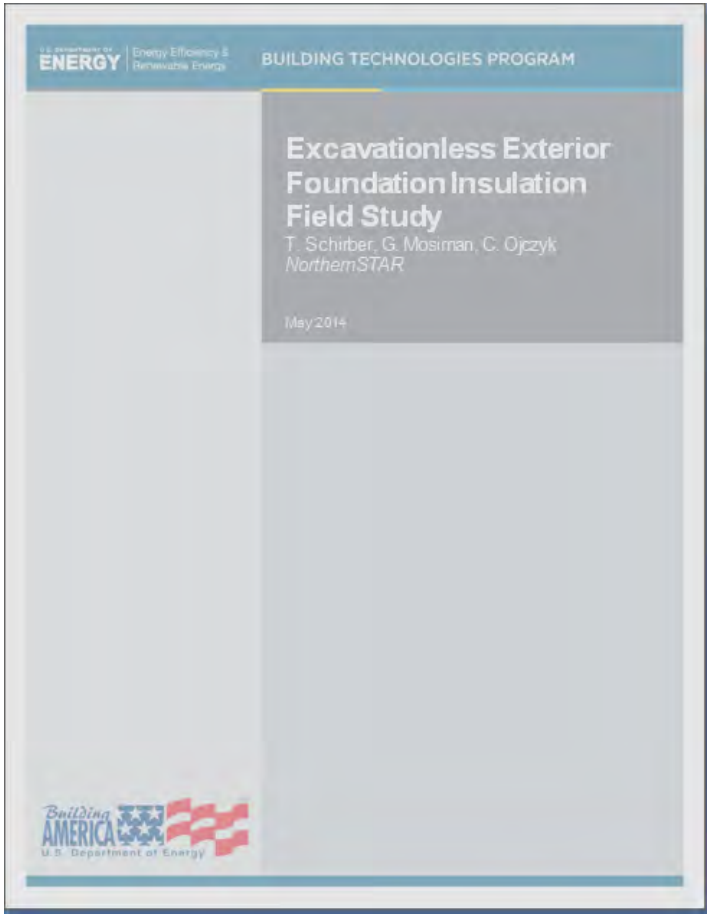
"Excavationless" is a combination of two existing, mature technologies:

1) Hydrovac excavation – developed by utilities
2) below grade polyurethane foam – available from several foam mfrs.

The Excavationless Approach

NorthernSTAR and team partners have completed 2 excavationless projects to date, which will be reviewed in 2nd half of presentation.

A Building America field study report based on the first project has passed peer review at the DOE and is published. Search “Northern-STAR excavationless” for more info.



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.

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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.)

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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 form-work. 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.

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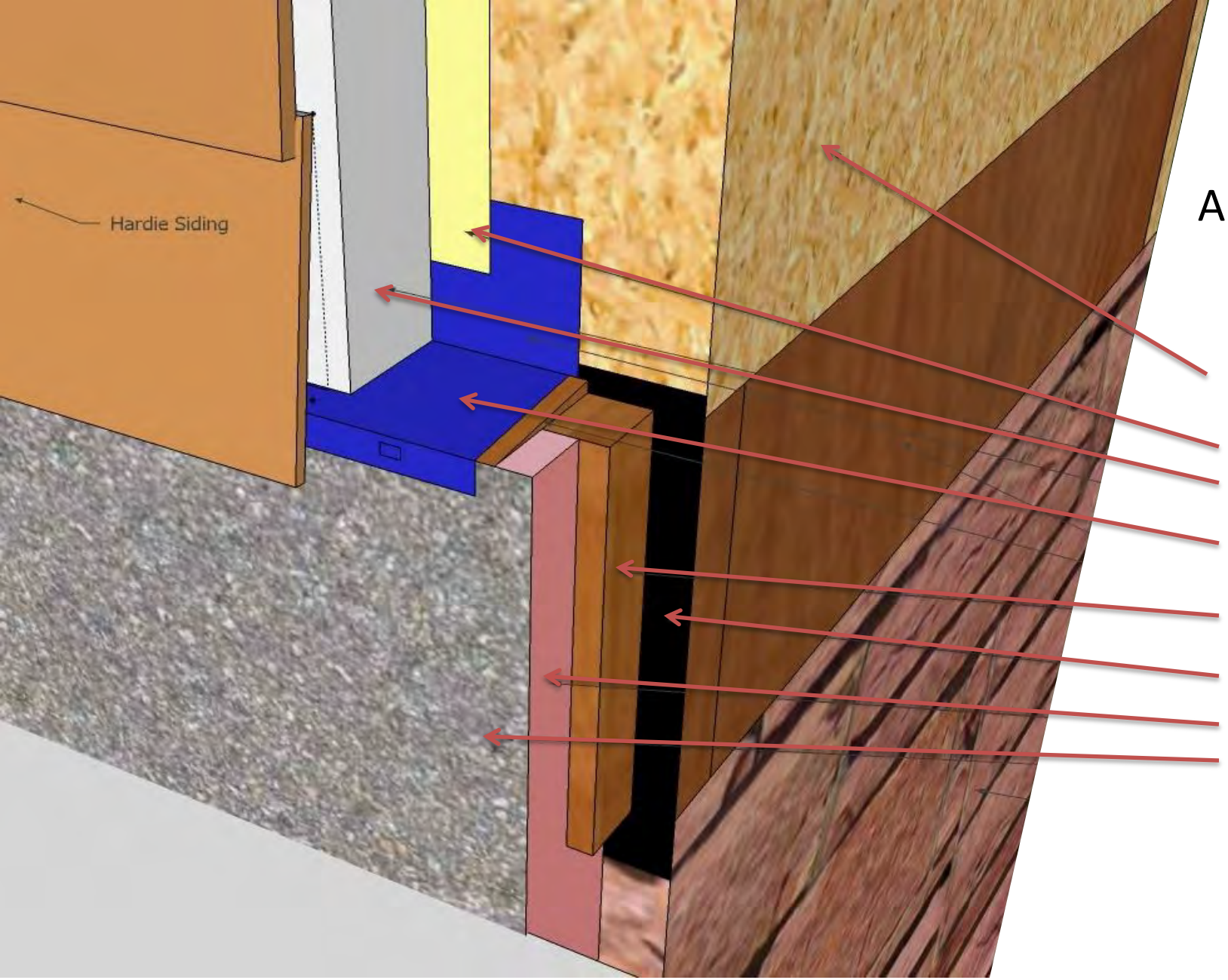
Some bowing occurred with 2x2s at 16” on center and 1.5” XPS. Thicker rigid insulation, closer spacing, or additional support such as a temporary plywood sheet is recommended.

Above grade detail



sheathing

house wrap WRB

exterior insulation

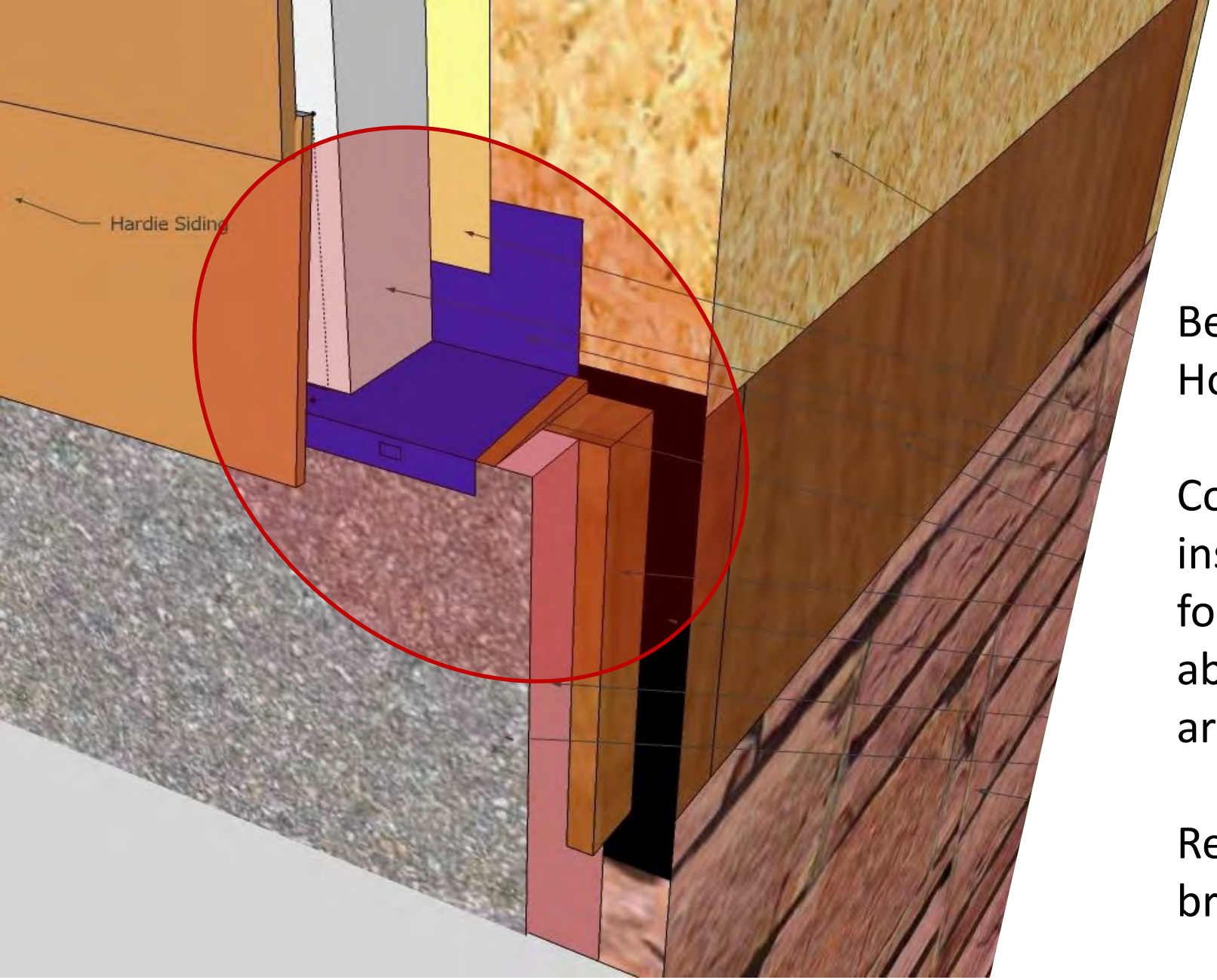
flashing or peel & stick membrane

2x2 furring

peel & stick membrane

rigid foam

stucco parge 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 2nd day of the retrofit.

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

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).
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