John Straube, Ph.D., P.Eng

Basements: New & Retrofit

Energy Efficient, Durable, Healthy

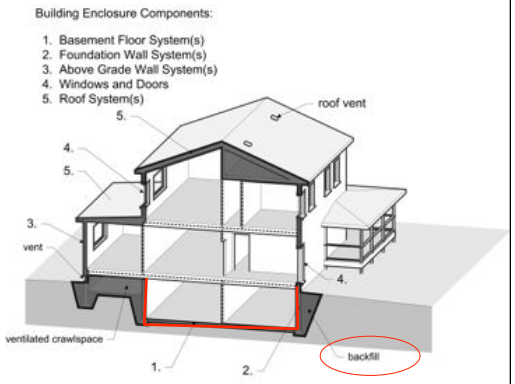
Building Science Corporation

presented by www.buildingscience.com

Basements are Changing

- Increasingly used as living space
  - Not a root /coal cellar anymore!
  - High quality space expected - new and retrofit
  - Owner can finish herself
  - Low cost for high density sites (cities)
  - Can now locate laundry, heating, hotwater elsewhere
- Modern basements are different – they need different approaches!
- Commercial basements are similar

Basements – Part of the Enclosure

- 

Basements

- Below grade enclosure
  - Includes floor slabs,
  - practically need to include transition
  - Separates exterior (soil/air) and interior
- Functions of <u>all parts</u> of the enclosure
  - Support – heavy lateral loads
  - Control – less temperature, more water
  - Finish (usually)

Moisture: Old ideas

- CBD#161 - 1974
- Drainage layer
- Exterior moisture barrier
- Exterior insulation
- Air barrier

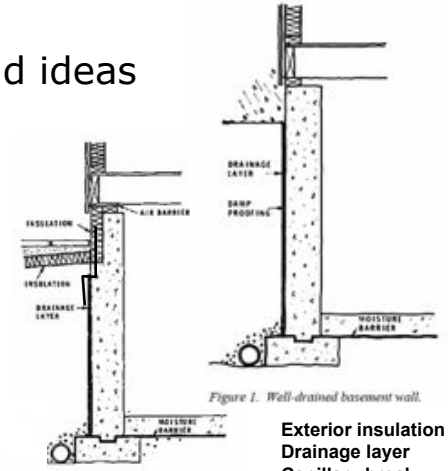


Figure 1. Well-drained basement wall.

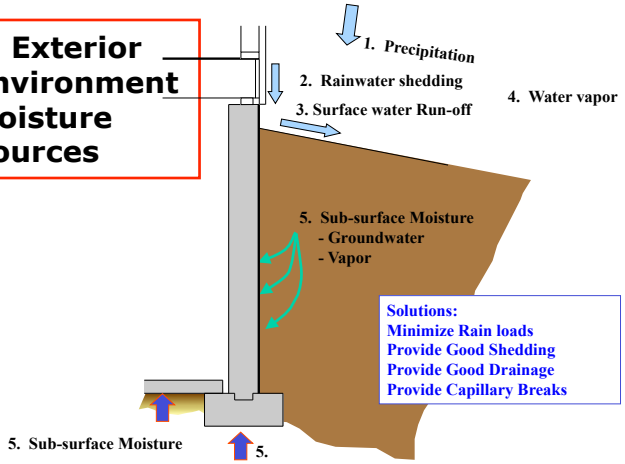
Fig 2. Exterior insulation of basement wall.

Exterior insulation
Drainage layer
Capillary break
Air tightness

Control: Moisture

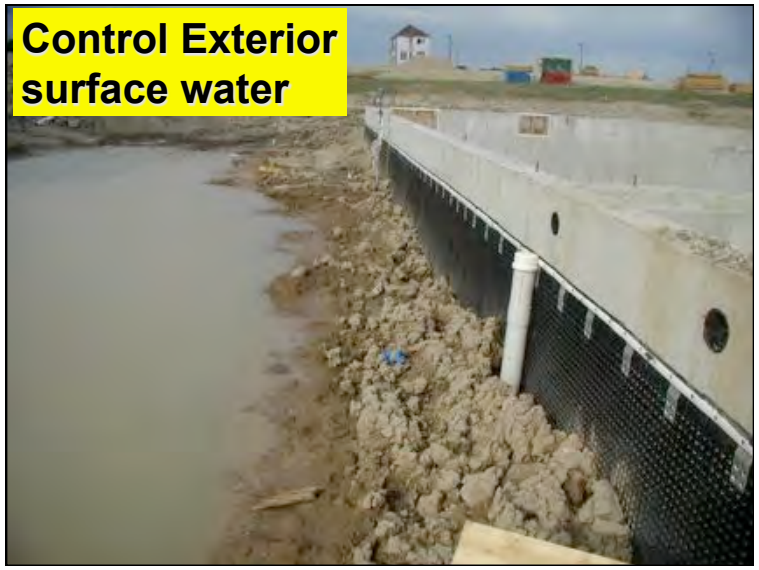
- Moisture causes most failures
  - Mold (musty basement smell)
  - Decay (especially rim joist)
  - Staining /Paint peeling
  - Floods and leaks, eventually causing the above
  - Salt damage to masonry – old basements
- Where does moisture come from?
  - 1. Exterior
  - 2. Built in
  - 3. Interior

1. Exterior Environment Moisture Sources



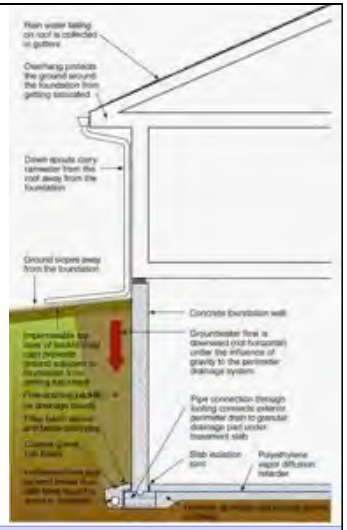
1. Controlling Exterior Moisture Sources

- Same approach as above-grade rain control
  - **D**eflection
    - Overhangs, slopes, gutters
  - **D**rainage/Exclusion/Storage
    - Three strategies for the enclosure
  - **D**rying
    - Remove built-in incidental moisture



Surface Drainage

- First step
  - Common problem
- Overhang
- Gutters
- Downspouts
- Sloped grade
- Perimeter drain



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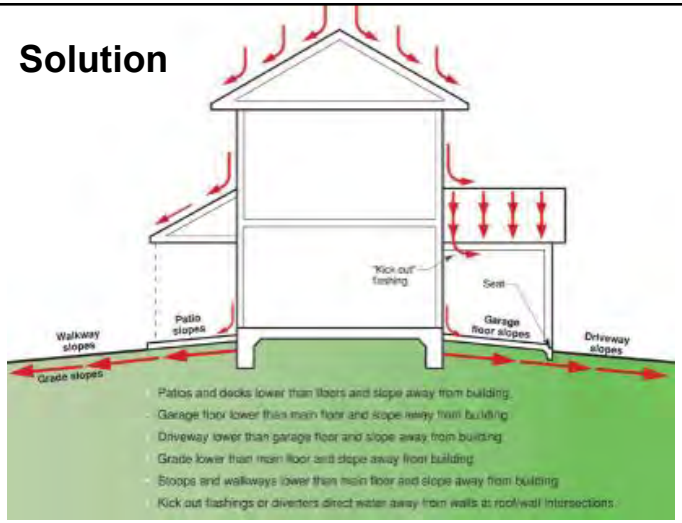
Solution



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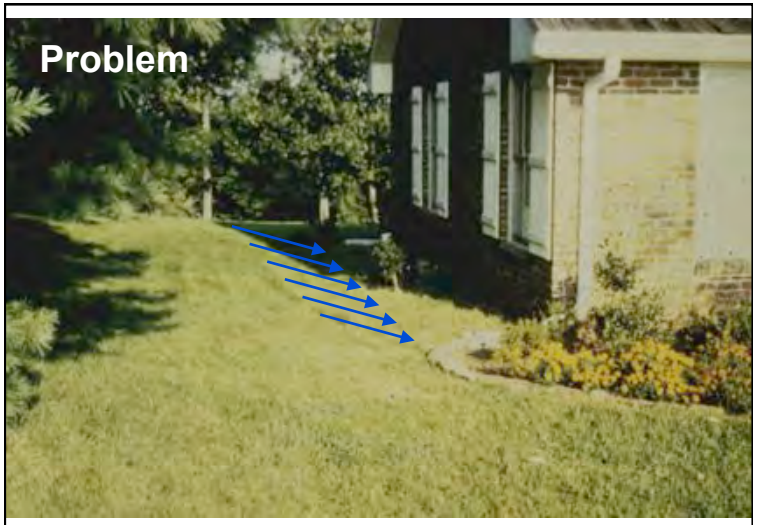
Problem



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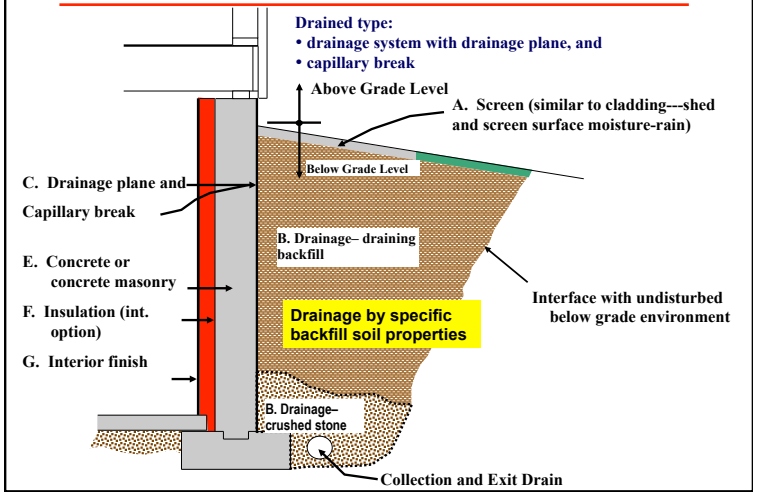
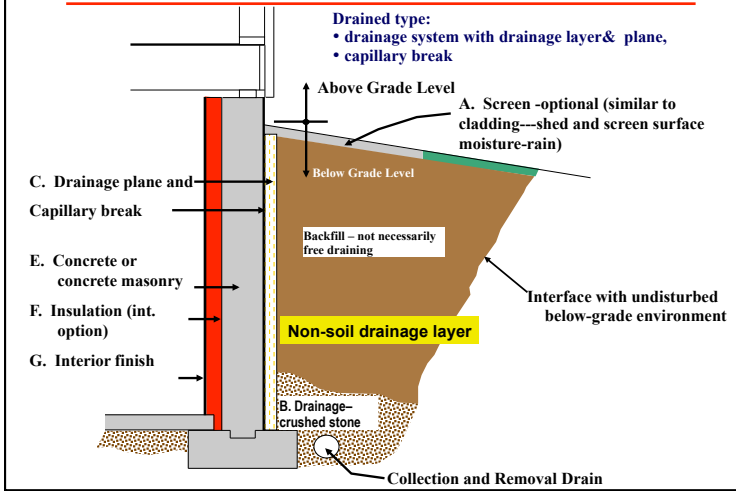
Basement Enclosure Strategies

- Classification of Groundwater control
  - 1. Drained
    - Needs capillary break and gap/drain space
  - 2. Perfect Barrier ("waterproofing")
    - One layer of perfect water resistance
    - Beware hydrostatic forces
  - 3. Storage (mass)
    - Safe storage capacity and drying
    - Don't use vapor barriers, do insulate (carefully)

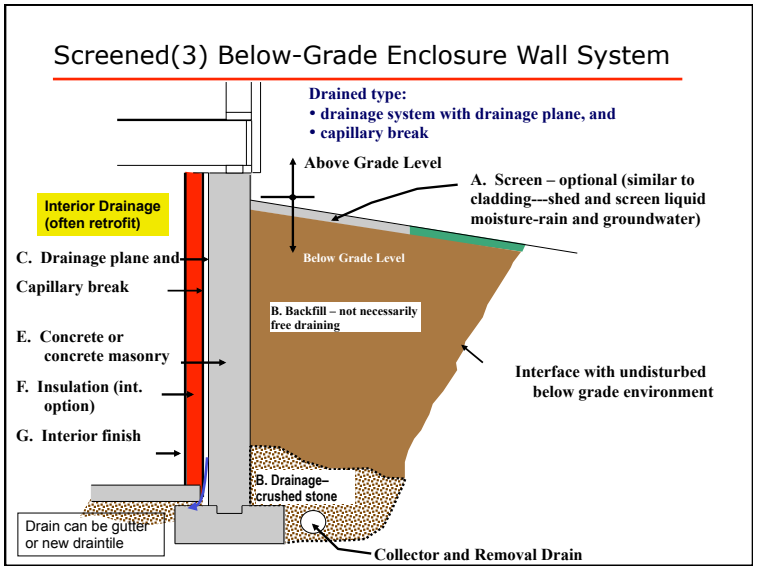
Screened(1) Below-Grade Enclosure Wall System



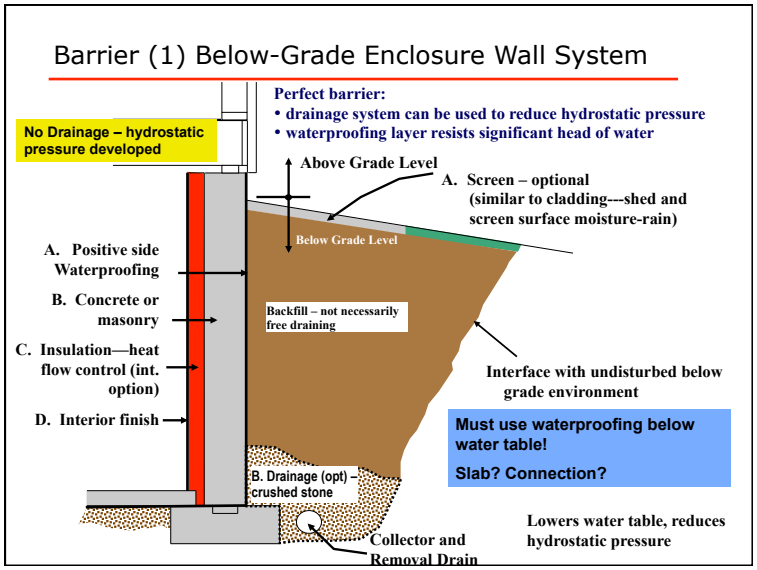
Screened(2) Below-Grade Enclosure Wall System



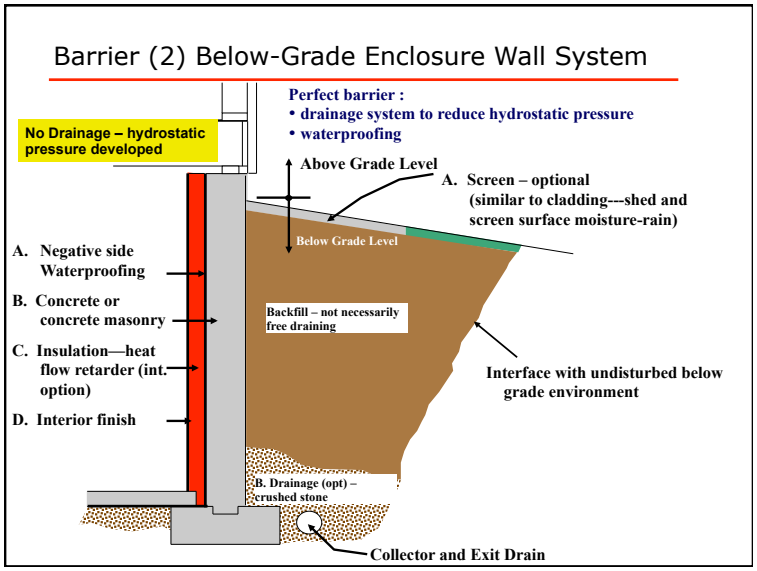
Screened(3) Below-Grade Enclosure Wall System



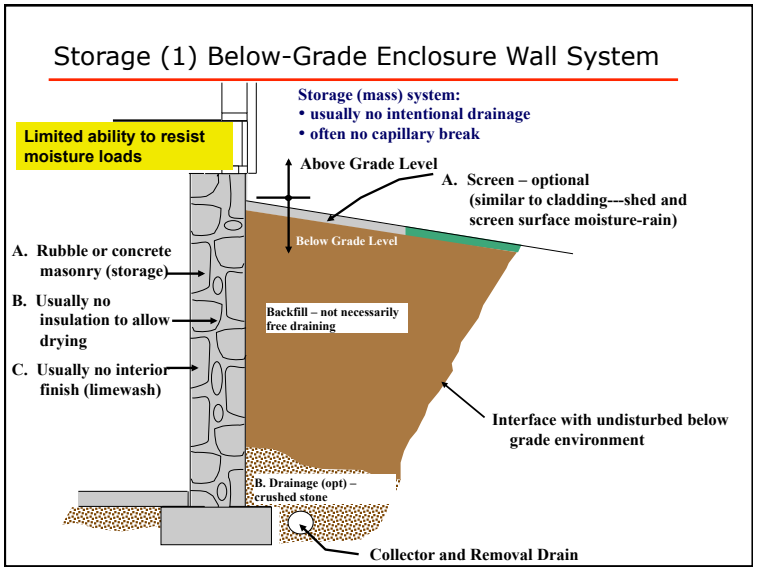
Barrier (1) Below-Grade Enclosure Wall System



Barrier (2) Below-Grade Enclosure Wall System



Storage (1) Below-Grade Enclosure Wall System




Damproofing
• Capillary break = drainage plane, but needs gap
• vapour barrier?
•NOT waterproofing
Waterproofing resists standing head of water
No. 21/73


Air gap membranes
aka Dimple Sheets
• provide drainage gap
• act as vapor barrier


Glassfiber Drainage Gap
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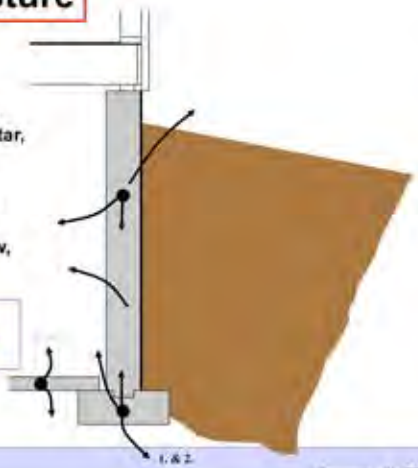
Rockwool Drainage Gap

2. Built-in Moisture

1. Built-in Moisture (from water in concrete, mortar, wood, etc.)

2. Construction moisture accumulated during construction (ice, snow, rain, etc.)

•Minimize by:
• Delay finishing internally
• Reduce water in concrete



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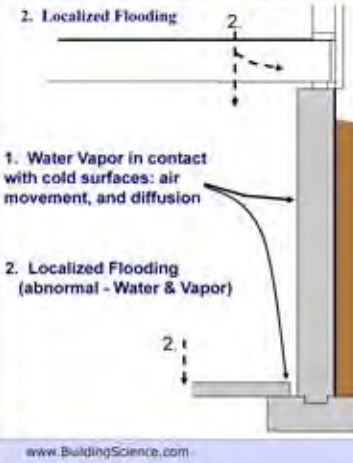
3. Interior Moisture Sources

2. Localized Flooding



1. Water Vapor in contact with cold surfaces: air movement, and diffusion

2. Localized Flooding (abnormal - Water & Vapor)

Solutions

1. Control interior vapor levels by:
   • winter ventilation
   • summer dehumidification
1. Avoid contact with cold surfaces
   • keep surfaces warm
   • stop water vapor moving
2. Control flooding
   • floor drains
   • disaster pans at appliances

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Vapor failure– not ground water

Managing Air and Vapor

- Need to solve
  - Surface condensation
    - Sol'n: Keep surface warm & air dry
  - Interstitial condensation
    - Control air/vapor flow to cold surfaces & dry air
  - Solar driven summer condensation
    - Allow vapor flow in, slow rate of flow

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Context: Below-grade Conditions

- Exterior soil is almost always at 100%RH
  - Plus liquid water can press against wall
- Never gets as cold or as hot as above grade
- Significant vertical temperature gradients
  - Top is different than bottom

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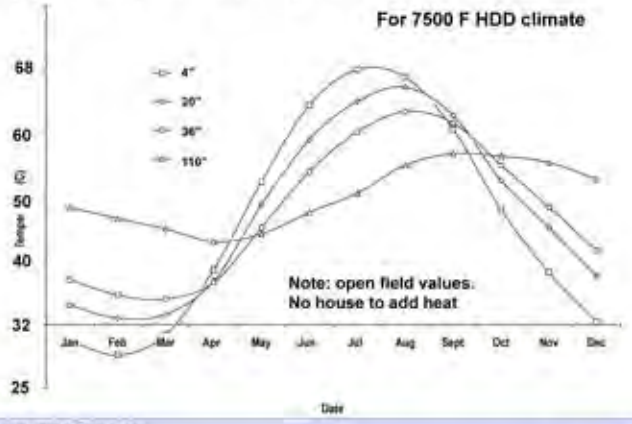
Typical Soil Temperatures



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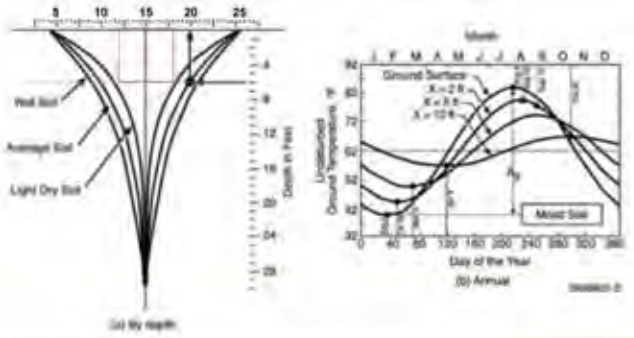
Soil Temperatures



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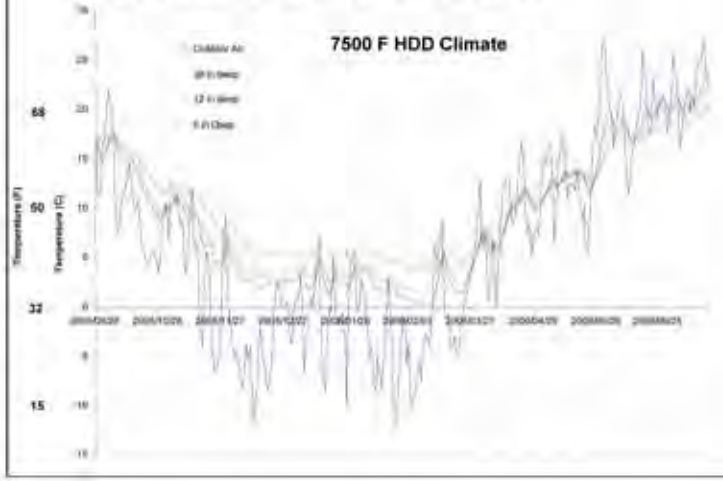
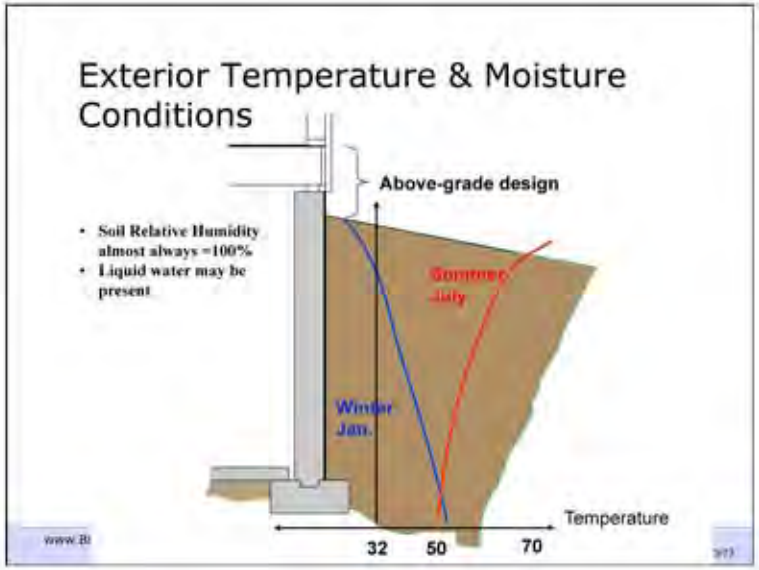
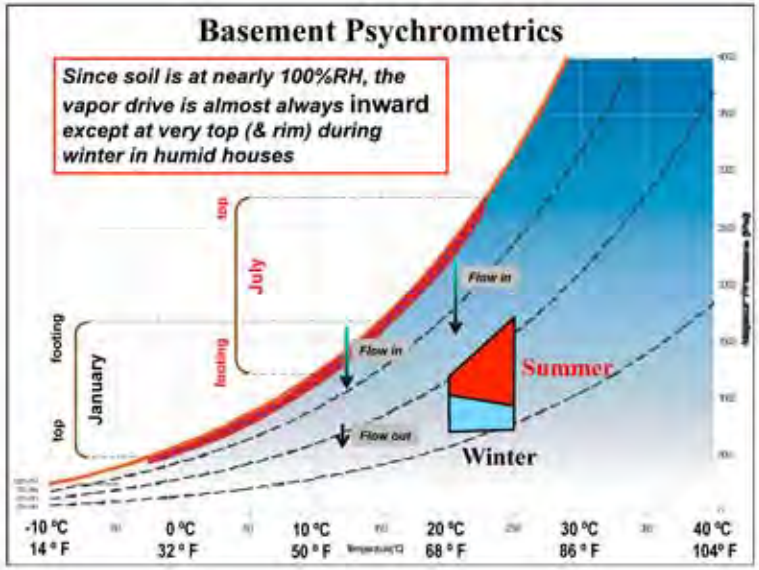
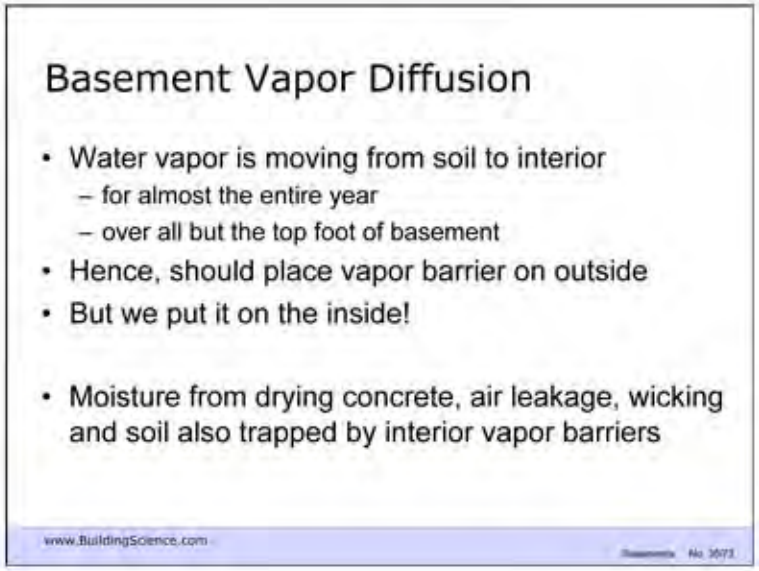
Measured Soil / Air Temperatures




Exterior Temperature & Moisture Conditions
Above-grade design
Soil Relative Humidity almost always =100%
Liquid water may be present
Summer July
Winter Jan.
Temperature
32
50
70


Basement Psychrometrics
Since soil is at nearly 100%RH, the vapor drive is almost always inward except at very top (& rim) during winter in humid houses
top
July
footing
January
top
footing
Flow in
Flow in
Flow out
Summer
Winter
-10 °C 14 ° F
0 °C 32 ° F
10 °C 50 ° F
20 °C 68 ° F
30 °C 86 ° F
40 °C 104° F


Basement Vapor Diffusion
• Water vapor is moving from soil to interior
– for almost the entire year
– over all but the top foot of basement
• Hence, should place vapor barrier on outside
• But we put it on the inside!
• Moisture from drying concrete, air leakage, wicking and soil also trapped by interior vapor barriers
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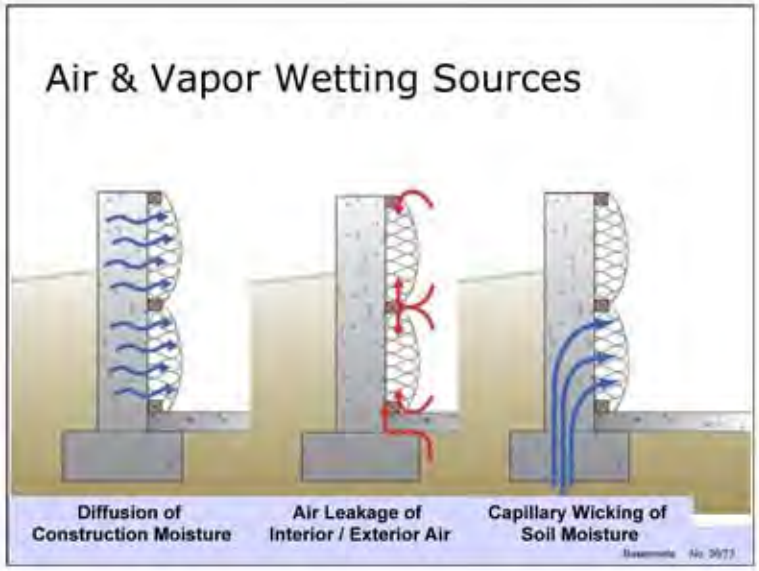
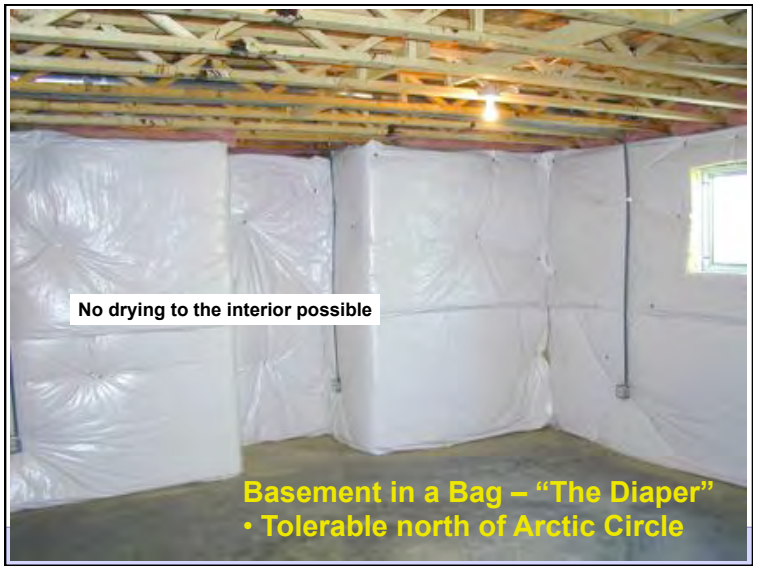
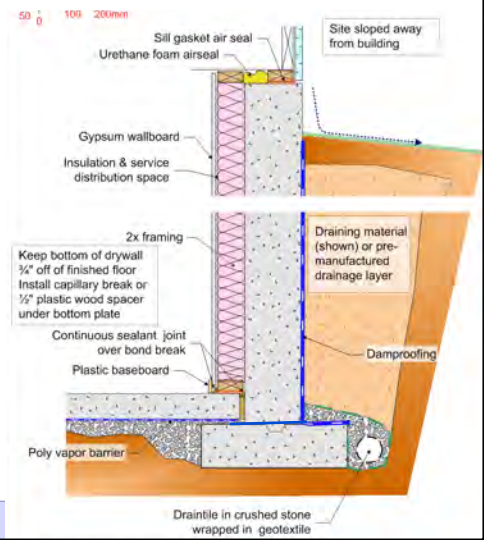

Air & Vapor Wetting Sources
Diffusion of Construction Moisture
Air Leakage of Interior / Exterior Air
Capillary Wicking of Soil Moisture



- Typical basement ("normal practice")
1. Start dry
2. No leaks
3. No poly
4. Be lucky



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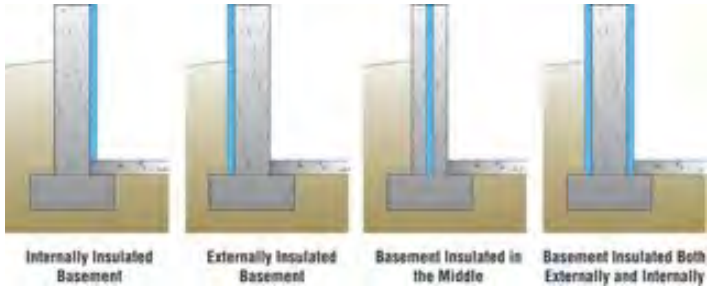
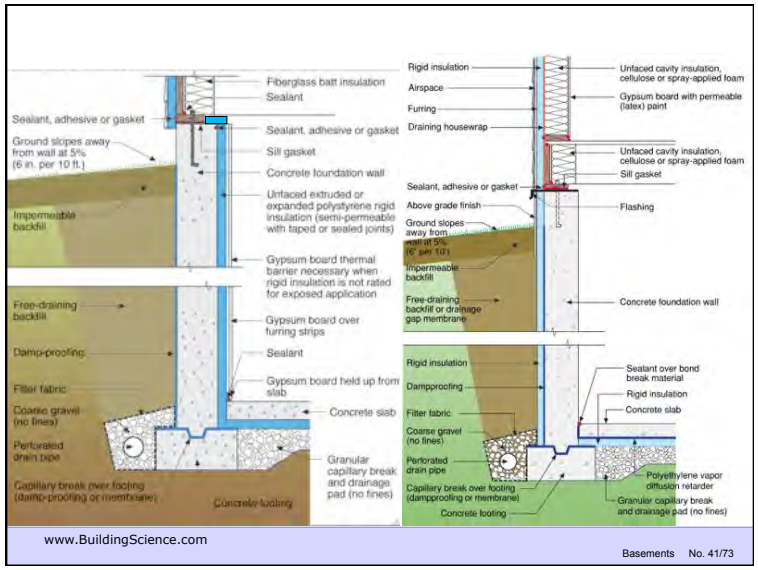
How to insulate/finish basement wall?

- We need to:
  - Control exterior ground water
  - Insulate (energy, comfort and moisture)
  - Control air leakage and diffusion condensation
  - Provide (a little) inward drying
  - Accommodate different conditions over height
- How to do we all this?

Insulation Location Choices

- Builders like to insulate the interior





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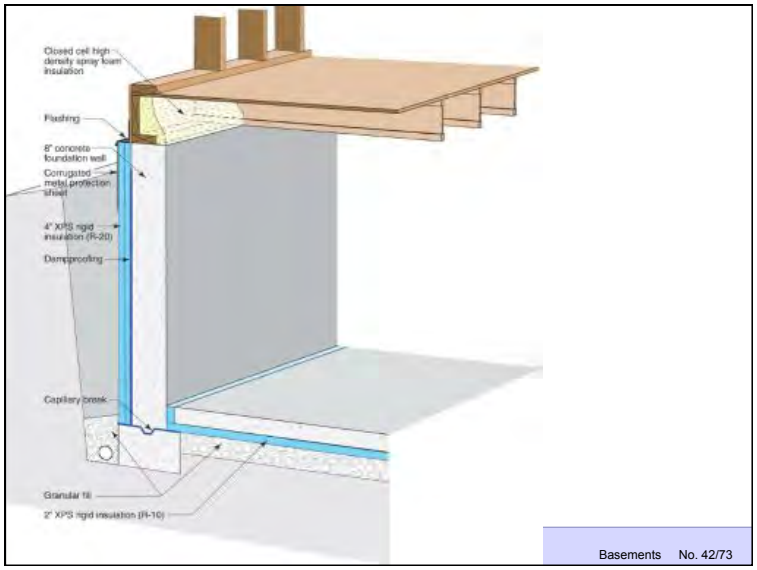

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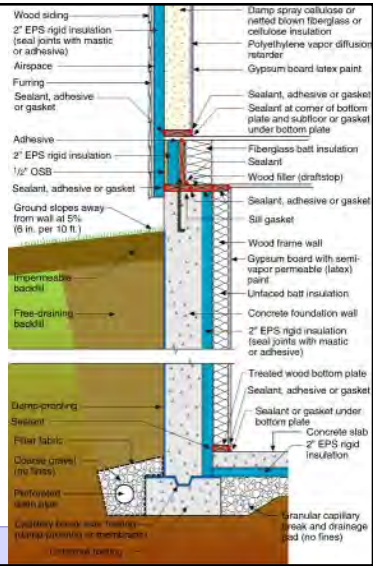
Hybrid

- Add layer of:
  - foam or
  - spray foam

To allow inward drying
• about 1 perm



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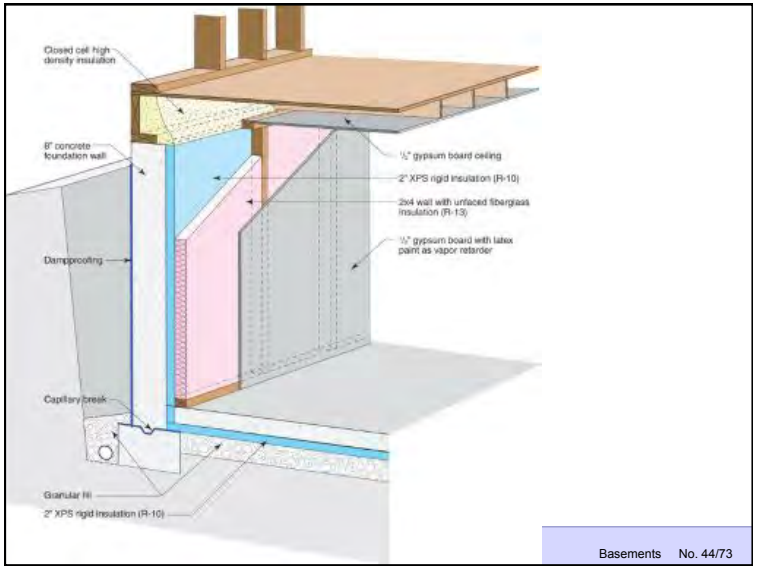
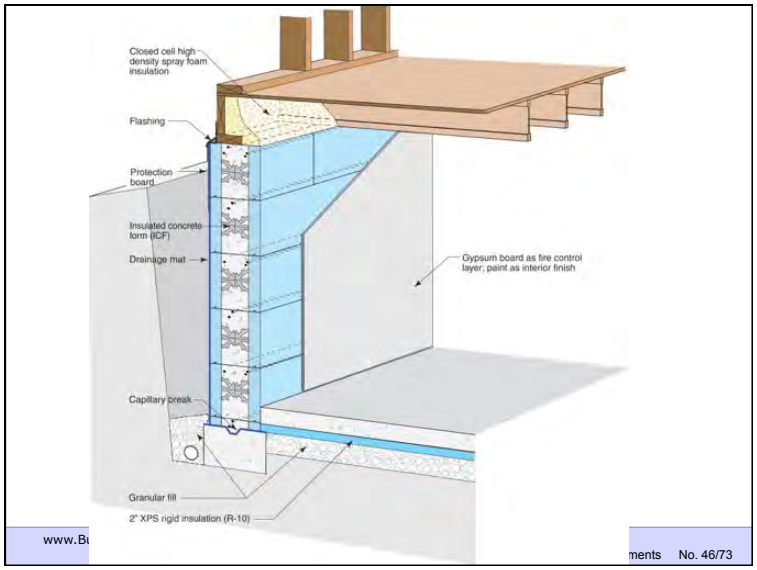
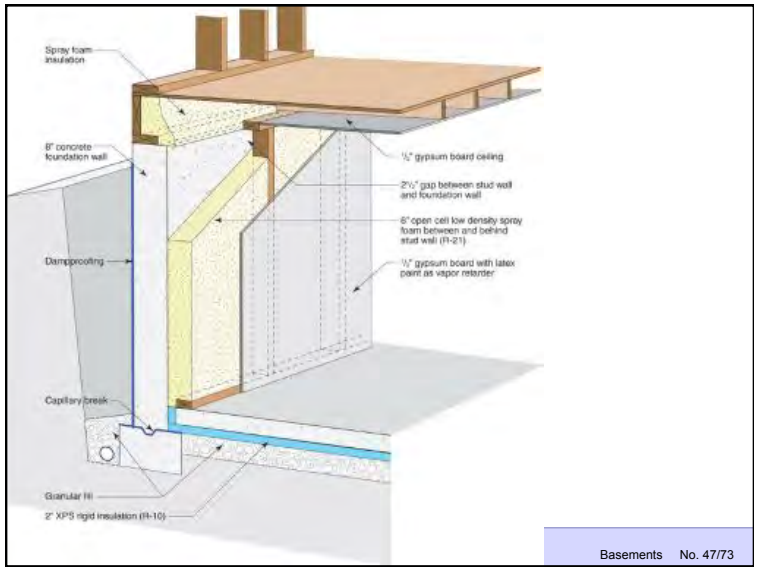
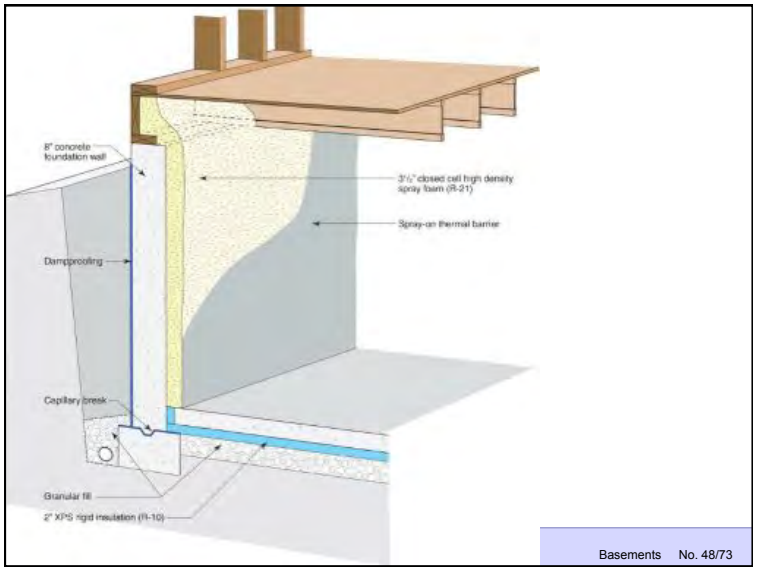
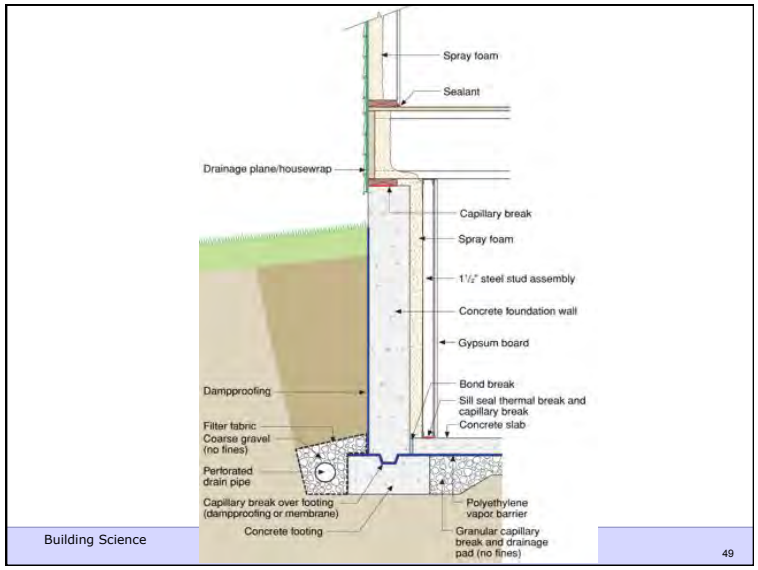


Basements No. 44/73


Closed cell high density spray foam insulation
Flashing
Protection board
Insulated concrete form (ICF)
Drainage mat
Gypsum board as fire control layer; paint as interior finish
Capillary break
Granular fill
2" XPS rigid insulation (R-10)


Spray foam insulation
8" concrete foundation wall
½" gypsum board ceiling
2"x4" gap between stud wall and foundation wall
6" open cell low density spray foam between and behind stud wall (R-21)
½" gypsum board with latex paint as vapor retarder
Dampproofing
Capillary break
Granular fill
2" XPS rigid insulation (R-10)
Basements No. 47/73


8" concrete foundation wall
3½" closed cell high density spray foam (R-21)
Spray-on thermal barrier
Dampproofing
Capillary break
Granular fill
2" XPS rigid insulation (R-10)
Basements No. 48/73


Spray foam
Sealant
Drainage plane/housewrap
Capillary break
Spray foam
1½" steel stud assembly
Concrete foundation wall
Gypsum board
Dampproofing
Bond break
Sill seal thermal break and capillary break
Concrete slab
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Capillary break over footing (dampproofing or membrane)
Concrete footing
Polyethylene vapor barrier
Granular capillary break and drainage pad (no fines)
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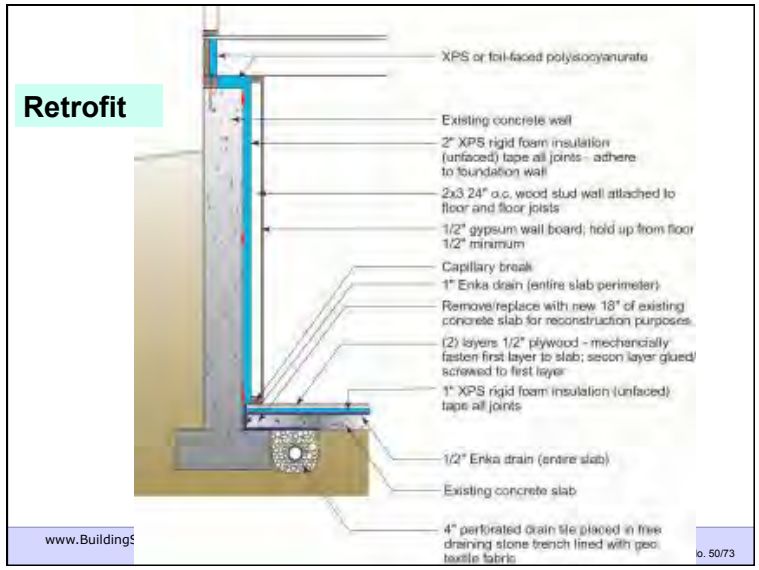
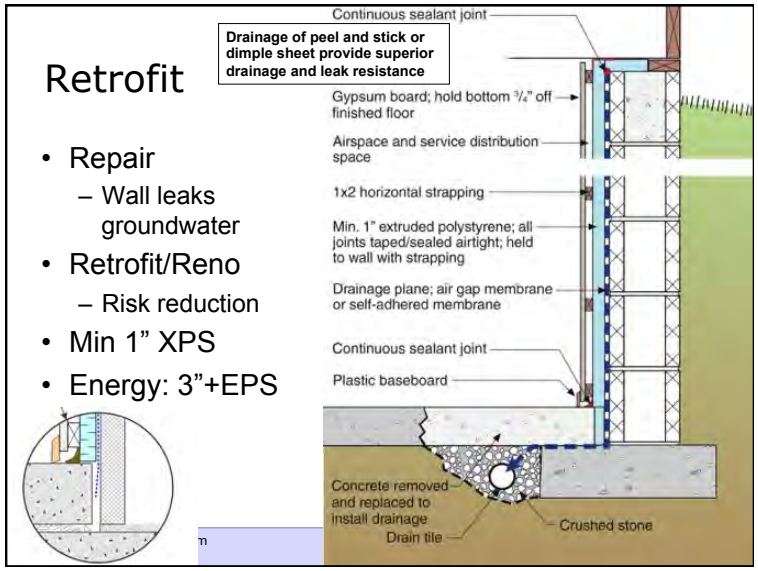

Retrofit
XPS or foil-faced polyisocyanurate
Existing concrete wall
2" XPS rigid foam insulation (unfaced) tape all joints - adhere to foundation wall
2x3 24" o.c. wood stud wall attached to floor and floor joists
1/2" gypsum wall board; hold up from floor 1/2" minimum
Capillary break
1" Enka drain (entire slab perimeter)
Remove/replace with new 18" of existing concrete slab for reconstruction purposes
(2) layers 1/2" plywood - mechanically fasten first layer to slab; secon layer glued/ screwed to first layer
1" XPS rigid foam insulation (unfaced) taps all joints
1/2" Enka drain (entire slab)
Existing concrete slab
4" perforated drain tile placed in free draining stone trench lined with geo textile fabric
www.BuildingS
o. 50/73


Retrofit
• Repair
– Wall leaks groundwater
• Retrofit/Reno
– Risk reduction
• Min 1" XPS
• Energy: 3"+EPS
Drainage of peel and stick or dimple sheet provide superior drainage and leak resistance
Continuous sealant joint
Gypsum board; hold bottom ¾" off finished floor
Airspace and service distribution space
1x2 horizontal strapping
Min. 1" extruded polystyrene; all joints taped/sealed airtight; held to wall with strapping
Drainage plane; air gap membrane or self-adhered membrane
Continuous sealant joint
Plastic baseboard
Concrete removed and replaced to install drainage
Drain tile
Crushed stone


Retrofit Slab, drainage and sump before wall insulated
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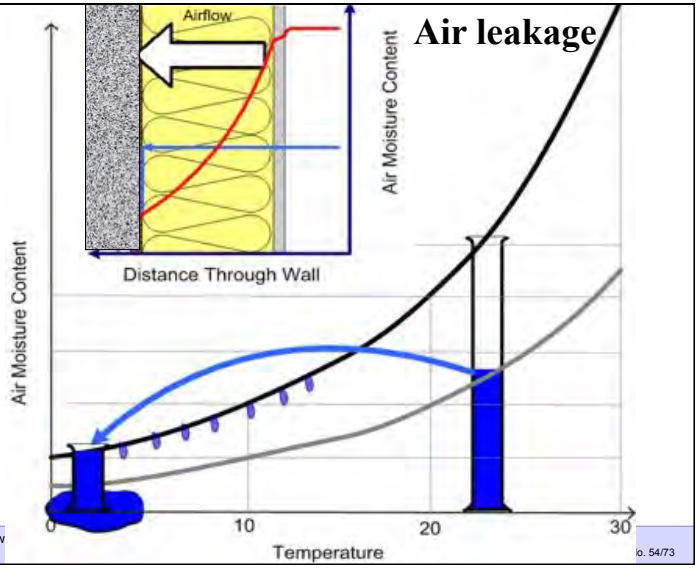
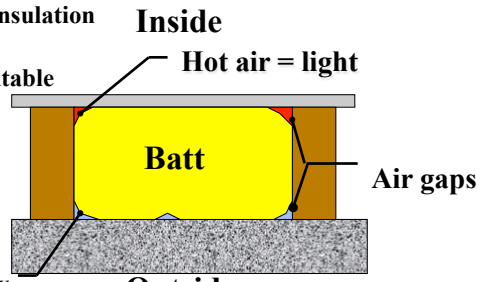
Basement Wall Air Movement

- Water vapor moves along with airflow
- If moist air touches a cold surface, condensation occurs
  - Summer and winter problem
- Control?
  - Include an air barrier
  - Avoid air loops
  - Manage pressures



Internal Stack Effect & Insulation

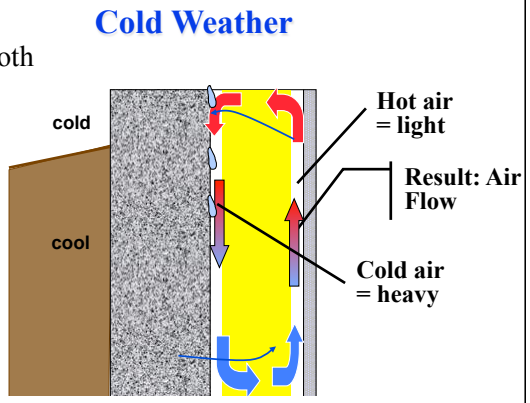
- Gaps in batt insulation on both sides
- Wrinkles inevitable



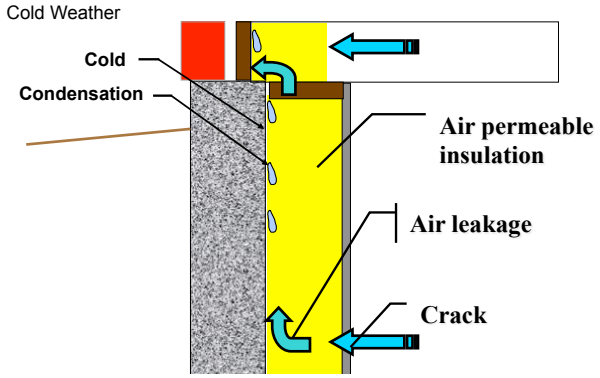
Common basement problem

Internal Stack Effect

- Gaps in batt insulation on both sides
- closed circuit
- energy cost
- condensation



Problems w/ air permeable insulation



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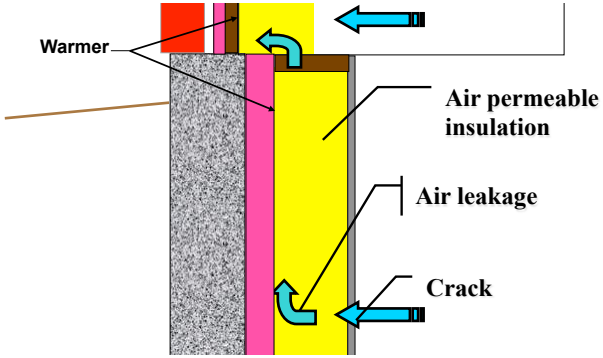
Solution w/ Insulated Sheathing



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- Foam only
- Vertical or horizontal furring

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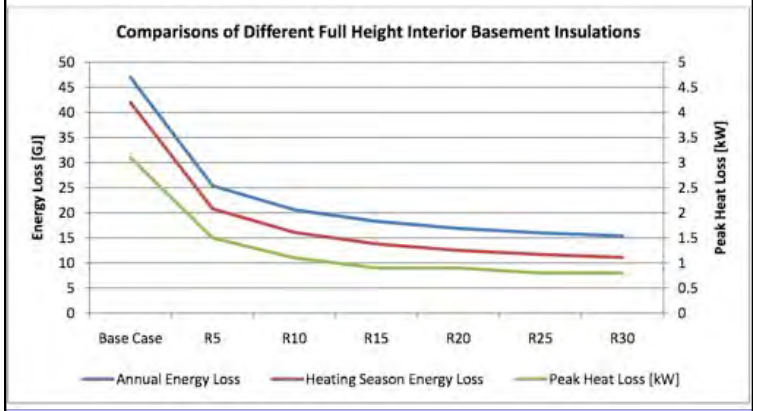
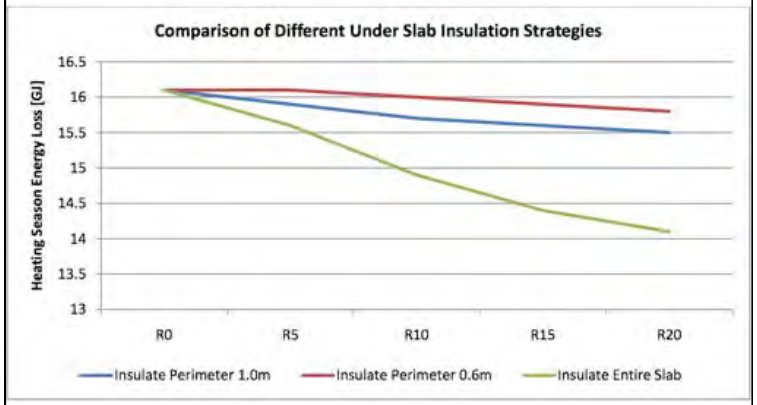
Basement Heat Loss

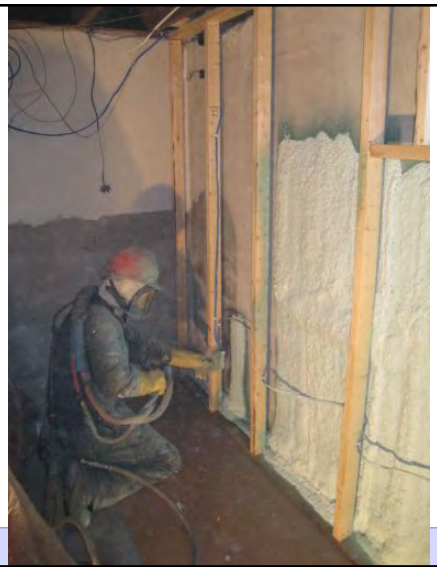


Slab heat loss



Spray foam basement insulation

- Open cell
  - Climate specific
- Closed cell



Materials to use?

- Foam Board: EPS, XPS, PIC
  - water tolerant
  - vapour barriers to vapour retarders
- spray foam
  - Semi-rigid (Icynene) and rigid (Spray polyurethane)
  - airtight
  - May allow some drainage
  - R values of 4 to 6/inch
  - vapour semi-permeable (Icynene much more)

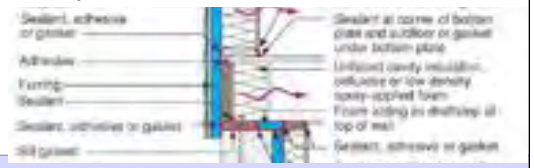
Insulated Concrete Forms (ICF)

- If you afford it, use them –
  - cap break,
  - insulation,
  - vapor retarder,
  - above grade

Thermomass

Rim joists

- Scenario
  - Wood generally on exterior
  - 1.5" wood is a vapor barrier
  - Practically difficult to stop air leakage
- Result
  - Condensation on rim joist in cold weather
  - Decay if it can't dry in or out
- Solutions
  - Insulate on exterior



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Basements No. 73/73

Slabs

- Slabs can loose significant energy
  - Currently the only uninsulated part of many buildings
- Keep warm (comfort & condensation)
- Control wicking and diffusion
- Make softer
- Consider floods

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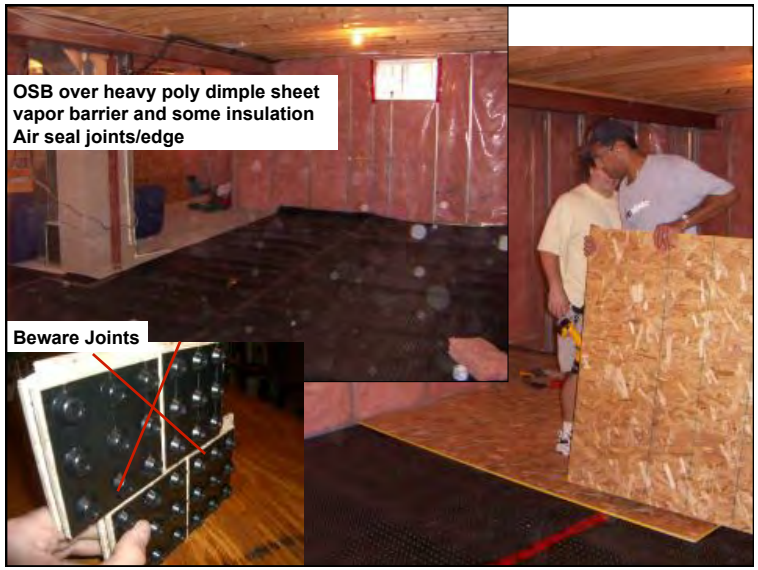
Basements No. 74/73



Slabs

Summary

- Control surface water by drainage
- Drainage layer on exterior of walls
- No vapor barriers on inside
- Painted drywall, stud, batt with foam OK
- Care needed at rim joist
- What happens if there is a flood, leak, etc.

Conclusions

- Building in a hole in the ground is hard
- Drainage is better than waterproofing
- Don't forget about built-in moisture
  - and remember summer
- Insulation and drainage are the best tools, not vapor barriers and waterproofing

Inward Solar Drives at Grade

- Wet concrete from rain, grade, built-in
- Sun shines on wall and heats it
- Water evaporates and diffuses in & out
- Can condense inside if cold and impermeable

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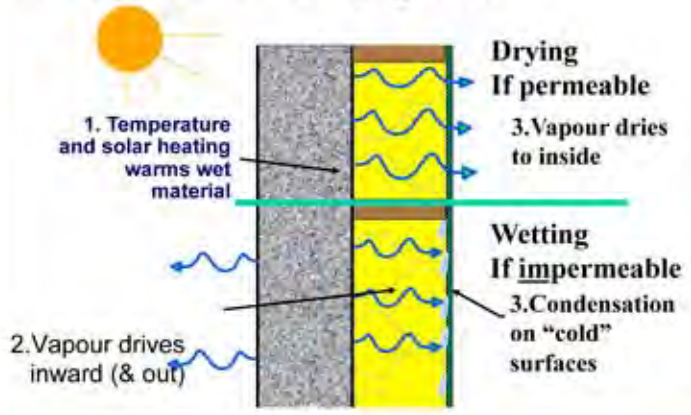
Inward Diffusion @ grade



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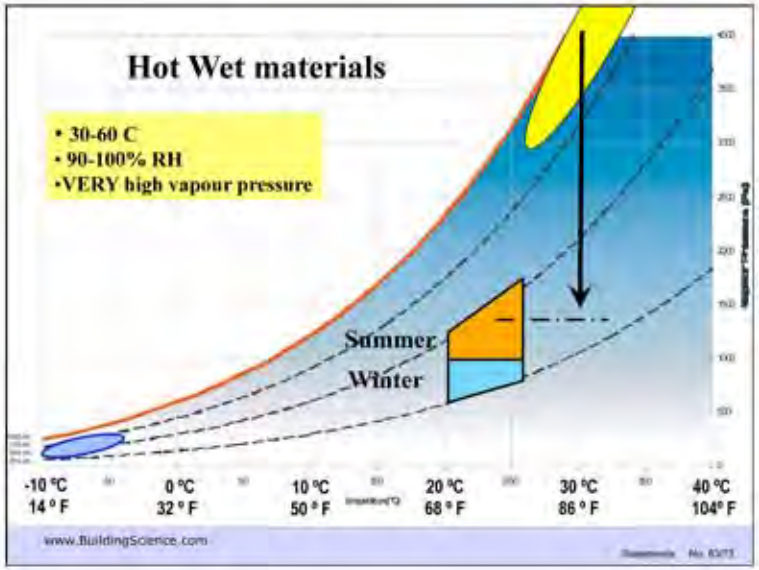
Hot Wet materials

- 30-60 C
- 90-100% RH
- VERY high vapour pressure



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