Hygrothermal Basement Performance, or "Why do we get water when we dig holes in the ground?"

Dr John Straube
October, 2004

www.BalancedSolutions.com

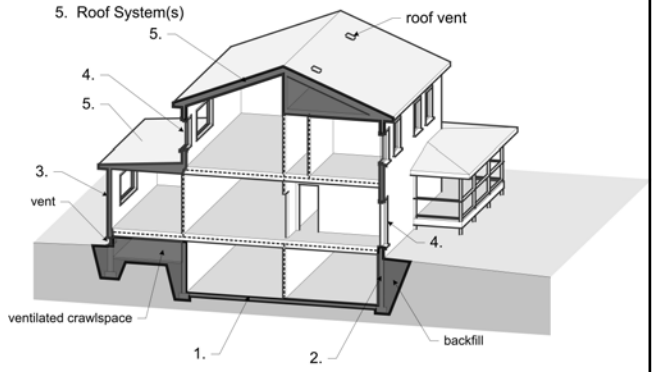
BEG
Building Engineering Group
University of Waterloo

This presentation

- What do basements do
- Examine performance
- Why problems
- What solutions

Building Enclosure Components:

1. Basement Floor System(s)
2. Foundation Wall System(s)
3. Above Grade Wall System(s)
4. Windows and Doors
5. Roof System(s)



Functions of the building enclosure

- Support
  - Structure: wind, gravity, earthquake
- Control
  - Heat
  - Air
  - Moisture (vapor, liquid)
- Finish
- Distribute (sometimes)

Basements

- Below grade enclosure
  - Includes floor slabs, and practically rim joist
  - Separates exterior (soil) and interior
- Increasingly used as living space
  - Not a root cellar anymore
  - High quality space new and retrofit expected
  - Owner can finish herself
  - Low cost for high density sites
  - Can locate heating, hotwater anywhere

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Basements

- Support
  - Foundations, stem walls, and footings
- Control
  - Ground water
  - Interstitial and surface condensation
  - Heat flow
  - Air, radon and soil gas
- Finish

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Support

- Structural system
  - Does not work based on rational analysis
- Failure modes
  - Poorly compacted subsoil
  - Top-edge Bracing
    - Raised bungalows
    - Stairwells parallel to wall

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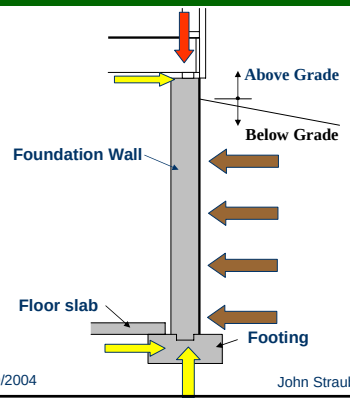
Basement Structural System

Similar for most basements



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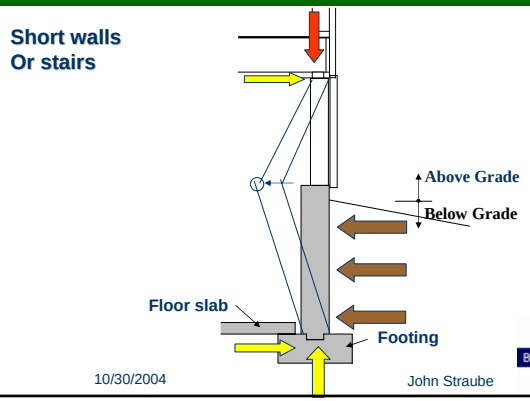
Basement Structural System



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Control: Moisture

- Moisture causes most failures (less spectacular)
  - Mold (musty smell)
  - Decay (especially rim joist)
  - Staining /Paint peeling
  - Floods and leaks, causing the above
  - Salt damage to masonry
- Where does moisture come from?
  - Exterior
  - Interior
  - Built in
- Recent studies – Minn, Chicago, CMHC IRC

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Special Exterior Conditions

- Exterior soil is almost always at 100%RH
  - Liquid water can press against wall
- Never gets as cold or as hot as above grade
- Significant vertical temperature gradients

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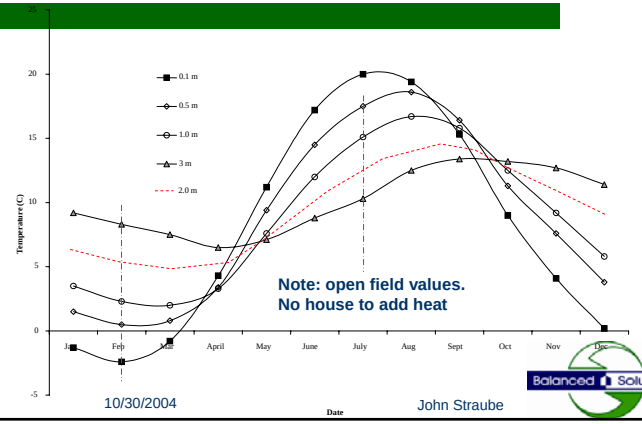
Toronto Measured Soil Temperatures



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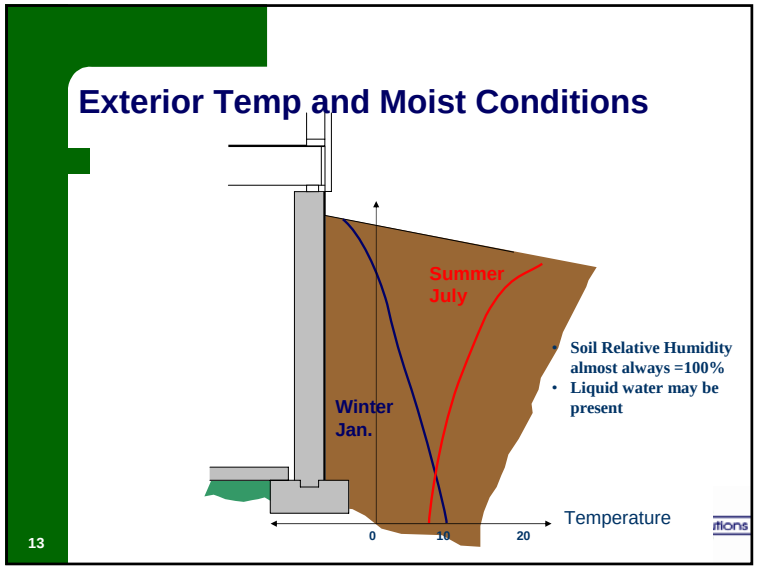
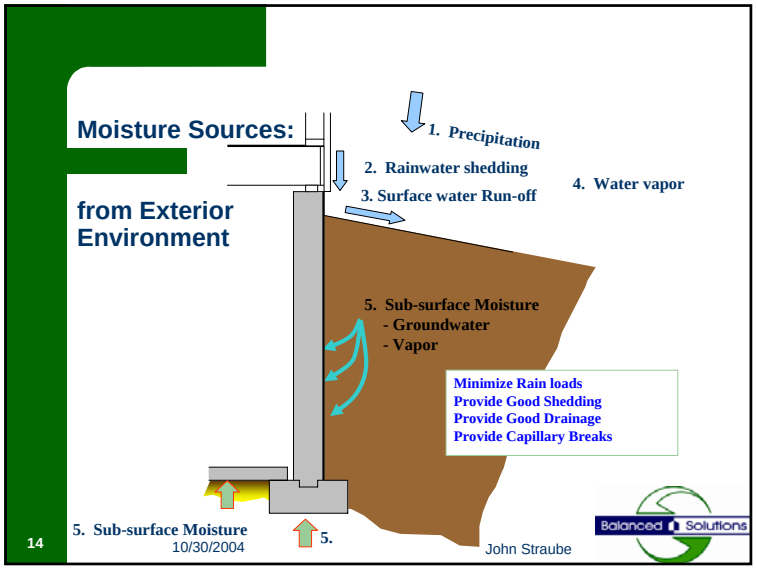

Exterior Temp and Moist Conditions
Summer
July
Winter
Jan.
Soil Relative Humidity almost always =100%
Liquid water may be present
Temperature
0
10
20
13


Moisture Sources:
from Exterior Environment
1. Precipitation
2. Rainwater shedding
3. Surface water Run-off
4. Water vapor
5. Sub-surface Moisture
- Groundwater
- Vapor
Minimize Rain loads
Provide Good Shedding
Provide Good Drainage
Provide Capillary Breaks
5. Sub-surface Moisture
5.
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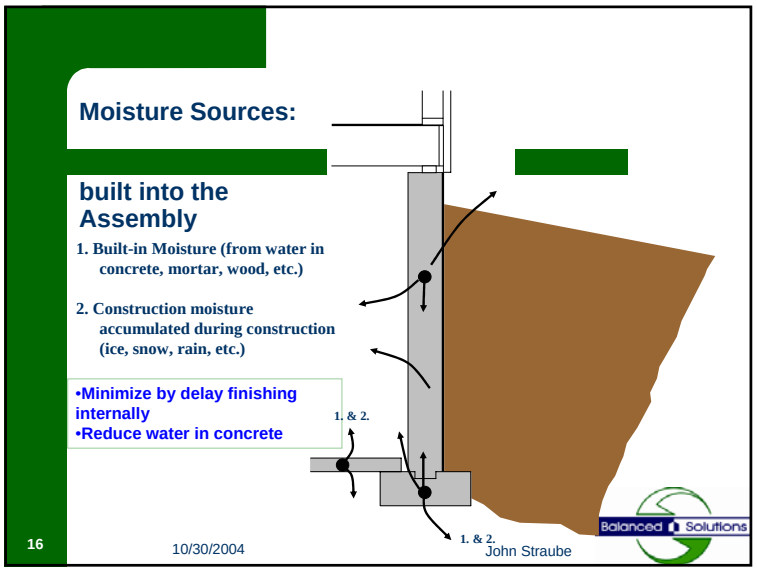
Exterior surface water


Moisture Sources:
built into the Assembly
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
1. & 2.
1. & 2.
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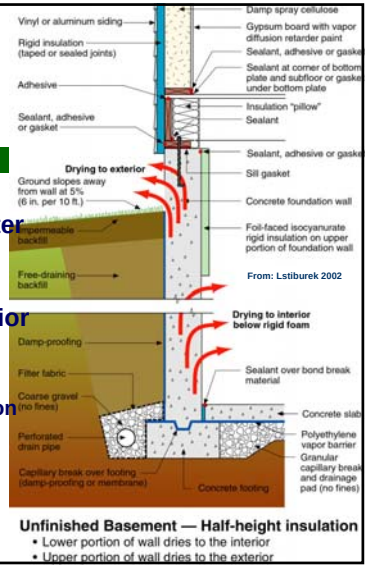
Initial Drying

- Soil cold for first yr
- Excavation collects water
- Concrete is wet
  - 30+ liters/m²
- Cannot dry to wet exterior
- Solutions
  - No low perm interior
  - Semi-permeable insulation
  - Smart vapor barrier



Unfinished Basement — Half-height insulation
- Lower portion of wall dries to the interior
- Upper portion of wall dries to the exterior

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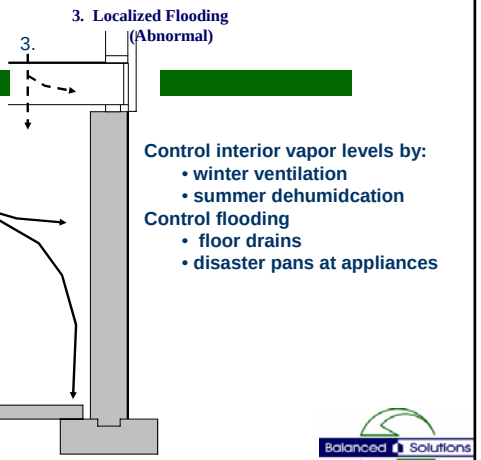
Moisture Sources:

from Interior



Control interior vapor levels by:
- winter ventilation
- summer dehumidcation

Control flooding
- floor drains
- disaster pans at appliances

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Exterior Moisture

Controlling ground/rain water

- Many different acceptable methods
- Classification of Groundwater control
  - 1. Drained
    - Needs capillary gap drain space
  - 2. Perfect Barrier
    - One layer of perfect water resistance
  - 3. Storage (mass)
    - Safe storage capacity and drying

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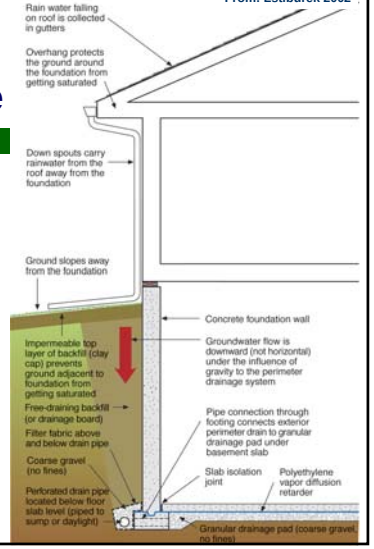
Surface Drainage

- First step
  - Common problem
- Eavestrough
- Downspouts
- Sloped grade
- Perimeter drain

From: Lstiburek 2002



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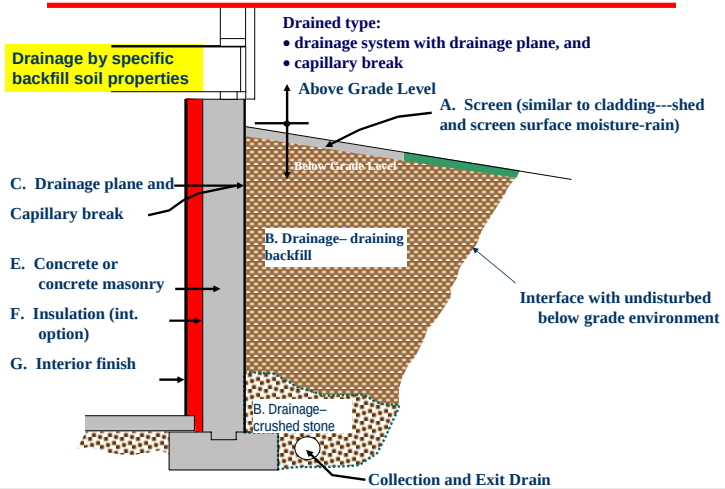
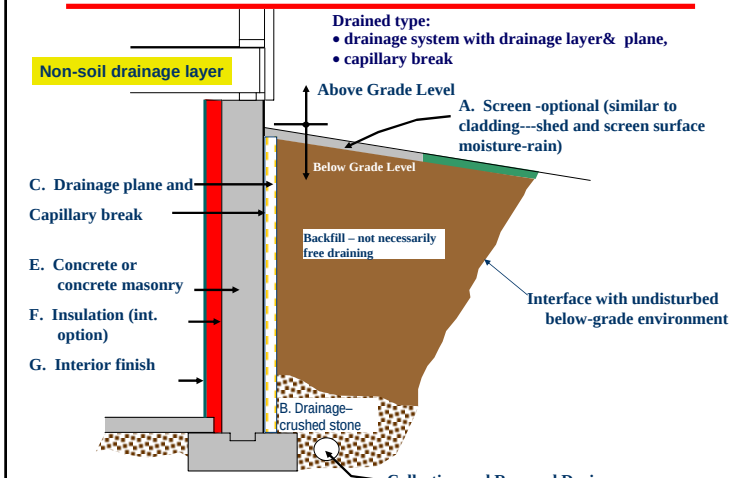
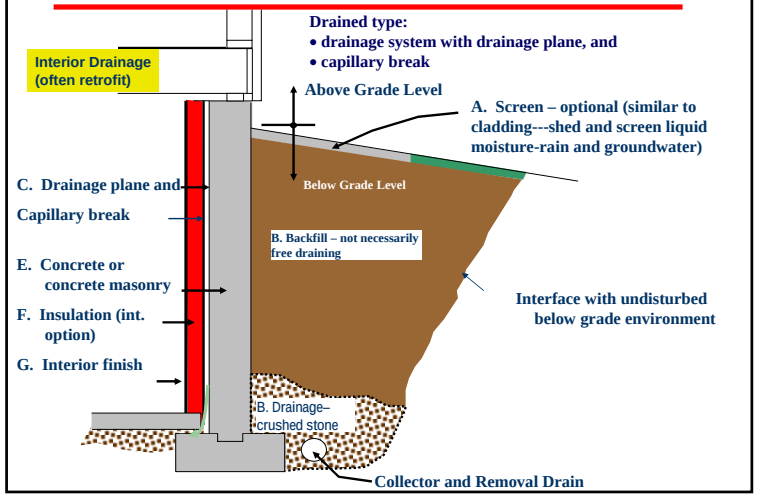
Screened(1) Below-Grade Enclosure Wall System



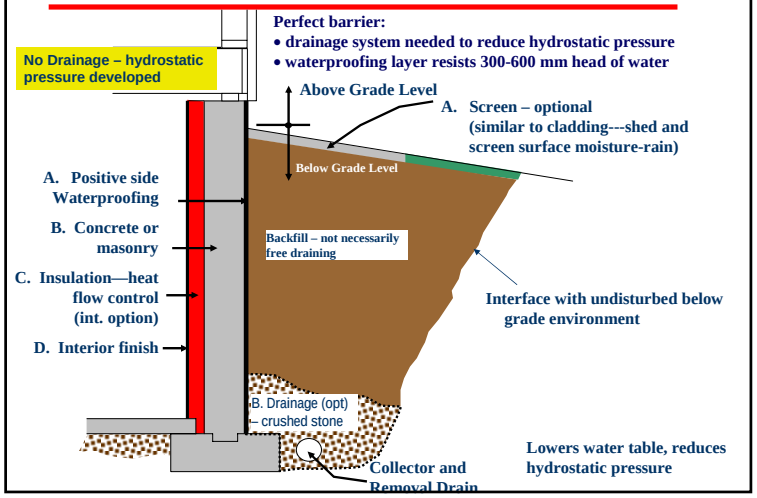
Screened(2) Below-Grade Enclosure Wall System



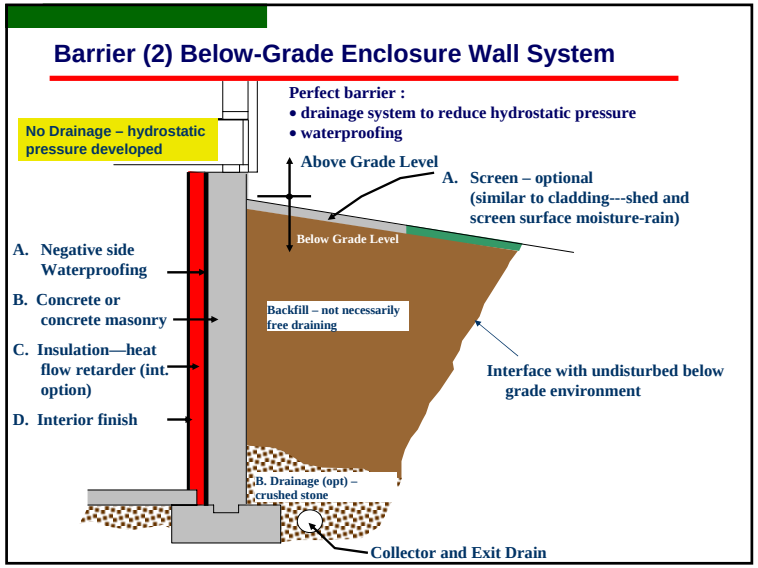
Screened(3) Below-Grade Enclosure Wall System



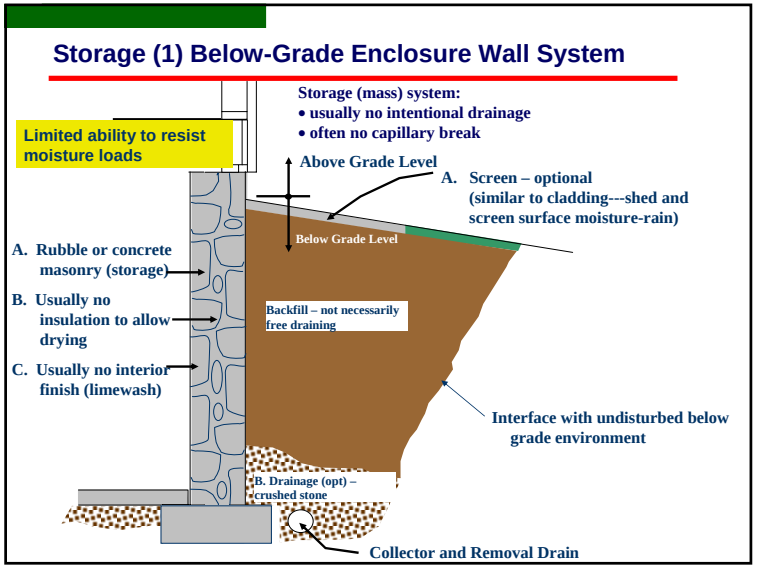
Barrier (1) Below-Grade Enclosure Wall System



Barrier (2) Below-Grade Enclosure Wall System



Storage (1) Below-Grade Enclosure Wall System




Damproofing
• Capillary break = drainage plane
• vapour barrier?
•NOT waterproofing


Glassfiber Drainage Layer


Glassfiber Drainage Layer


Rockwool Drainage Layer

Air and vapor

- Surface condensation
- Interstitial condensation
- Solar driven summer condensation
- Drying retarders
- Psychrometric Chart

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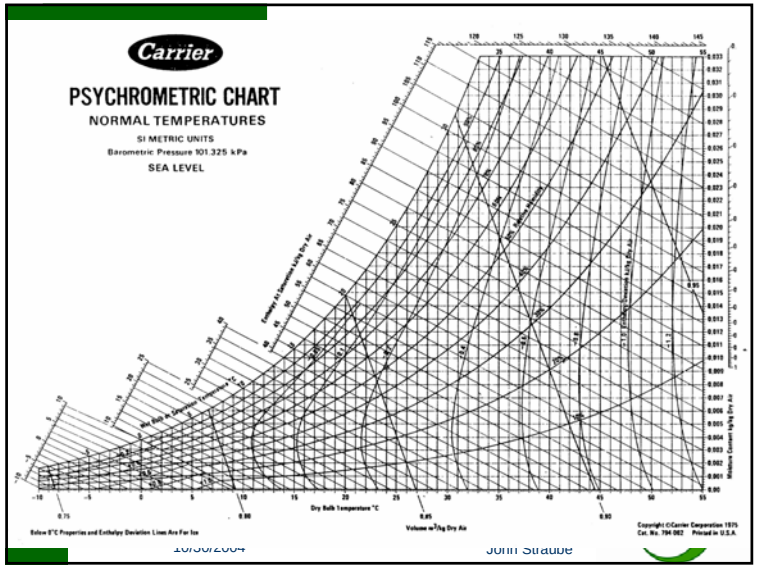
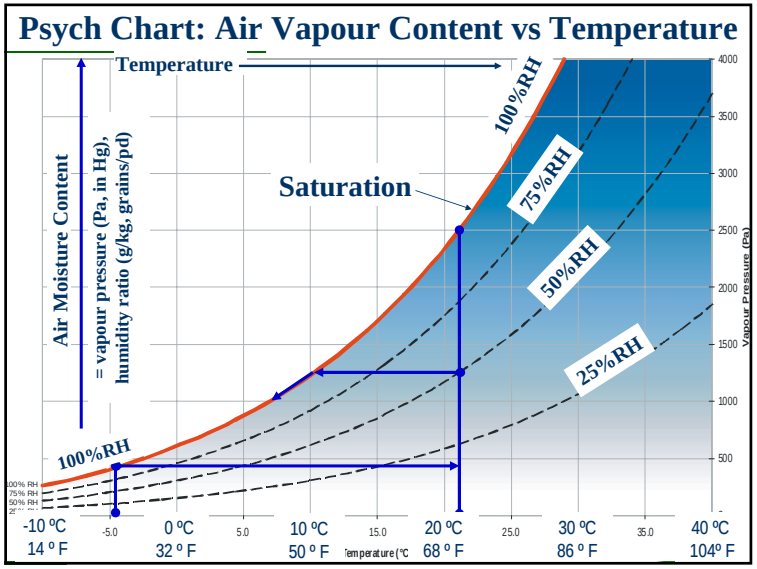
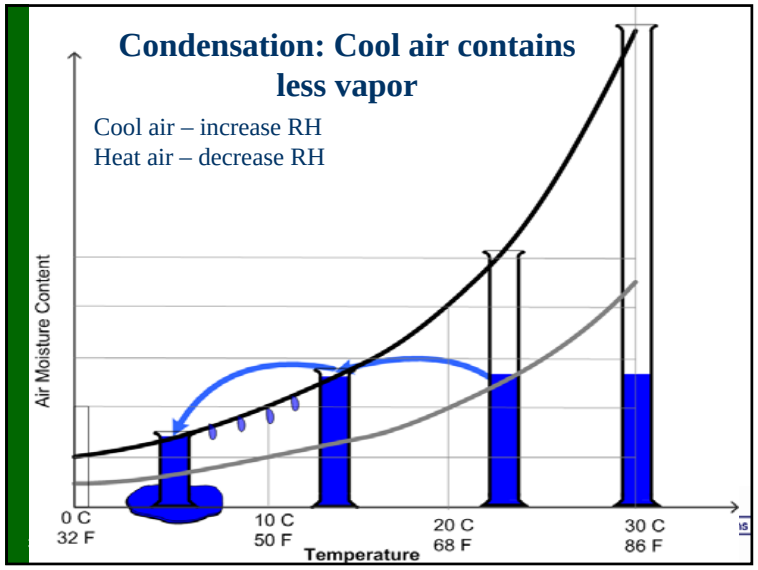
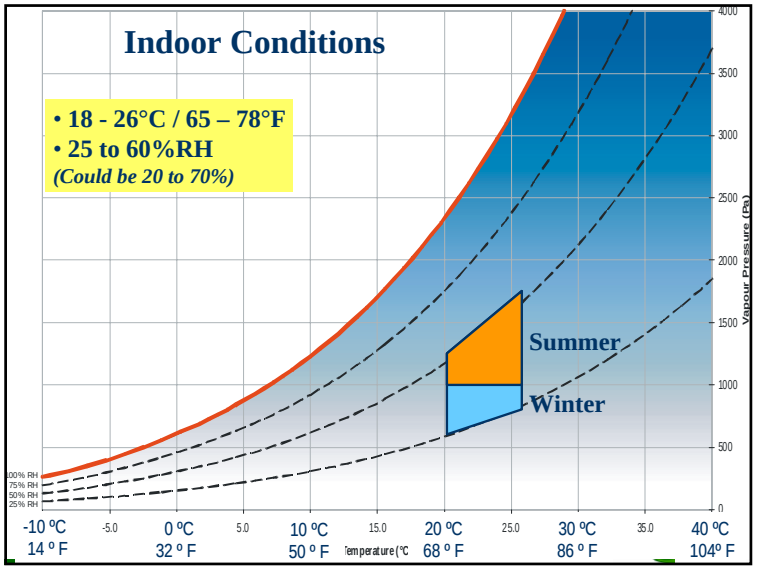
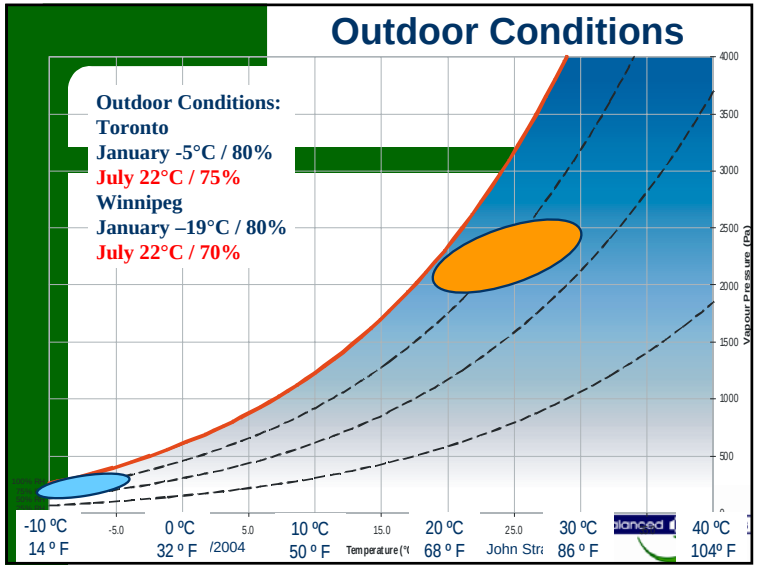
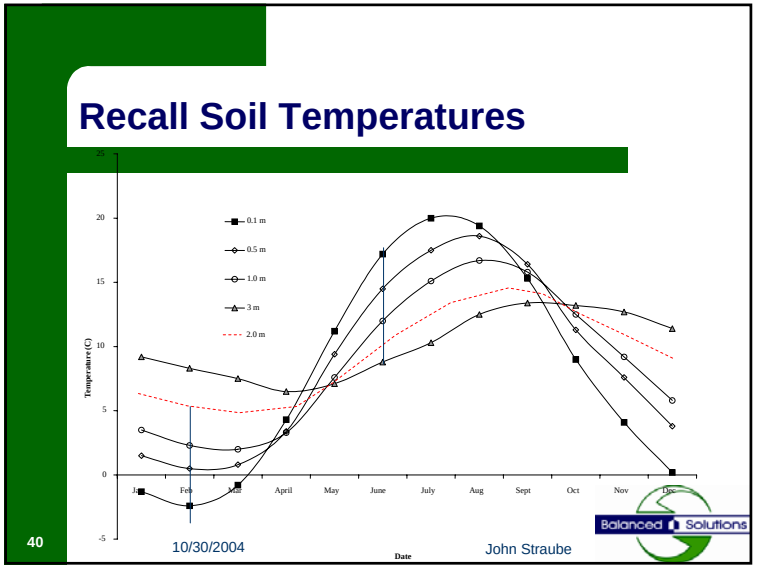





Condensation: Cool air contains less vapor
Cool air – increase RH
Heat air – decrease RH
Air Moisture Content
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature


Indoor Conditions
• 18 - 26°C / 65 – 78°F
• 25 to 60%RH
(Could be 20 to 70%)
Summer
Winter
Vapour Pressure (Pa)
-10 ºC
14 º F
0 ºC
32 º F
10 ºC
50 º F
20 ºC
68 º F
30 ºC
86 º F
40 ºC
104º F


Outdoor Conditions
Outdoor Conditions:
Toronto
January -5°C / 80%
July 22°C / 75%
Winnipeg
January –19°C / 80%
July 22°C / 70%
Vapour Pressure (Pa)
-10 ºC
14 º F
0 ºC
32 º F
10 ºC
50 º F
20 ºC
68 º F
30 ºC
86 º F
40 ºC
104º F


Recall Soil Temperatures
0.1 m
0.5 m
1.0 m
3 m
2.0 m
Temperature (C)
Jan
Feb
April
May
June
July
Aug
Sept
Oct
Nov
Date
40
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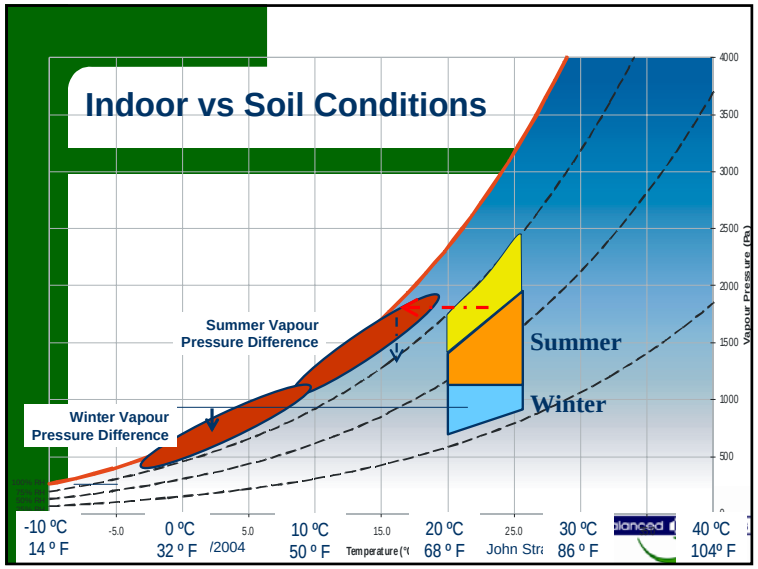
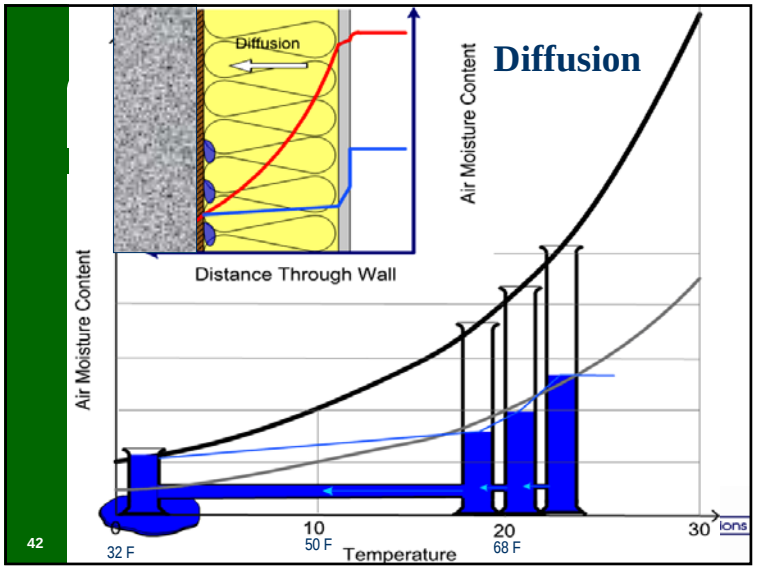
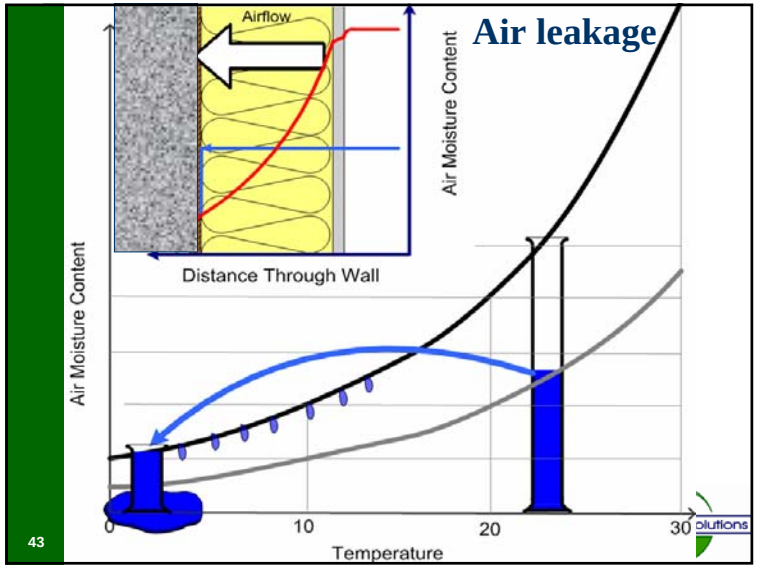
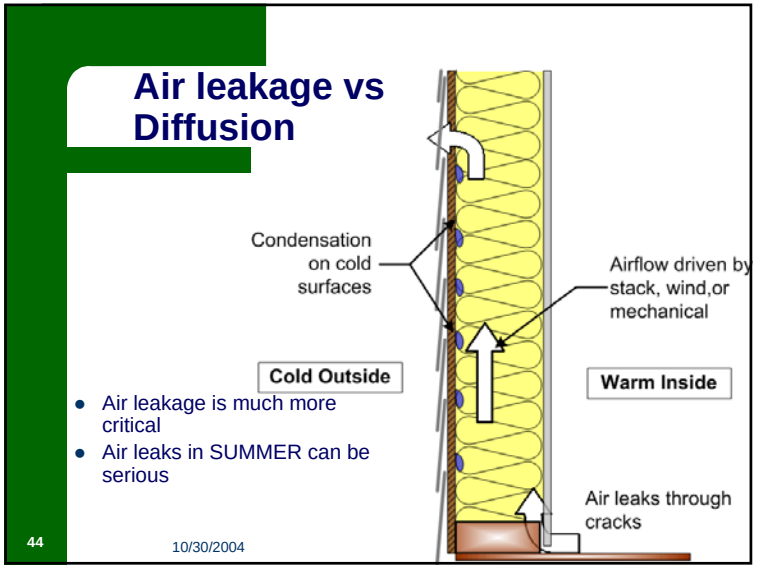
Balanced Solutions


Indoor vs Soil Conditions
Summer Vapour Pressure Difference
Winter Vapour Pressure Difference
Summer
Winter
-10 ºC 14 º F
0 ºC 32 º F
10 ºC 50 º F
20 ºC 68 º F
30 ºC 86 º F
40 ºC 104º F


Diffusion
Air Moisture Content
Distance Through Wall
Temperature
32 F
50 F
68 F
42


Air leakage
Airflow
Air Moisture Content
Distance Through Wall
Temperature
43


Air leakage vs Diffusion
Condensation on cold surfaces
Airflow driven by stack, wind,or mechanical
Cold Outside
Warm Inside
Air leaks through cracks
Air leakage is much more critical
Air leaks in SUMMER can be serious
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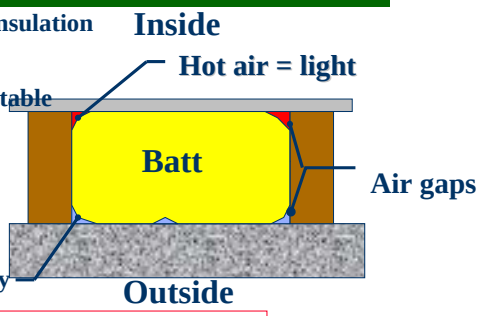
Internal Stack Effect & Insulation

- Gaps in batt insulation on both sides
- Wrinkles inevitable



Common basement problem

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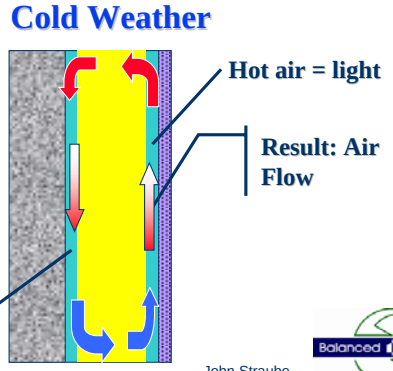
Internal Stack Effect

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



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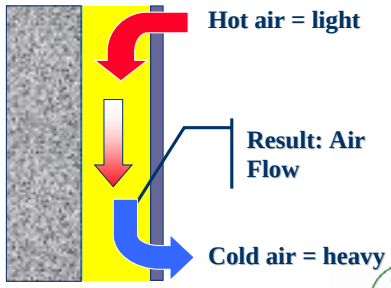
Air movement (Stack Effect)

Cold concrete = summer & winter



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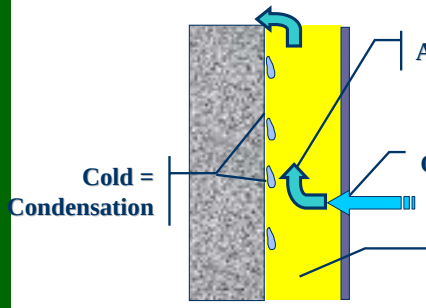
Wall w/o Insulation



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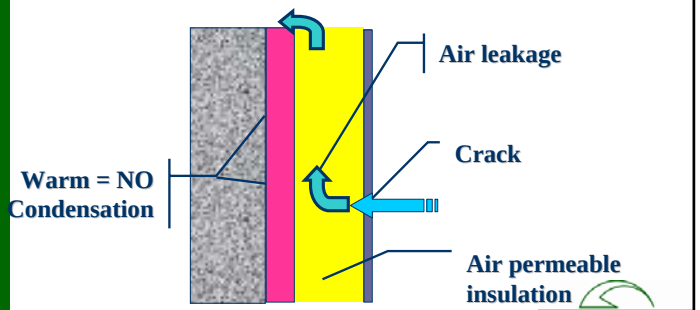
Wall w/ Insulation



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Insulation

- Foam Board: EPS, XPS, PIC
  - water tolerant
  - vapour barriers to vapour retarders
- spray foam
  - Semi-rigid (Icynene) and rigid (Spray polyurethane)
  - airtight
  - Allow some drainage
  - R values of 4 to 4.4/inch
  - vapour semi-permeable

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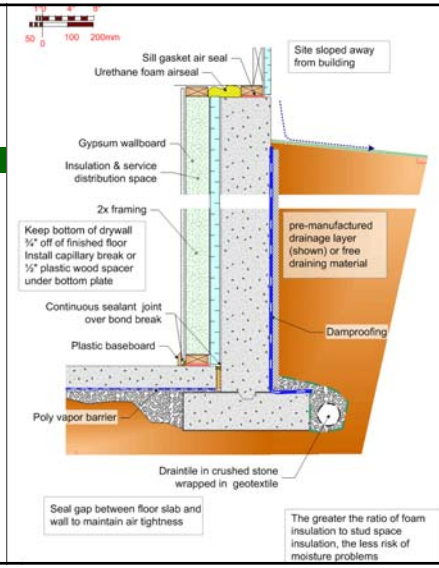
Better



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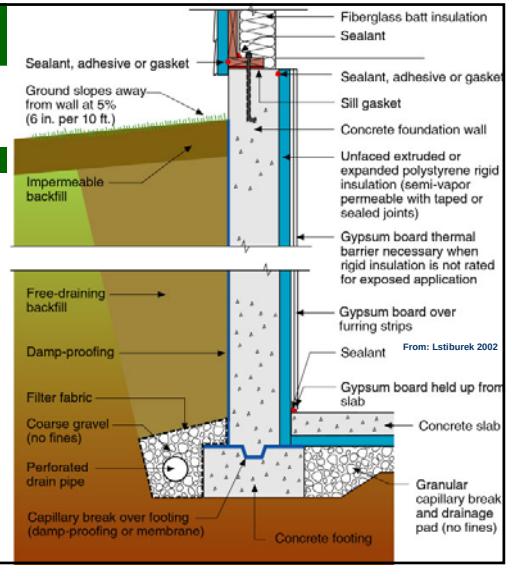
Best



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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 of cold and impermeable

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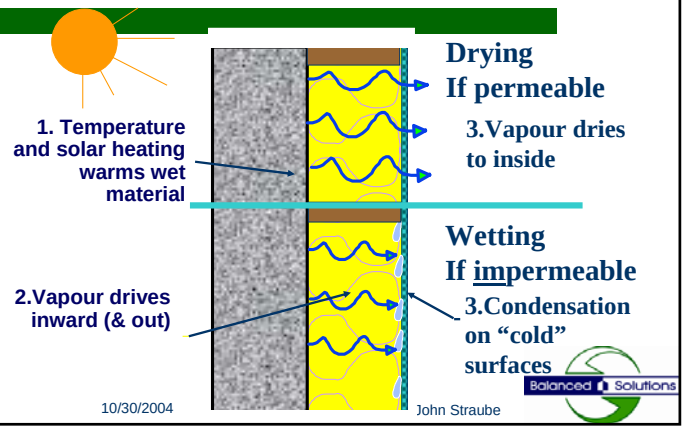
Inward Diffusion @ grade



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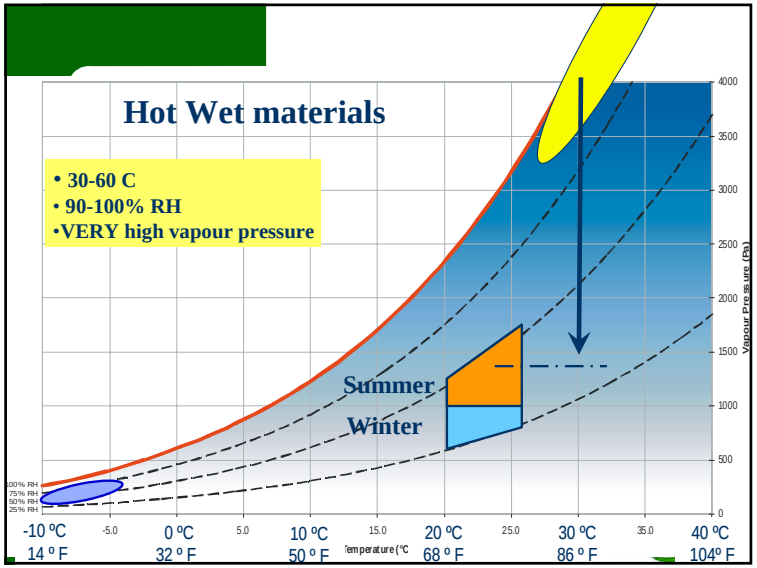
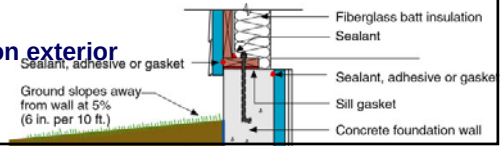
Hot Wet materials

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



Rim joists

- Scenario
  - Wood generally on exterior
  - 38 mm 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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Basement Floors

- Basement floors
  - Part of enclosure
- Concrete alone fine but when you finish…
  - Comfort (cold and hard)
  - Water under finish (winter)
  - Water condensing on top (summer)
- Solutions
  - Install finish over small amount of insulation
  - Install vapor barrier

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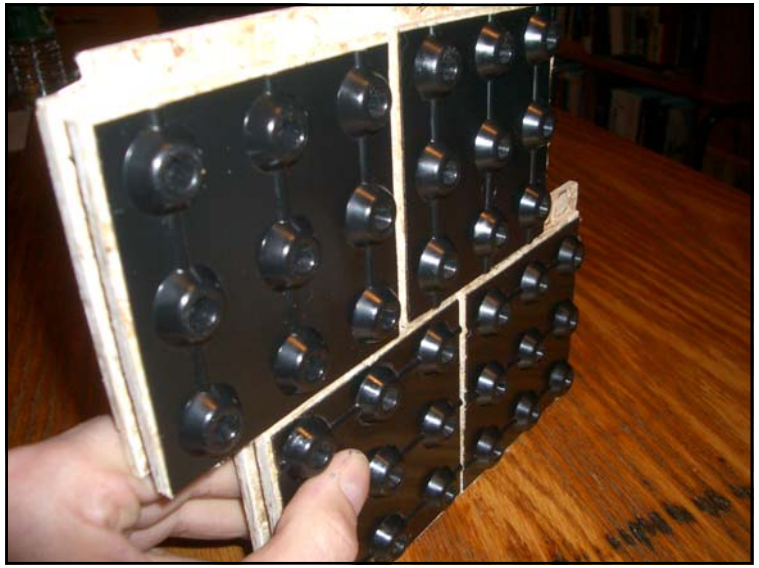
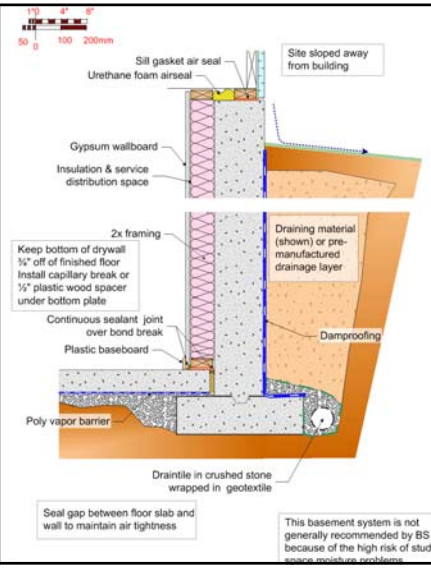


Summary

- Tolerable



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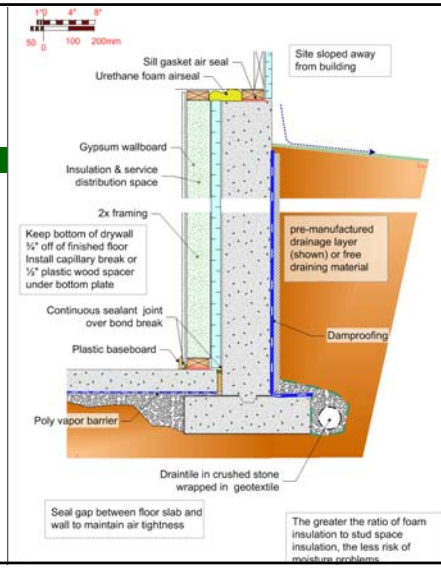
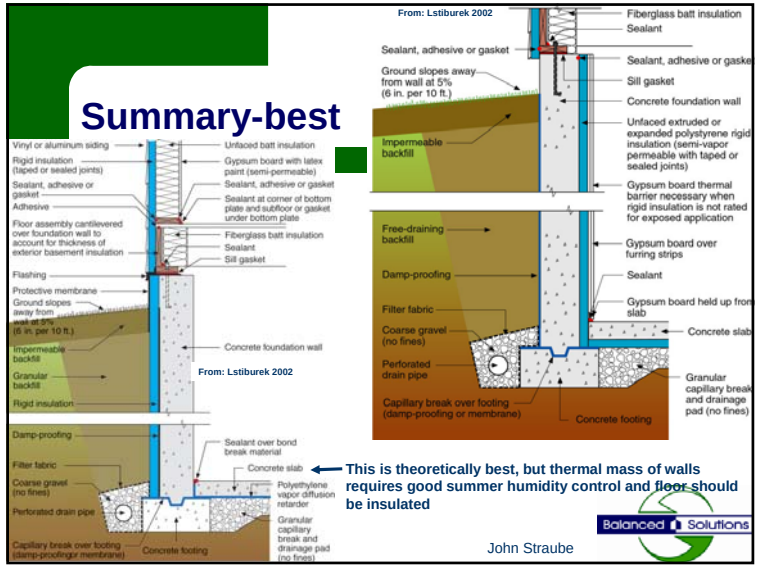
Summary

- good



Summary-best



This is theoretically best, but thermal mass of walls requires good summer humidity control and floor should be insulated

Conclusions

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

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Addition

- Repair
  - Wall leaks groundwater
- Retrofit/Reno
  - Risk reduction