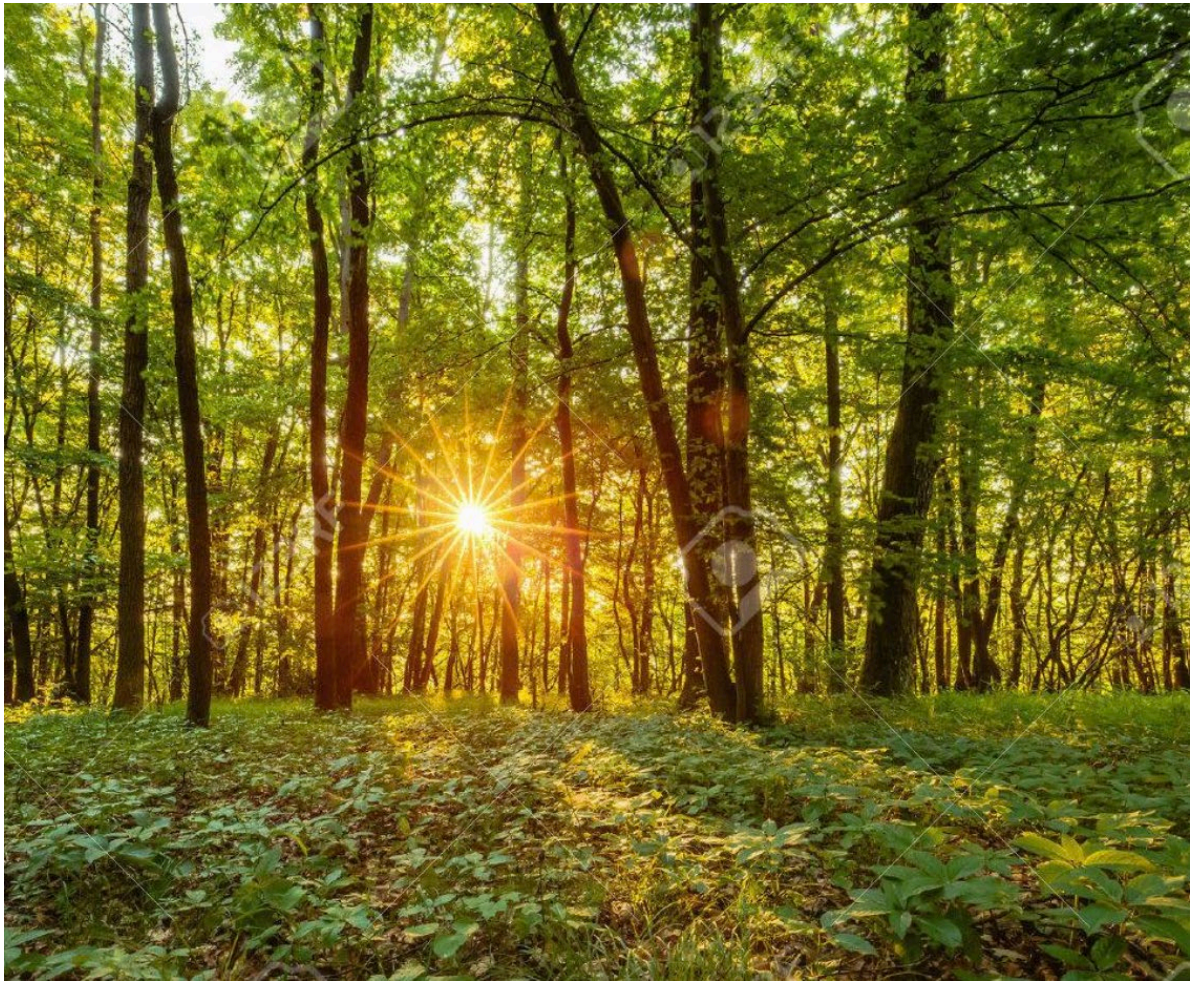
Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

Adventures In Building Science

www.buildingscience.com

Wood is Good…It Grows on Trees…



Carbon + Water + Sunlight = Wood

(photosynthesis)

Wood Is The Ultimate Building Material

When We Are Done It Turns Back To Carbon and Water and Releases The Energy

Plants Do A Better Job Of Converting Solar Energy Than Rocks

Wood Is A Battery For Energy From The Sun

Wood Is Fabulous Carbon Sequestration

Some Physics….

2nd Law of Thermodynamics

Heat Flow Is From Warm To Cold

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Air Flow Is From A Higher Pressure to a Lower Pressure

Gravity Acts Down

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion

Concentration Gradient – Molecular Diffusion

Moisture Flow Is From Warm To Cold

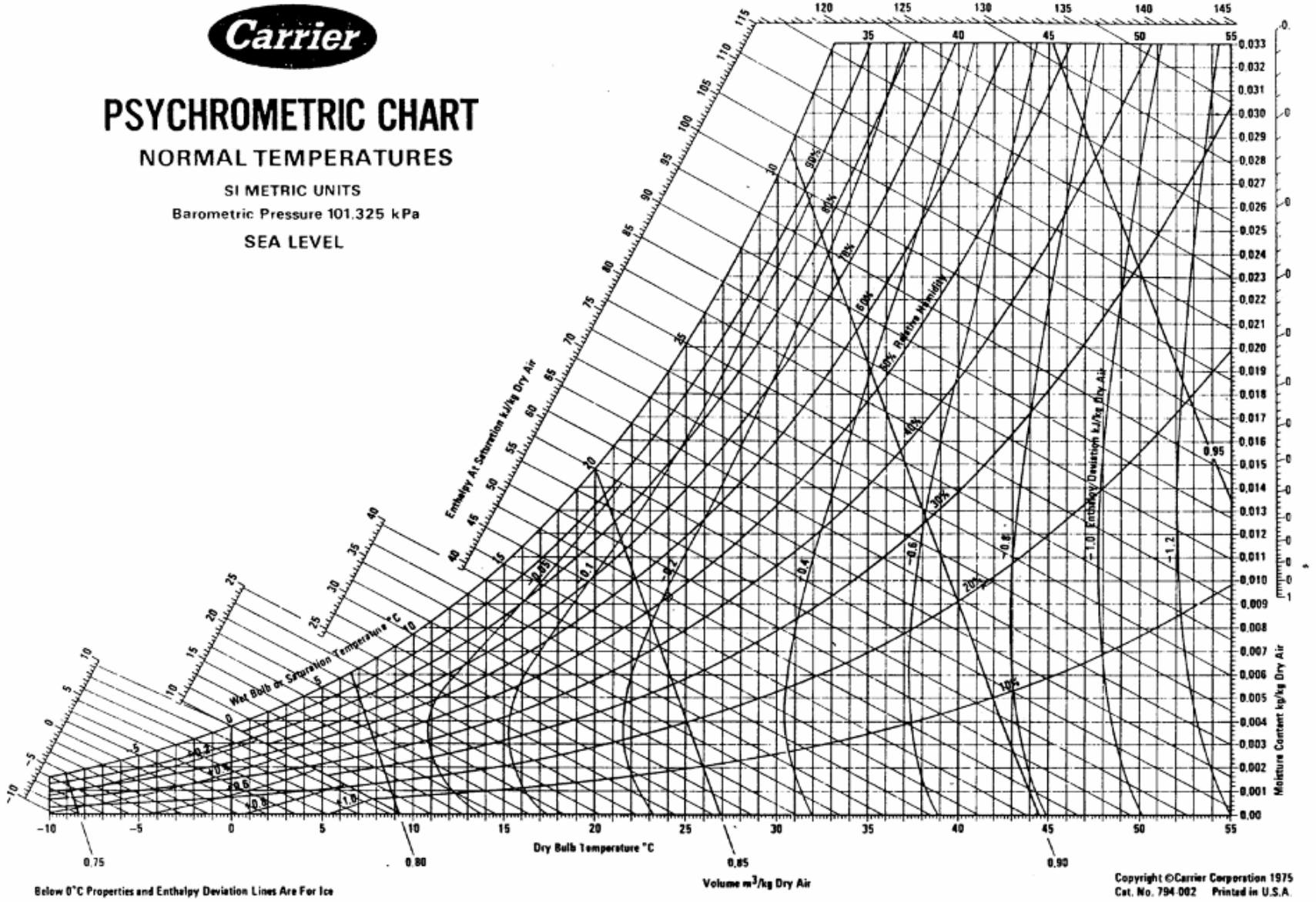
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion

Concentration Gradient – Molecular Diffusion

Vapor Diffusion

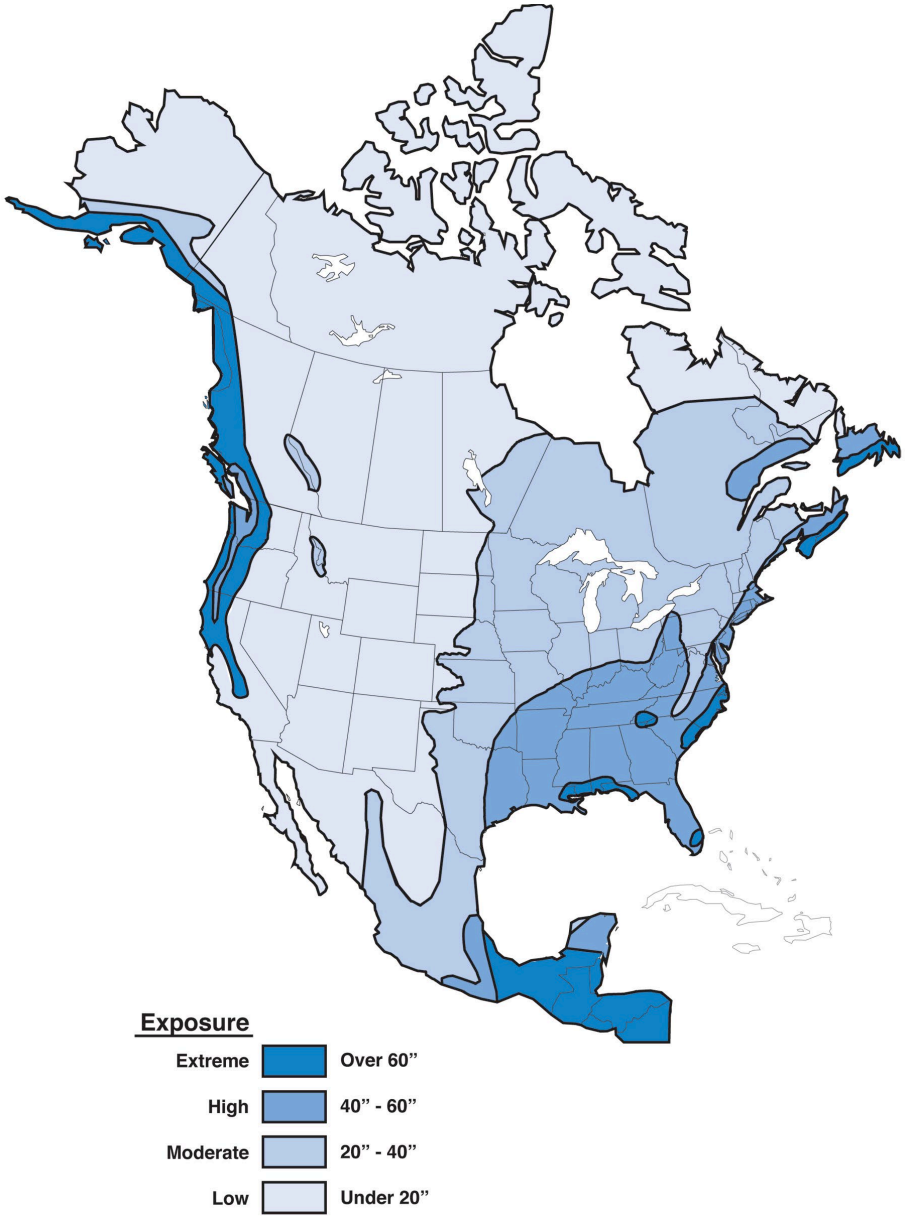
Thermodynamic Potential

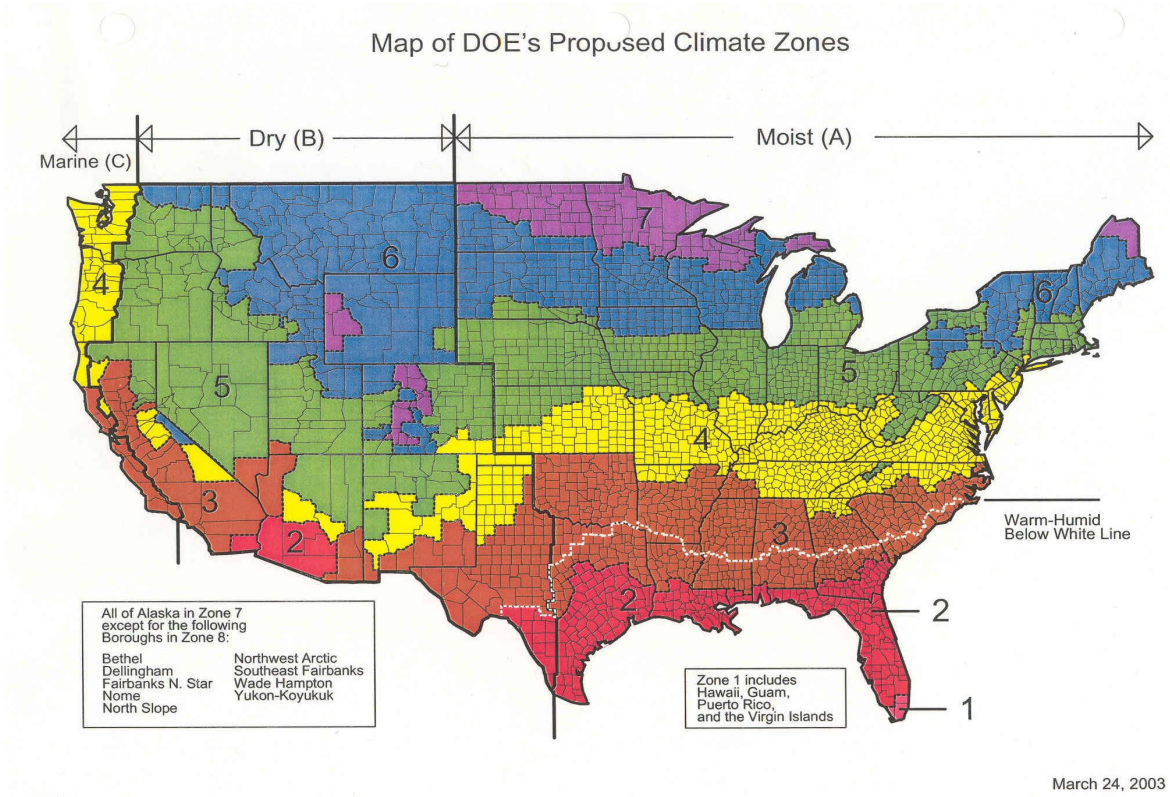

Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Dry Bulb Temperature °C
Wet Bulb or Saturation Temperature °C
Enthalpy At Saturation kJ/kg Dry Air
Moisture Content kg/kg Dry Air
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice
Volume m³/kg Dry Air
Copyright ©Carrier Corporation 1975
Cat. No. 794-002 Printed in U.S.A.

The Effect of Climate


Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Mixed-Dry
Hot-Humid
Hot-Dry


Arctic Bay
Anchorage
Seattle
Minneapolis
Los Angeles
El Paso
Houston
Monterrey
Havana
Belize City
Tropical Wet
Tropical Wet-Dry
Steppe
Desert
Mediterranean
Subtropical humid
Marine West Coast
Continental humid
Subarctic
Tundra
Ice sheet
Highlands


Exposure
Extreme
Over 60”
High
40” - 60”
Moderate
20” - 40”
Low
Under 20”


Map of DOE's Proposed Climate Zones
Marine (C)
Dry (B)
Moist (A)
Warm-Humid
Below White Line
All of Alaska in Zone 7
except for the following
Boroughs in Zone 8:
Bethel
Dellingham
Fairbanks N. Star
Nome
North Slope
Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon-Koyukuk
Zone 1 includes
Hawaii, Guam,
Puerto Rico,
and the Virgin Islands
March 24, 2003

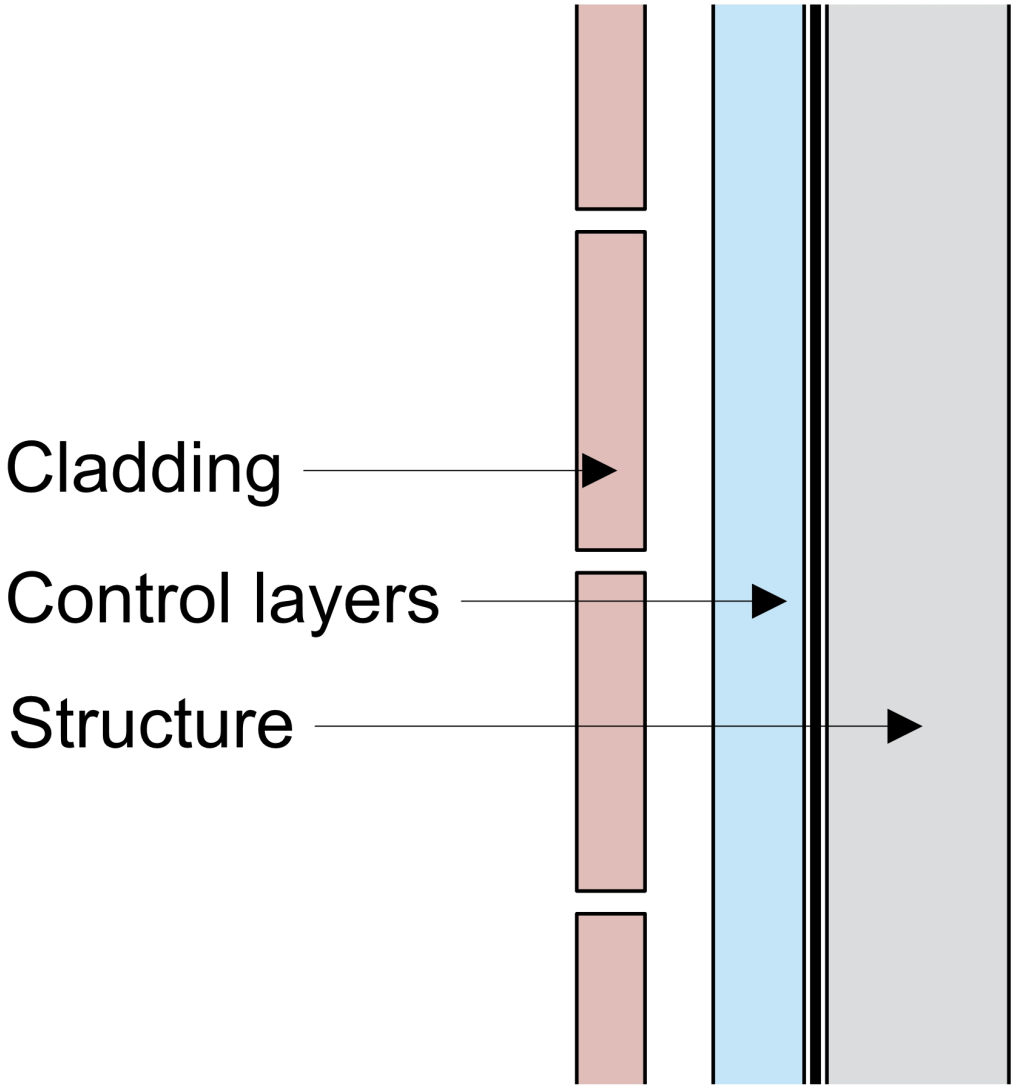
The Perfect Wall

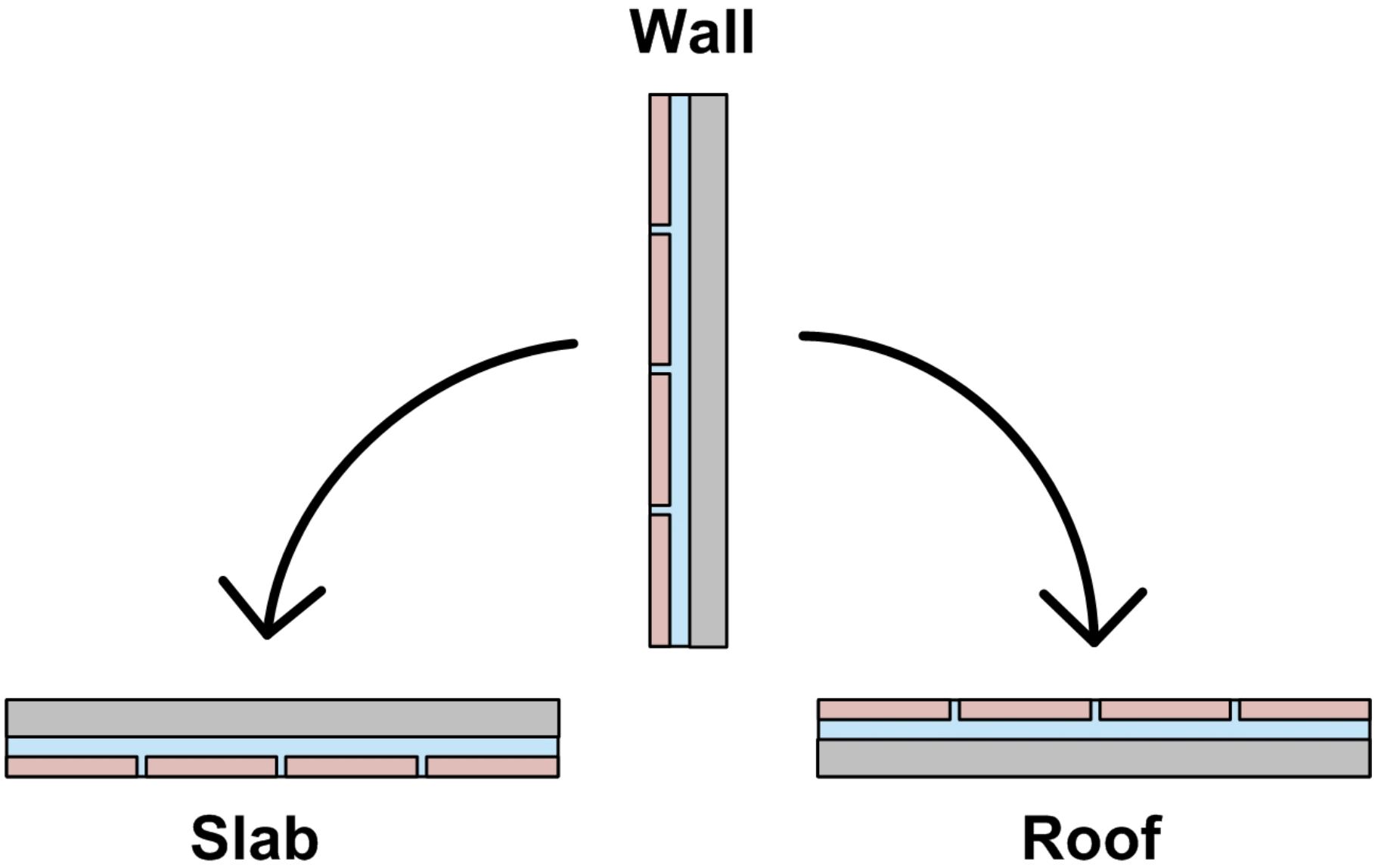
Water Control Layer

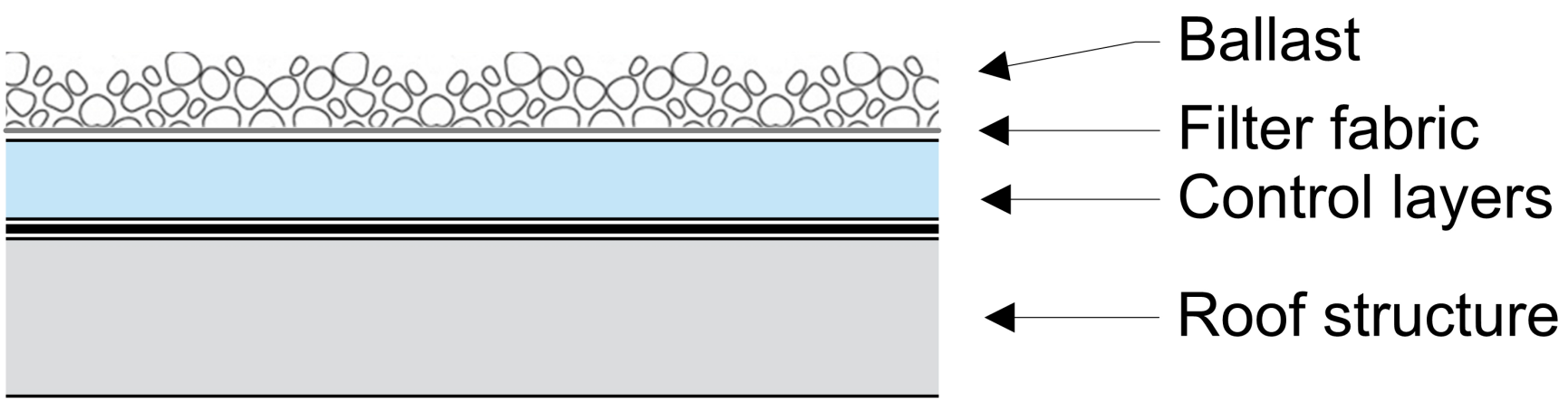
Air Control Layer

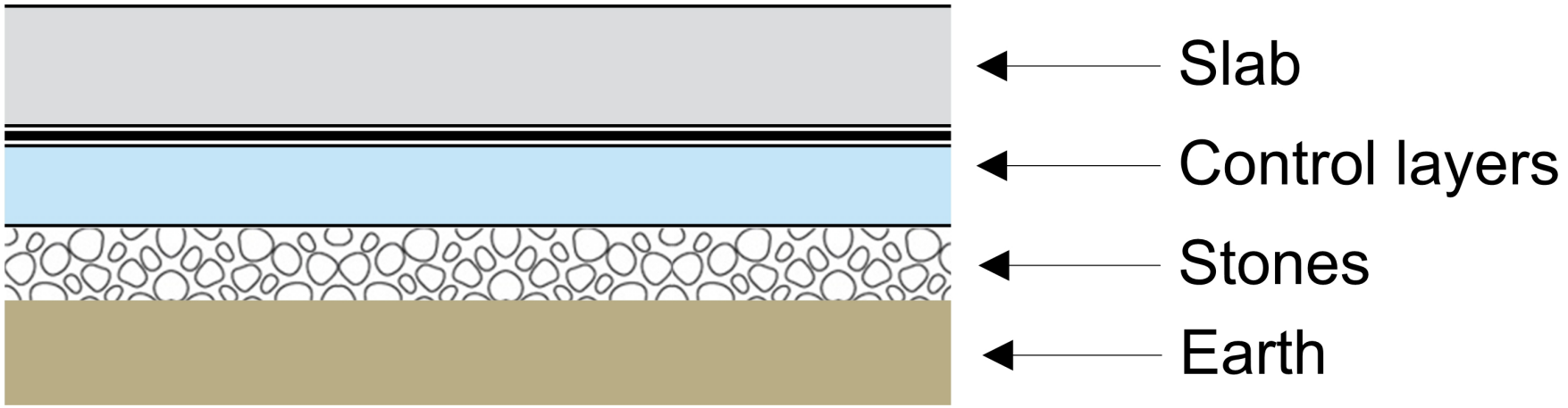
Vapor Control Layer

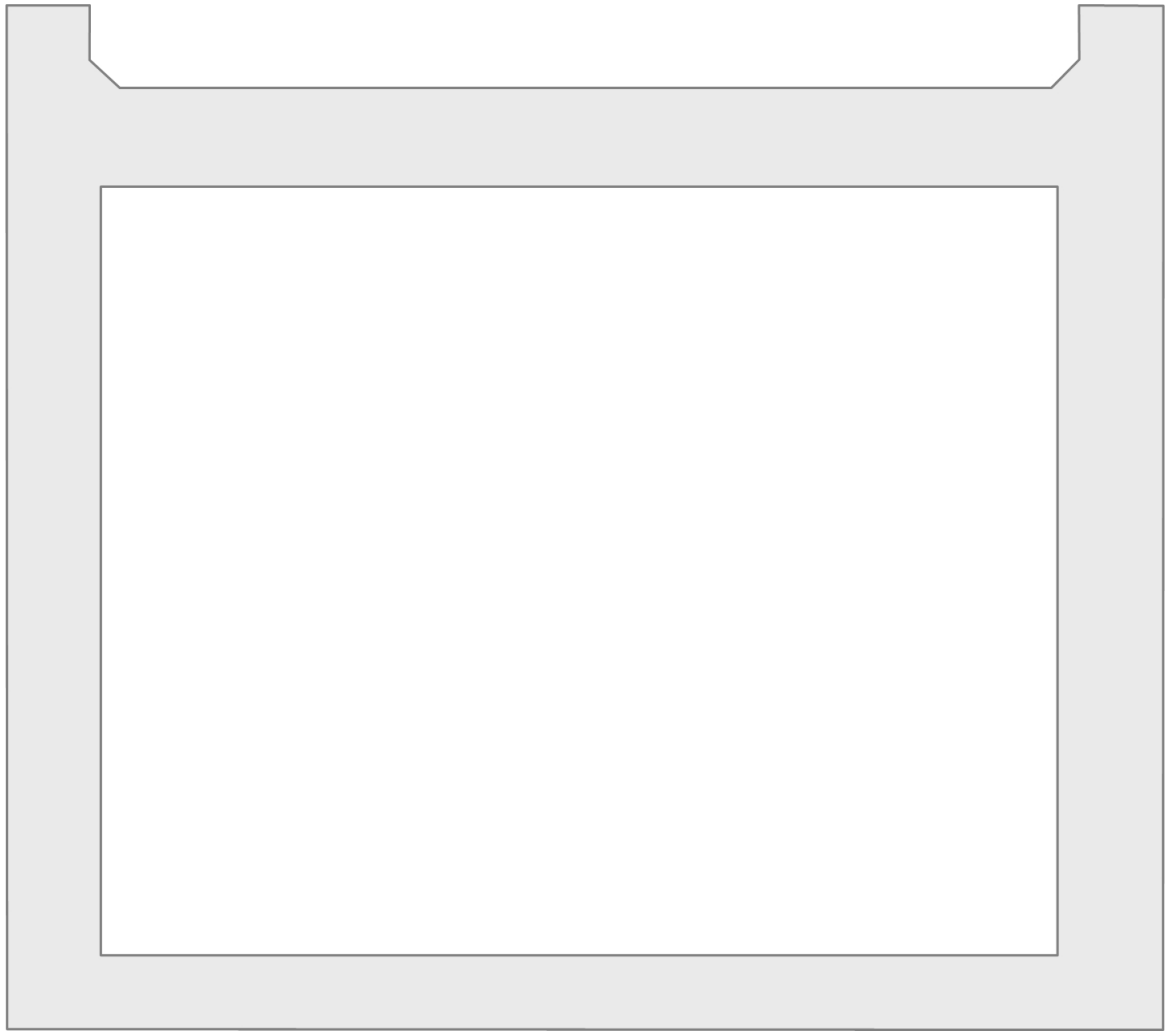
Thermal Control Layer

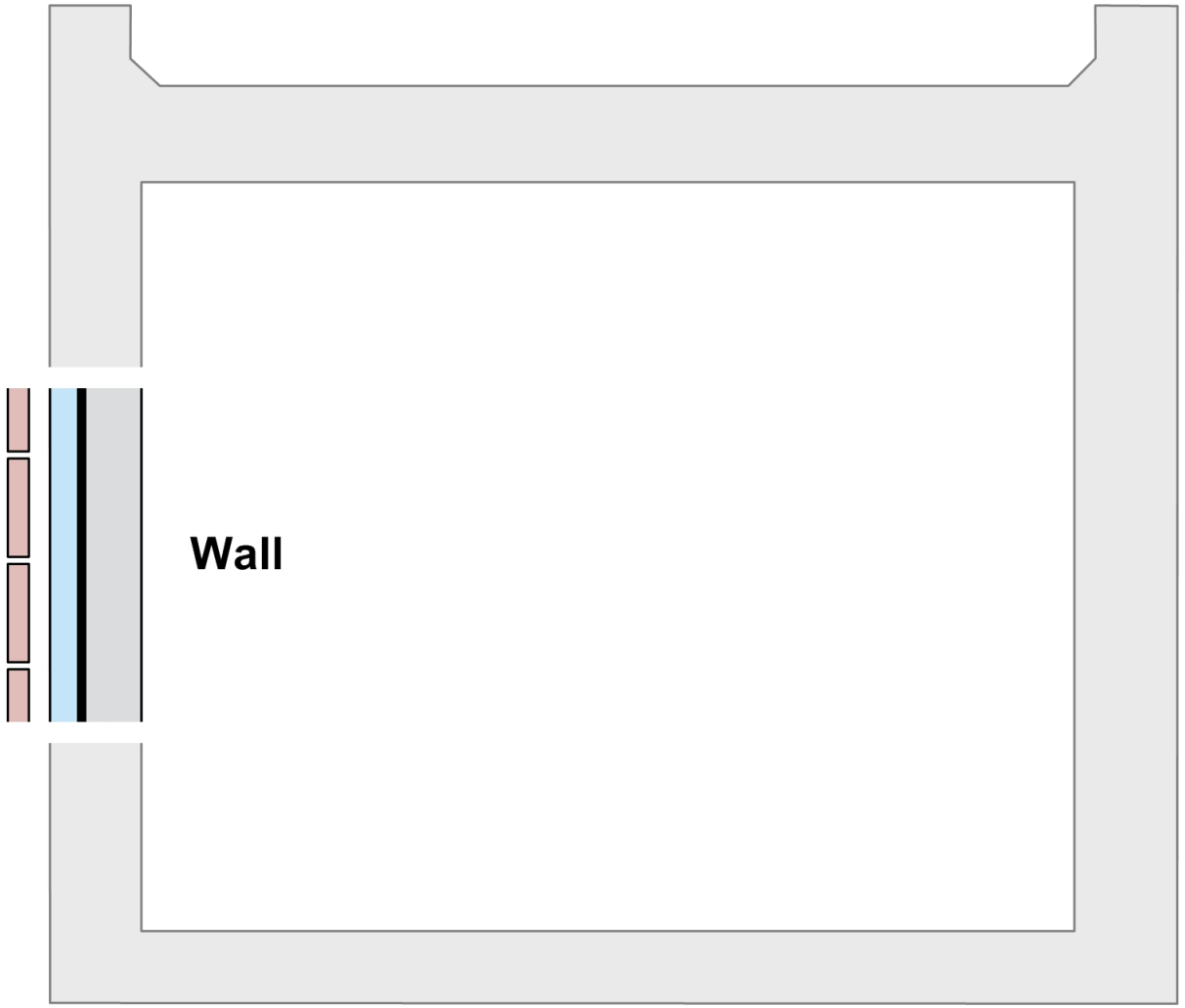

Cladding
Control layers
Structure

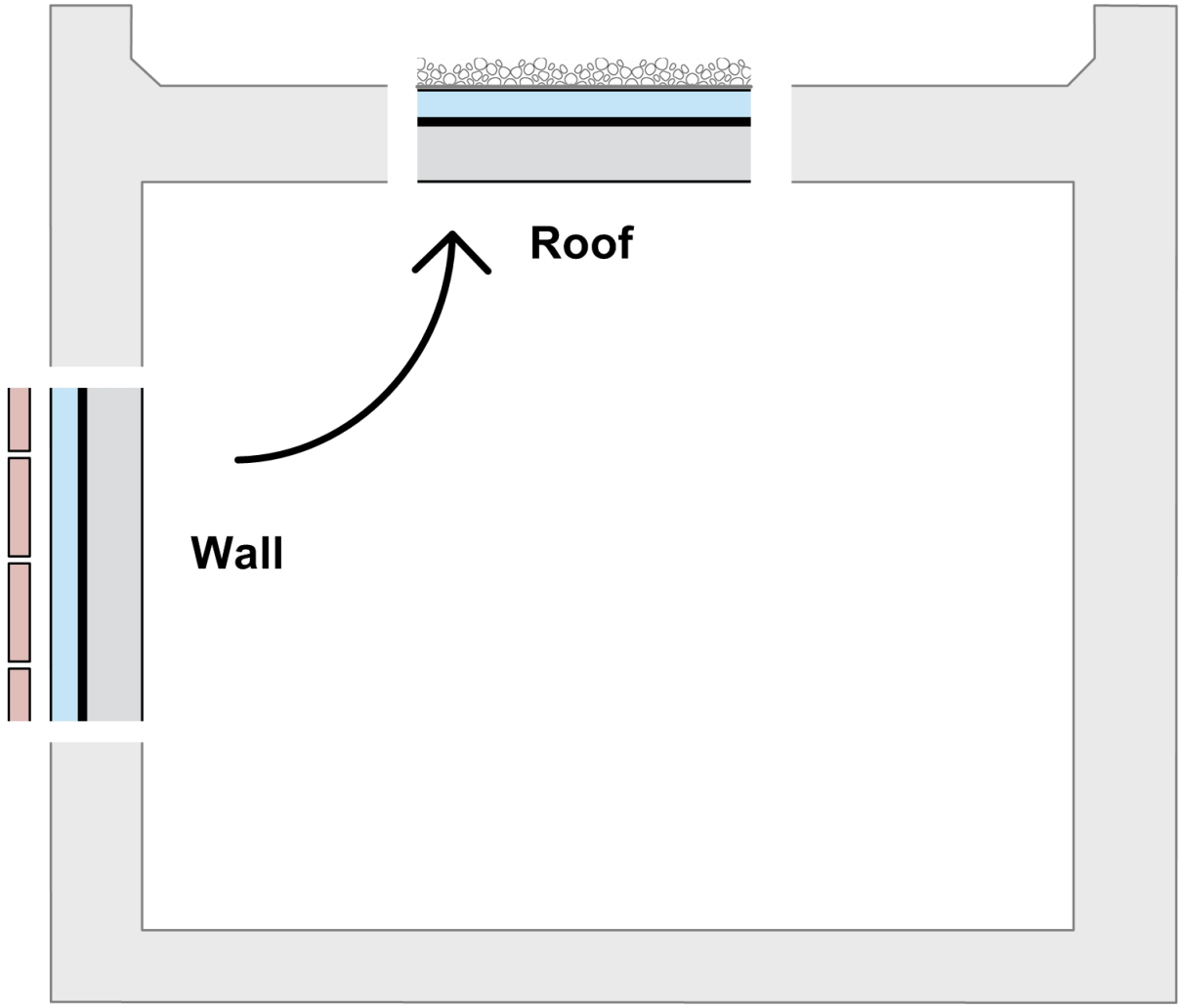

Wall
Slab
Roof

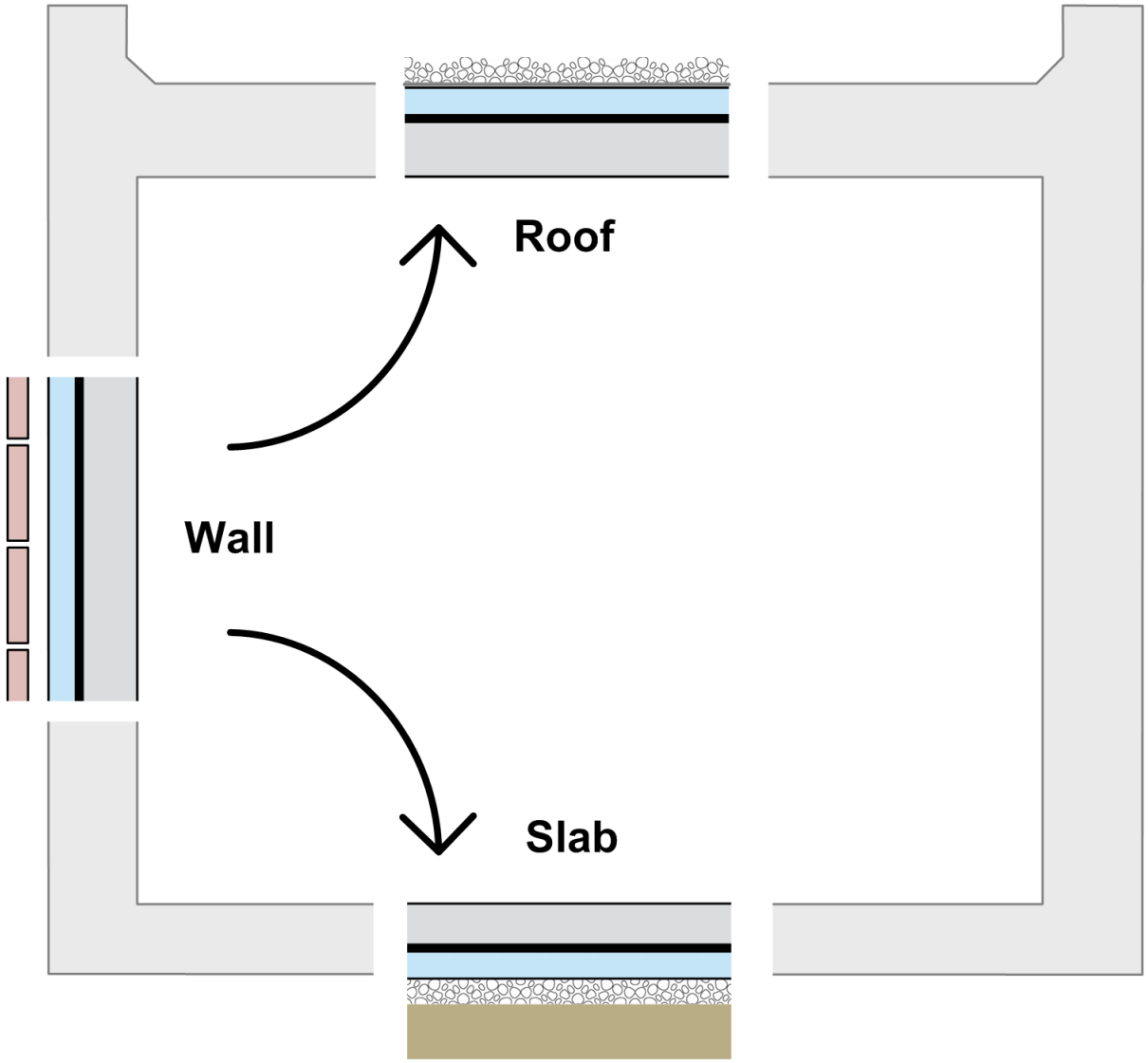

Ballast
Filter fabric
Control layers
Roof structure

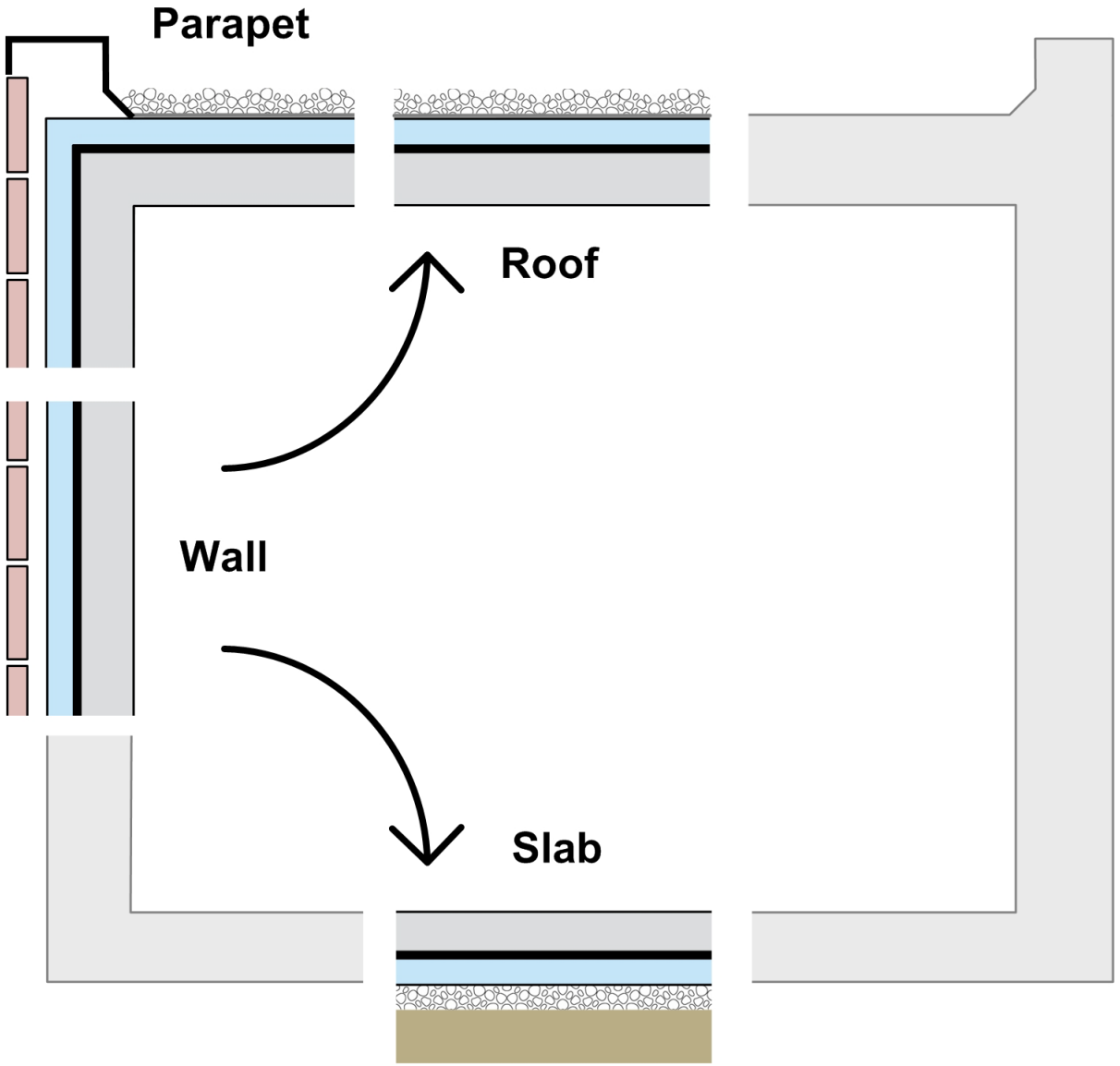

Slab
Control layers
Stones
Earth

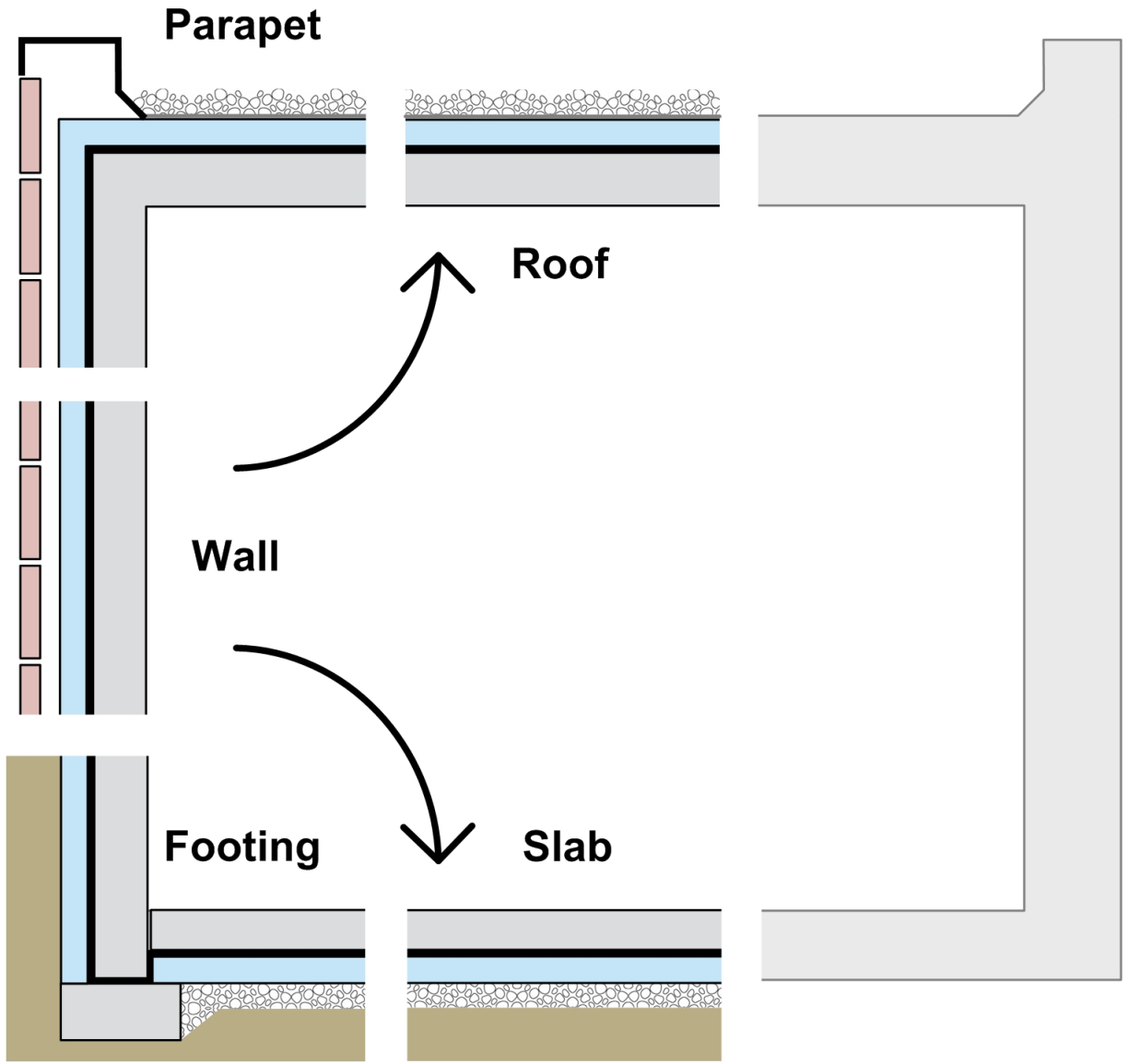


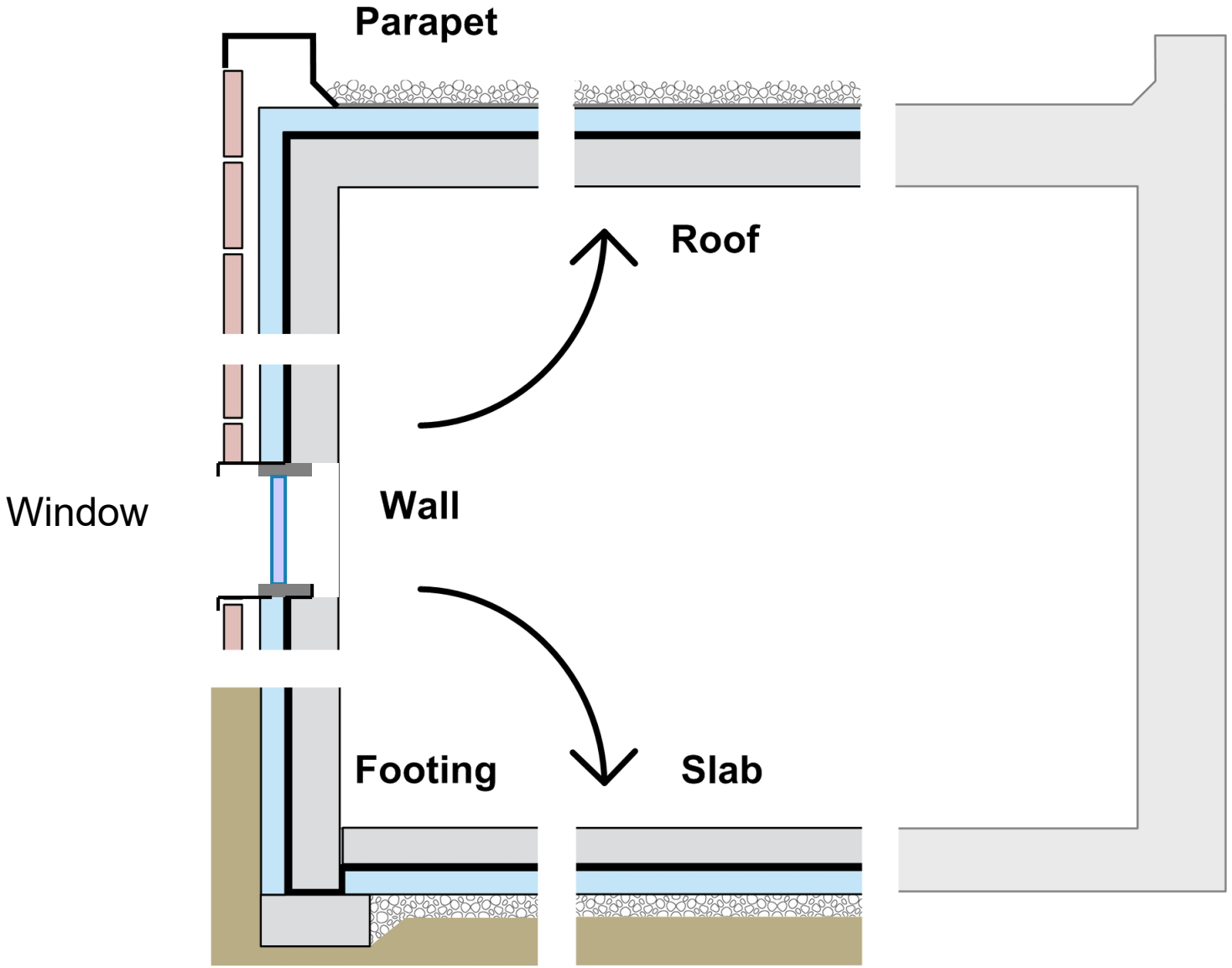

Wall

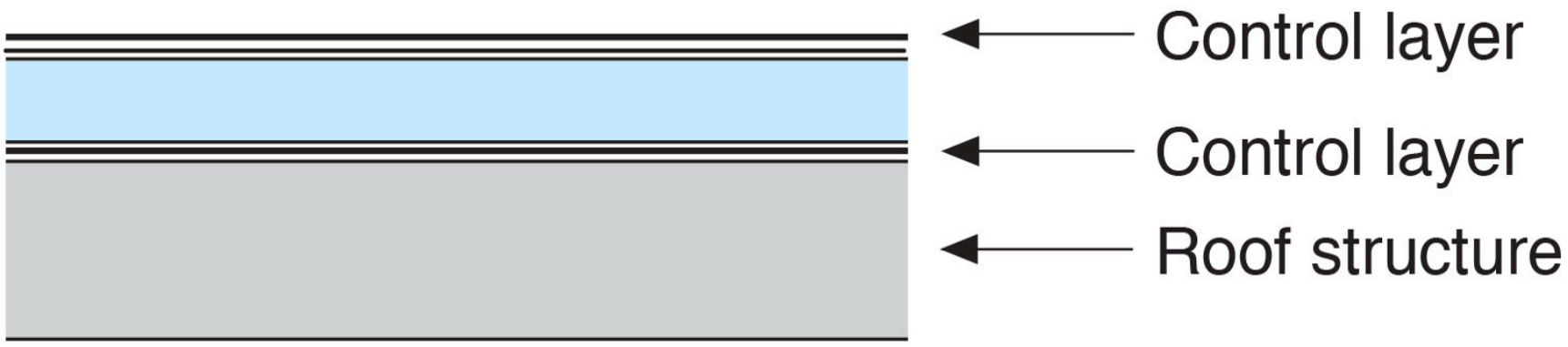

Roof
Wall

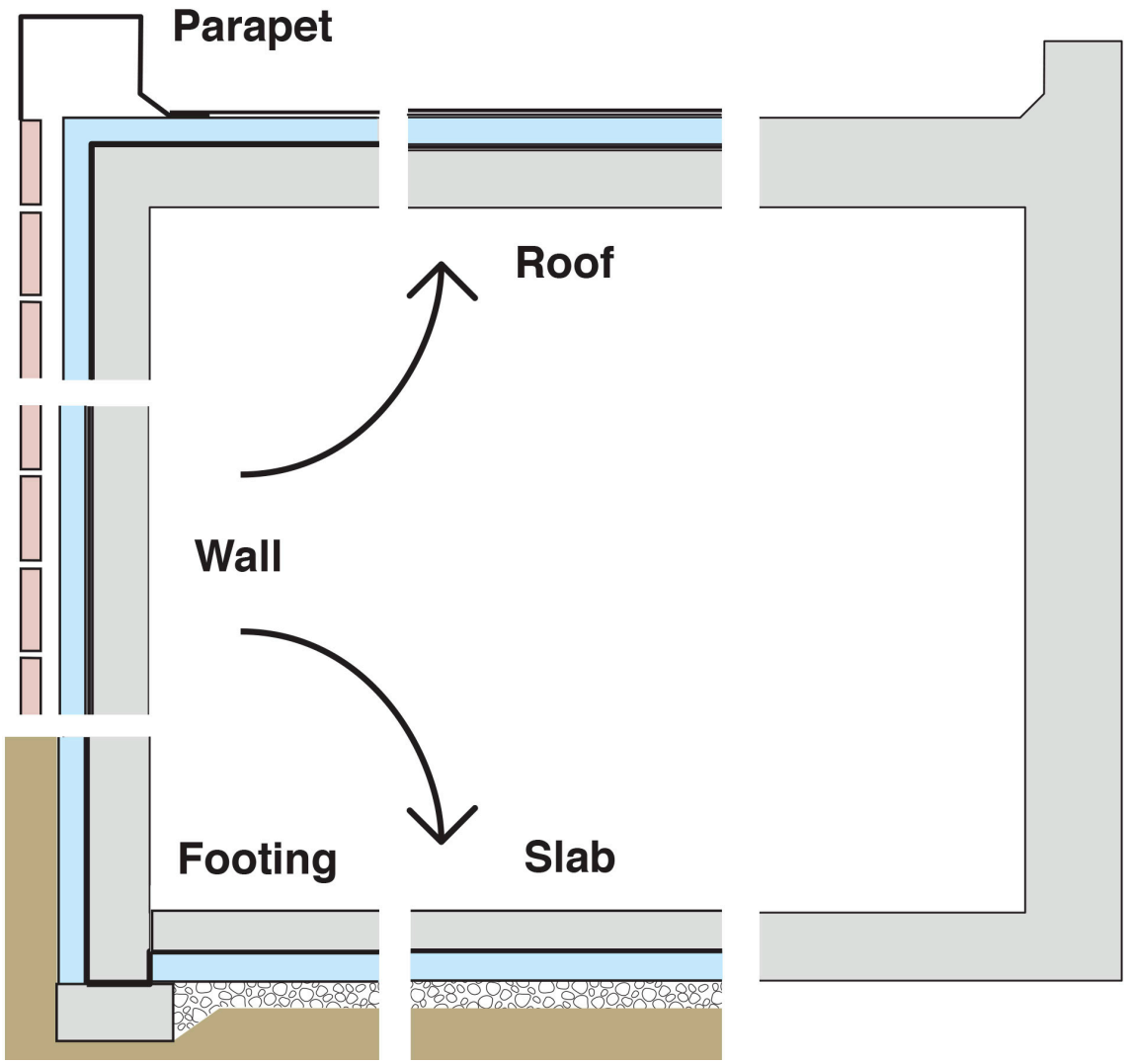

Roof
Wall
Slab

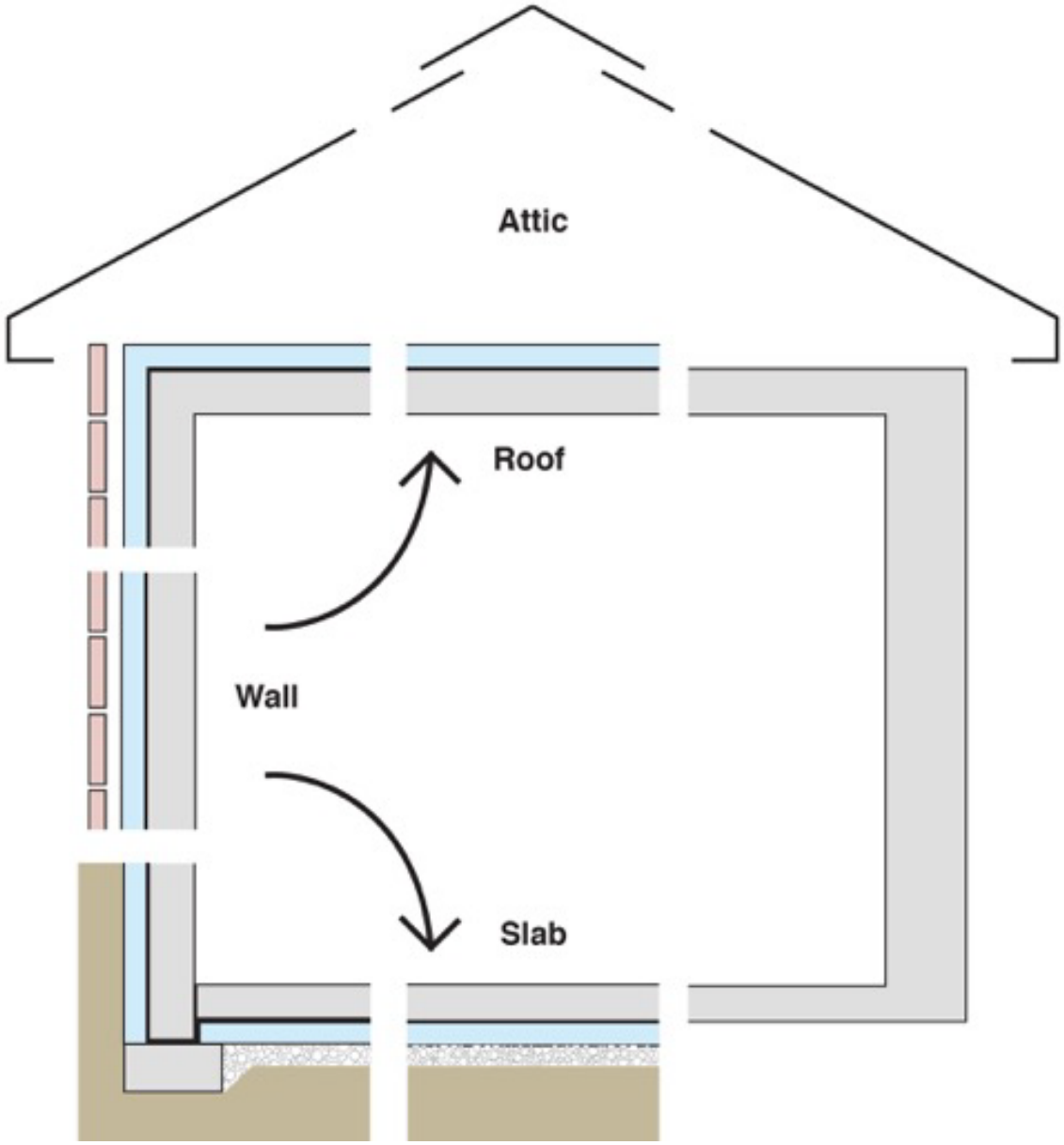

Parapet
Roof
Wall
Slab

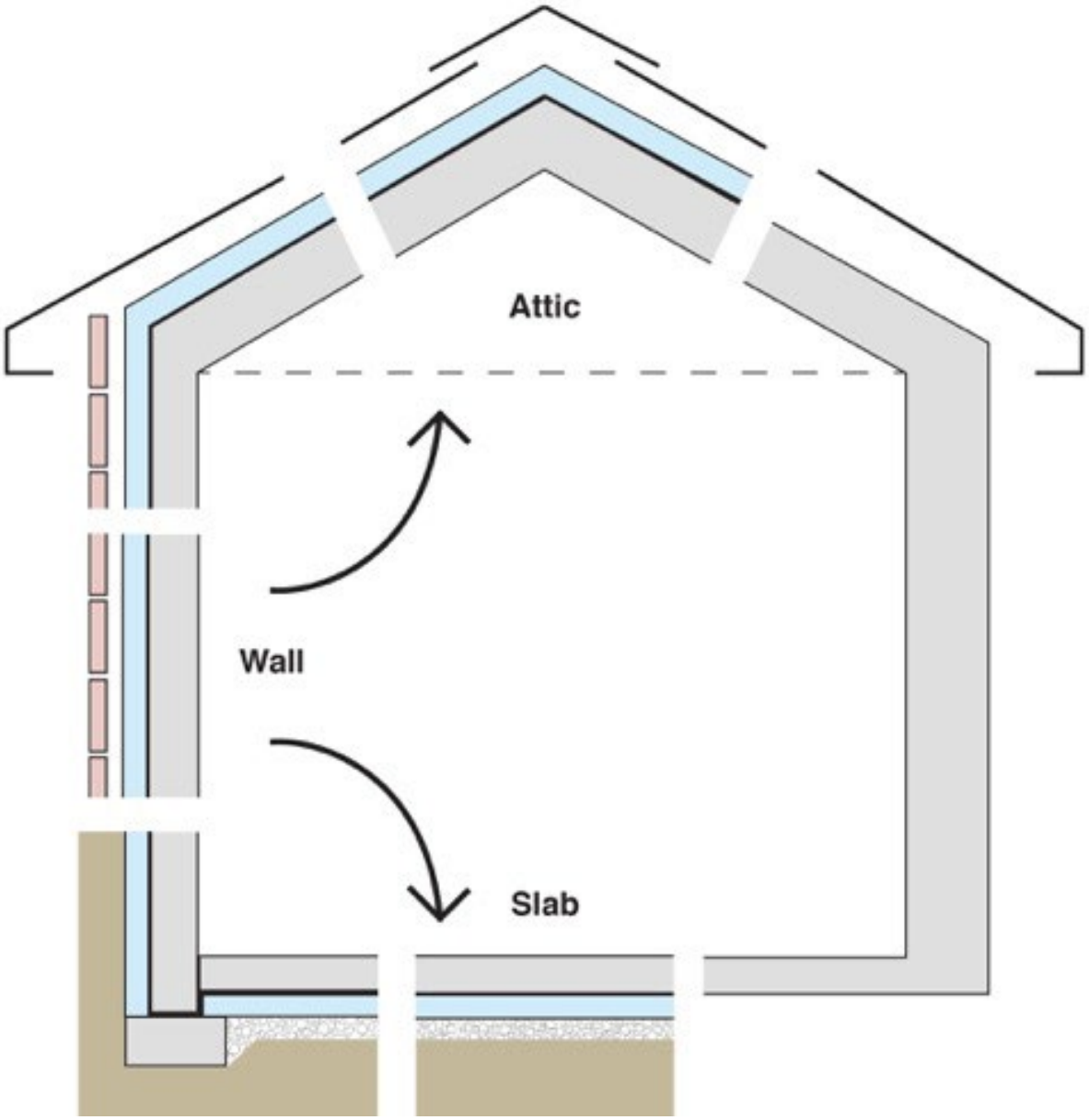

Parapet
Roof
Wall
Footing
Slab

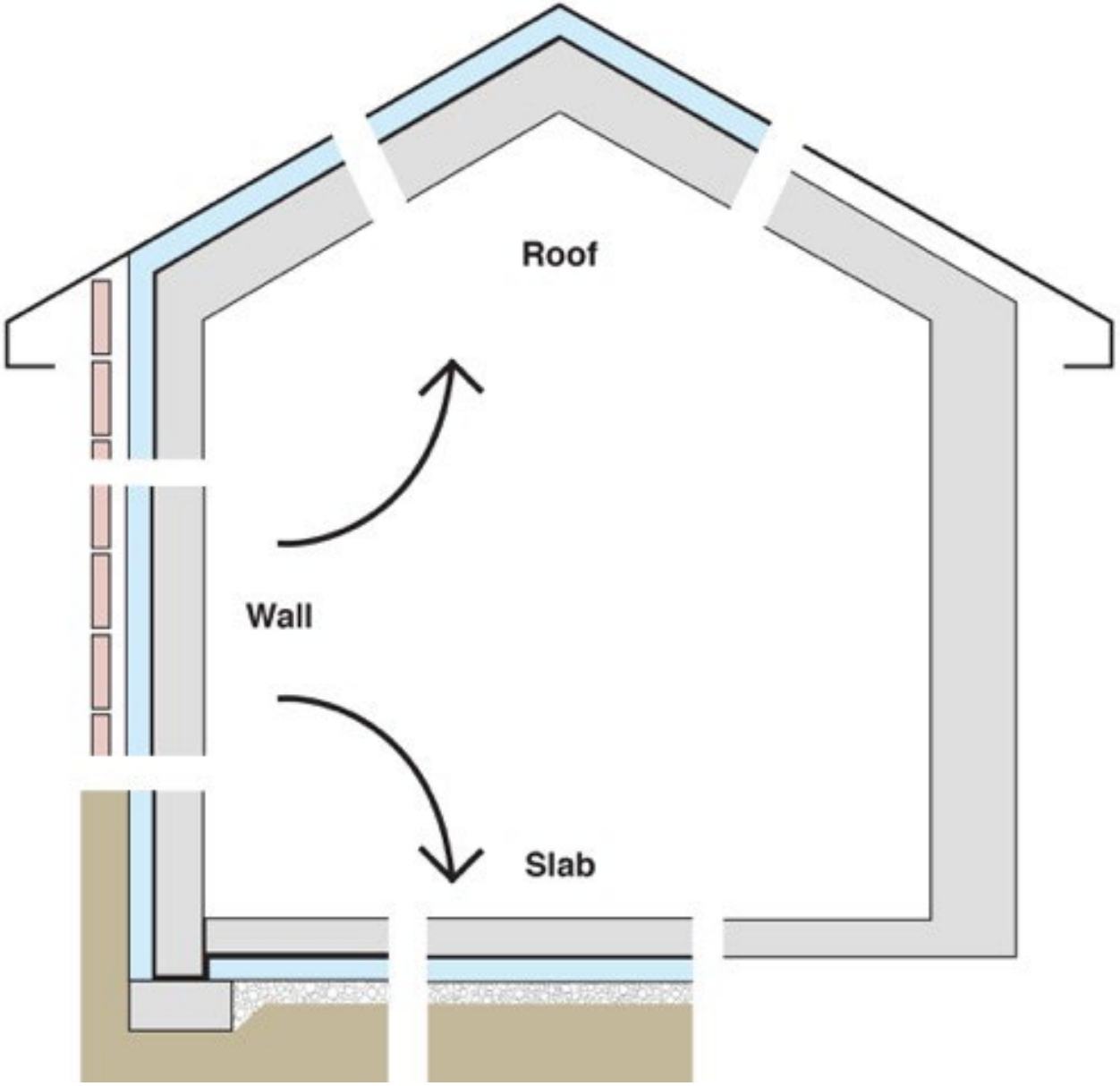

Parapet
Roof
Window
Wall
Footing
Slab

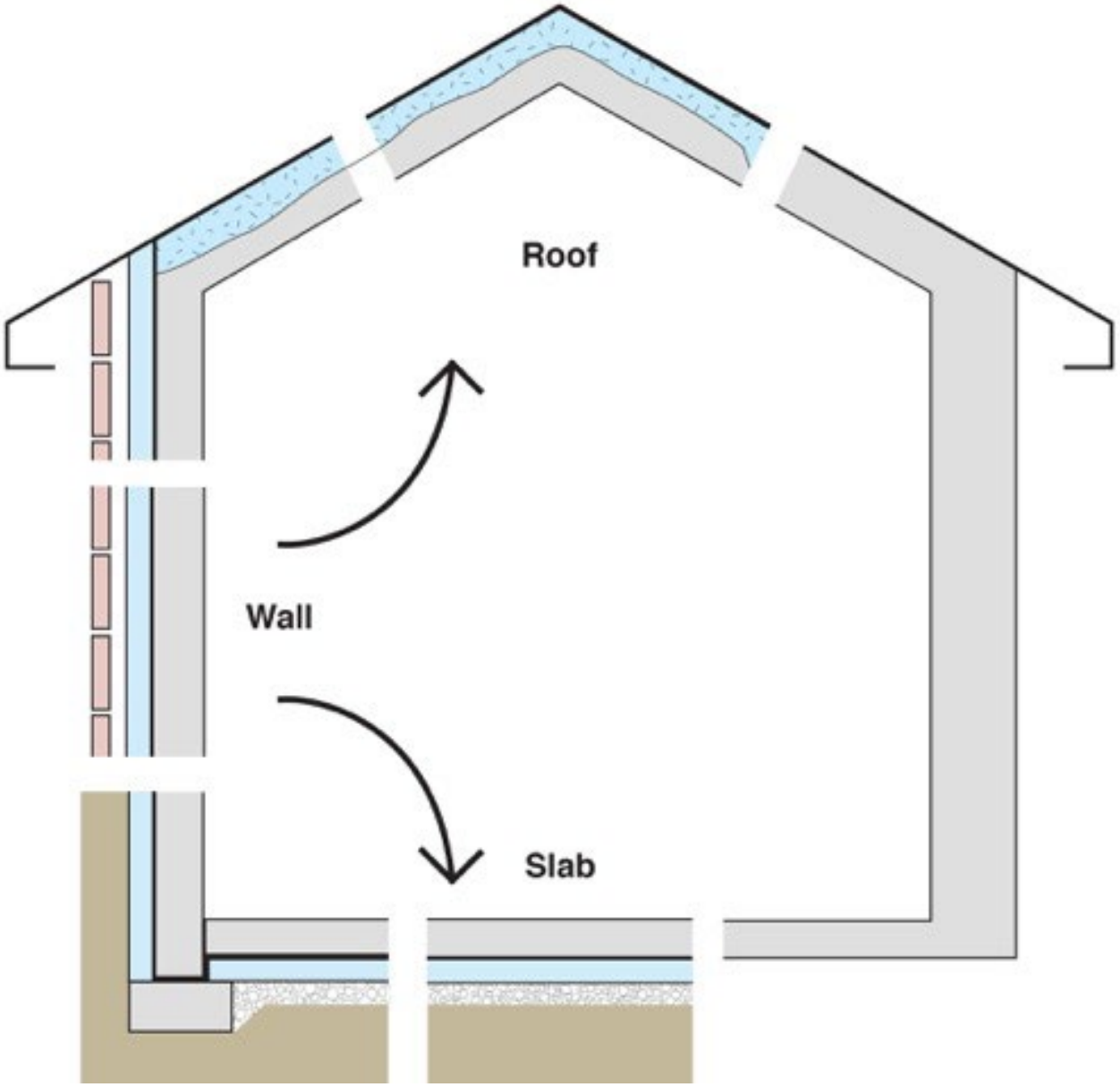

Control layer
Control layer
Roof structure


Parapet
Roof
Wall
Footing
Slab

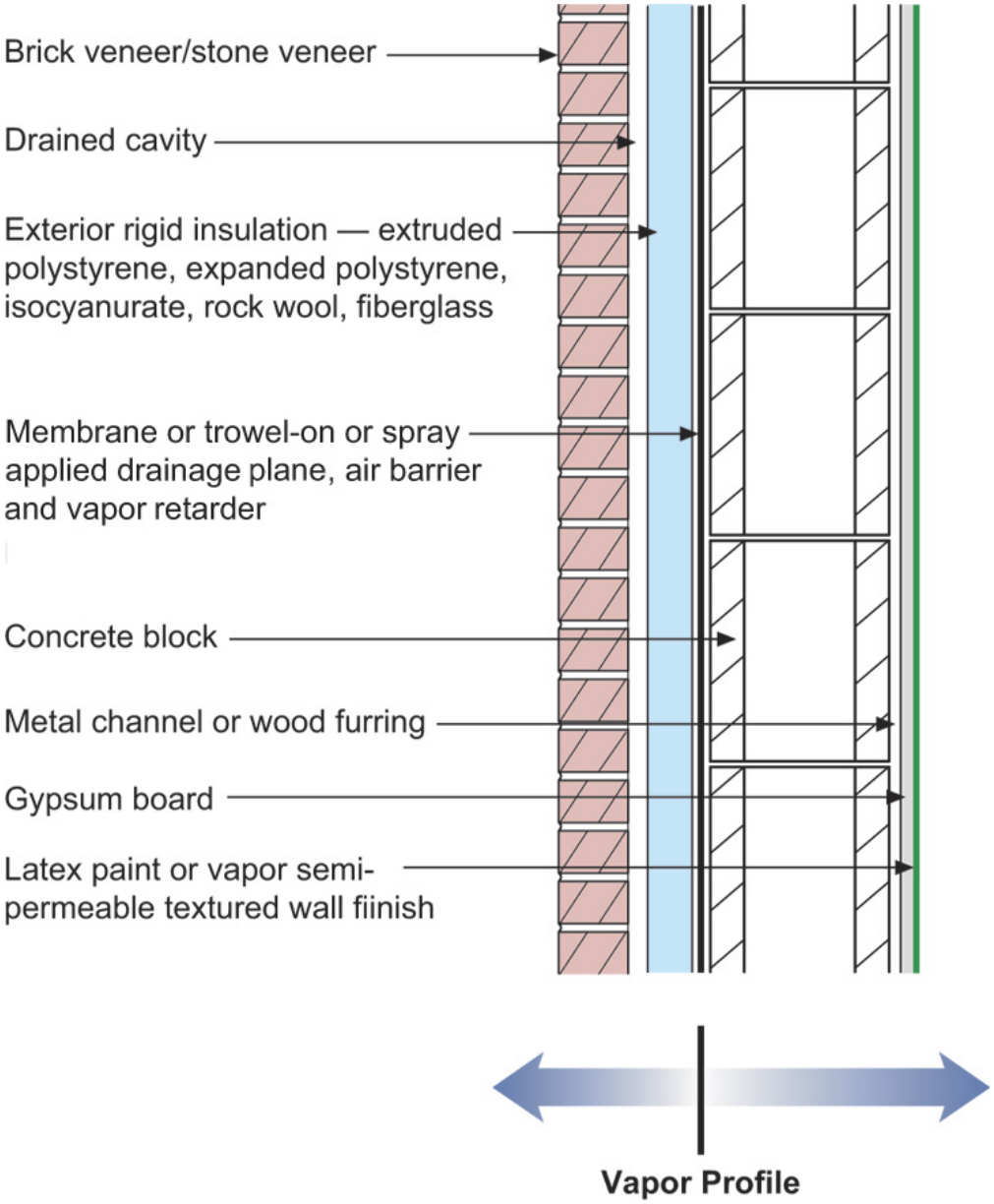

Attic
Roof
Wall
Slab

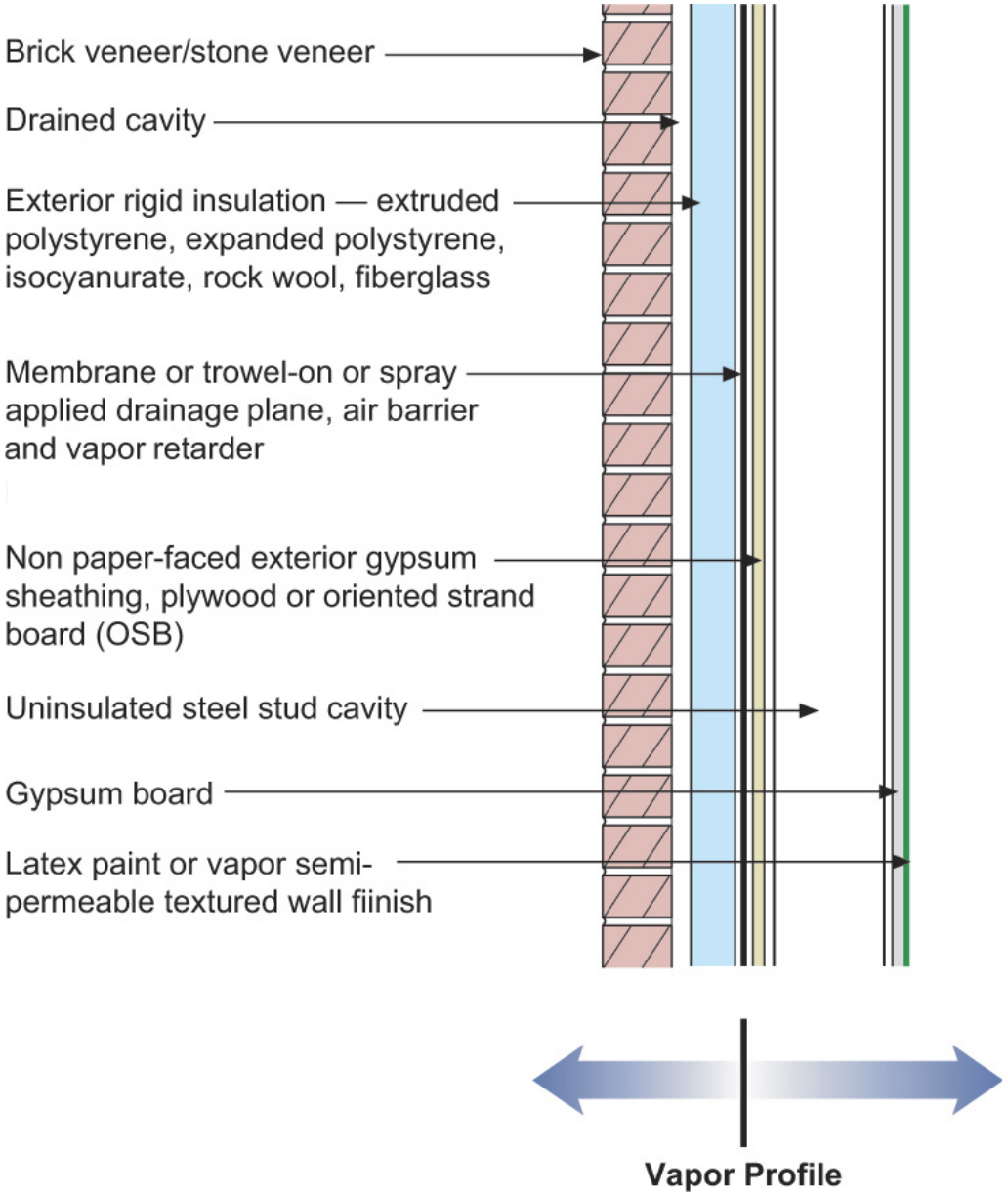

Attic
Wall
Slab

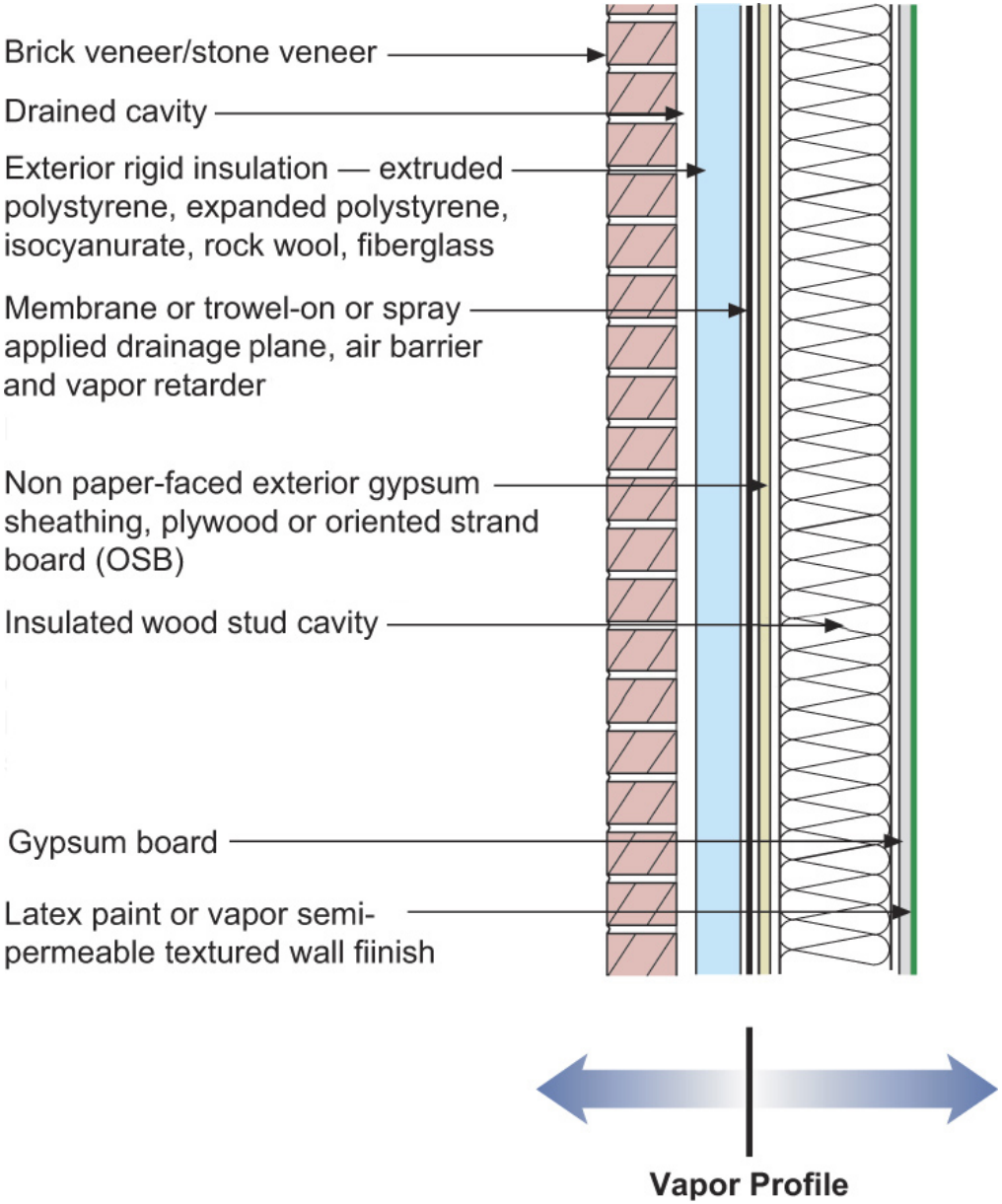

Roof
Wall
Slab


Roof
Wall
Slab

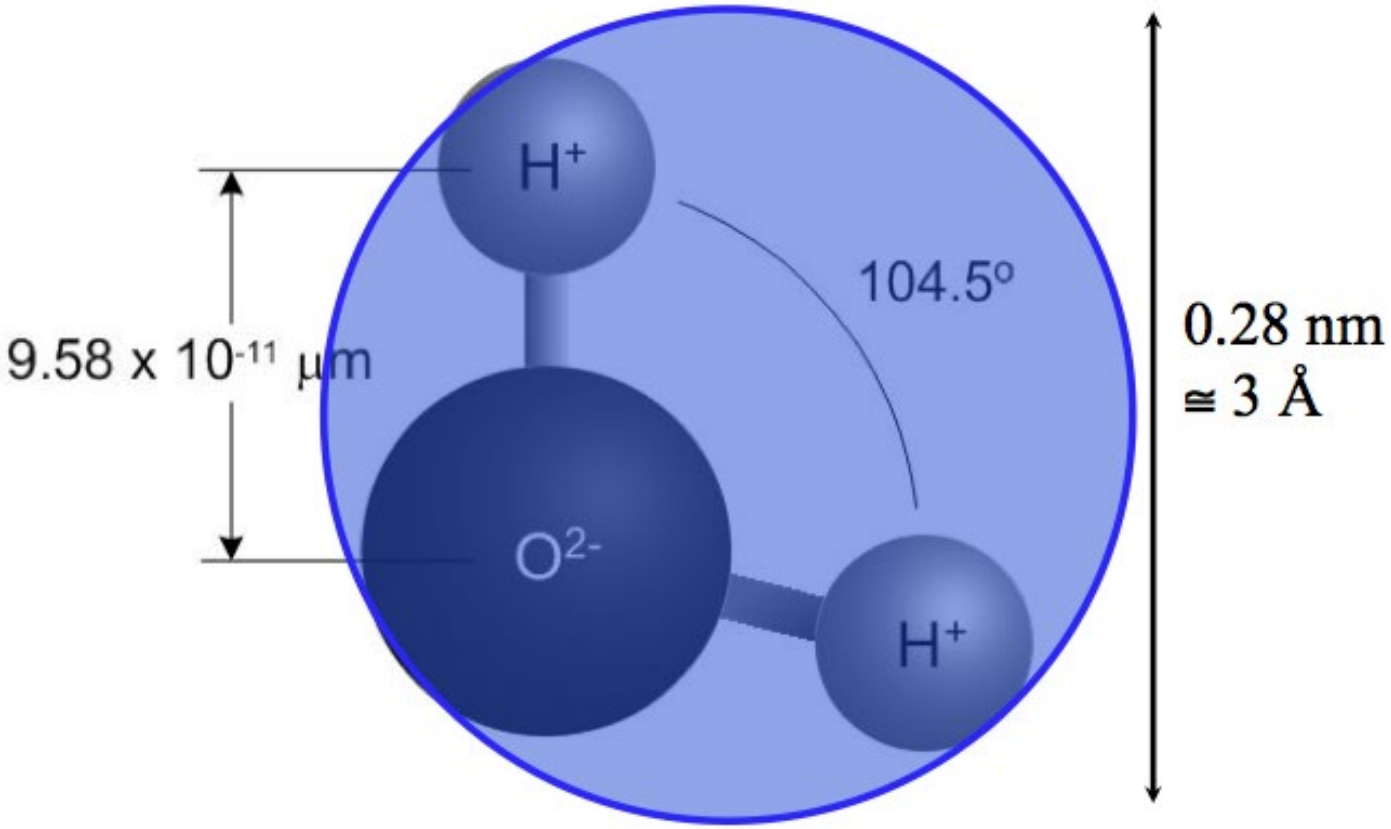
Configurations of the Perfect Wall


Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Concrete block
Metal channel or wood furring
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile

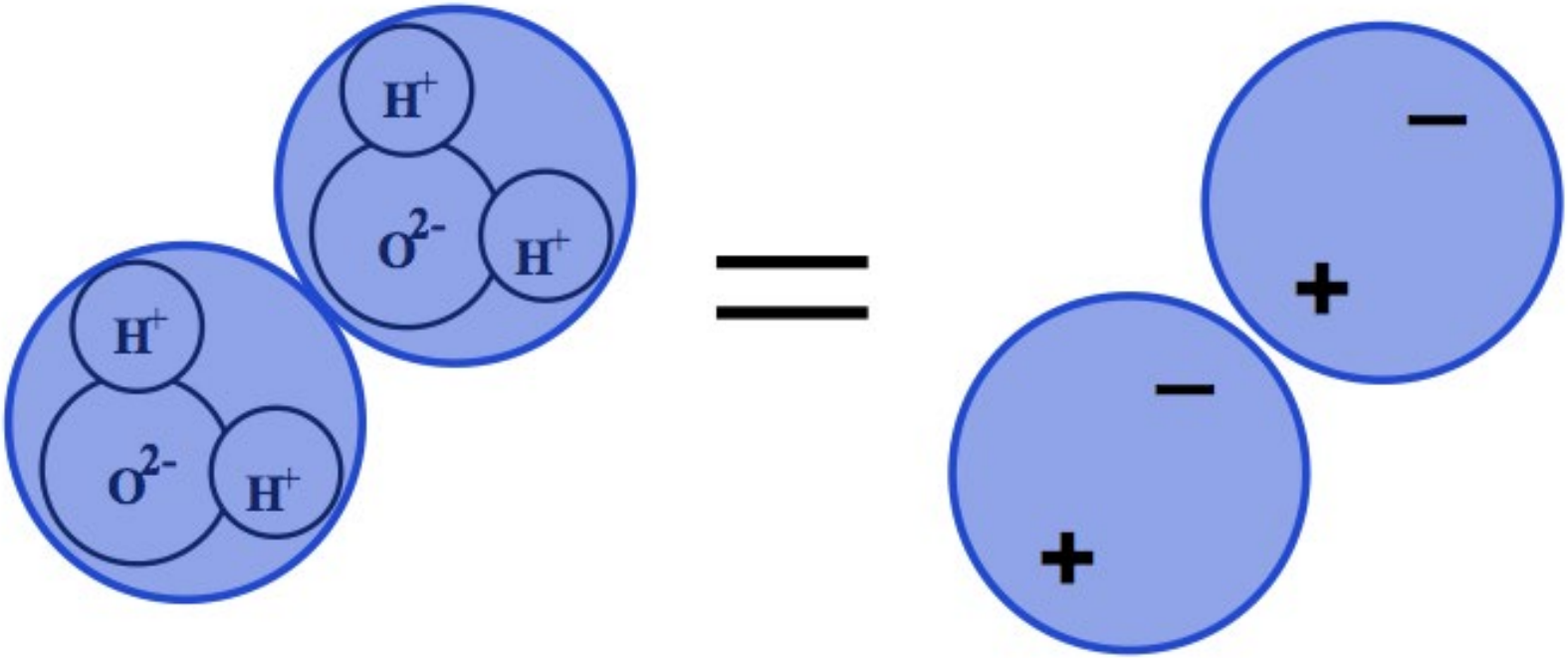

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Uninsulated steel stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile


Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile

The Water Molecule

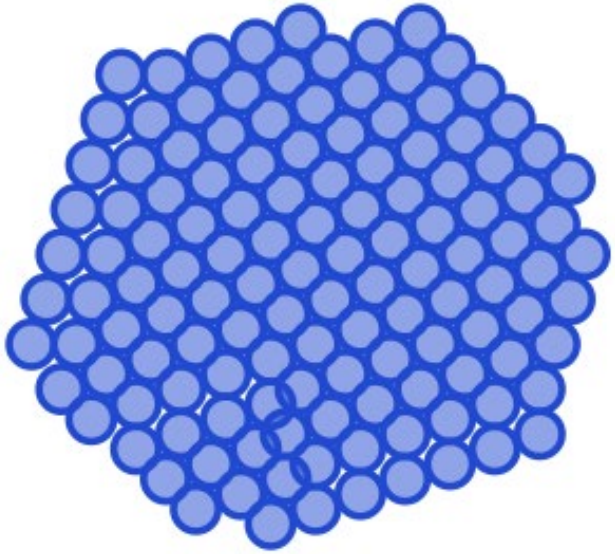

H+
104.5°
9.58 x 10-11 µm
0.28 nm
≅ 3 Å
O2-
H+

Polar Molecule


H+
O2-
H+
H+
O2-
H+
=
−
+
−
+

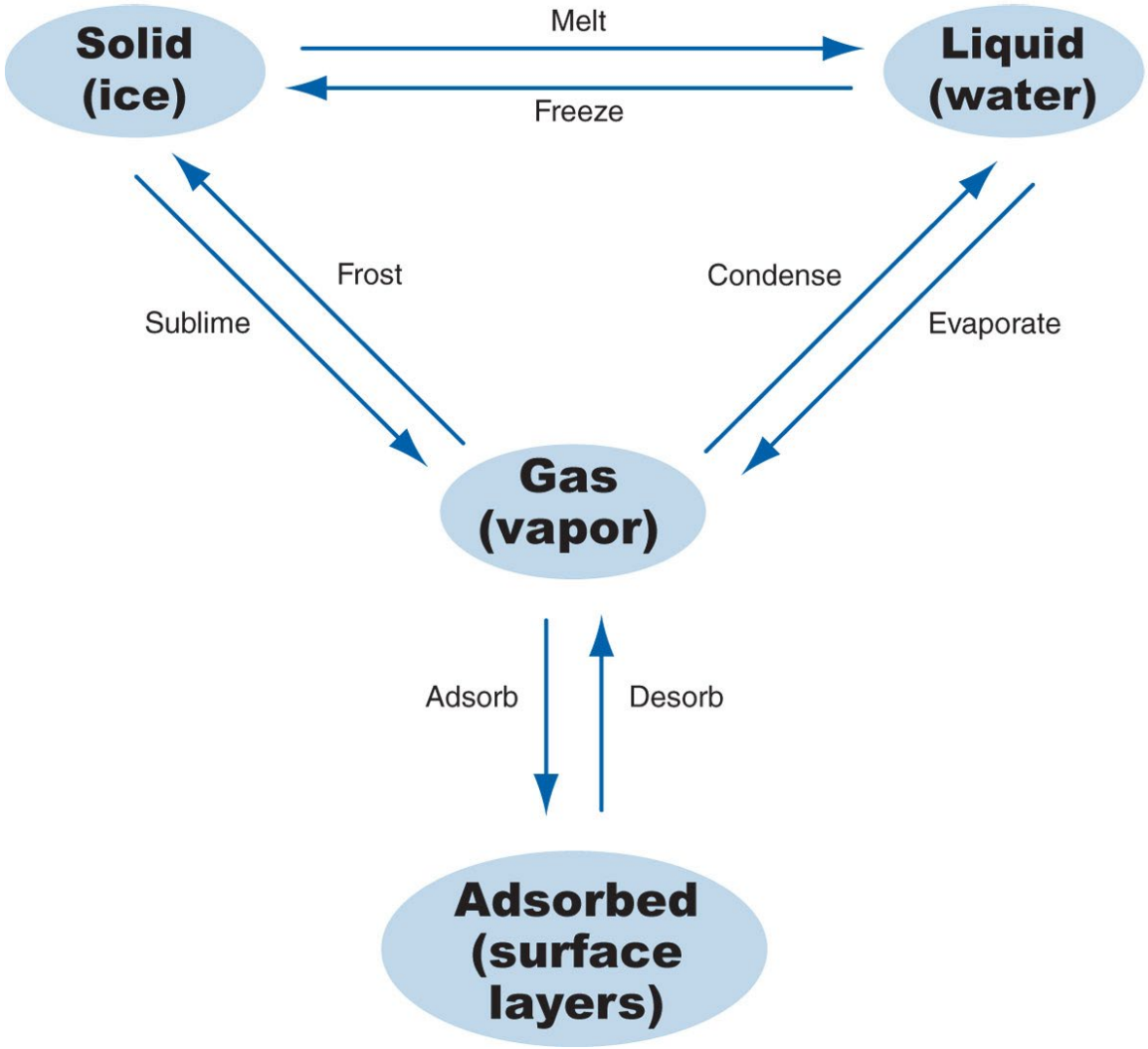
Size Matters

Vapor



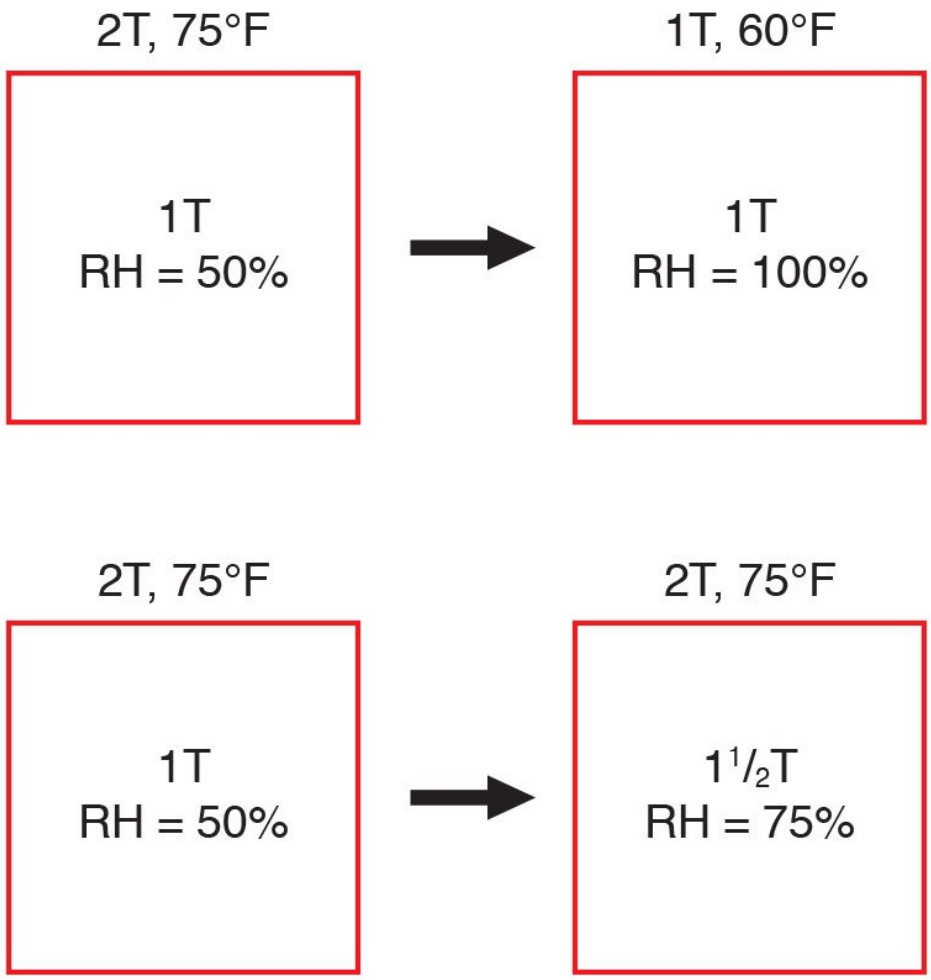
Liquid

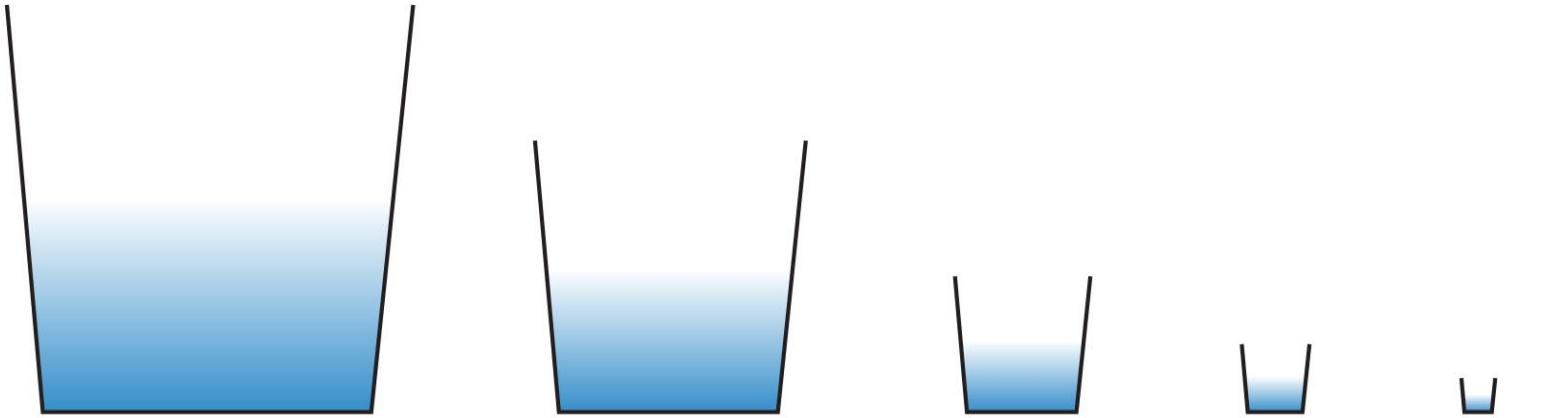
Phases of Water

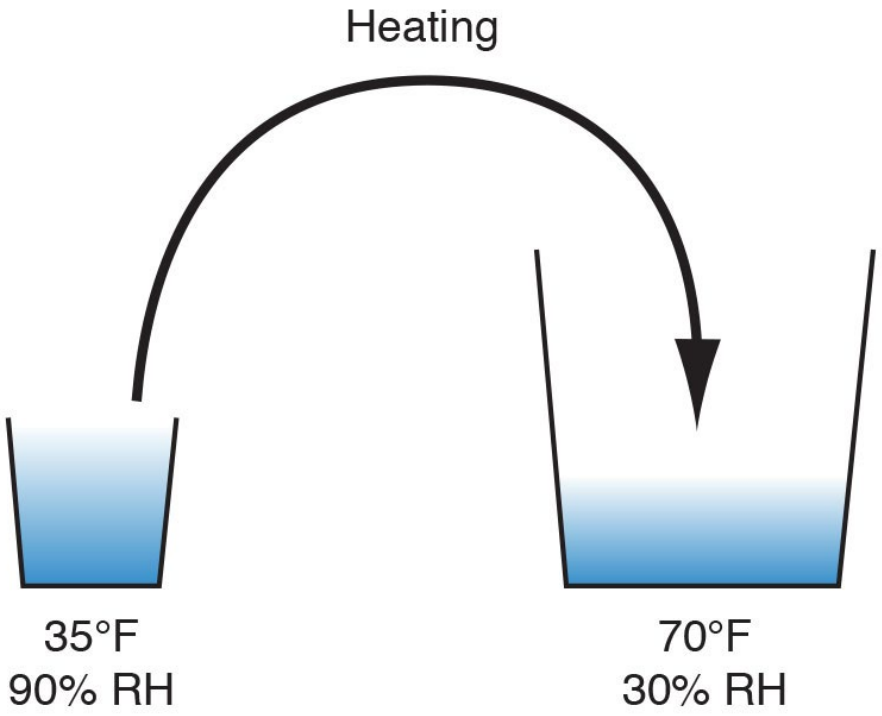

Solid (ice)
Melt
Freeze
Liquid (water)
Frost
Sublime
Condense
Evaporate
Gas (vapor)
Adsorb
Desorb
Adsorbed (surface layers)

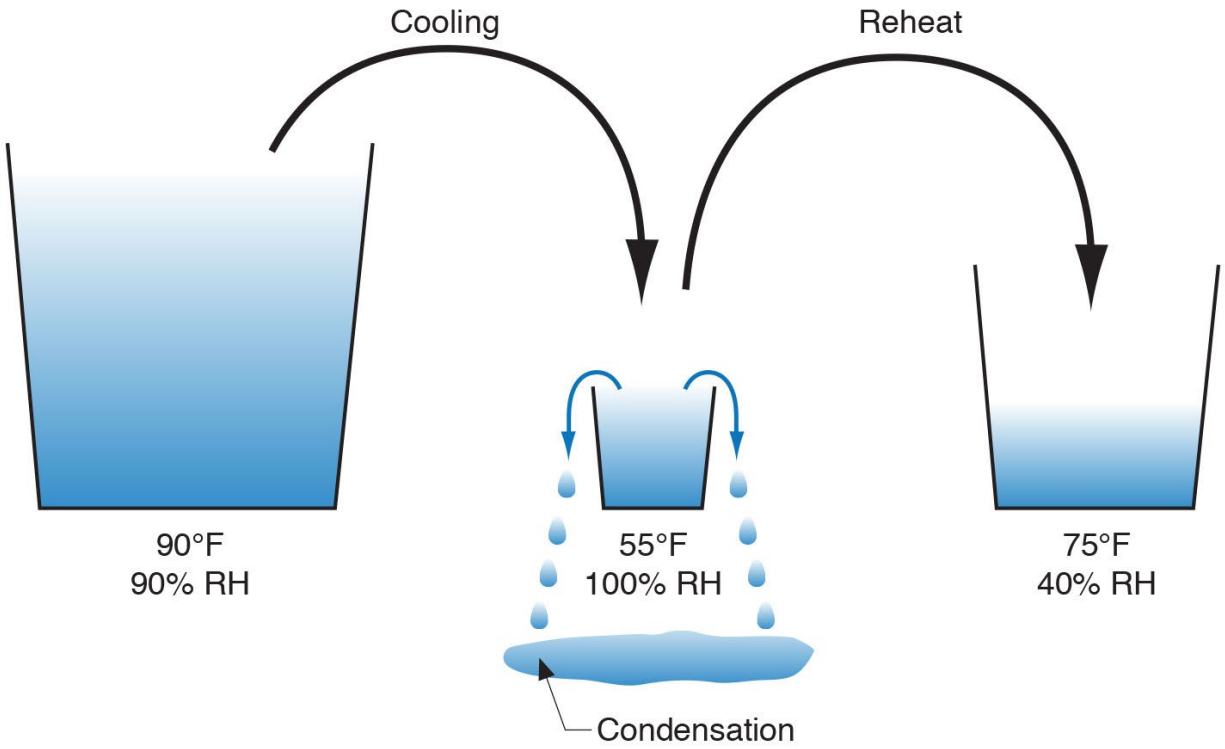
Relative Humidity

Vapor Pressure

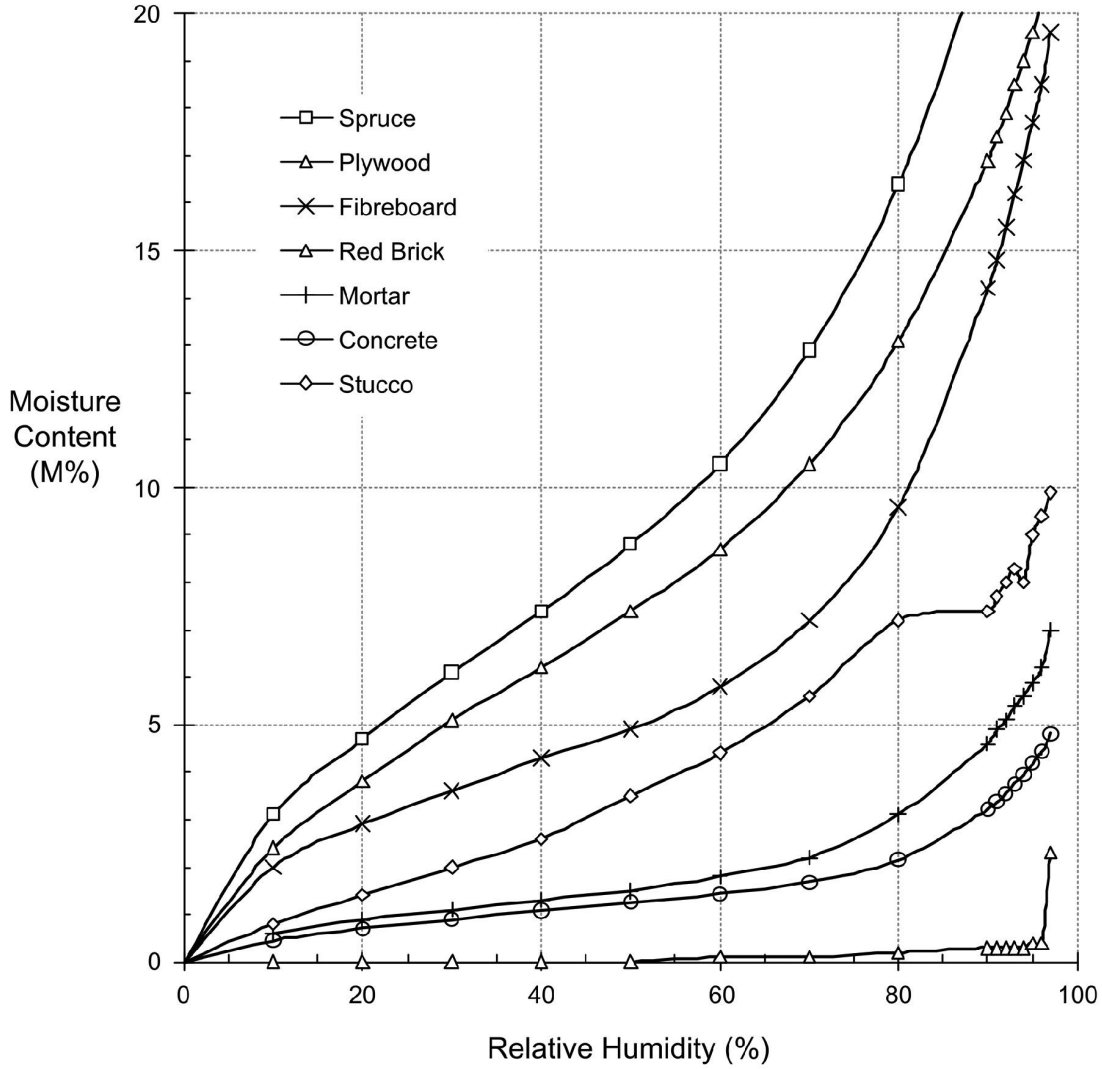

2T, 75°F
1T
RH = 50%
1T, 60°F
1T
RH = 100%
2T, 75°F
1T
RH = 50%
2T, 75°F
1 1/2T
RH = 75%


90°F
50% RH
75°F
50% RH
60°F
50% RH
45°F
50% RH
30°F
50% RH


Heating
35°F
90% RH
70°F
30% RH


Cooling
Reheat
90°F
90% RH
55°F
100% RH
75°F
40% RH
Condensation

Sorption



Sorption isotherm for several building materials [Kumaran 2002]
From Straube & Burnett, 2005

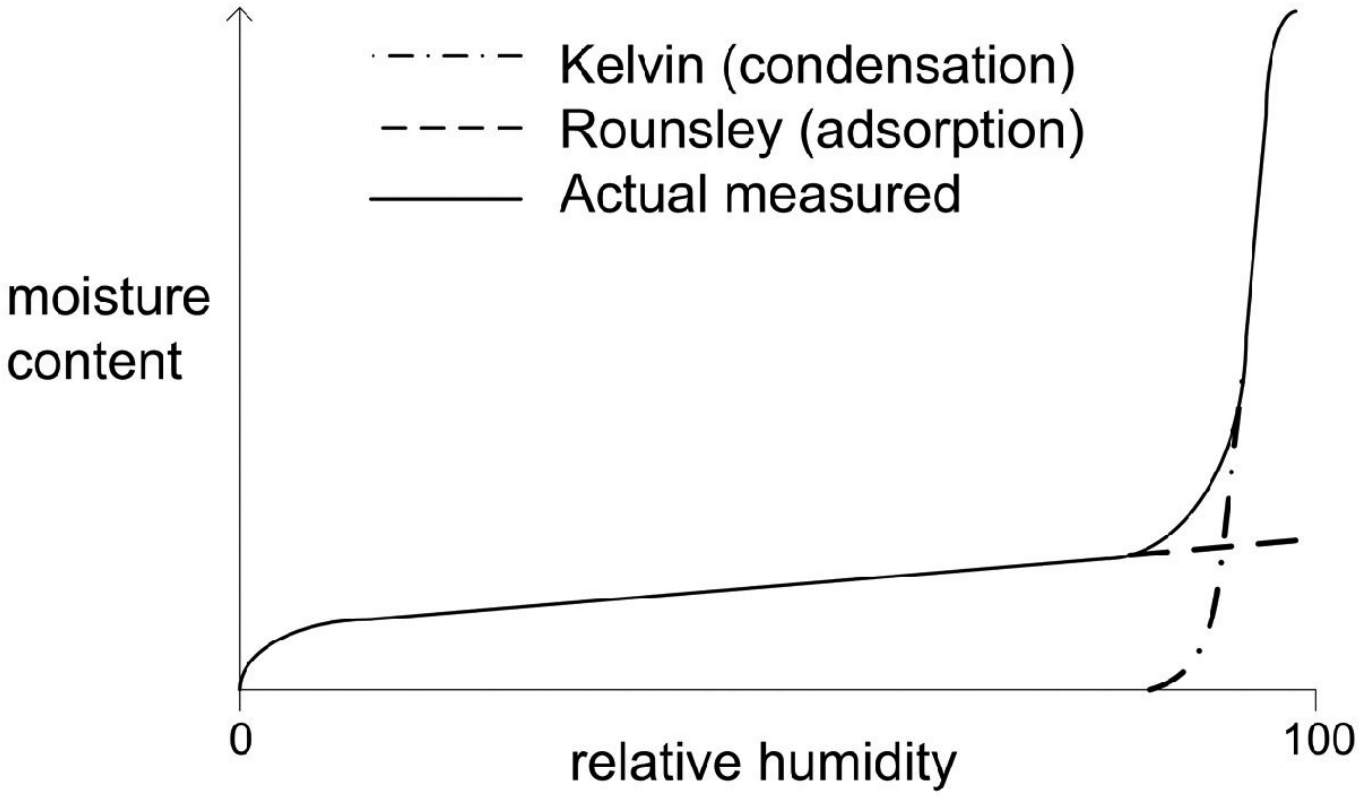
BET Theory

BET Theory

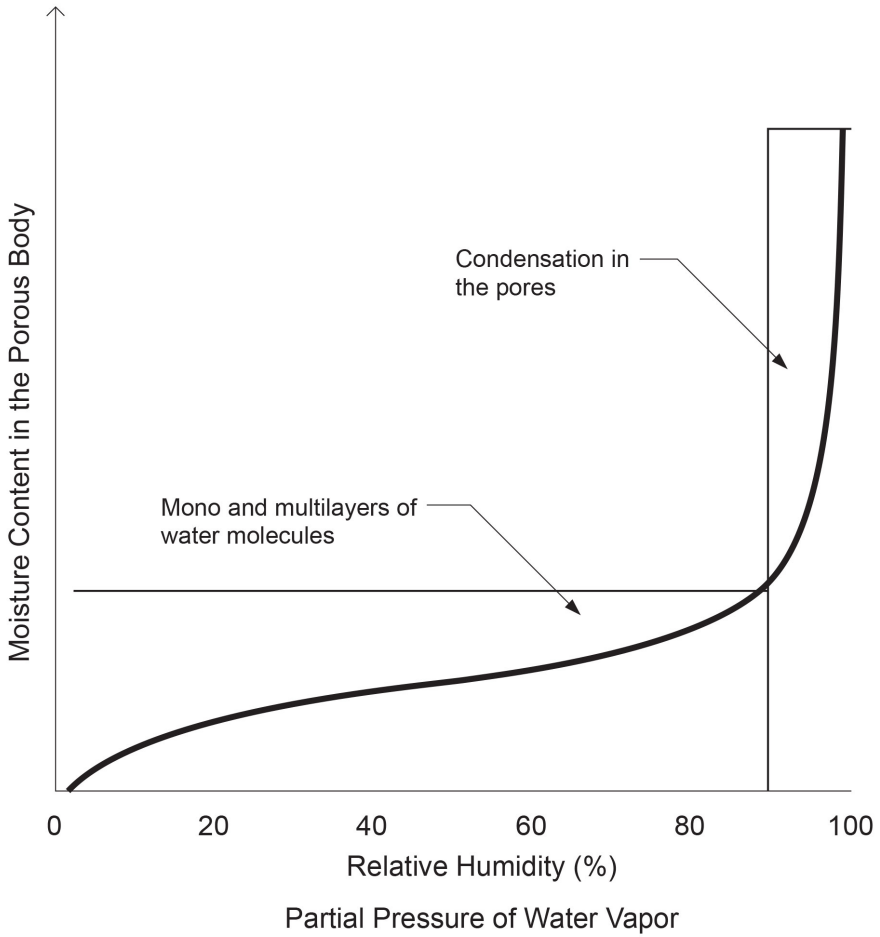
Stephen Brunauer

Paul Emmett

Edward Teller



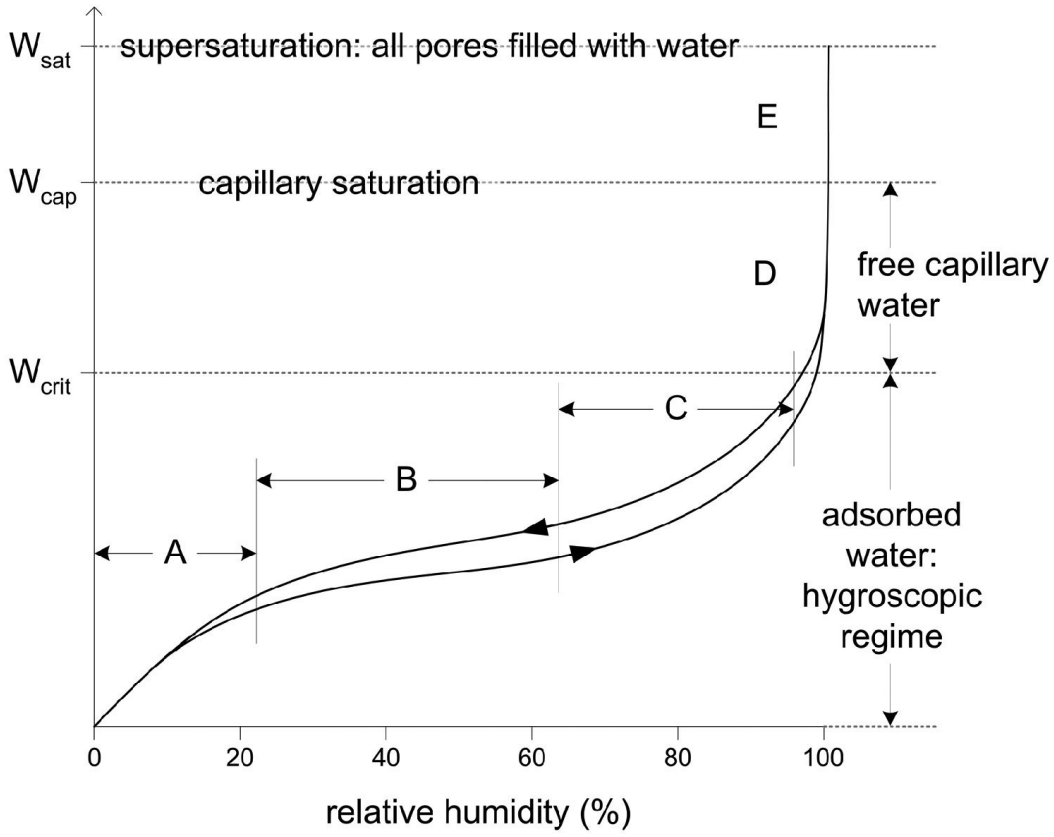
Typical predicted sorption isotherm according to Kelvin equation and modified BET theory
From Straube & Burnett, 2005



Change in the storage of moisture in a porous building material as the partial pressure of water vapor in the ambient air increases from zero to full saturation value at a given temperature.

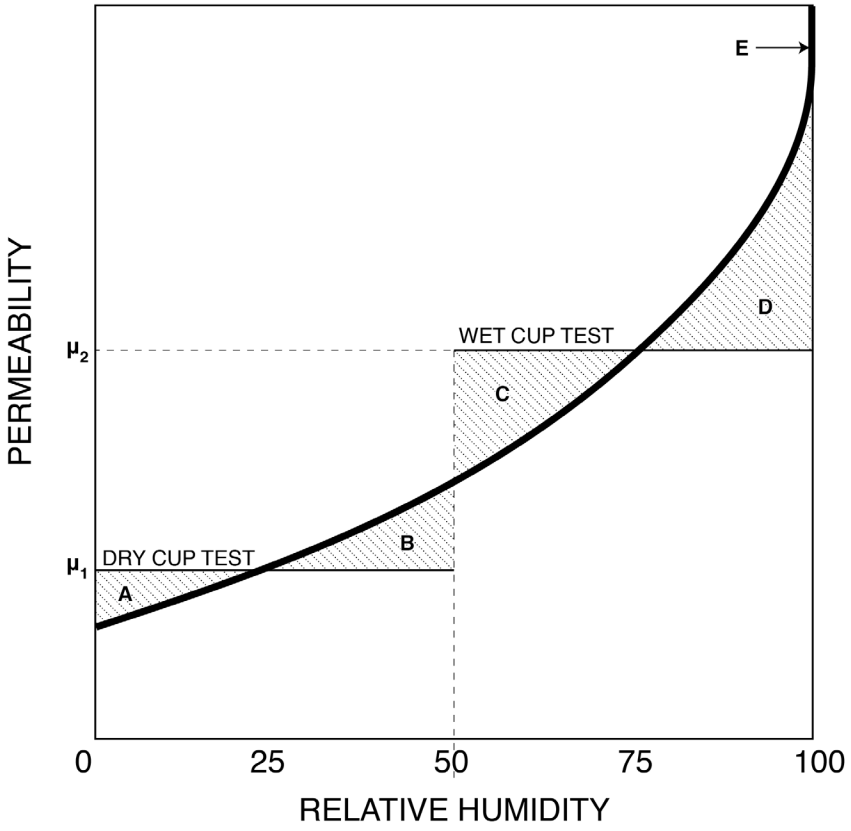
Sorption Curve

From M.K. Kumaran, ASTM MNL 18-2nd Edition, Moisture Control in Buildings, 2009



A: Single-layer of adsorbed molecules
B: Multiple layers of adsorbed molecules
C: Interconnected layers (internal capillary condensation
D: Free water in Pores, capillary suction
E: Supersaturated Regime

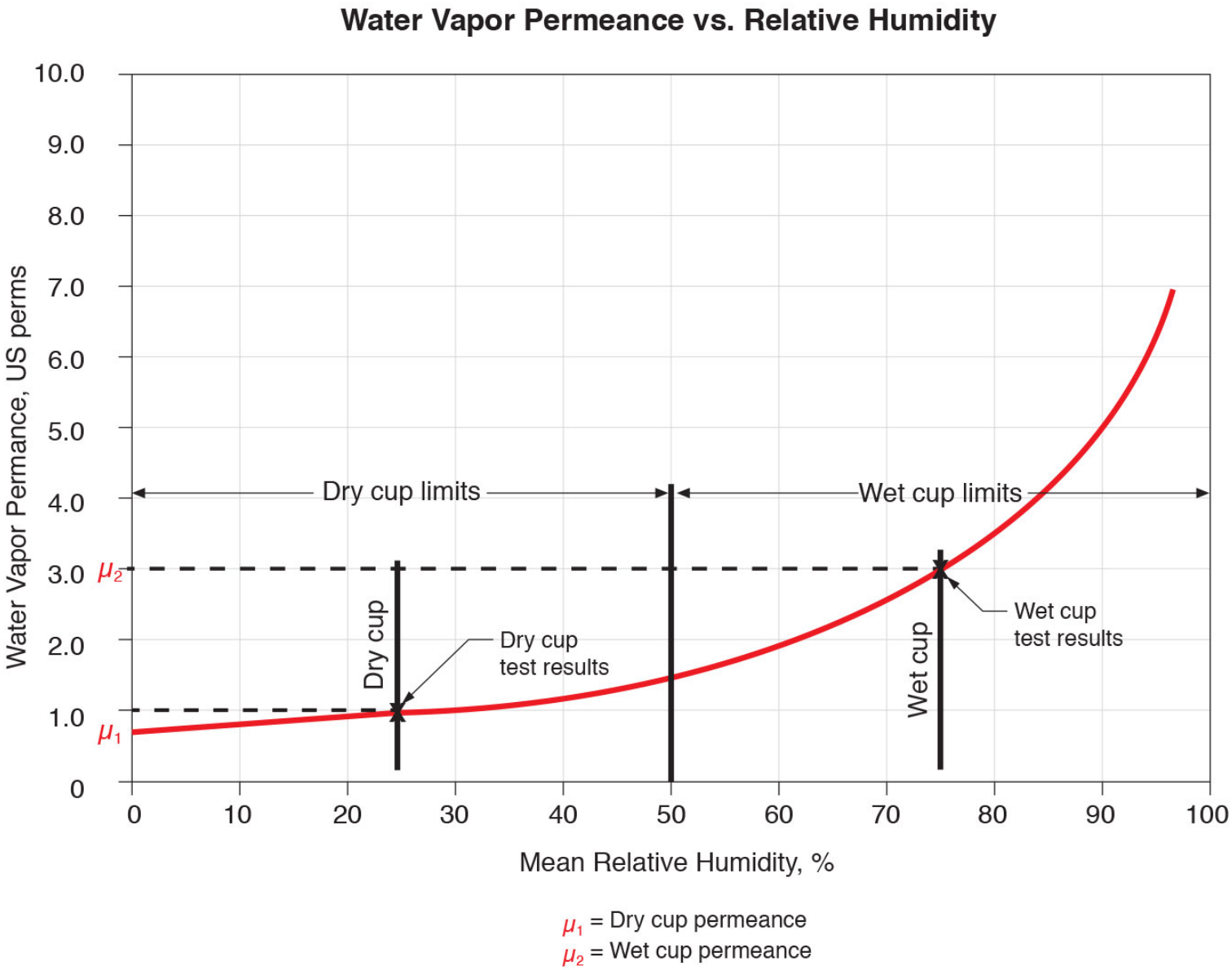
Regimes of moisture storage in a hygroscopic porous material
From Straube & Burnett, 2005

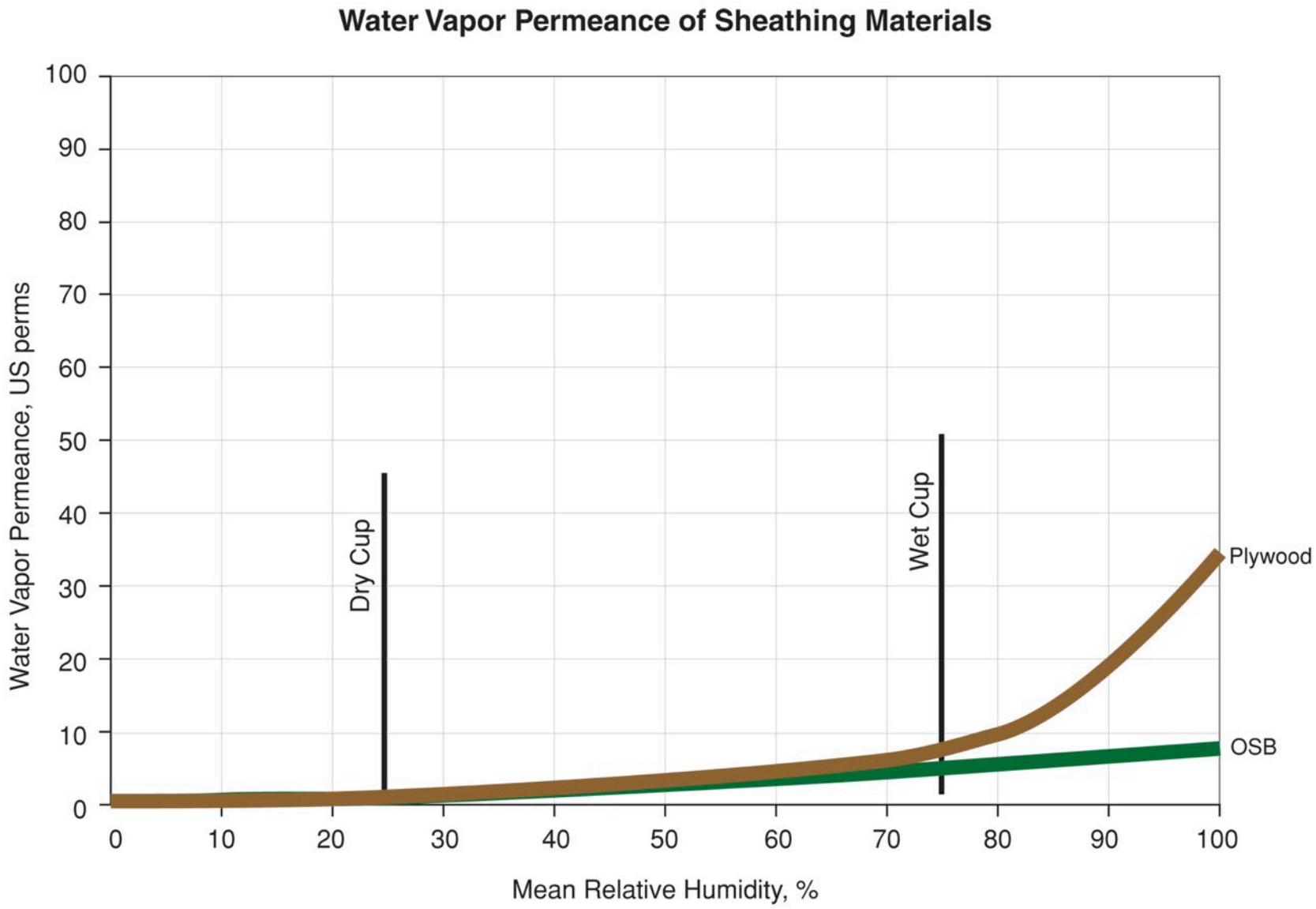


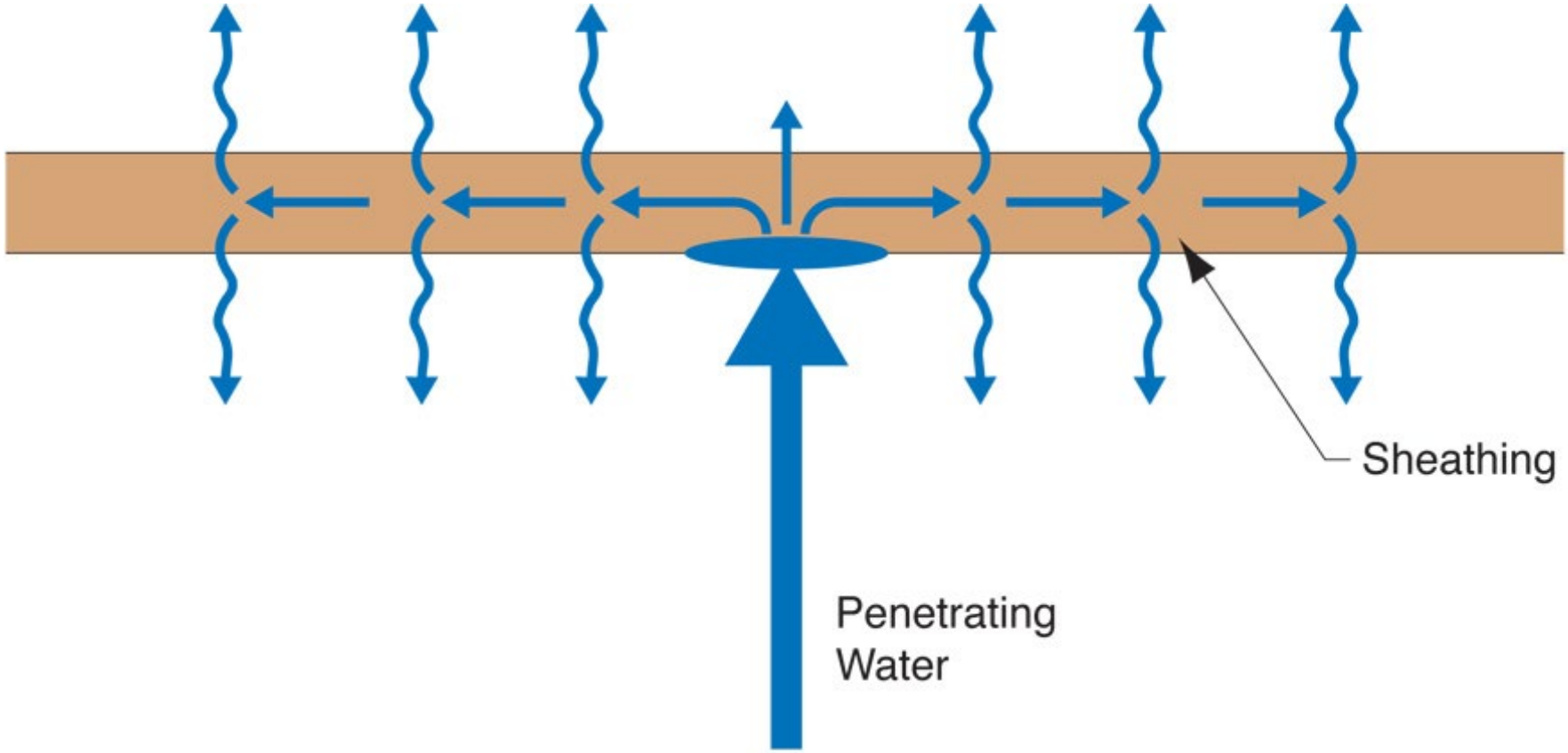
A - Single-layer of absorbed molecules
B - Multiple layers of absorbed molecules
C - Interconnected layers (internal capillary condensation)
D - Free water in pores, capillary suction
E - Supersaturated regime

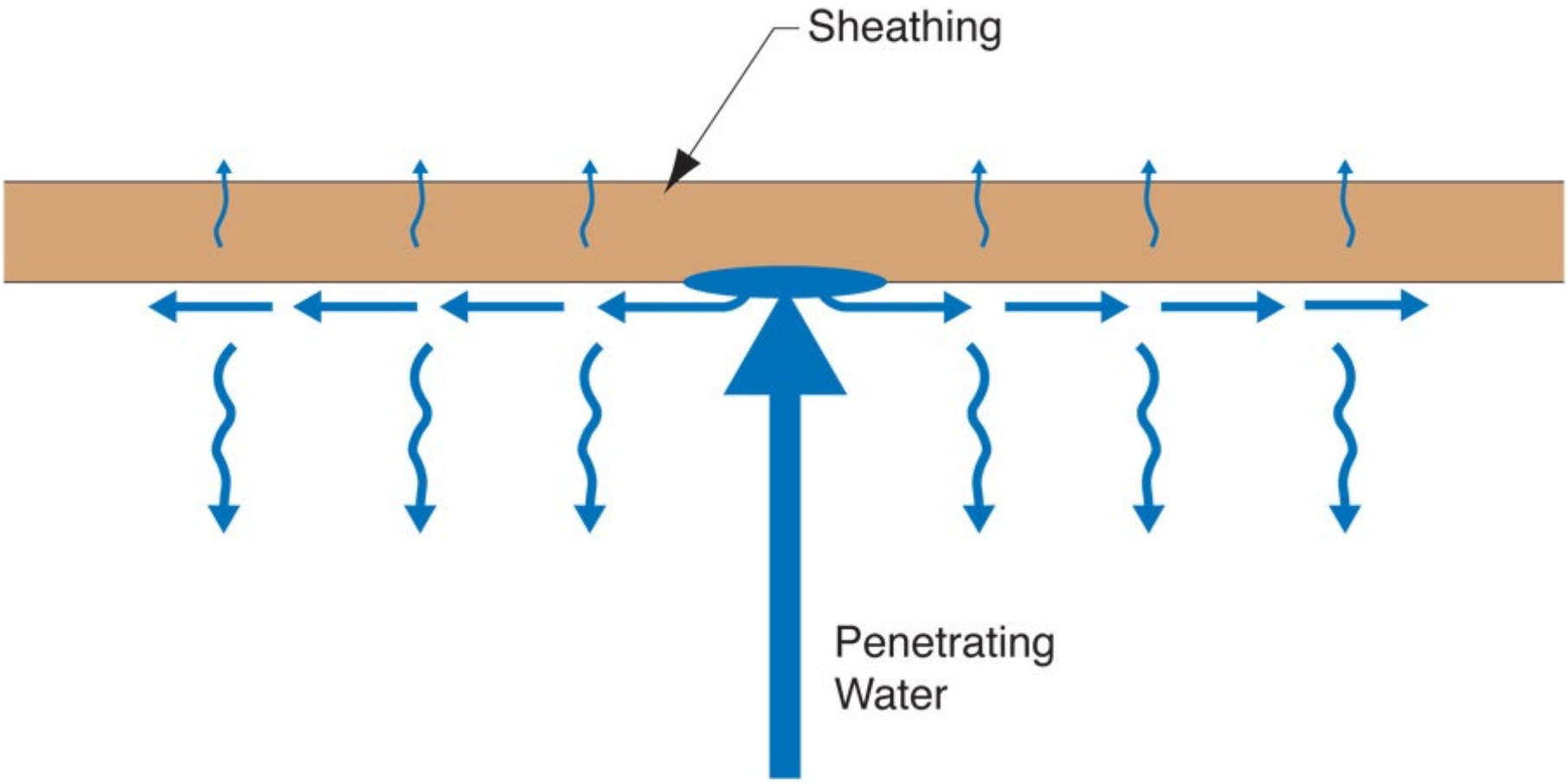
Relationship between Dry Cup and Wet Cup
Adapted from Joy & Wilson, 1963

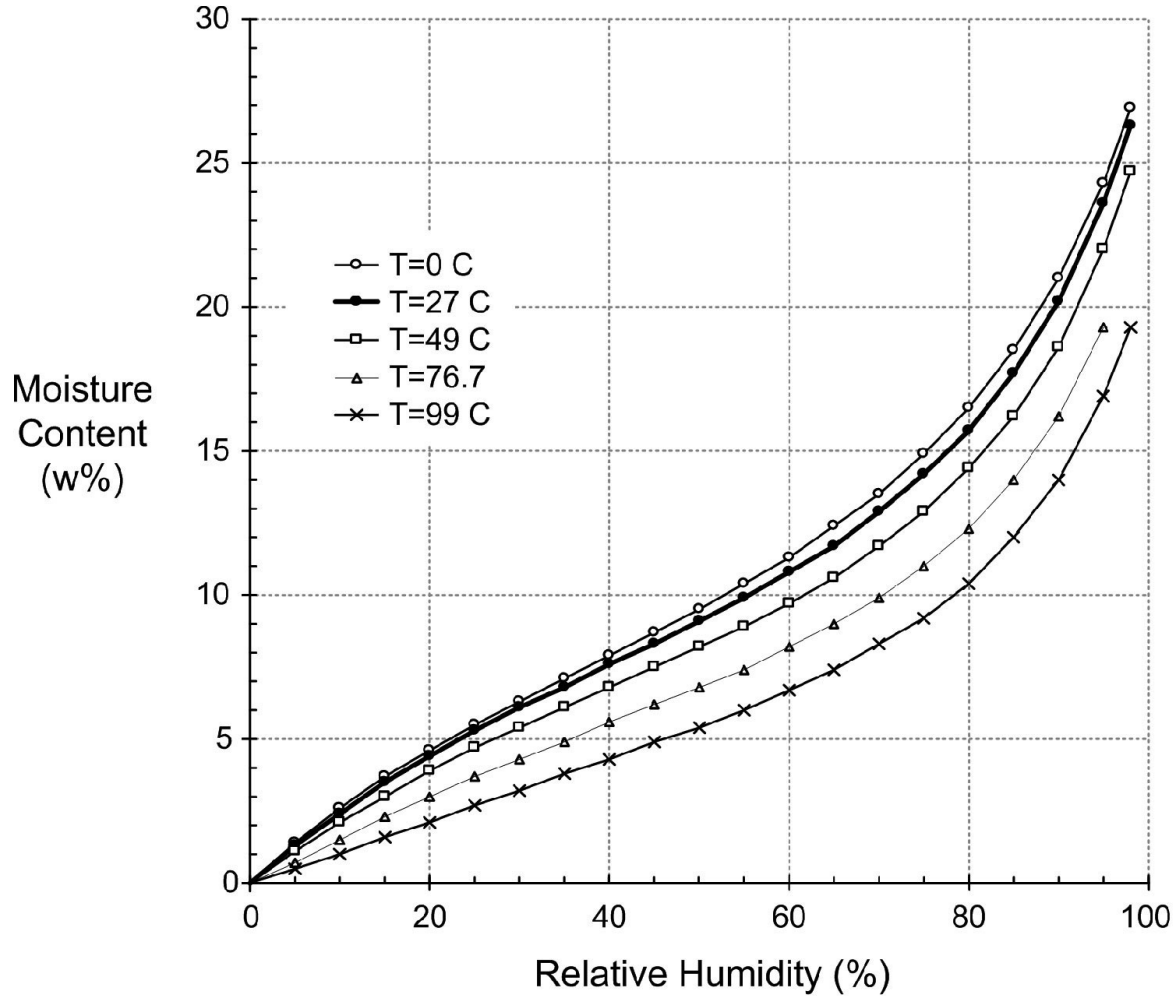

OWENS-CORNING
Fiberglas
Building
Insulation
FIBERGLAS
R-11
3½"
ASSURED THERMAL
PERFORMANCE
WARNING: The FACING on this insulation will BURN AND SHOULD NOT BE LEFT EXPOSED. Special care should be taken when working close to the facing


Water Vapor Permeance vs. Relative Humidity
Water Vapor Permance, US perms
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
μ_2
μ_1
Dry cup limits
Wet cup limits
Dry cup
Dry cup test results
Wet cup
Wet cup test results
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %
μ_1 = Dry cup permeance
μ_2 = Wet cup permeance

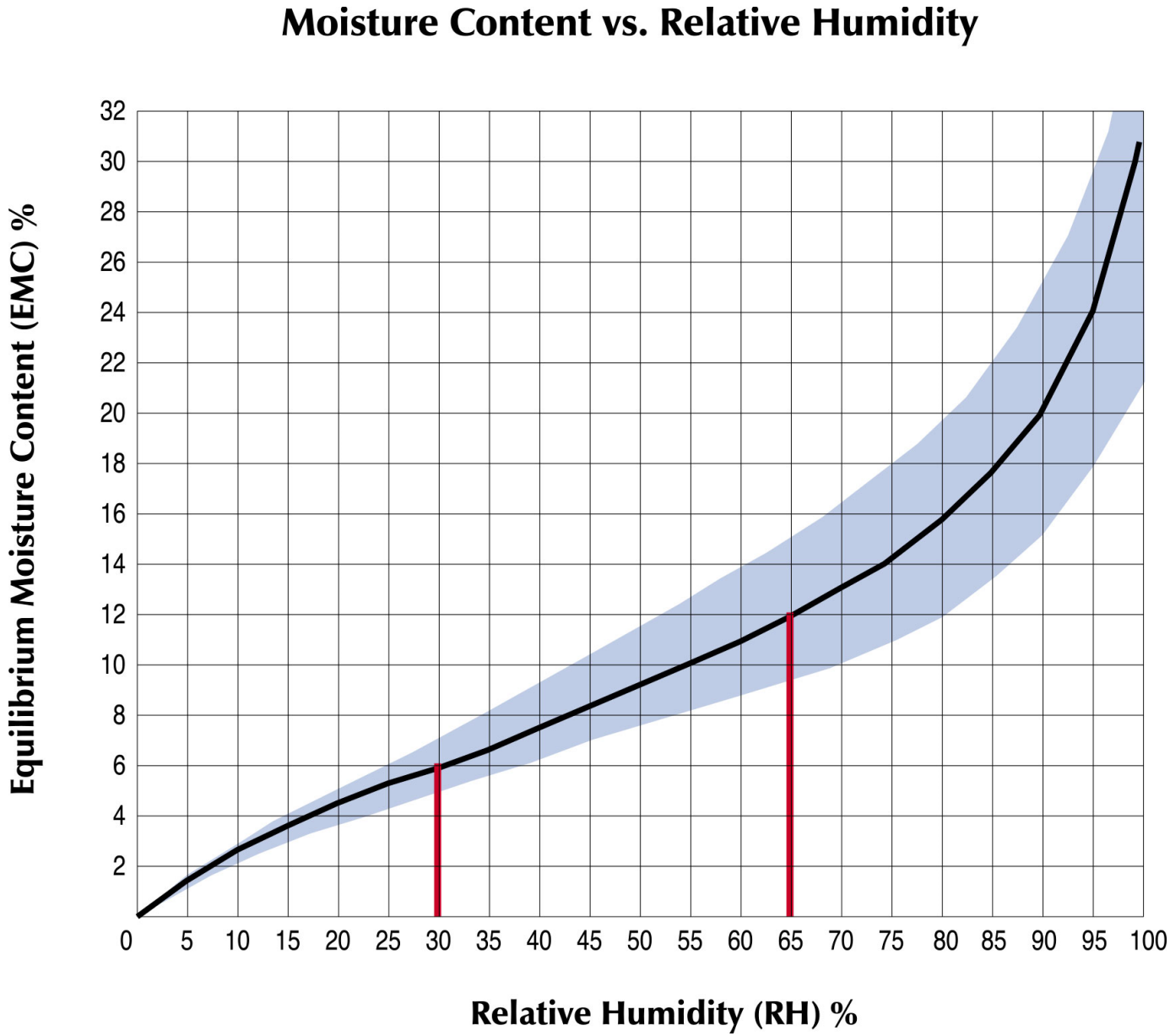

Water Vapor Permeance of Sheathing Materials
Water Vapor Permeance, US perms
100
90
80
70
60
50
40
30
20
10
0
Dry Cup
Wet Cup
Plywood
OSB
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %

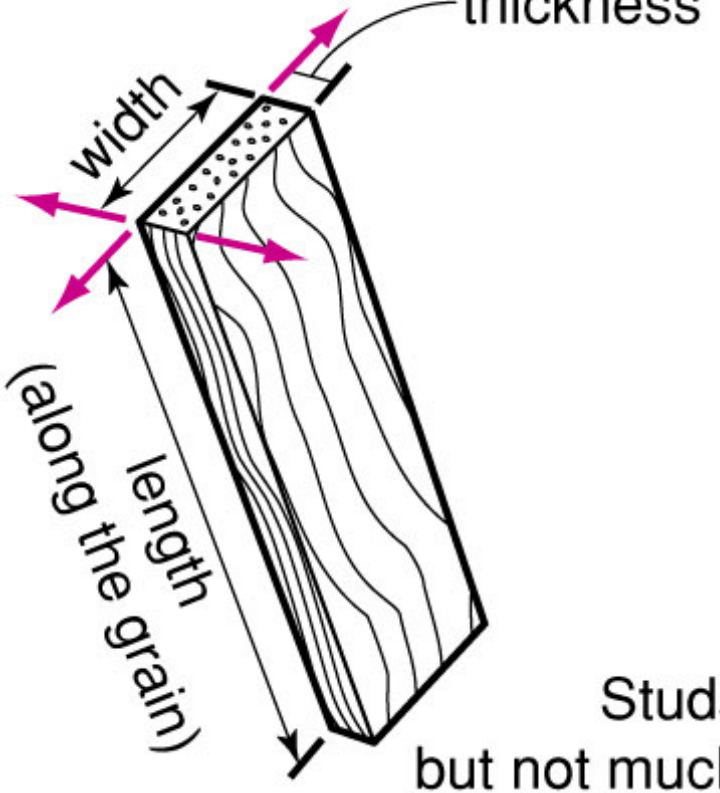

Sheathing
Penetrating
Water

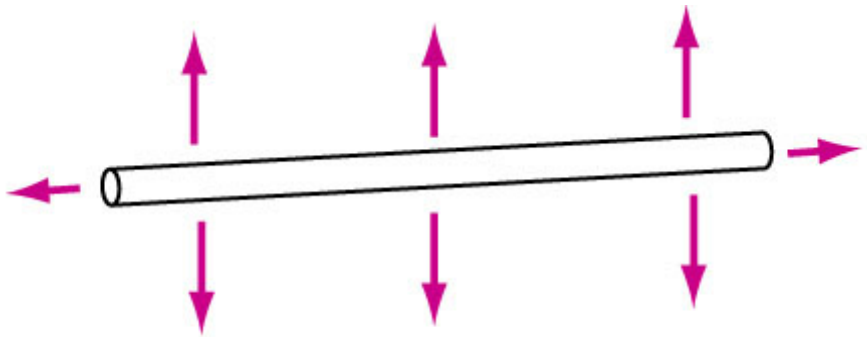

Sheathing
Penetrating
Water



Average sorption isotherm for wood as a function of temperature
From Straube & Burnett, 2005


Moisture Content vs. Relative Humidity
Equilibrium Moisture Content (EMC) %
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Relative Humidity (RH) %

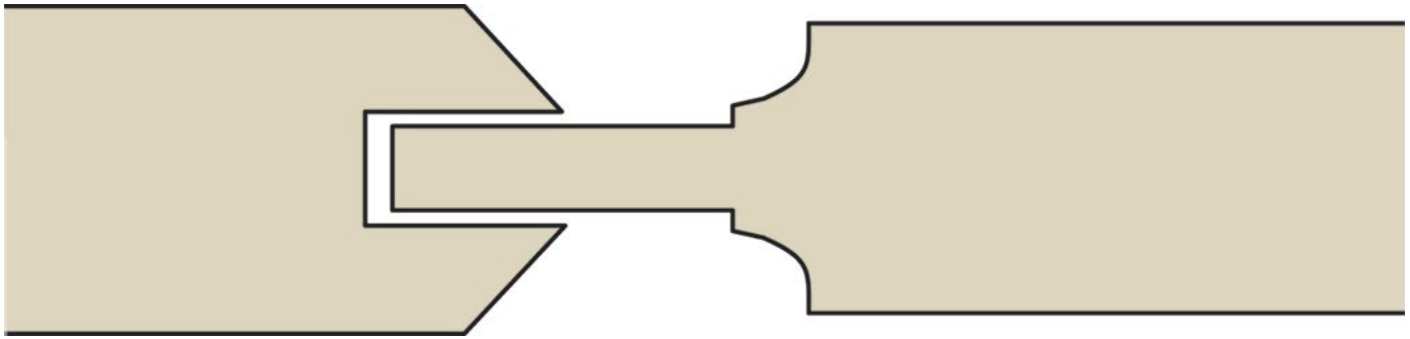


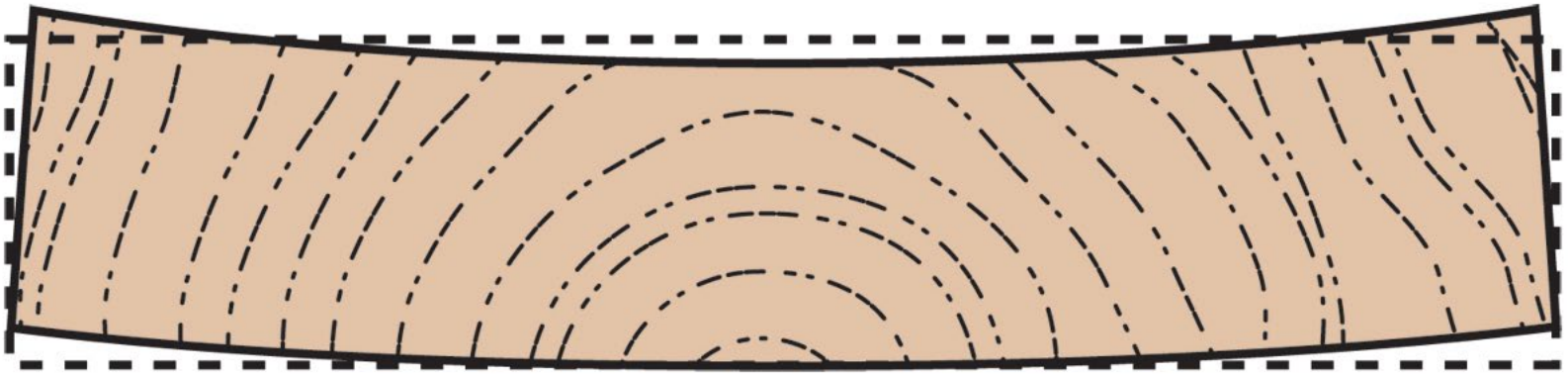


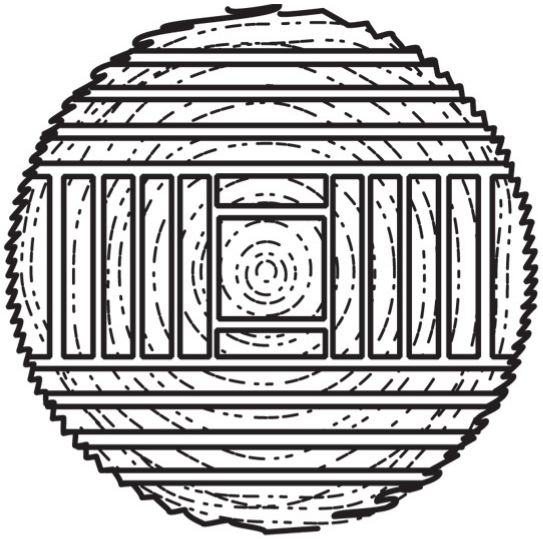
Wood Fiber

Fibers get much thicker than longer when they pick up moisture

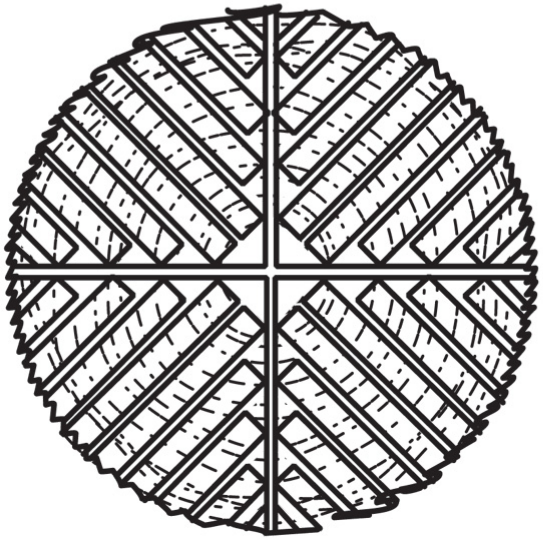
Studs get much wider and thicker, but not much longer, when they pick up moisture



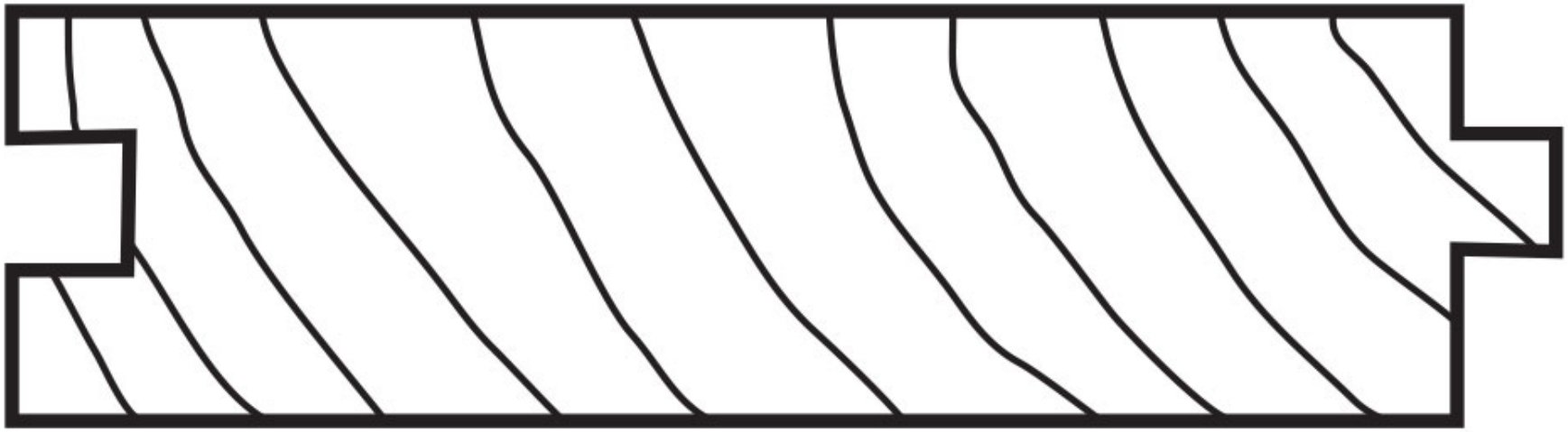




Plain sawn log

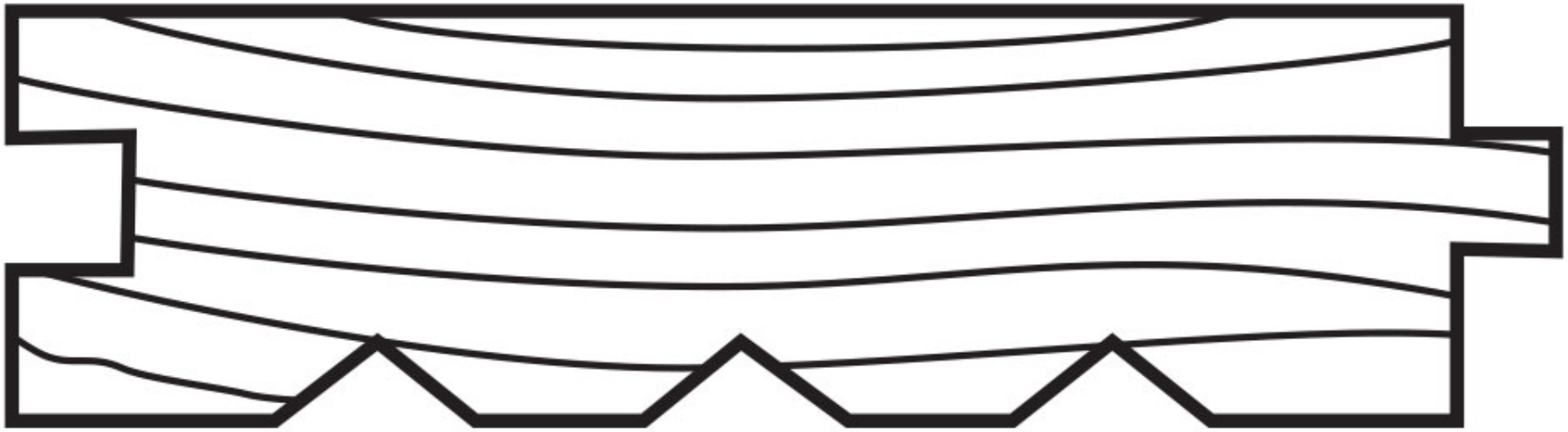


Quarter sawn log

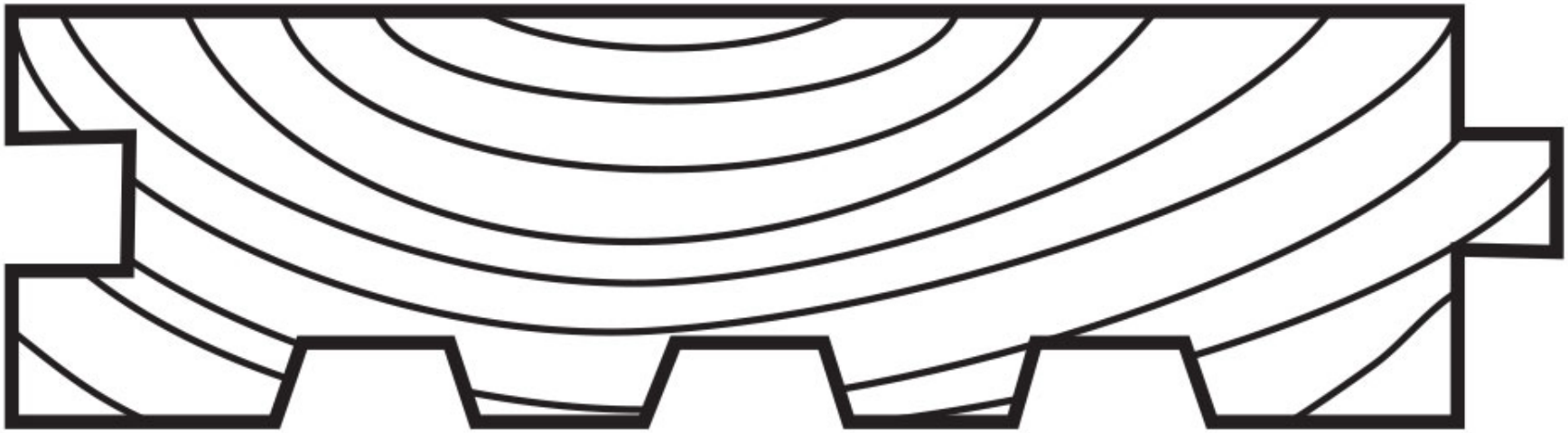


Plain

Hollow Back

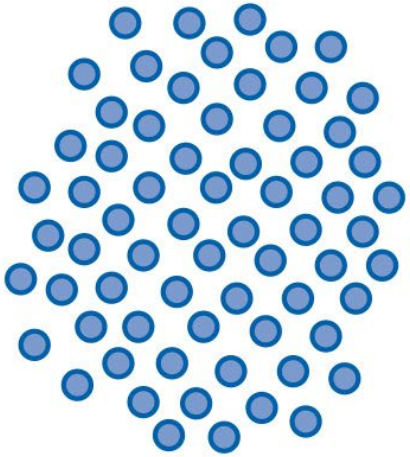


Scratch Back

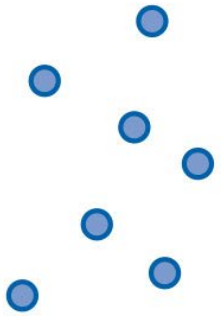


Hollow or Scratch Back

Air Flow and Vapor Diffusion



DIFFUSION



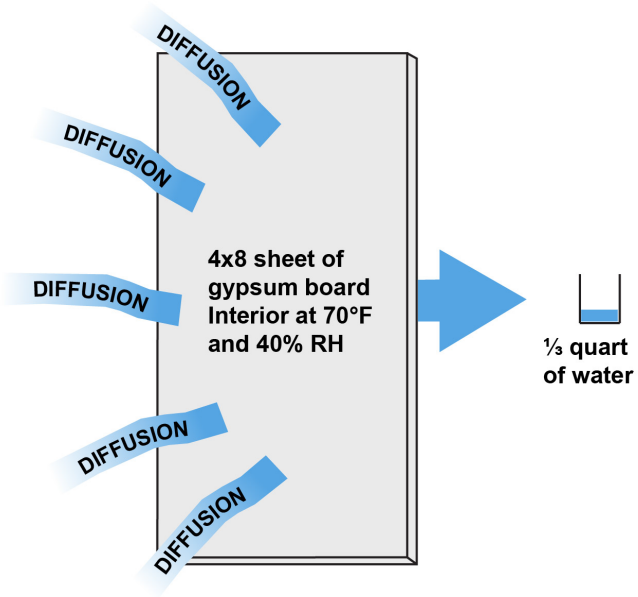
Higher Dewpoint Temperature
Higher Water Vapor Density
or Concentration
(Higher Vapor Pressure)
on Warm Side of Assembly

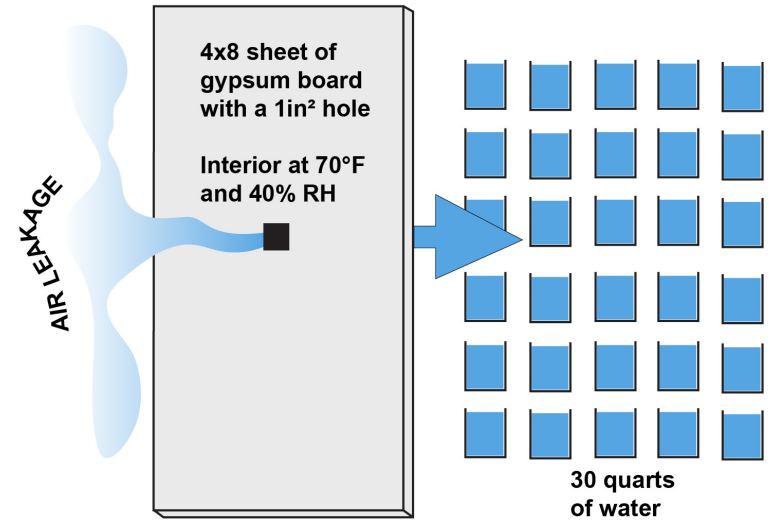
Low Dewpoint Temperature
Lower Water Vapor Density
or Concentration
(Lower Vapor Pressure)
on Cold Side of Assembly

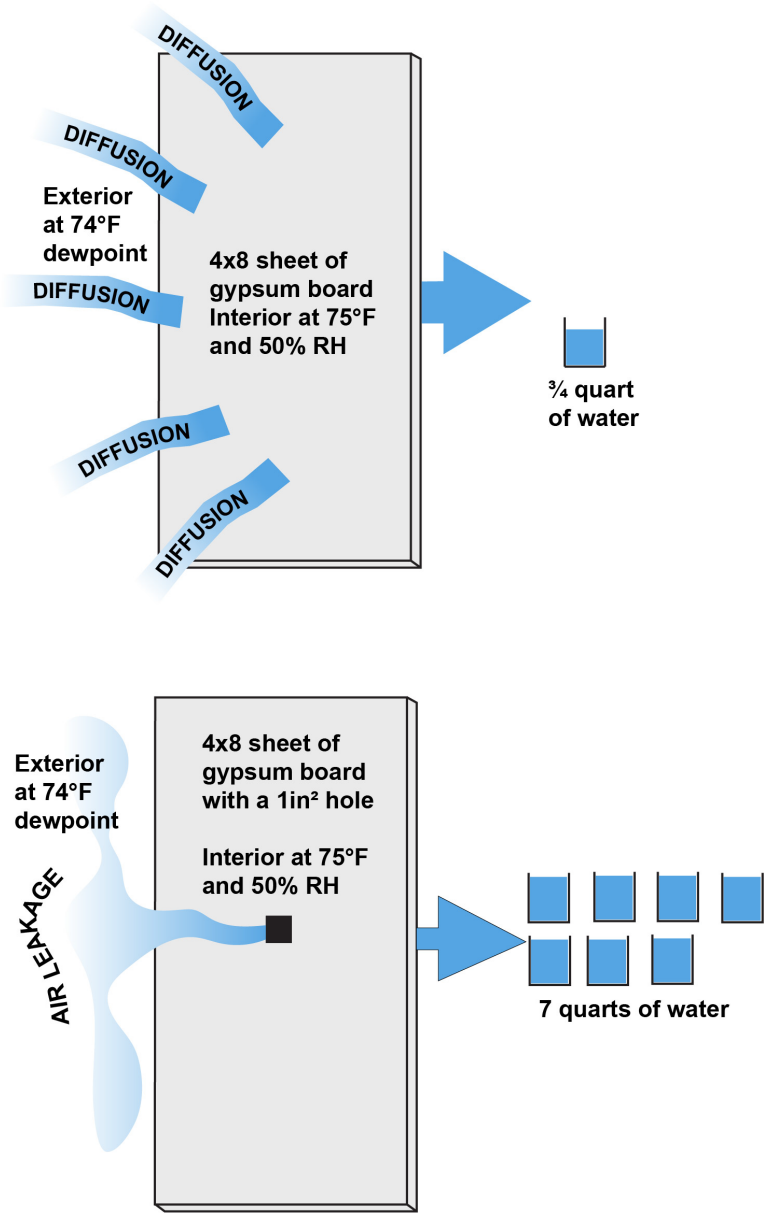
AIR TRANSPORT

Higher Air Pressure

Lower Air Pressure


DIFFUSION
DIFFUSION
DIFFUSION
DIFFUSION
DIFFUSION
4x8 sheet of gypsum board Interior at 70°F and 40% RH
⅓ quart of water


AIR LEAKAGE
4x8 sheet of gypsum board with a 1in² hole
Interior at 70°F and 40% RH
30 quarts of water


DIFFUSION
DIFFUSION
Exterior
at 74°F
dewpoint
DIFFUSION
4x8 sheet of
gypsum board
Interior at 75°F
and 50% RH
DIFFUSION
DIFFUSION
¾ quart
of water
Exterior
at 74°F
dewpoint
AIR LEAKAGE
4x8 sheet of
gypsum board
with a 1in² hole
Interior at 75°F
and 50% RH
7 quarts of water

Capillarity

William Thomson

William Thomson – Lord Kelvin

Kelvin Equation

$$\ln \frac{P_v}{P_{sat}} = -\frac{2H\gamma V_l}{RT}$$

Where...

P_v = equilibrium vapor pressure

P_{sat} = saturation vapor pressure

H = mean curvature of meniscus

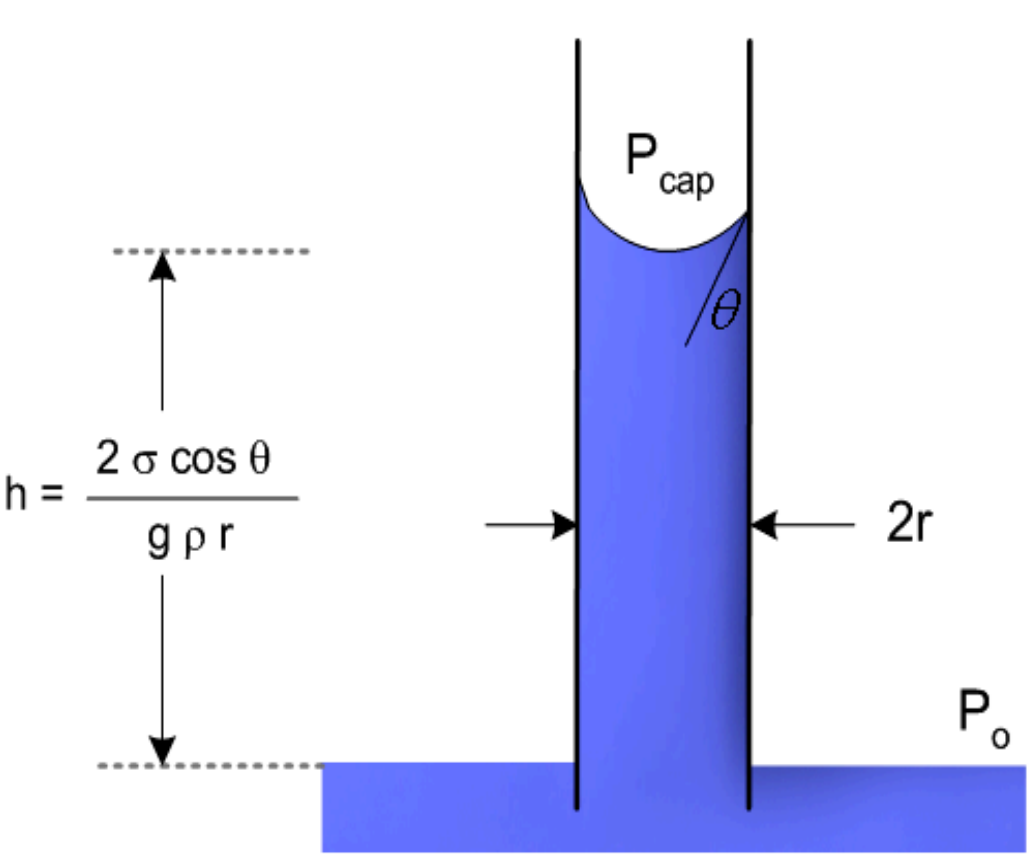
γ = liquid/vapor surface tension

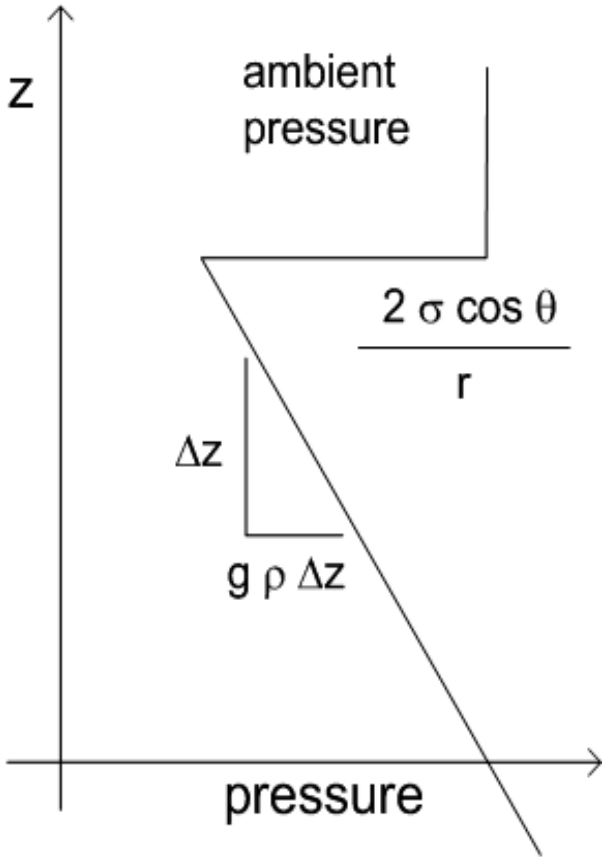
V_l = liquid molar volume

R = ideal gas constant

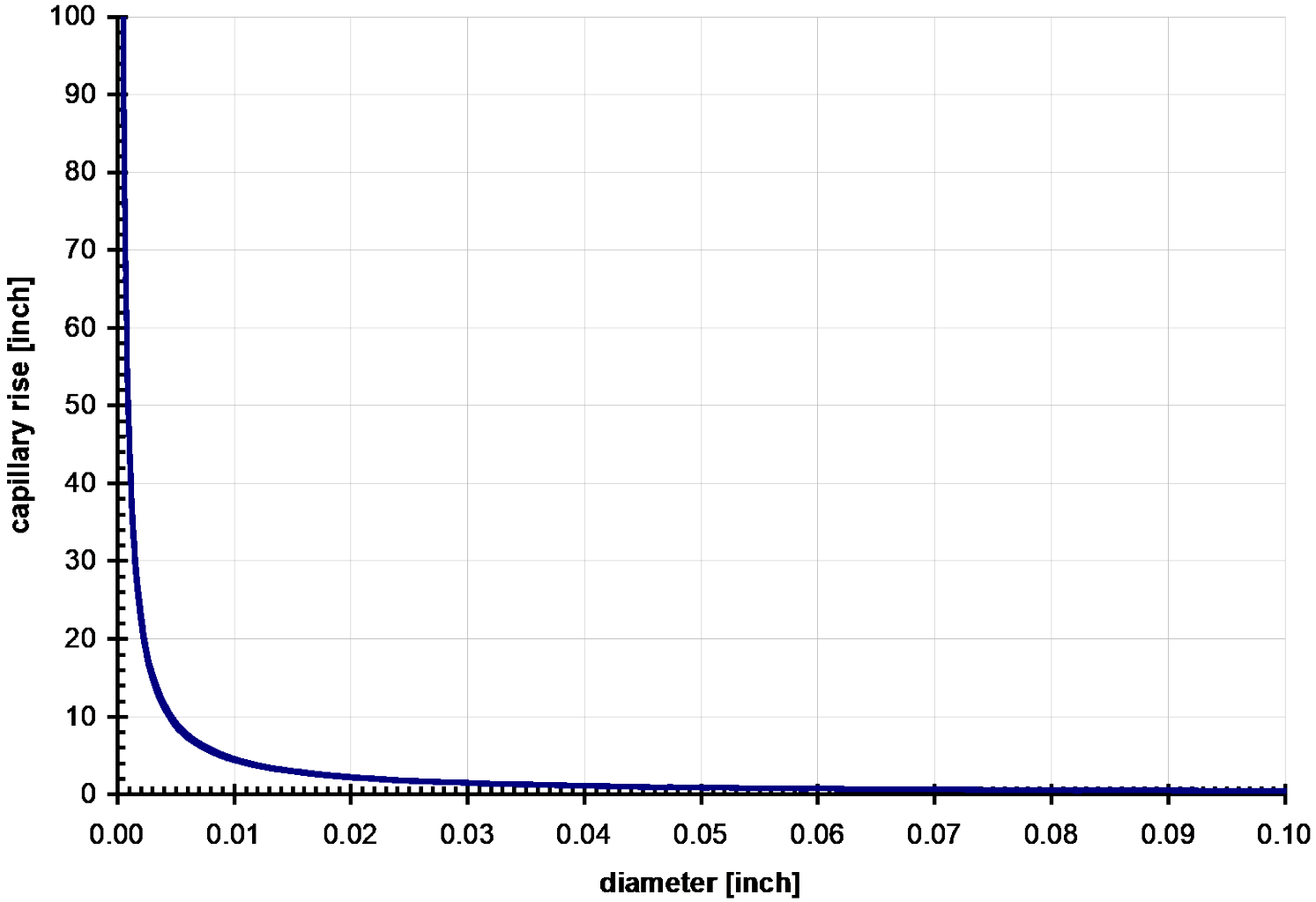
T = temperature

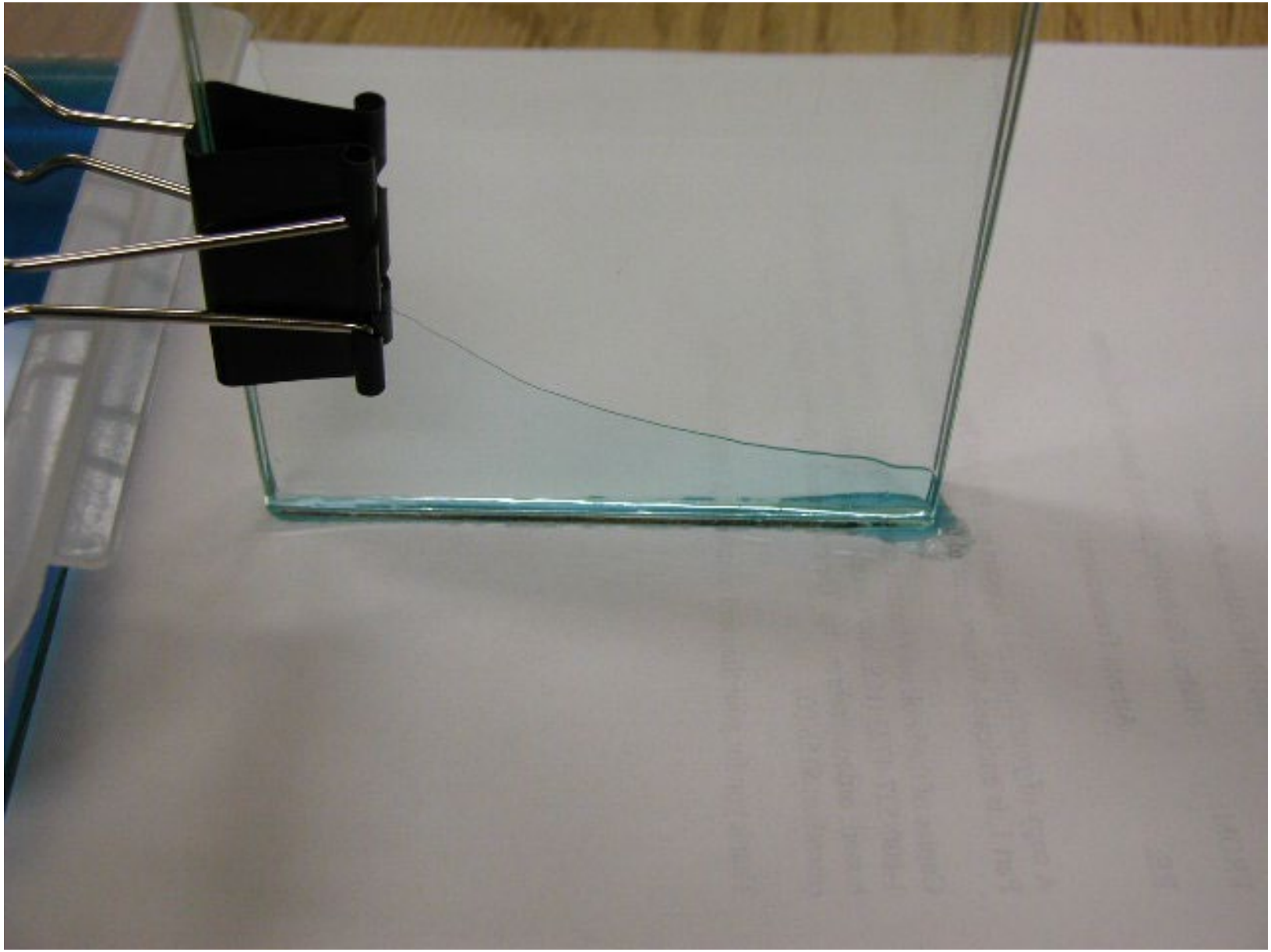
Calculating capillary rise

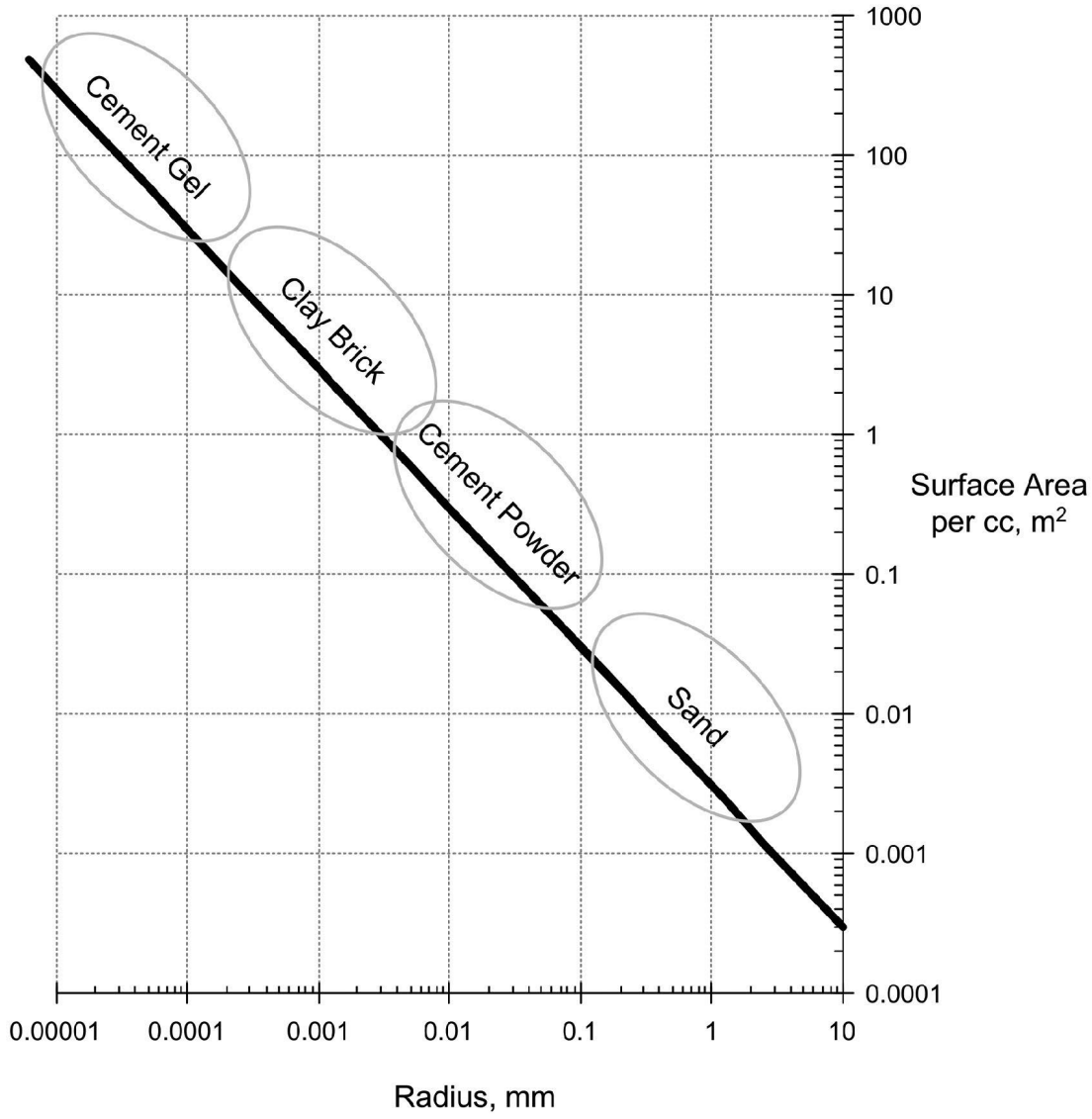




Capillary rise versus diameter







Surface area vs. particle size
From Straube & Burnett, 2005

Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

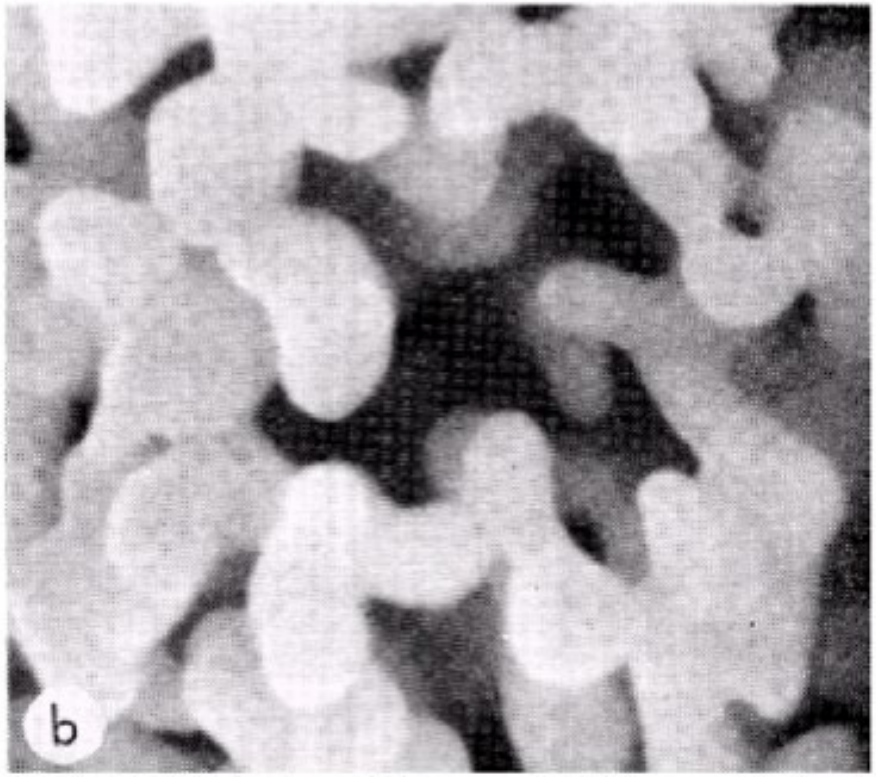
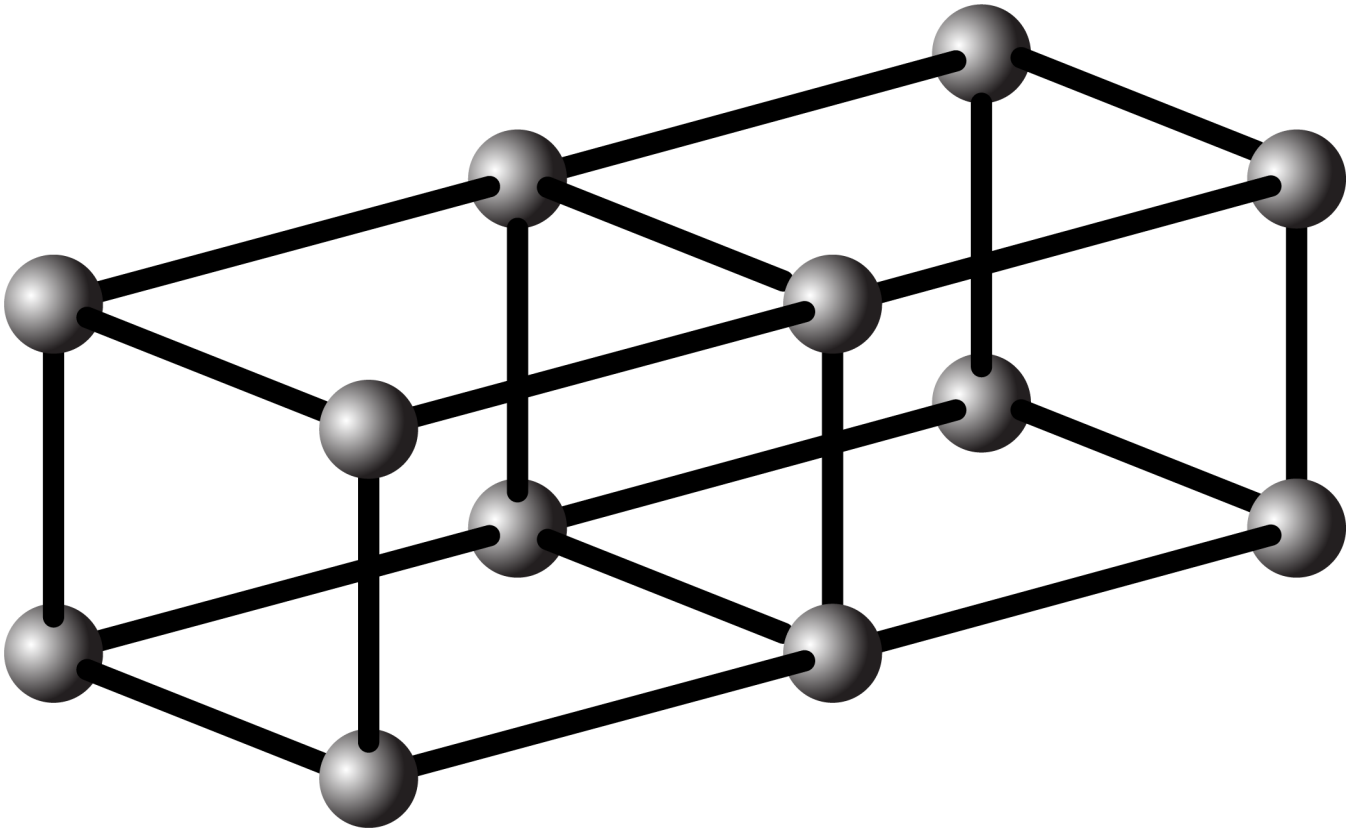
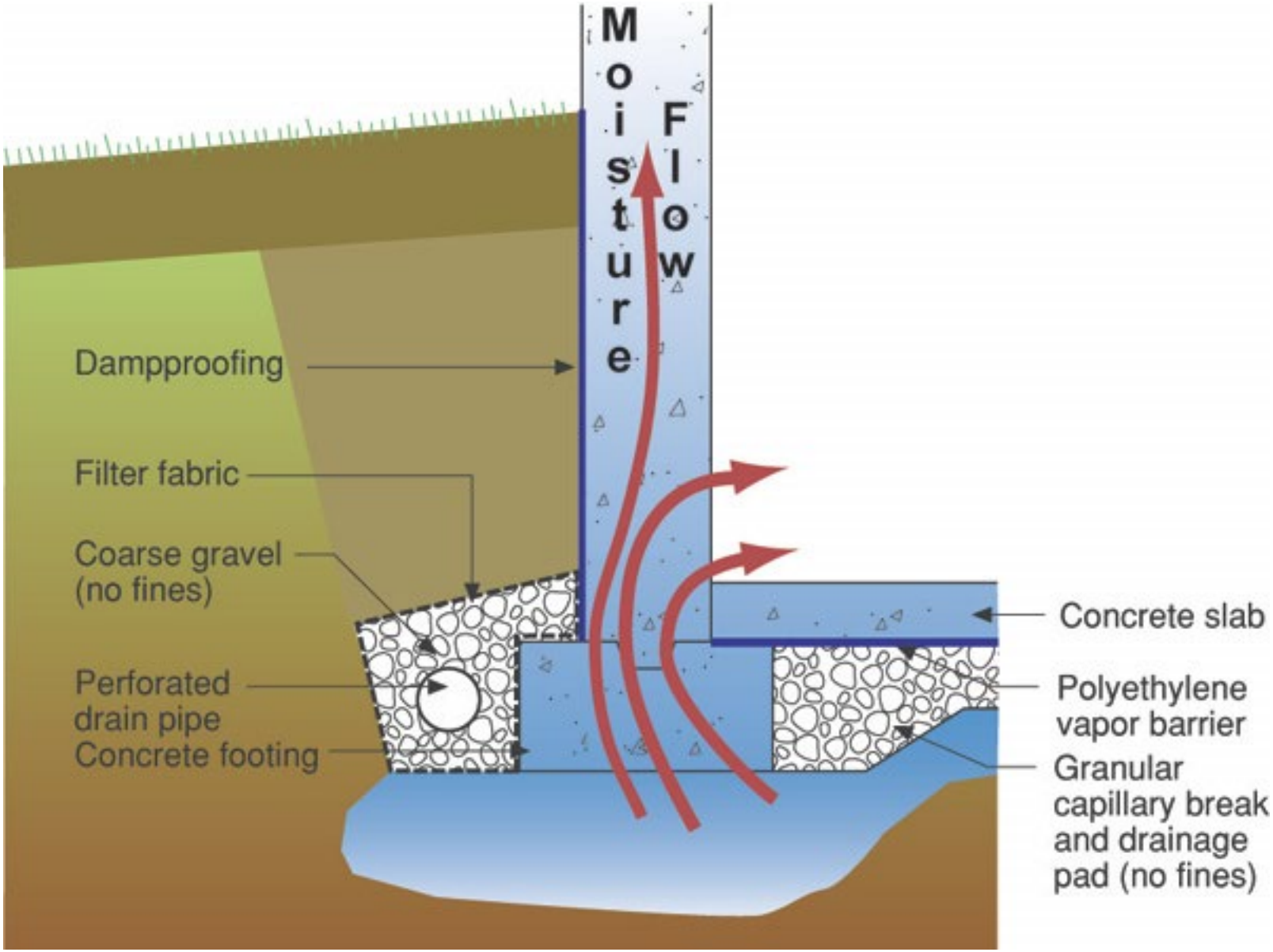
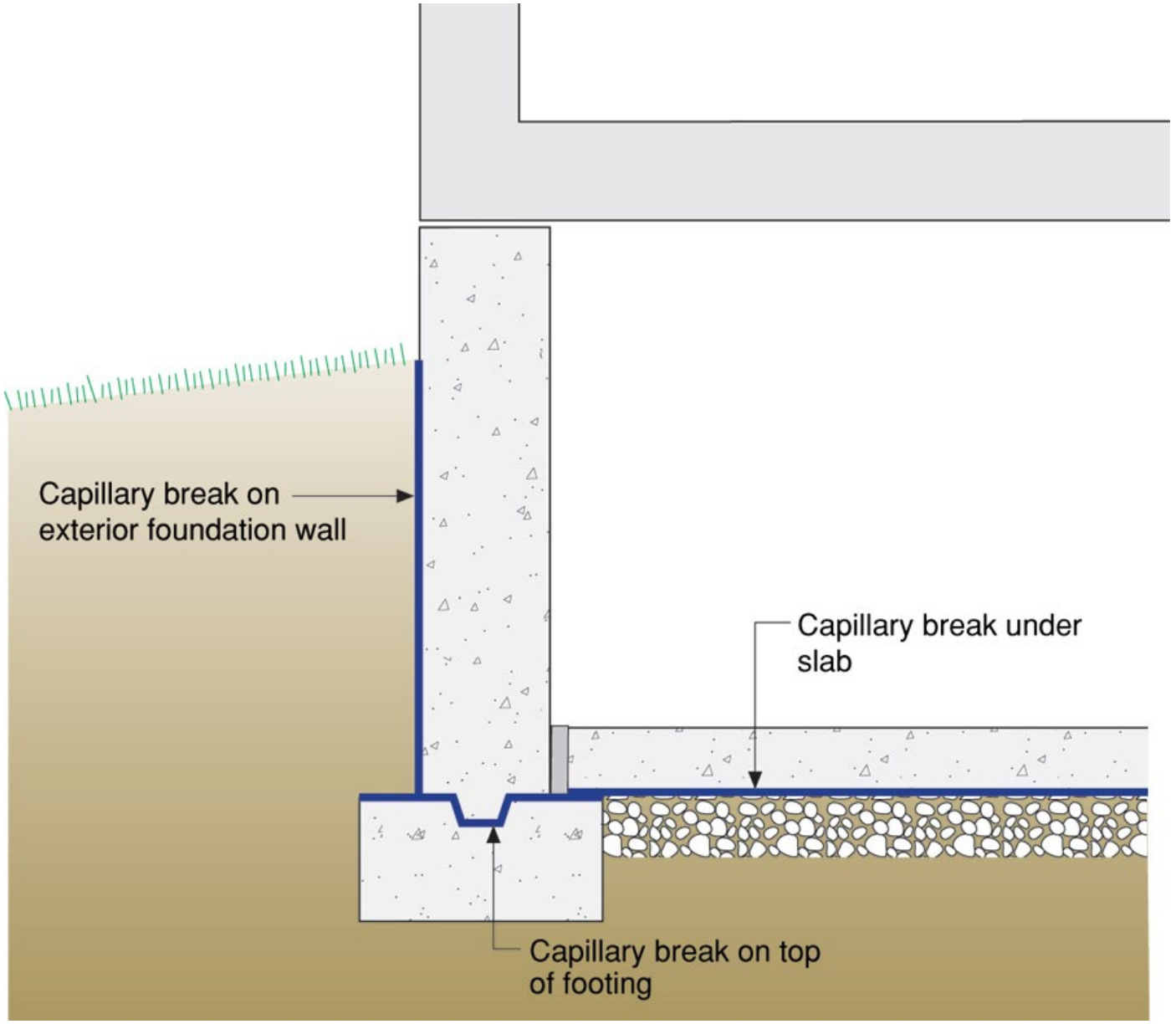


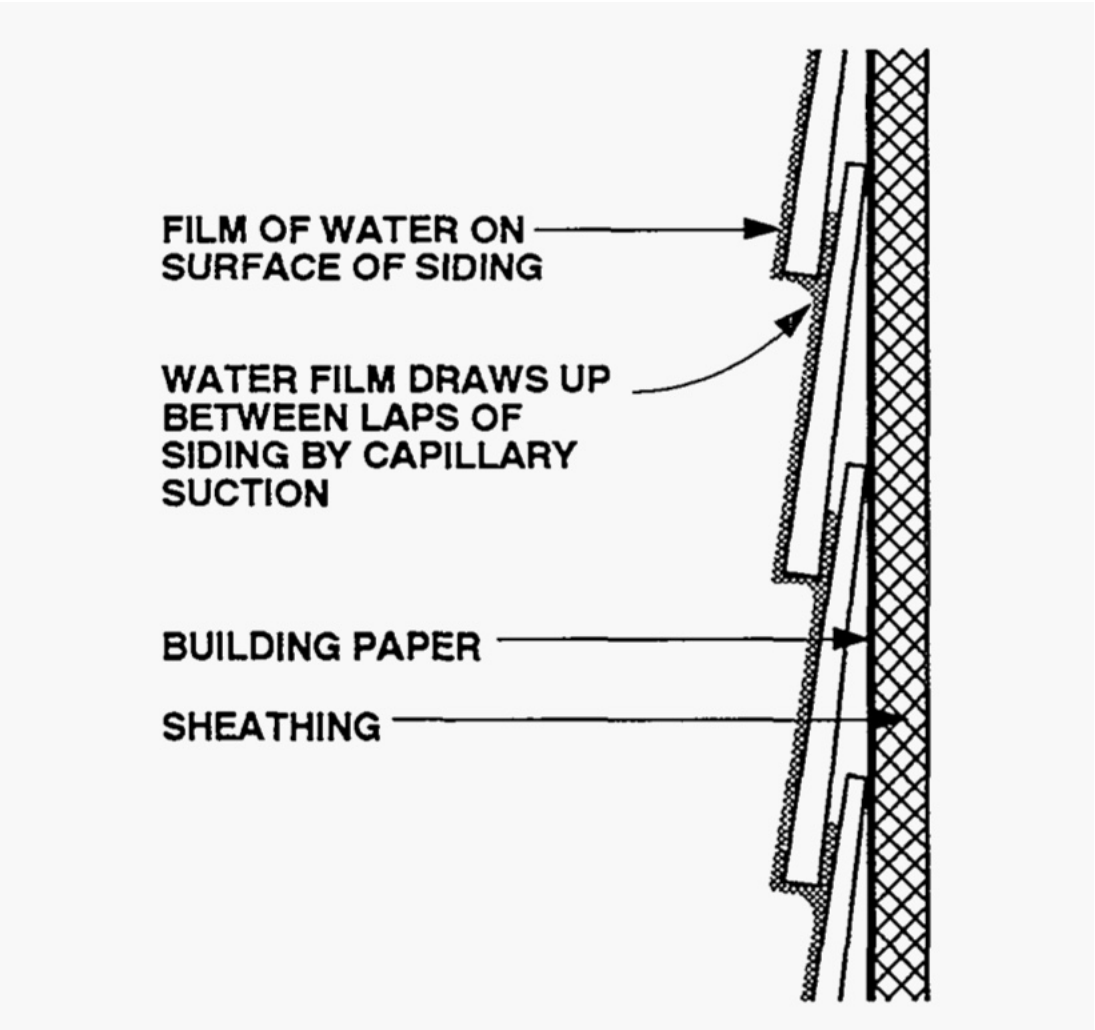
Figure 1b. Brick, sintered clay, porosity 40 per cent.

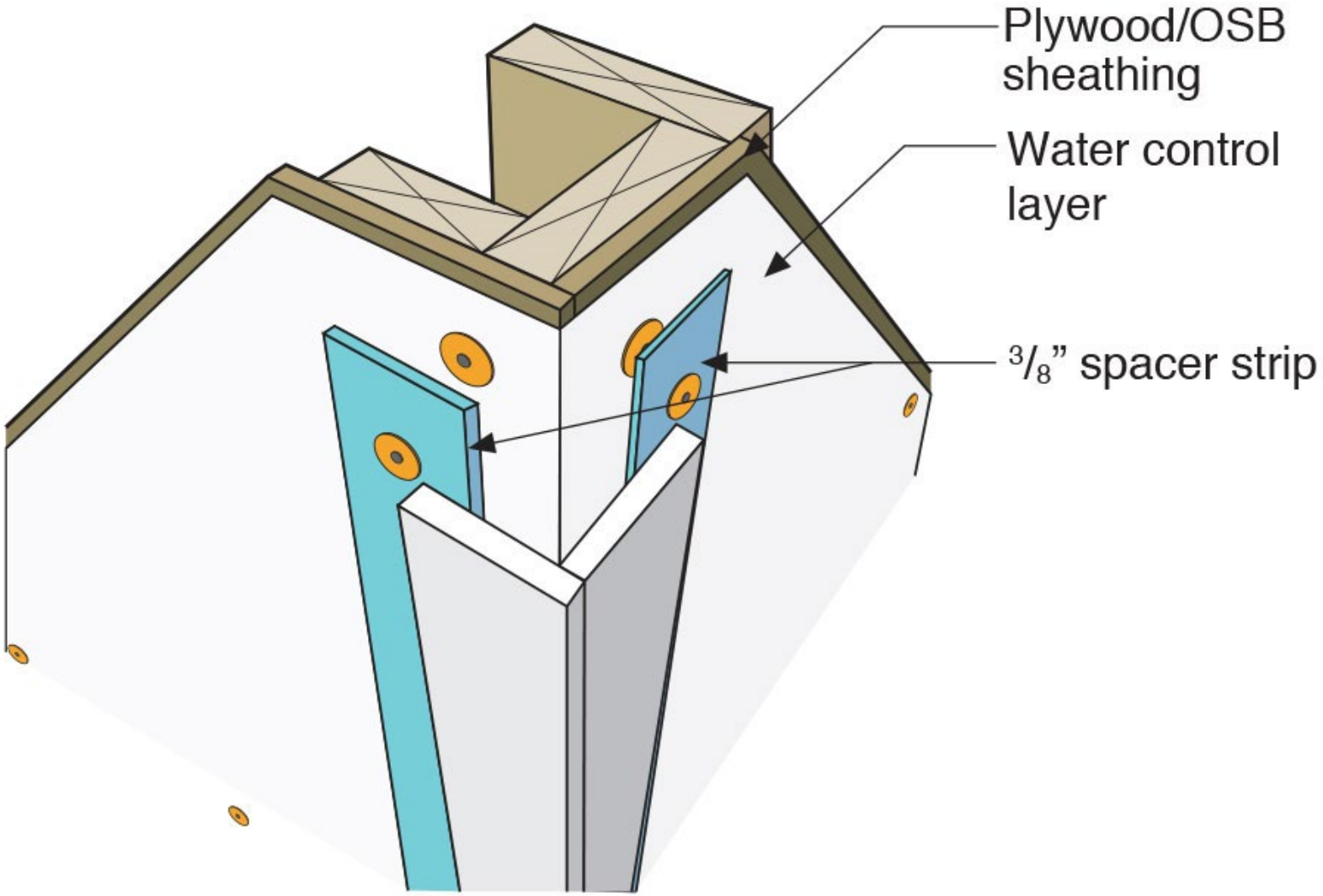


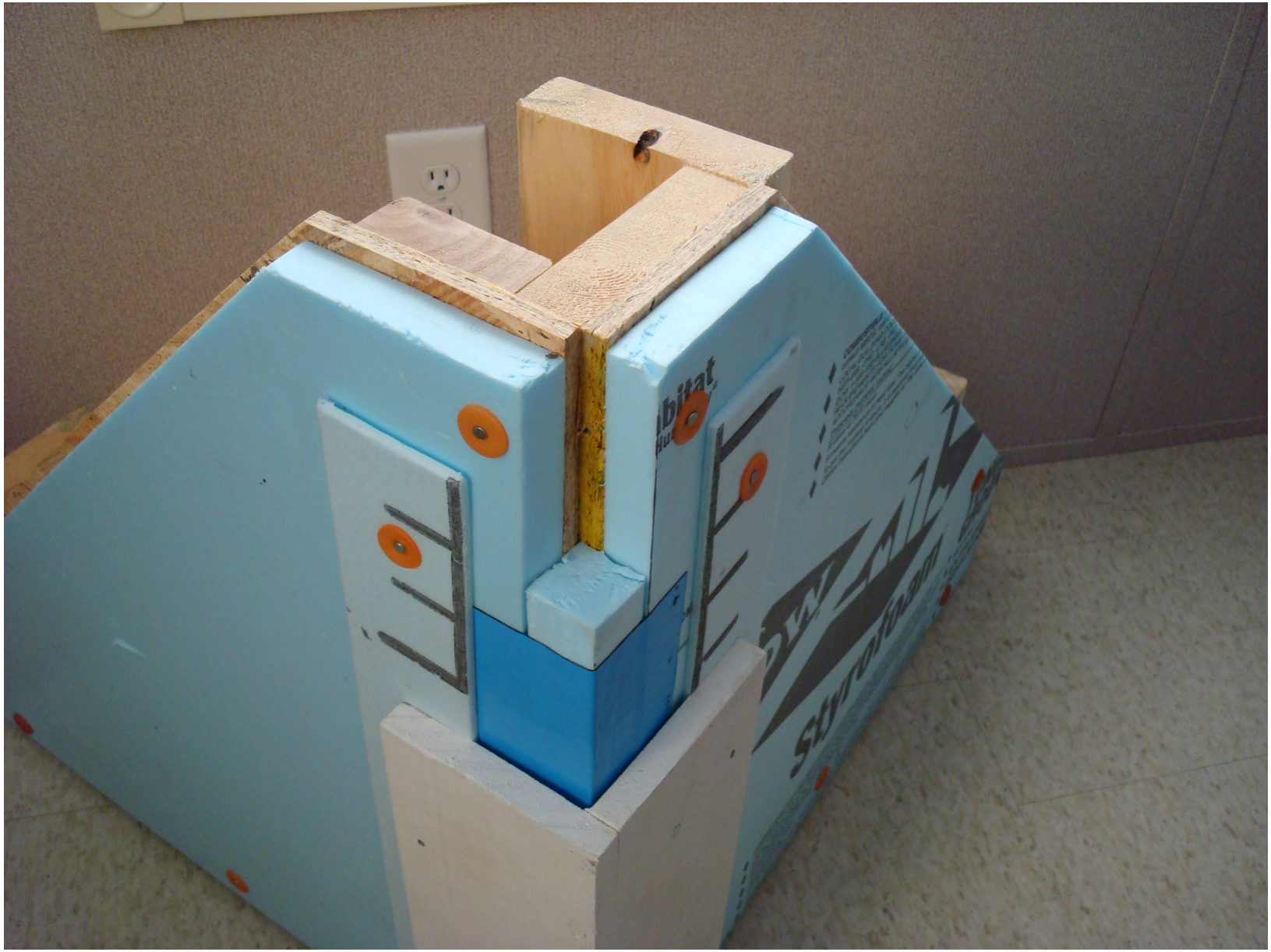

Moisture Flow
Dampproofing
Filter fabric
Coarse gravel
(no fines)
Perforated
drain pipe
Concrete footing
Concrete slab
Polyethylene
vapor barrier
Granular
capillary break
and drainage
pad (no fines)


Capillary break on
exterior foundation wall
Capillary break under
slab
Capillary break on top
of footing

Siding Laps

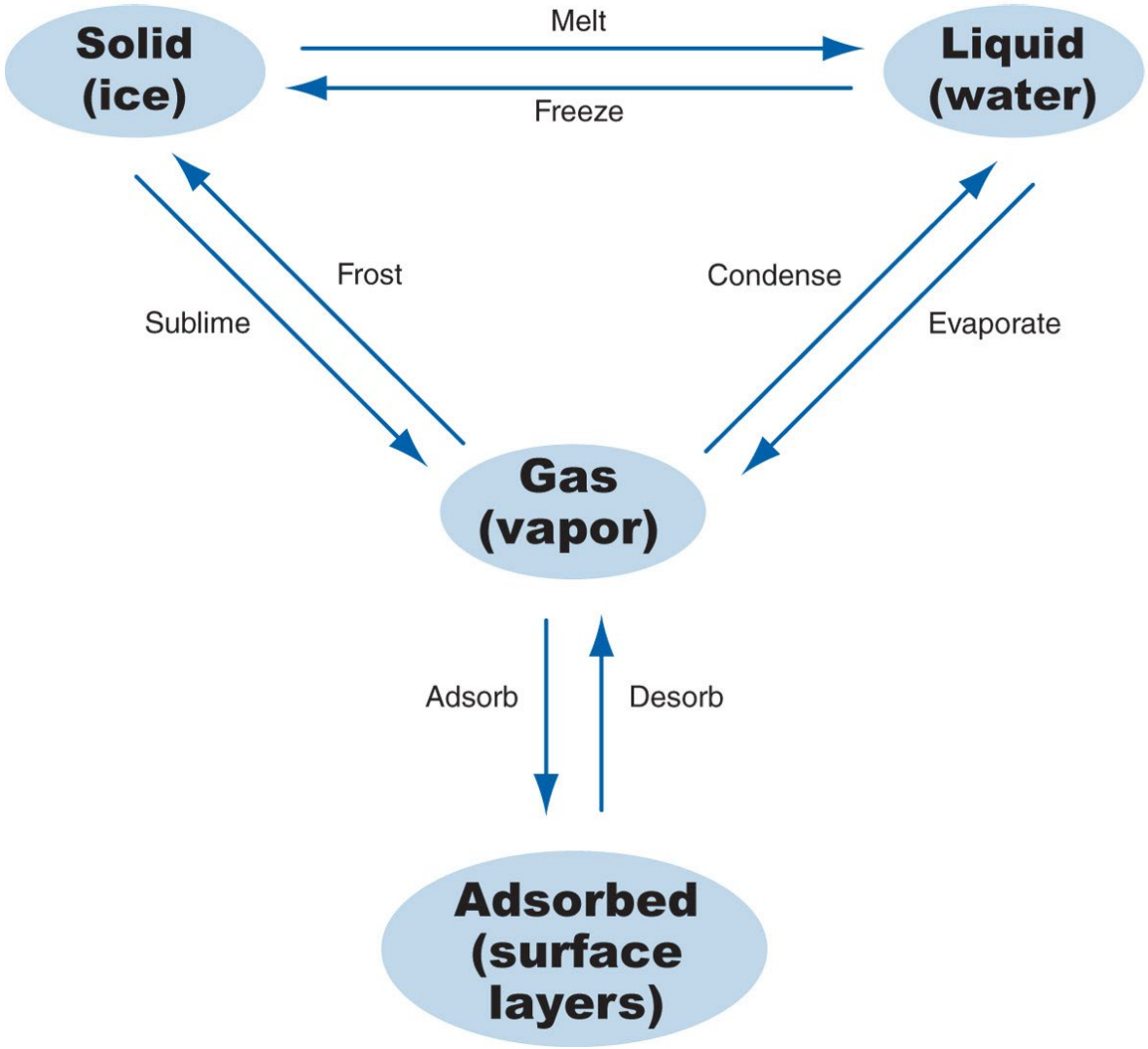

FILM OF WATER ON SURFACE OF SIDING
WATER FILM DRAWS UP BETWEEN LAPS OF SIDING BY CAPILLARY SUCTION
BUILDING PAPER
SHEATHING

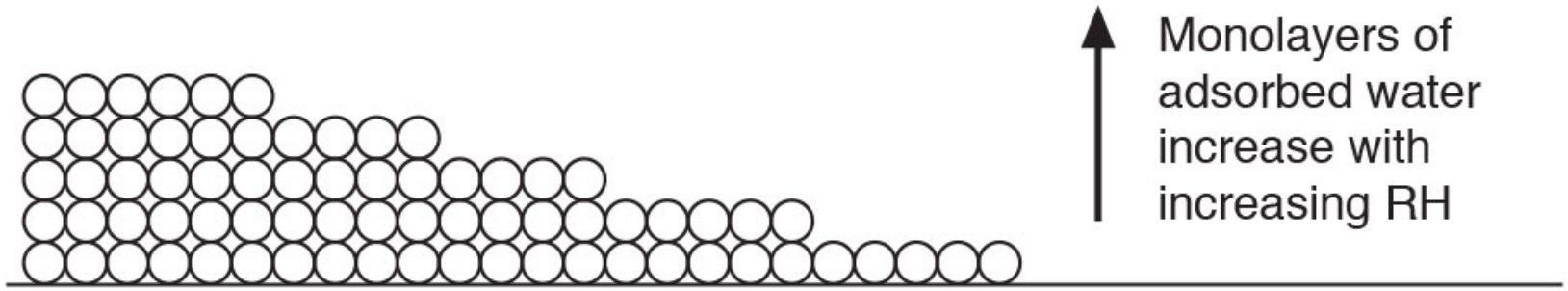

Plywood/OSB sheathing
Water control layer
3/8" spacer strip

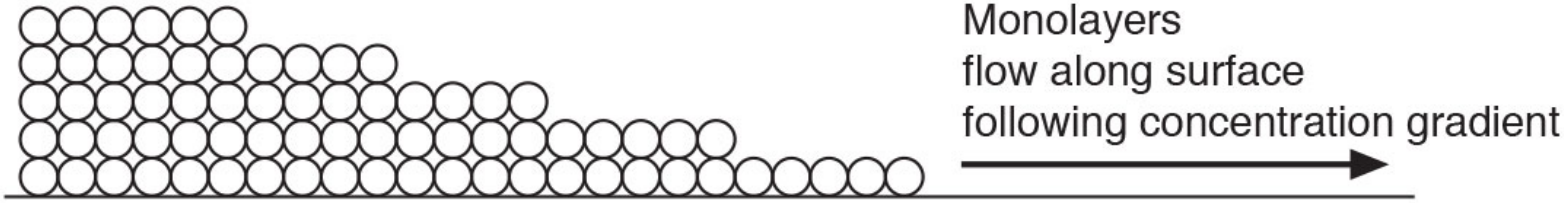

Styrofoam

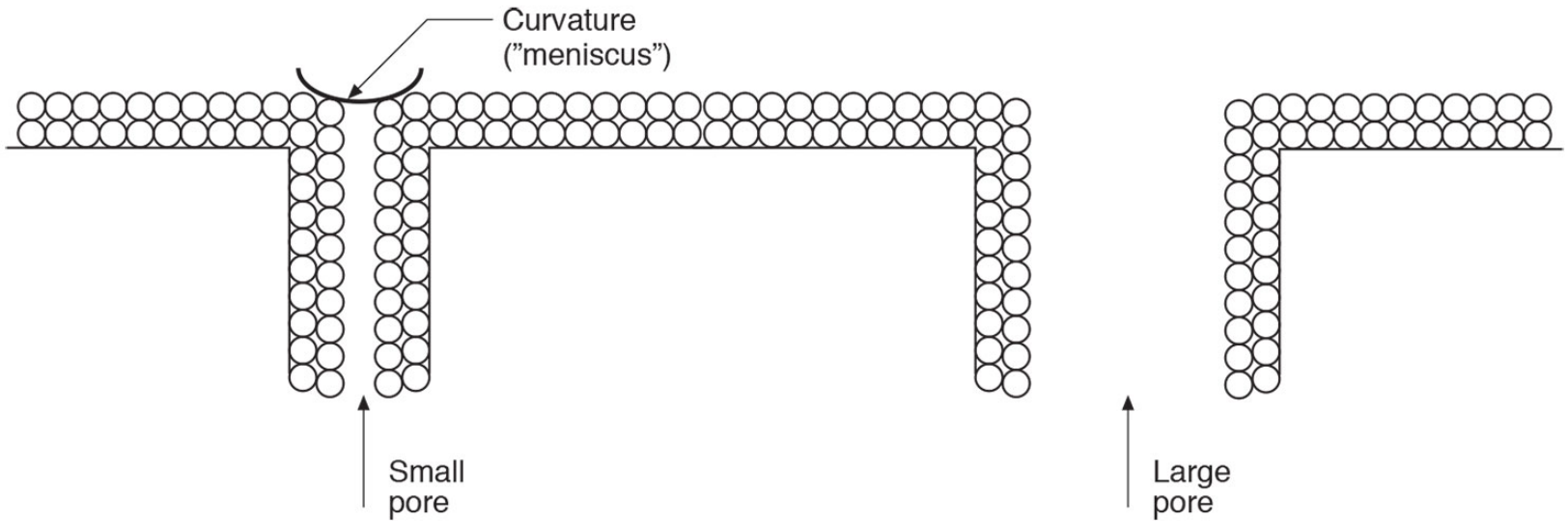
Kelvin Equation Again….

$$\ln \frac{p}{p_0} = \frac{2\gamma V_{\mathrm{m}}}{rRT}$$

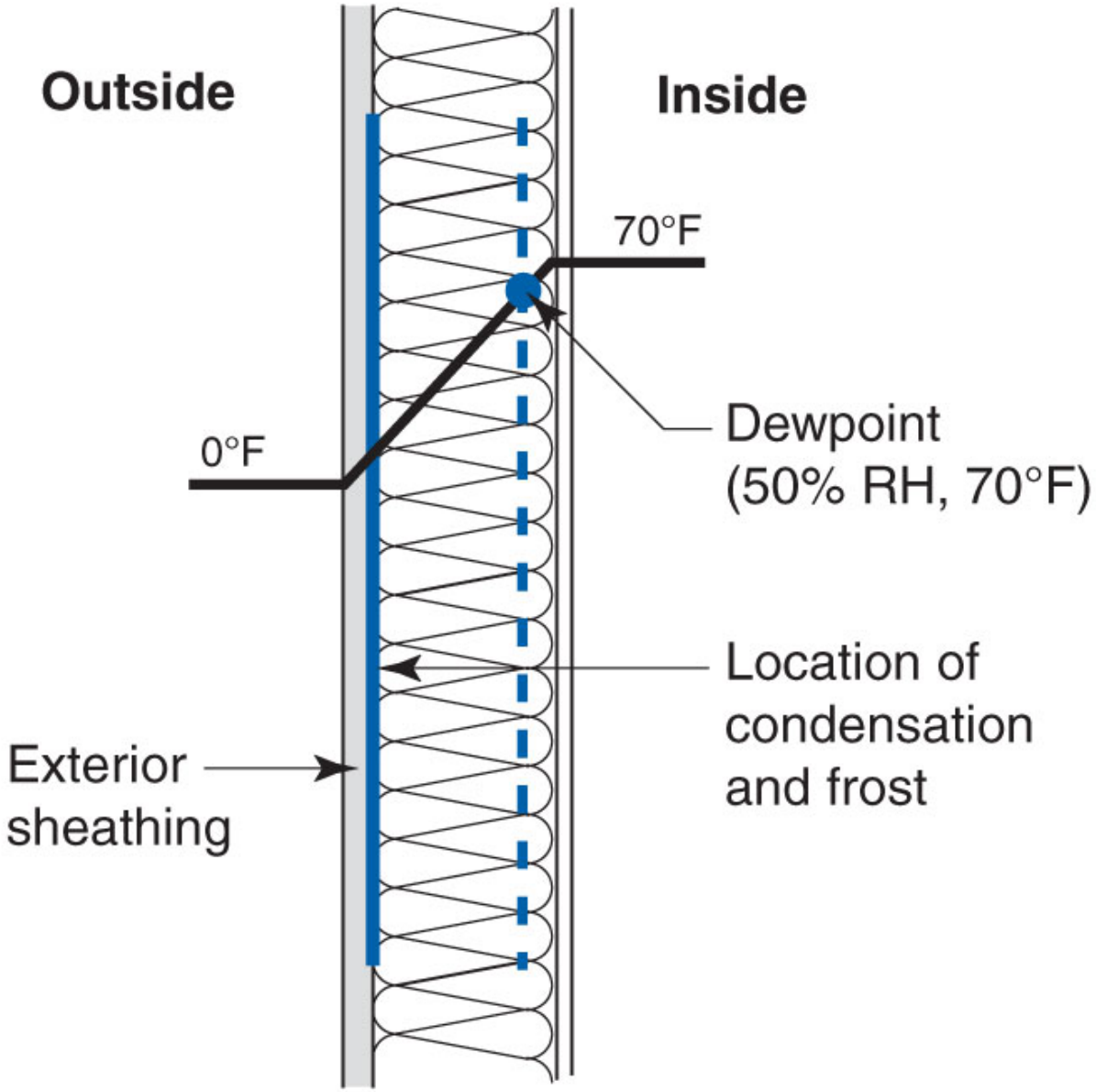

Solid (ice)
Melt
Freeze
Liquid (water)
Frost
Sublime
Condense
Evaporate
Gas (vapor)
Adsorb
Desorb
Adsorbed (surface layers)

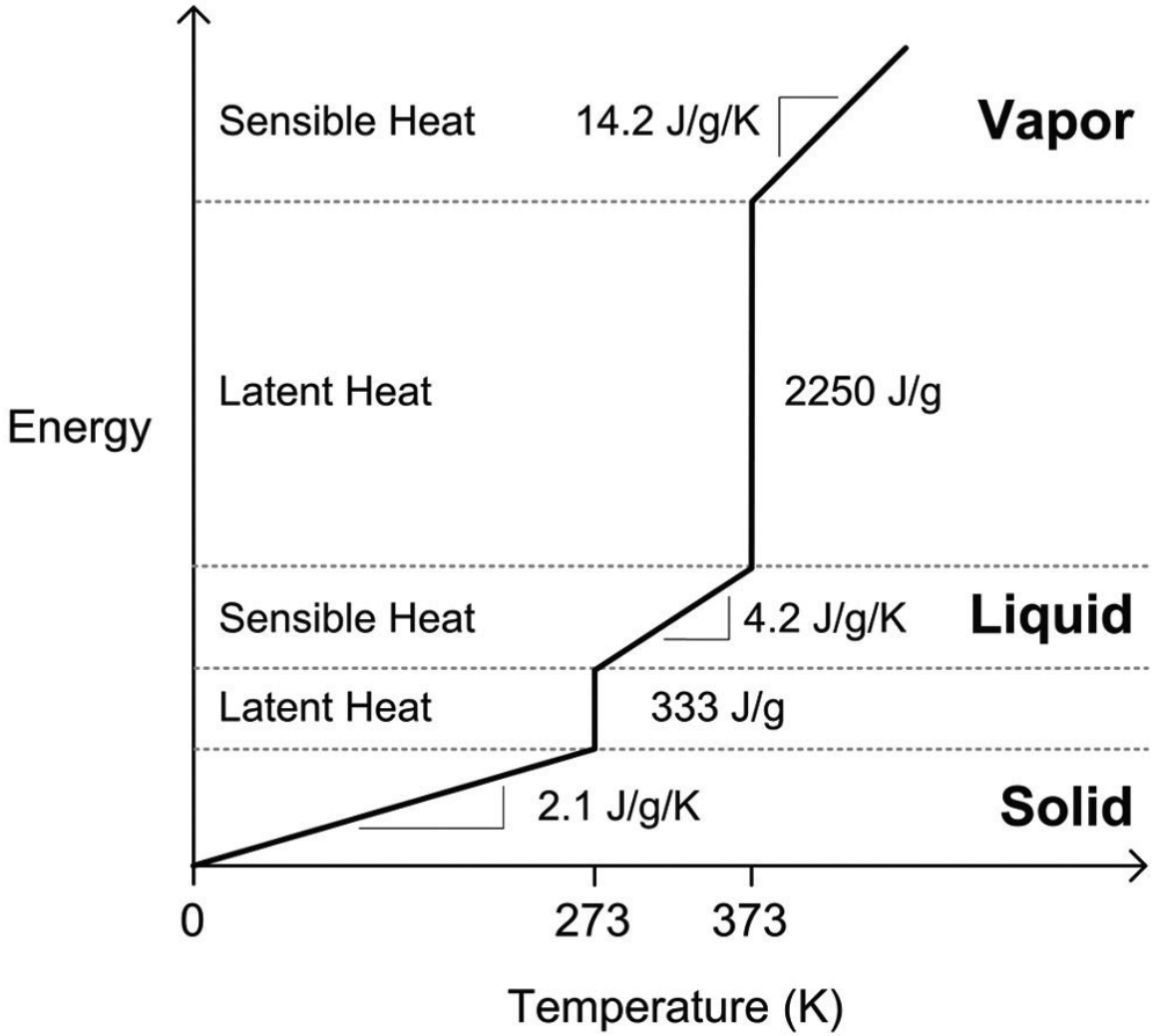

Monolayers of
adsorbed water
increase with
increasing RH


Monolayers
flow along surface
following concentration gradient

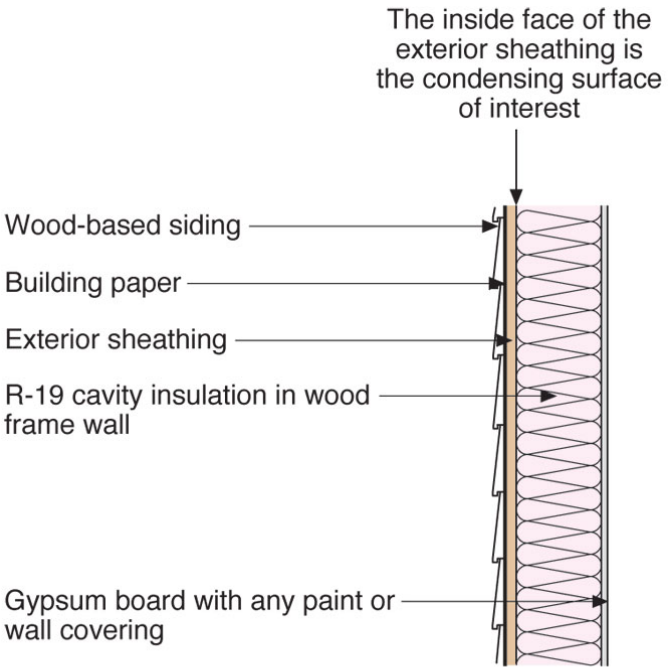

Curvature
("meniscus")
Small
pore
Large
pore

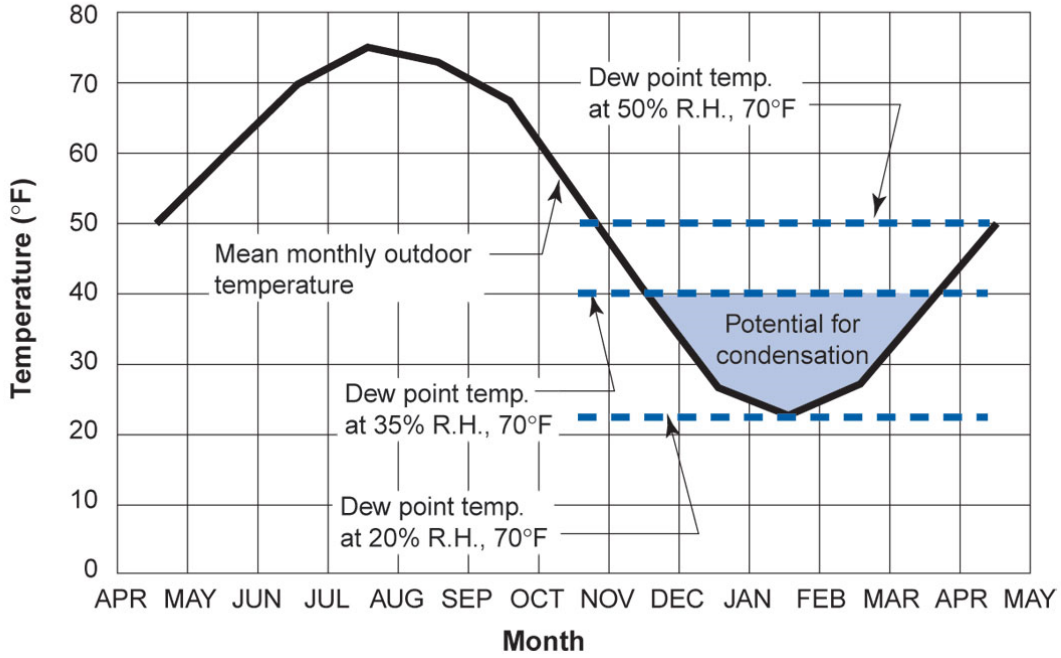
The Myth of the Dew Point

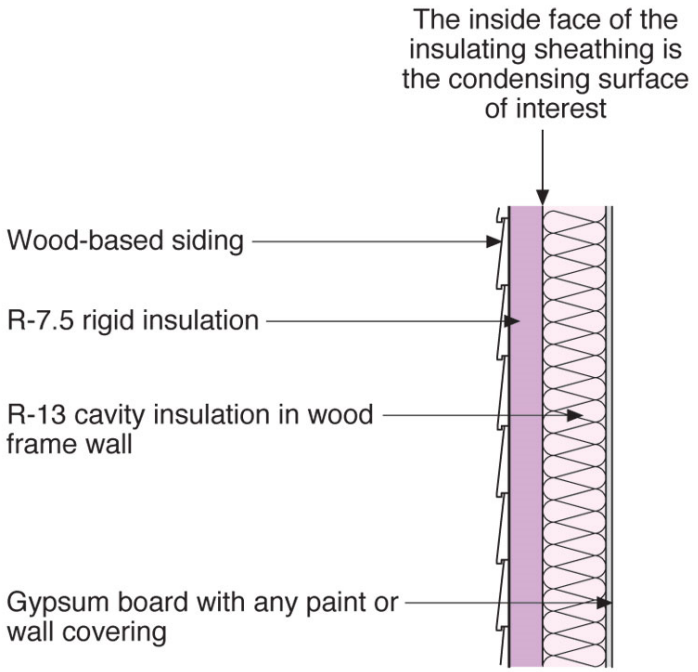

Outside
Inside
70°F
0°F
Dewpoint
(50% RH, 70°F)
Location of
condensation
and frost
Exterior
sheathing

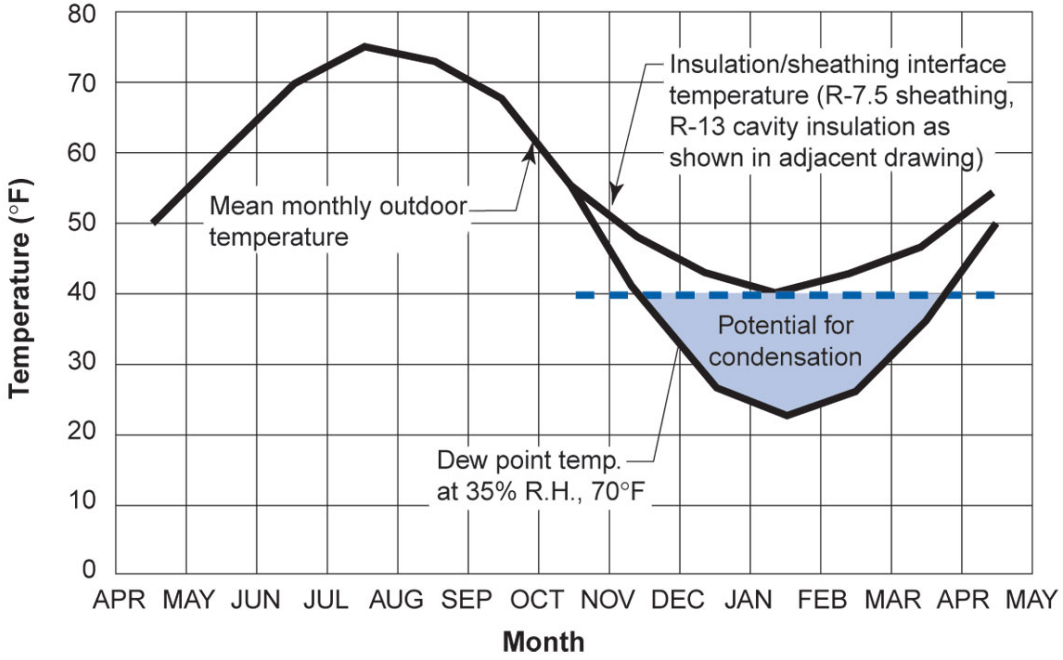


Simple linearized energy-temperature relation for water
From Straube & Burnett, 2005


The inside face of the exterior sheathing is the condensing surface of interest
Wood-based siding
Building paper
Exterior sheathing
R-19 cavity insulation in wood frame wall
Gypsum board with any paint or wall covering


Temperature (°F)
80
70
60
50
40
30
20
10
0
APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
Month
Dew point temp. at 50% R.H., 70°F
Mean monthly outdoor temperature
Potential for condensation
Dew point temp. at 35% R.H., 70°F
Dew point temp. at 20% R.H., 70°F

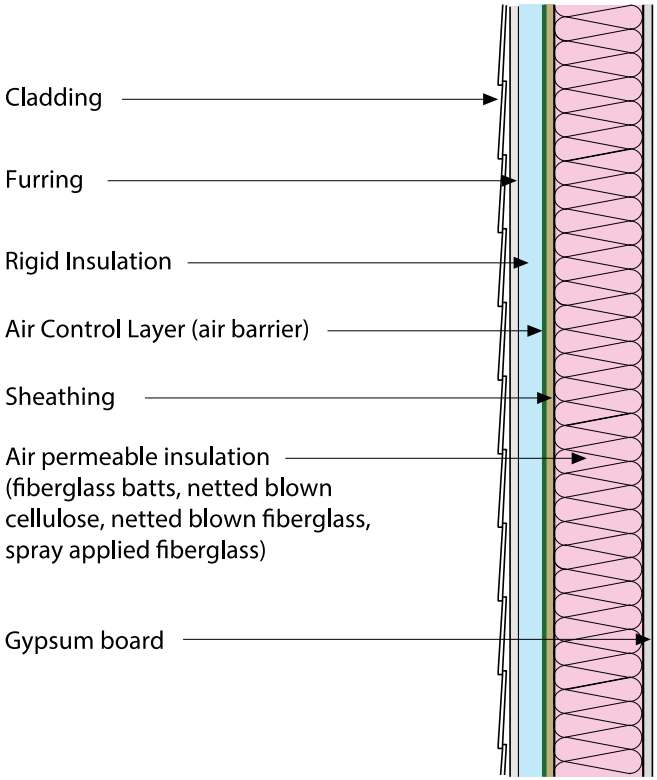

The inside face of the insulating sheathing is the condensing surface of interest
Wood-based siding
R-7.5 rigid insulation
R-13 cavity insulation in wood frame wall
Gypsum board with any paint or wall covering


Temperature (°F)
80
70
60
50
40
30
20
10
0
APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
Month
Insulation/sheathing interface temperature (R-7.5 sheathing, R-13 cavity insulation as shown in adjacent drawing)
Mean monthly outdoor temperature
Potential for condensation
Dew point temp. at 35% R.H., 70°F

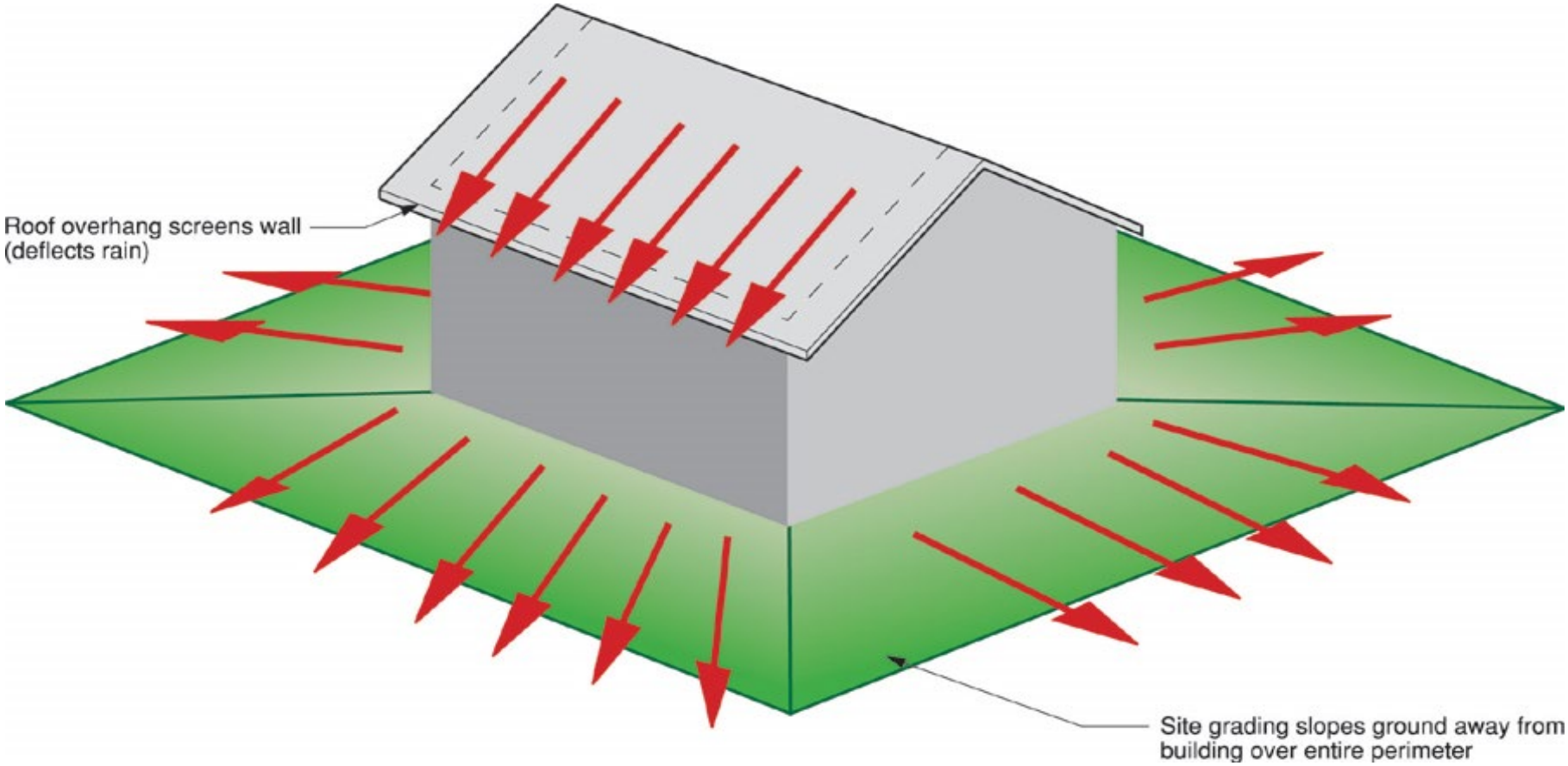
Insulation for Condensation Control*

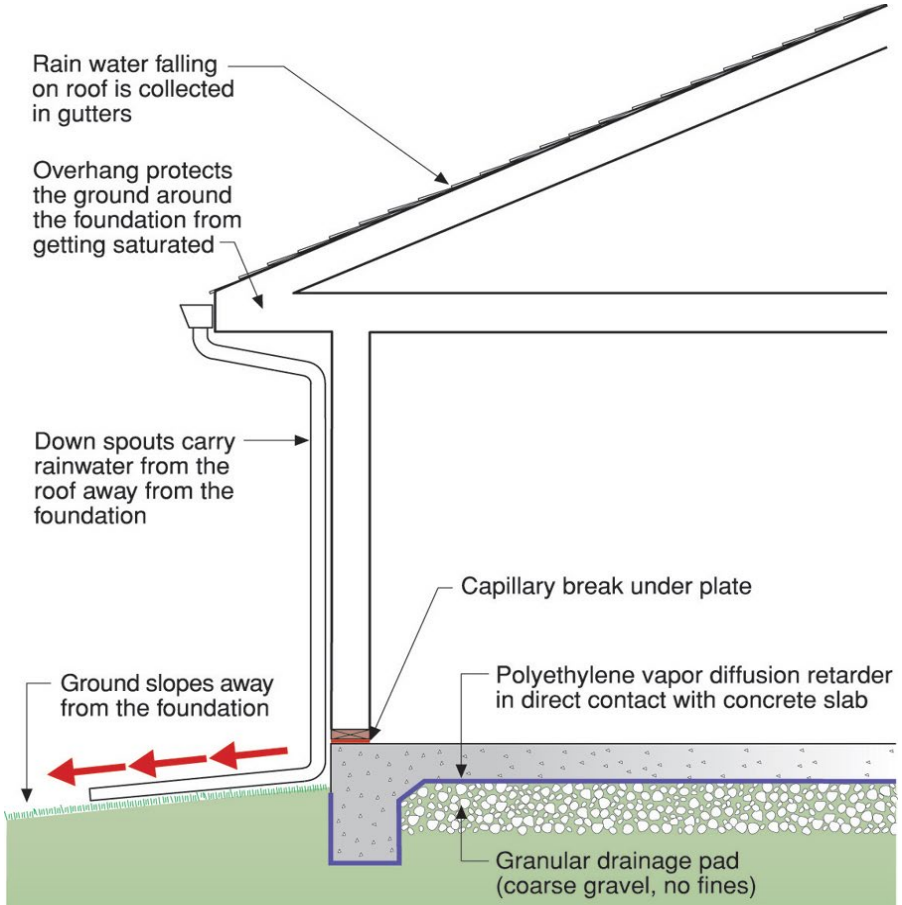
Climate Zone	Rigid Board or Air Impermeable Insulation	Total Cavity Insulation	Total Wall Assembly Insulation	Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value
4C	R-2.5	R-13	R-15.5	15%
	R-3.75	R-20	R-23.75	15%
5	R-5	R-13	R-18	30%
	R-7.5	R-20	R-27.5	30%
6	R-7.5	R-13	R-20.5	35%
	R-11.25	R-20	R-31.25	35%
7	R-10	R-13	R-28	45%
	R-15	R-20	R-35	45%
8	R-15	R-13	R-28	50%
	R-20	R-20	R-40	50%

*Adapted from Table R 702.1 2015 International Residential Code

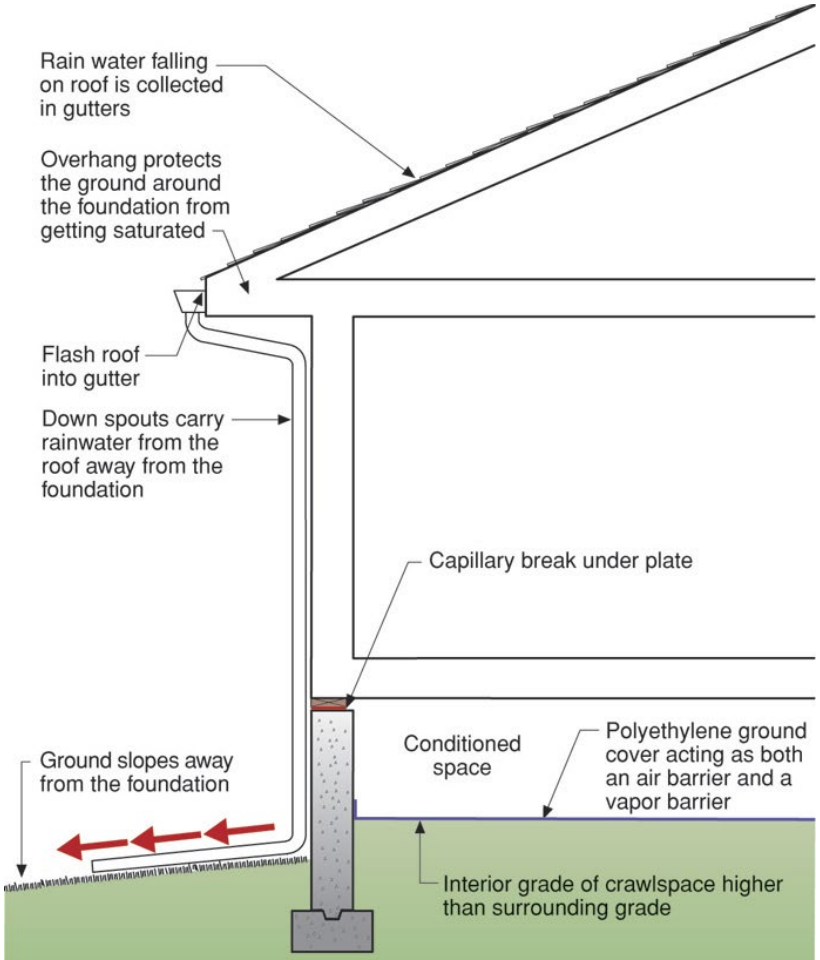

Cladding
Furring
Rigid Insulation
Air Control Layer (air barrier)
Sheathing
Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass)
Gypsum board

Foundations

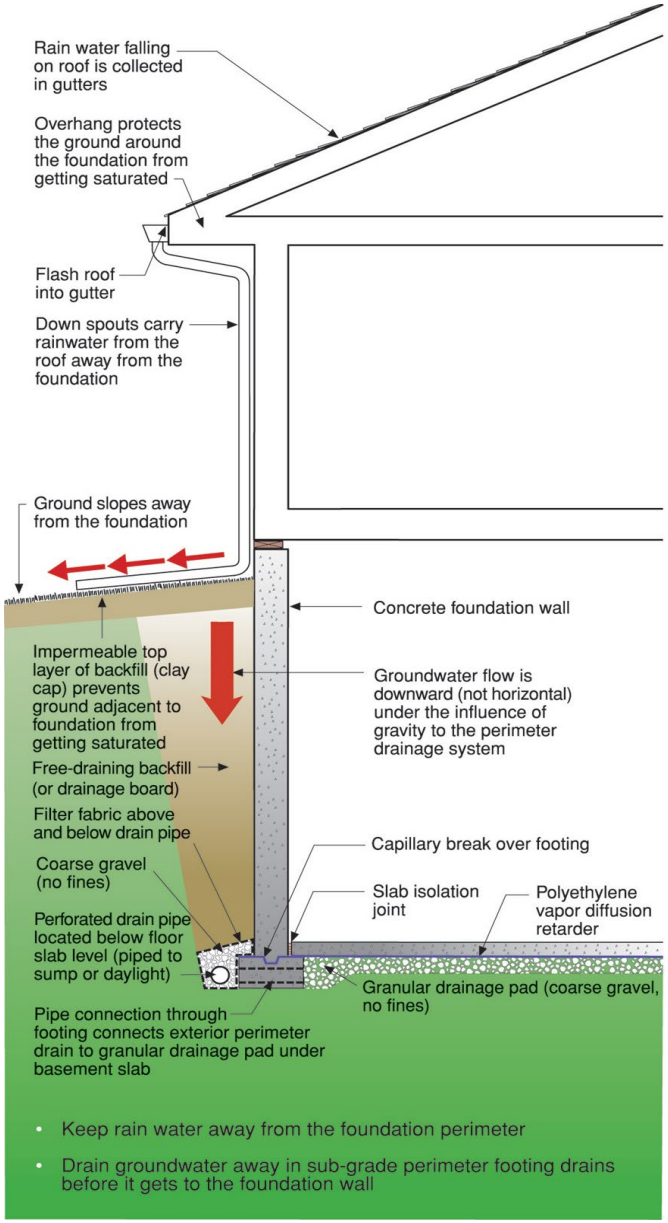

Roof overhang screens wall
(deflects rain)
Site grading slopes ground away from
building over entire perimeter

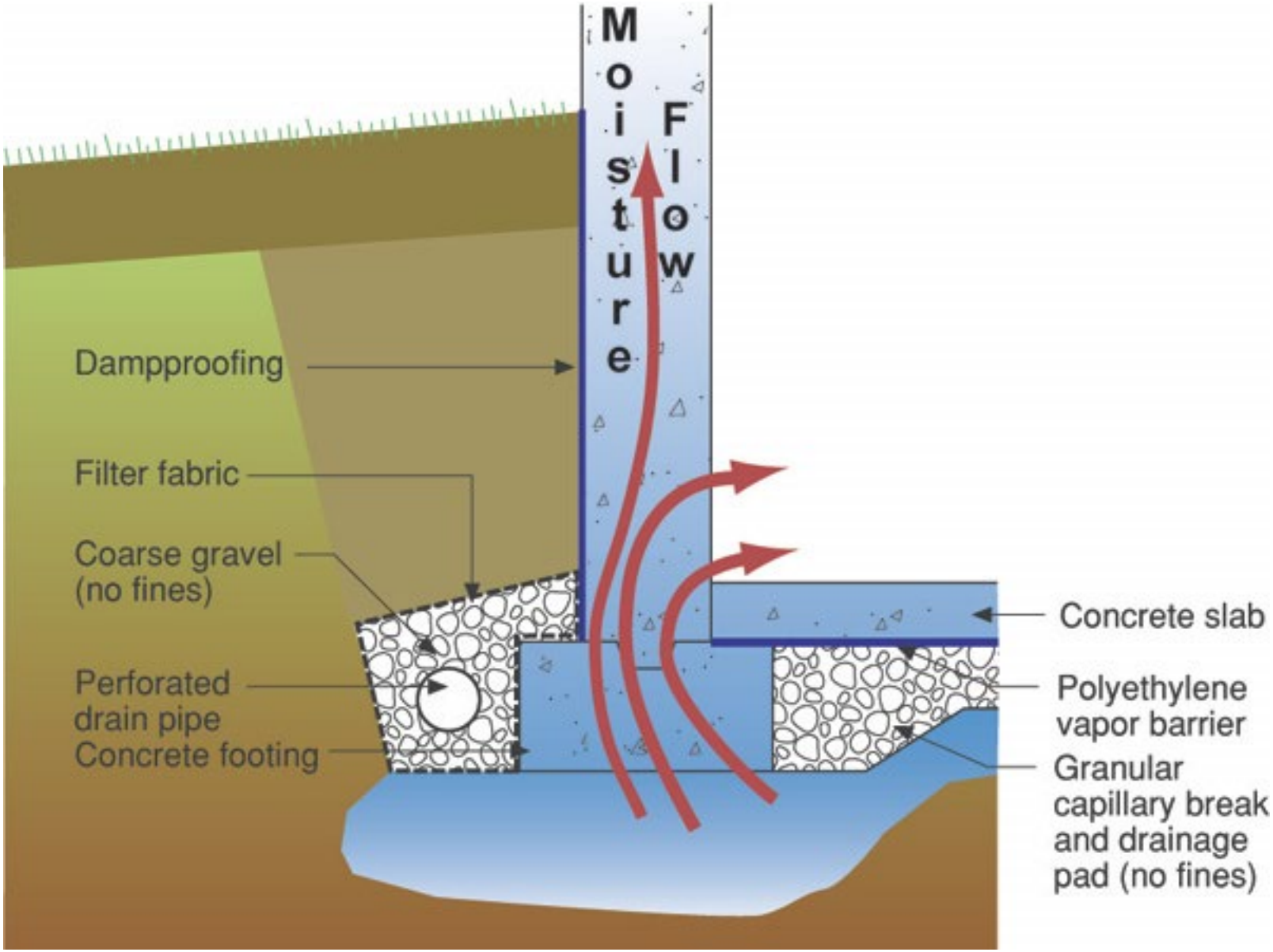


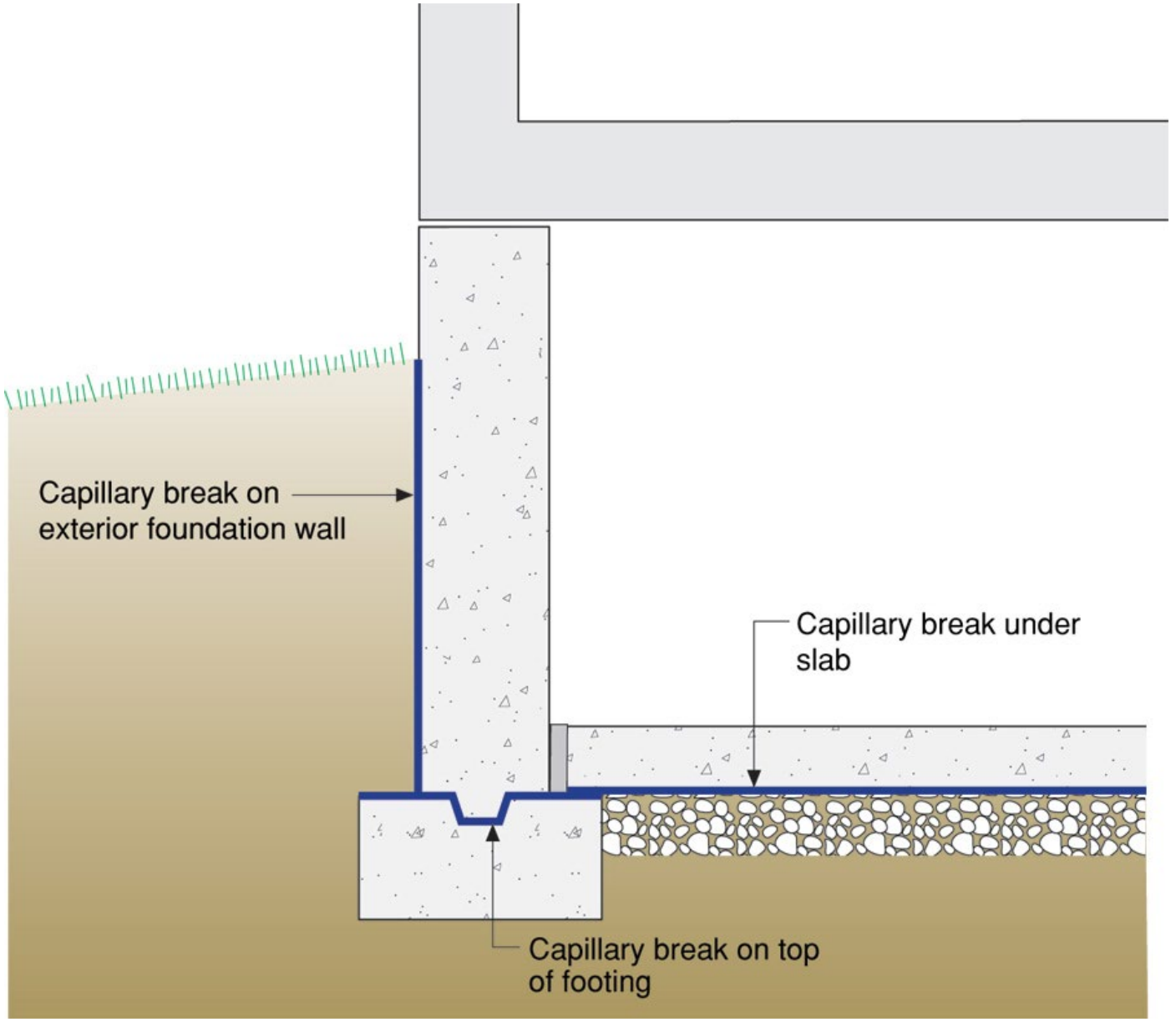
- Keep rain water away from the foundation perimeter
- Do not place sand layer over polyethylene vapor diffusion retarder under concrete slab
- Where vinyl flooring is installed over slabs, a low water-to-cement (w/c) ratio (≅ 0.45 or less is recommended) to reduce water content in the concrete; alternatively, the slab should be allowed to dry (less than 0.3 grams/24 hrs/ft^2) prior to flooring installation



- Keep rain water away from the foundation perimeter
- If the interior crawlspace is lower than the exterior grade, a sub-grade perimeter footing drain is necessary as in a basement foundation
- The crawlspace is conditioned space; it is part of the "interior" of the building and should be heated, cooled and ventilated as part of the building's heating, cooling and ventilating strategy


Rain water falling on roof is collected in gutters
Overhang protects the ground around the foundation from getting saturated
Flash roof into gutter
Down spouts carry rainwater from the roof away from the foundation
Ground slopes away from the foundation
Concrete foundation wall
Impermeable top layer of backfill (clay cap) prevents ground adjacent to foundation from getting saturated
Groundwater flow is downward (not horizontal) under the influence of gravity to the perimeter drainage system
Free-draining backfill (or drainage board)
Filter fabric above and below drain pipe
Capillary break over footing
Coarse gravel (no fines)
Slab isolation joint
Polyethylene vapor diffusion retarder
Perforated drain pipe located below floor slab level (piped to sump or daylight)
Granular drainage pad (coarse gravel, no fines)
Pipe connection through footing connects exterior perimeter drain to granular drainage pad under basement slab
• Keep rain water away from the foundation perimeter
• Drain groundwater away in sub-grade perimeter footing drains before it gets to the foundation wall


Moisture Flow
Dampproofing
Filter fabric
Coarse gravel
(no fines)
Perforated
drain pipe
Concrete footing
Concrete slab
Polyethylene
vapor barrier
Granular
capillary break
and drainage
pad (no fines)


Capillary break on
exterior foundation wall
Capillary break under
slab
Capillary break on top
of footing

Crawl Spaces

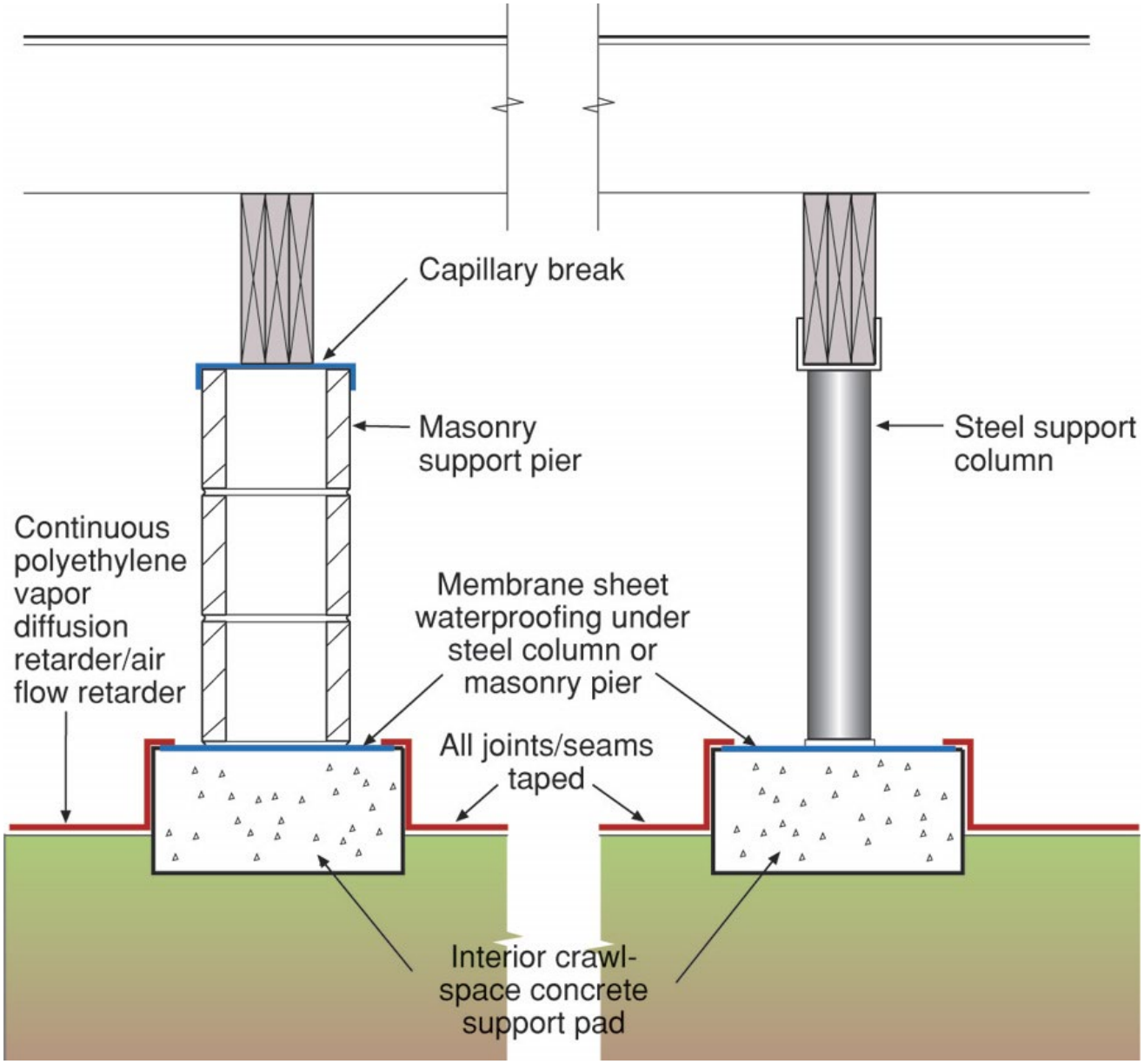
Crawl spaces must be completely connected to either the outside or the inside

Crawl spaces must be completely connected to either the outside or the inside

Vented crawl spaces work

Unvented conditioned crawl spaces work


Styrofoam


Capillary break
Masonry support pier
Steel support column
Continuous polyethylene vapor diffusion retarder/air flow retarder
Membrane sheet waterproofing under steel column or masonry pier
All joints/seams taped
Interior crawl-space concrete support pad

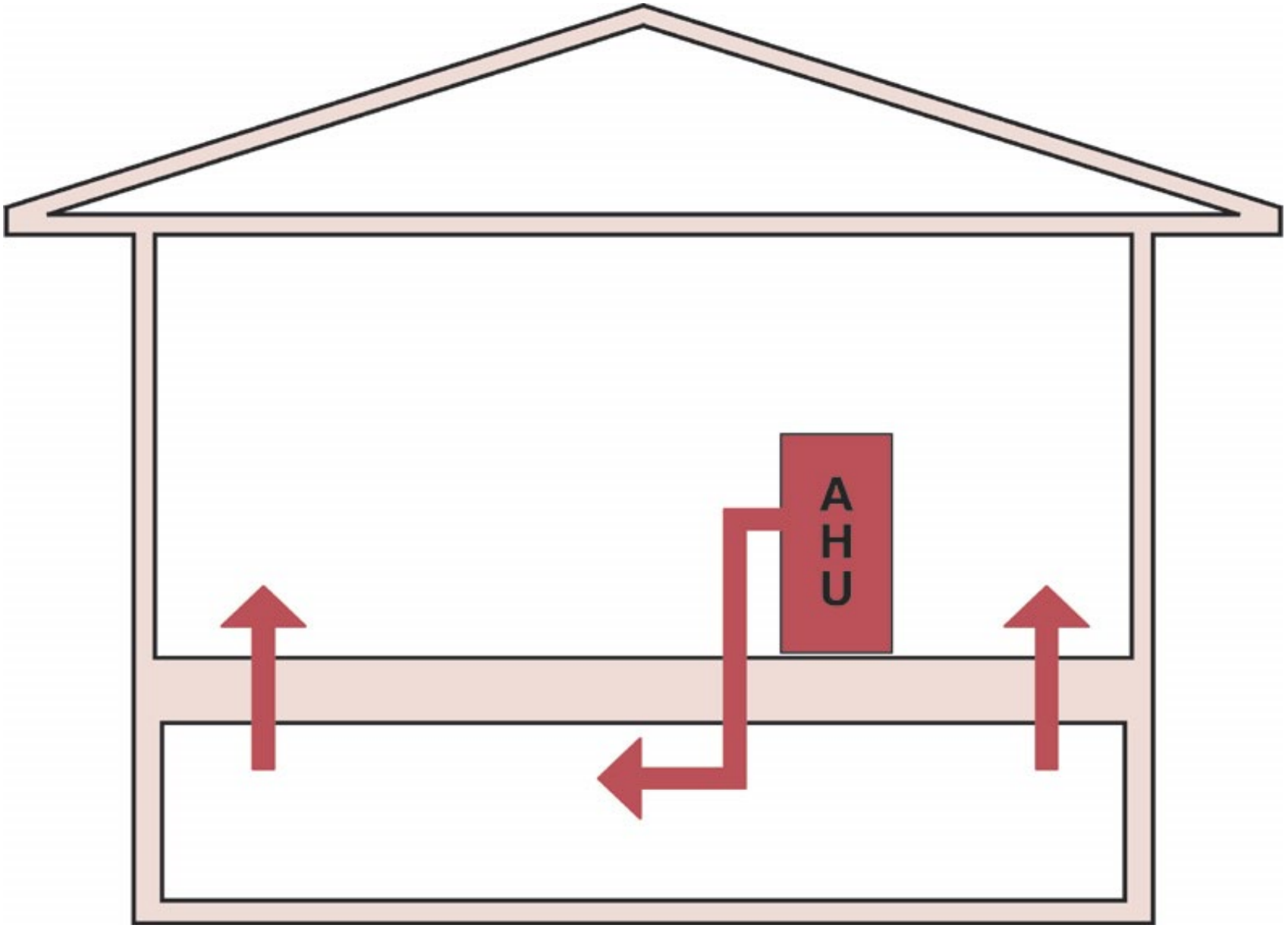
Conditioned Crawlspaces Not Unvented Crawlspaces

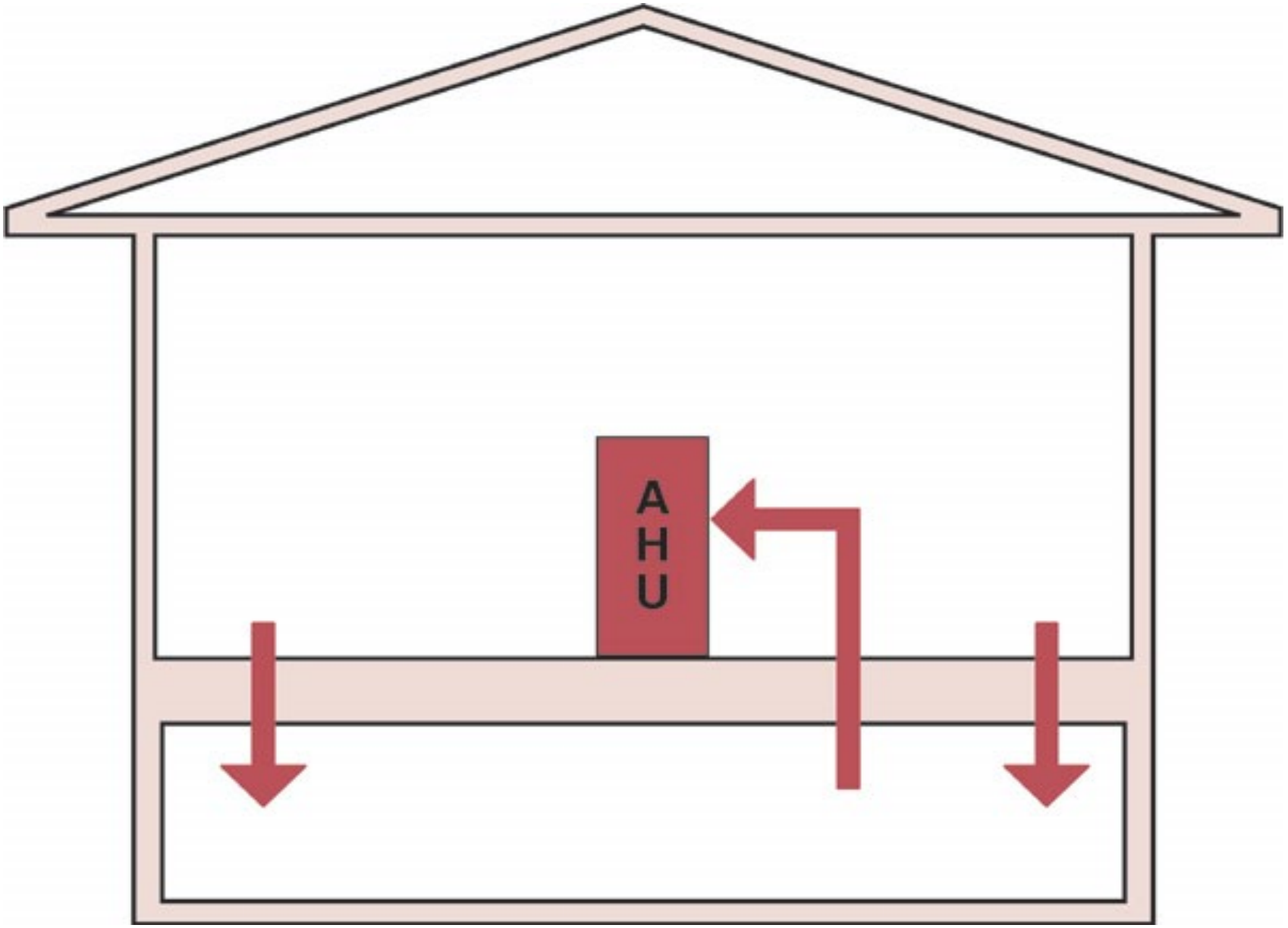
Need Supply Air

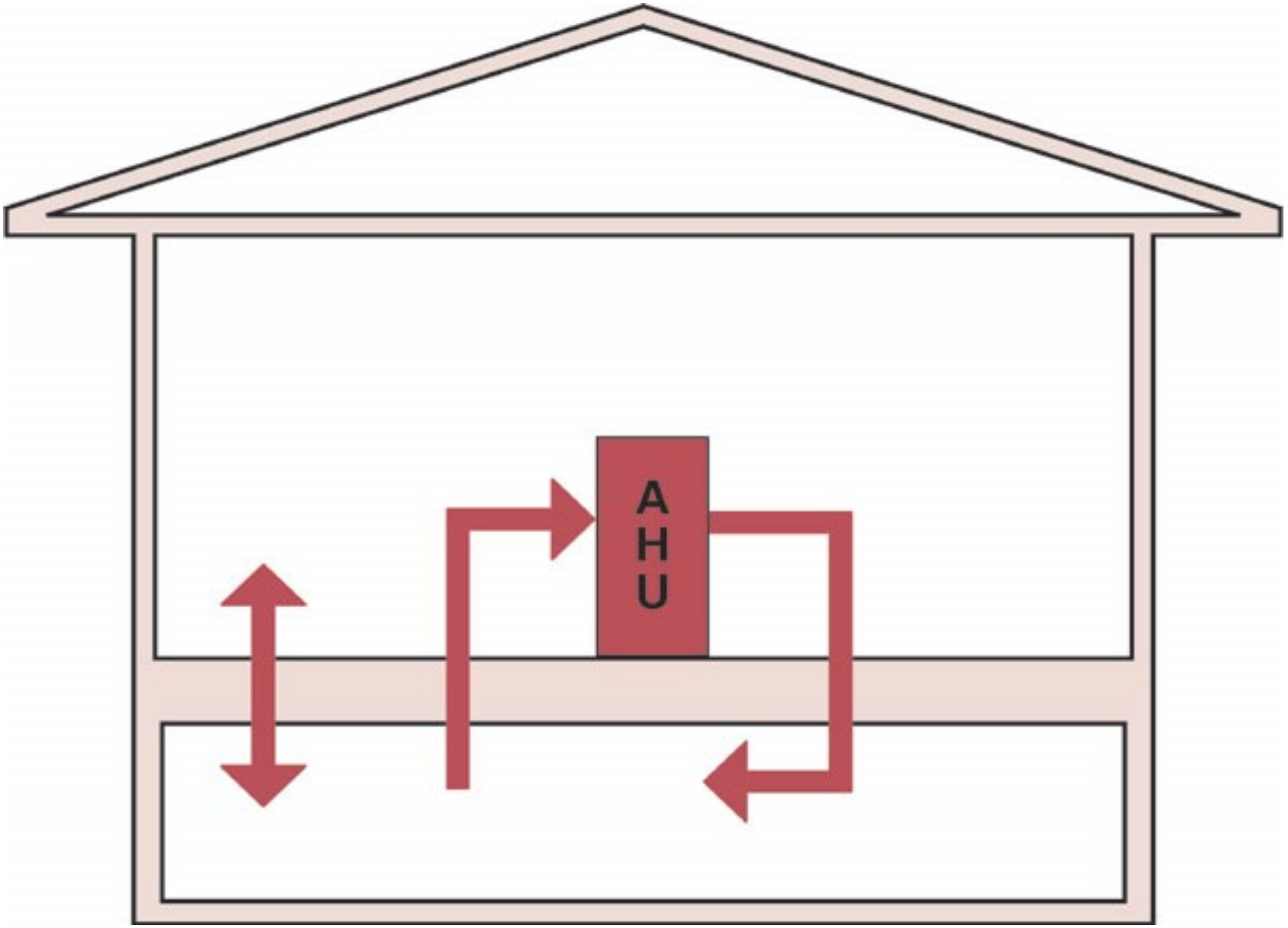
50 cfm/1000 ft2 of Crawlspace Area

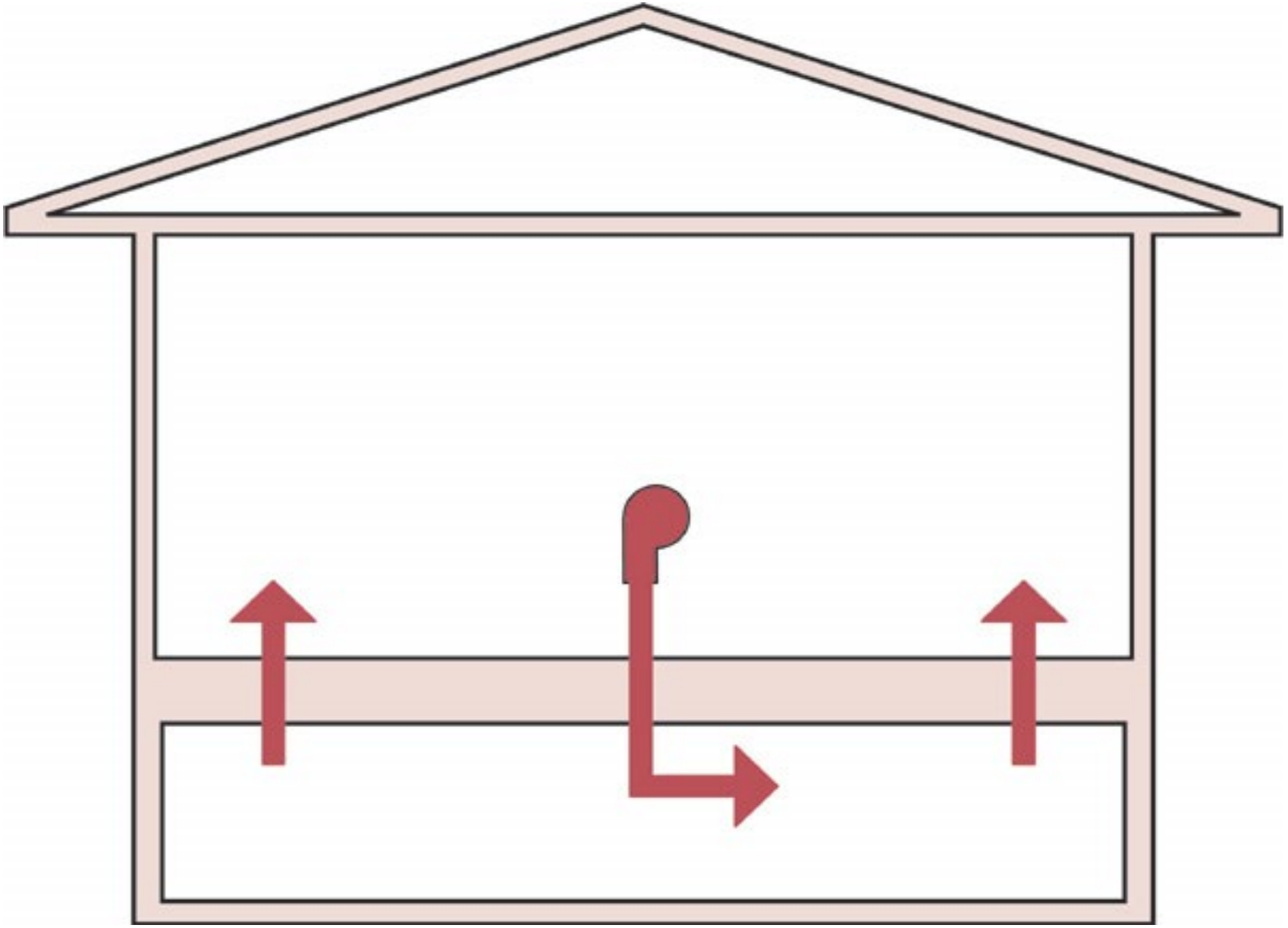
Or

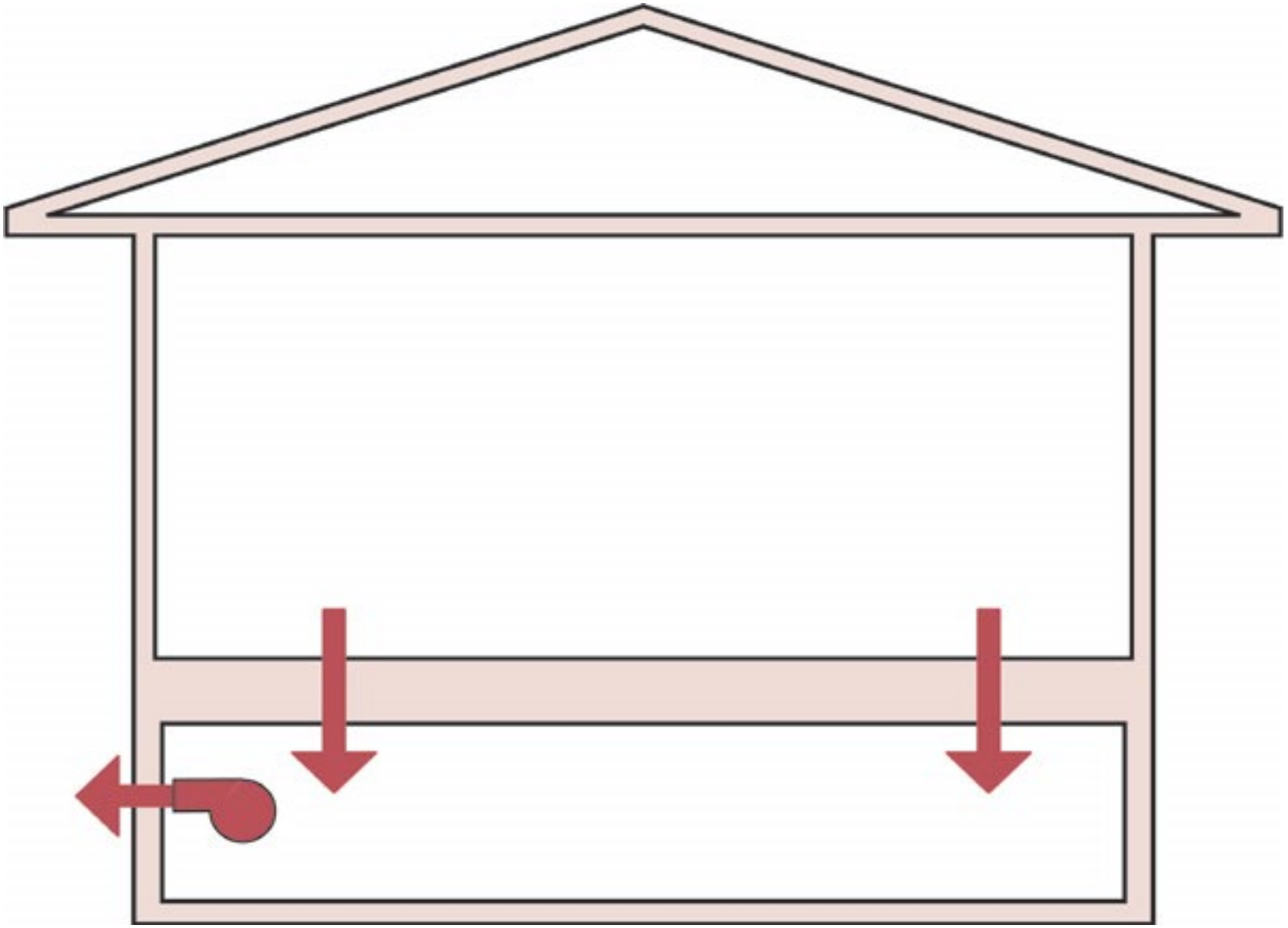
Dehumidification

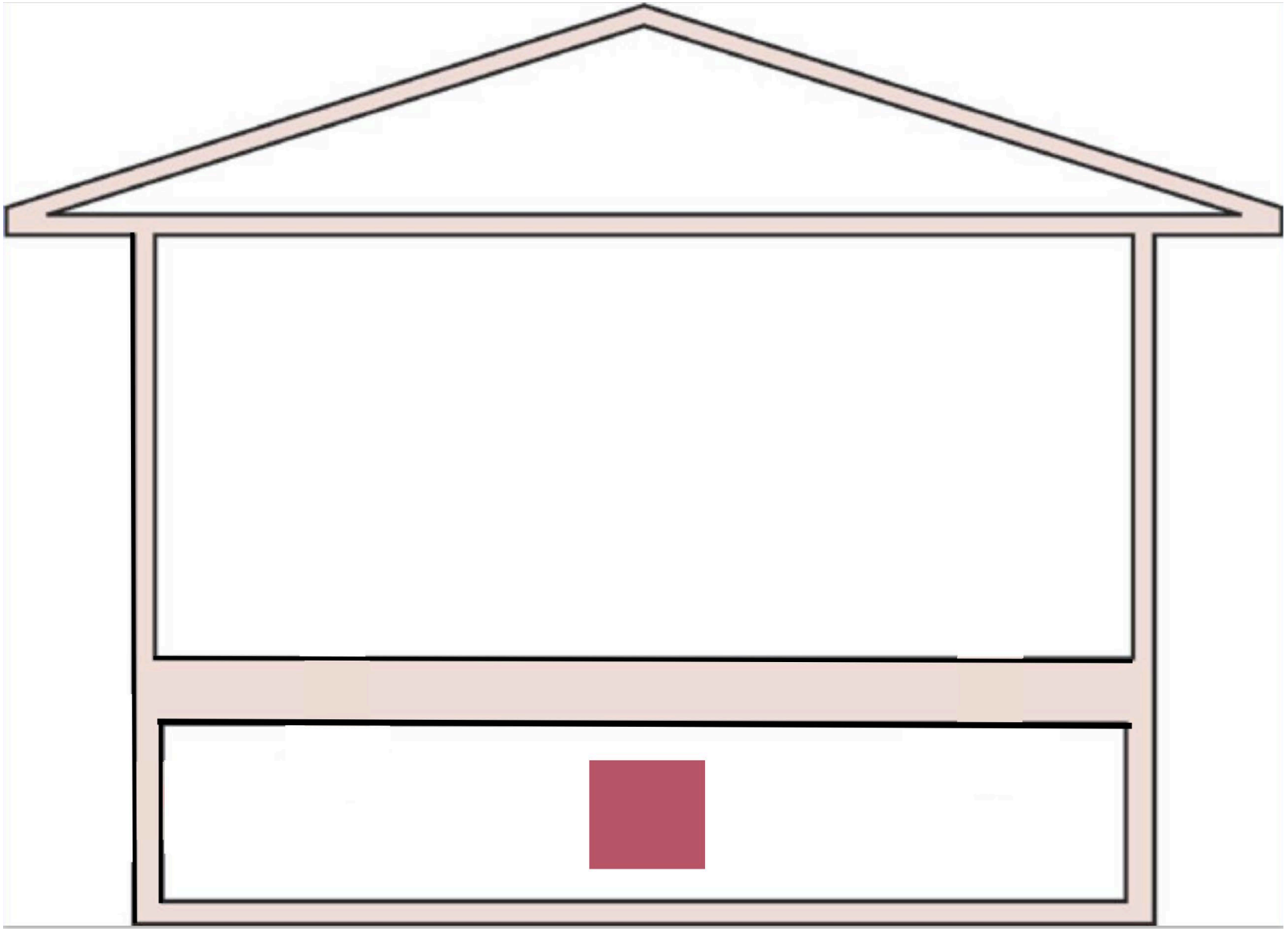

AHU

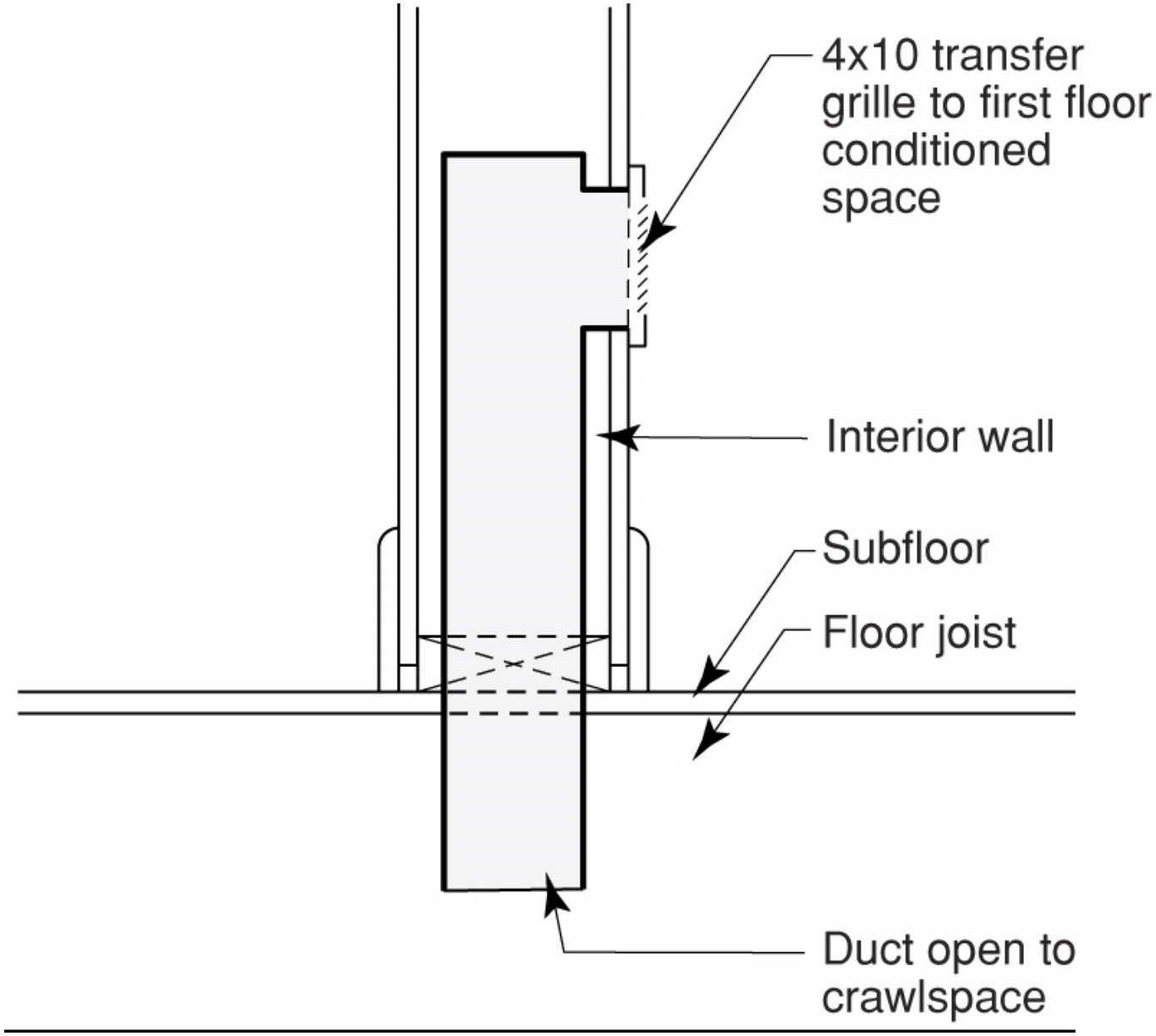

AHU


AHU

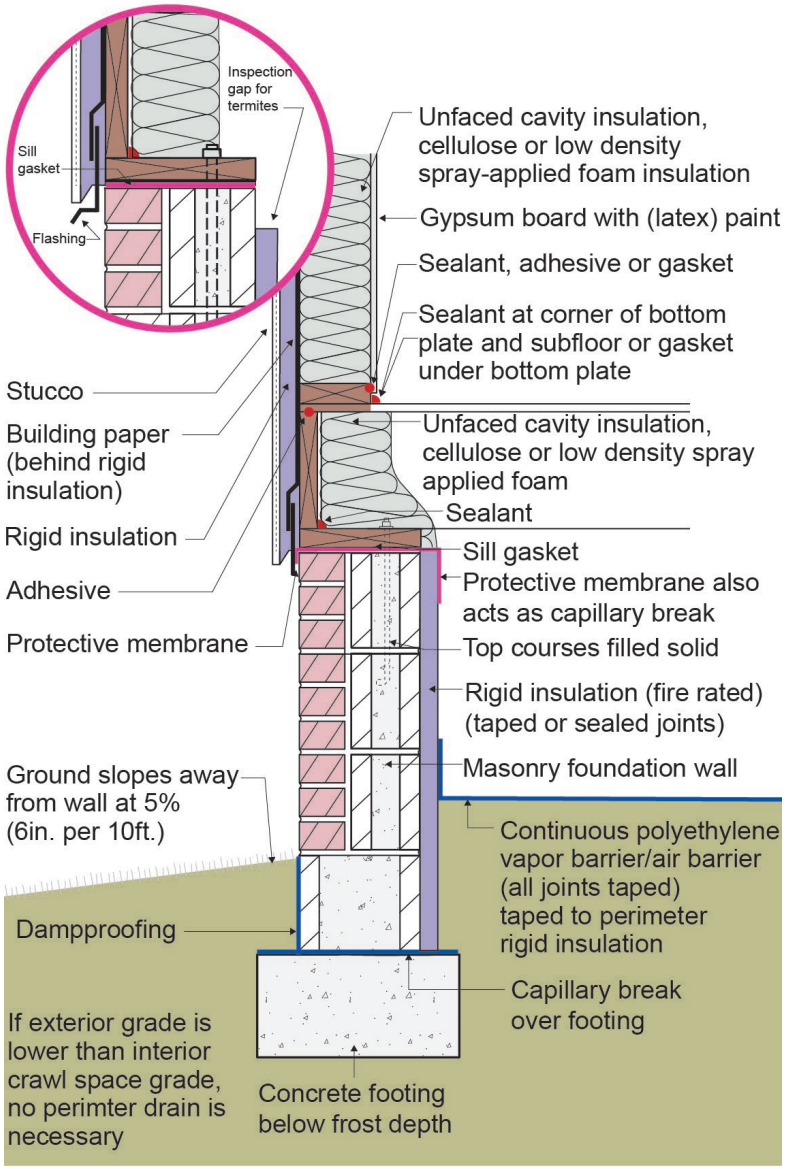




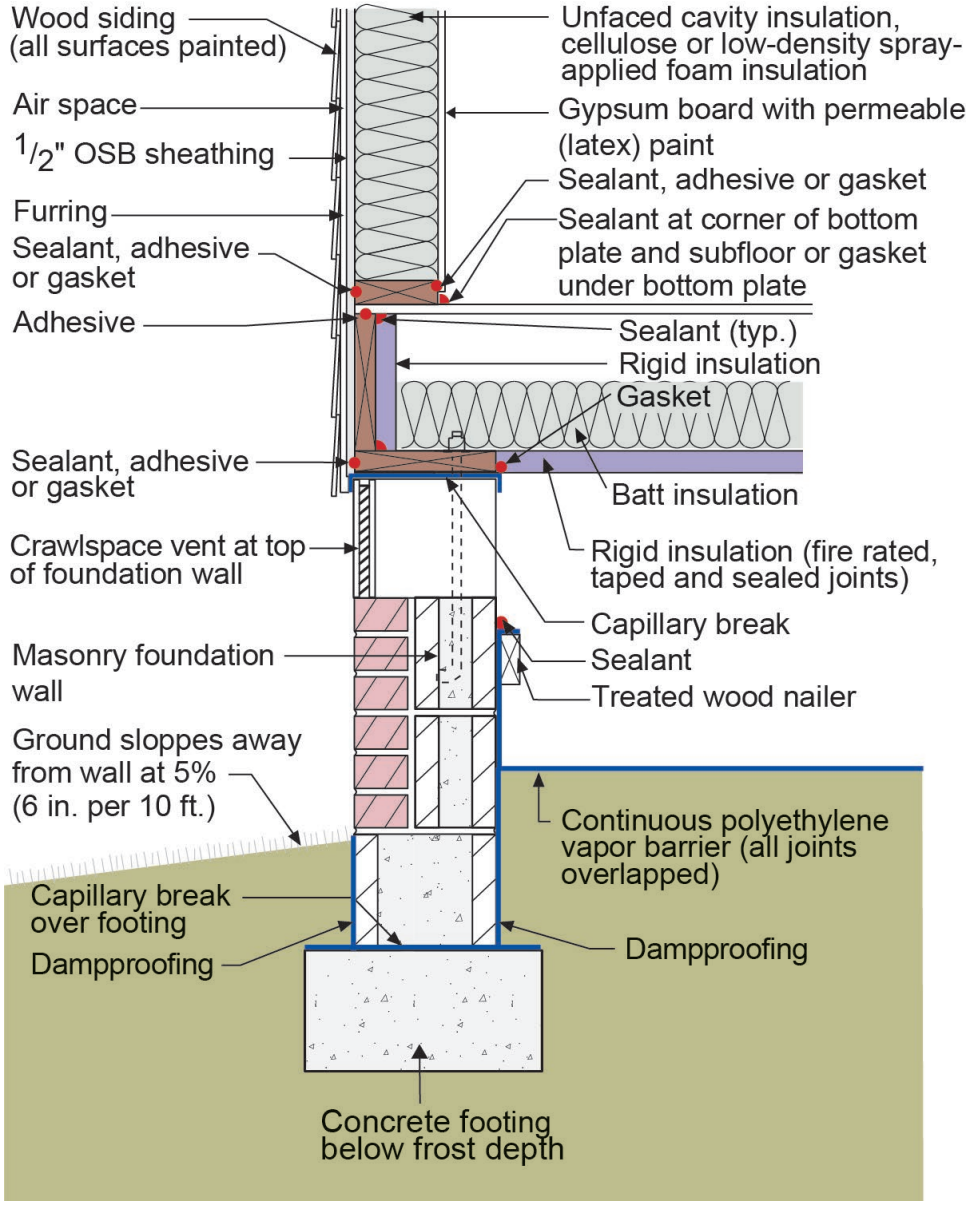


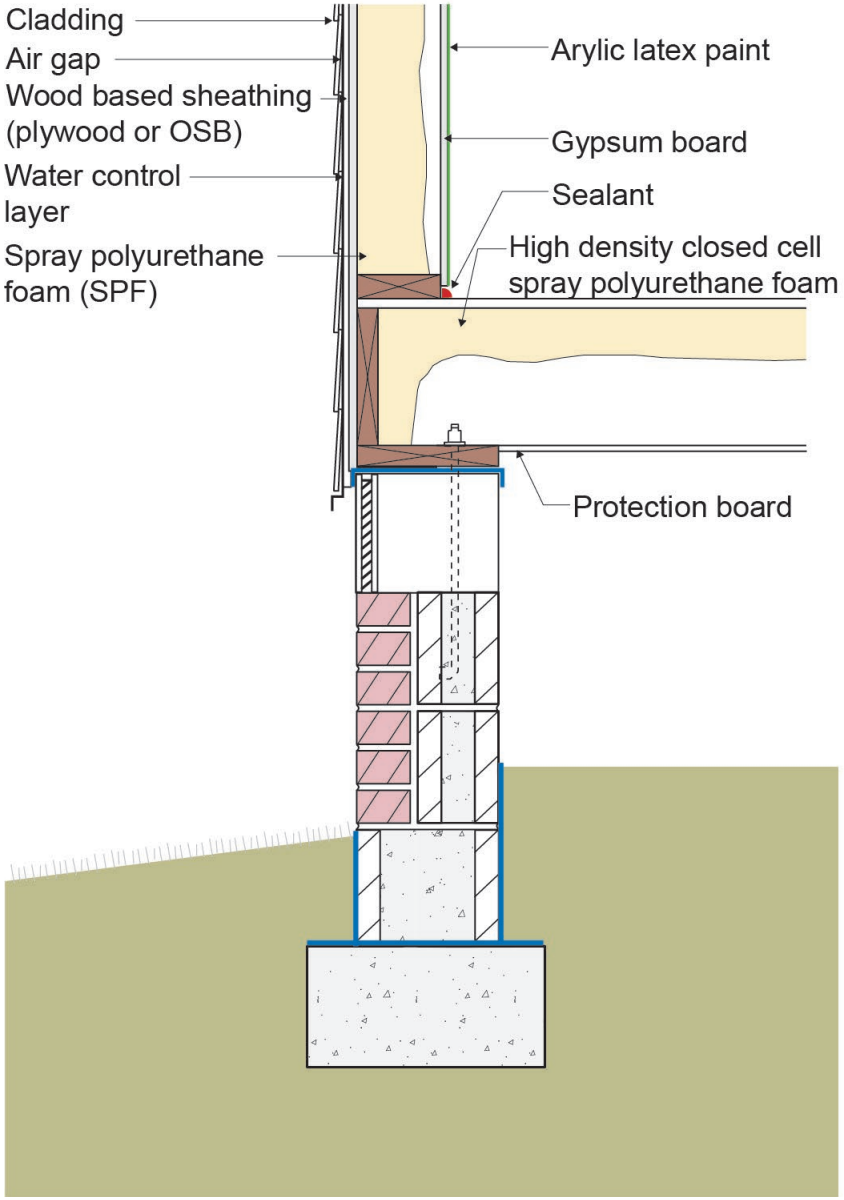

4x10 transfer grille to first floor conditioned space
Interior wall
Subfloor
Floor joist
Duct open to crawlspace

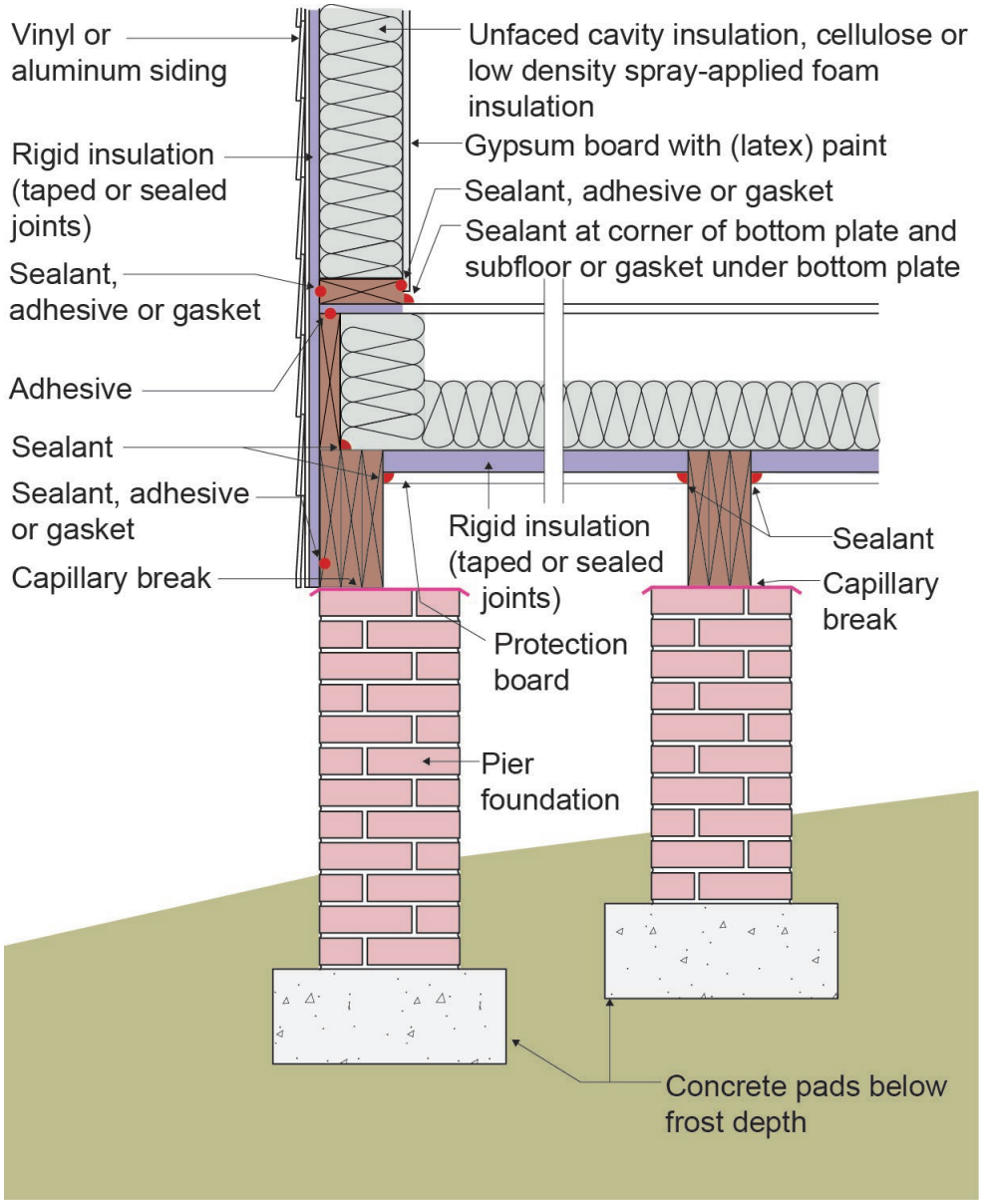
Alternative Detail

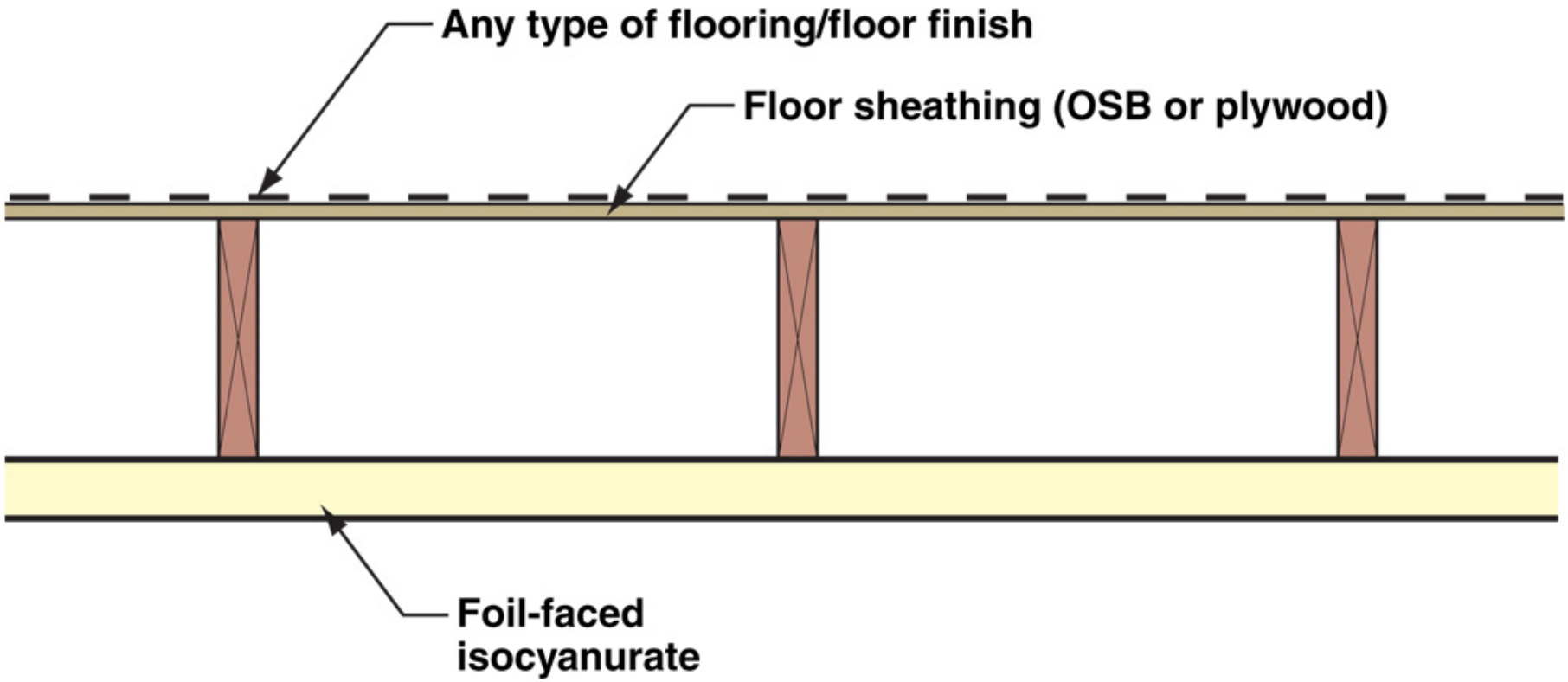


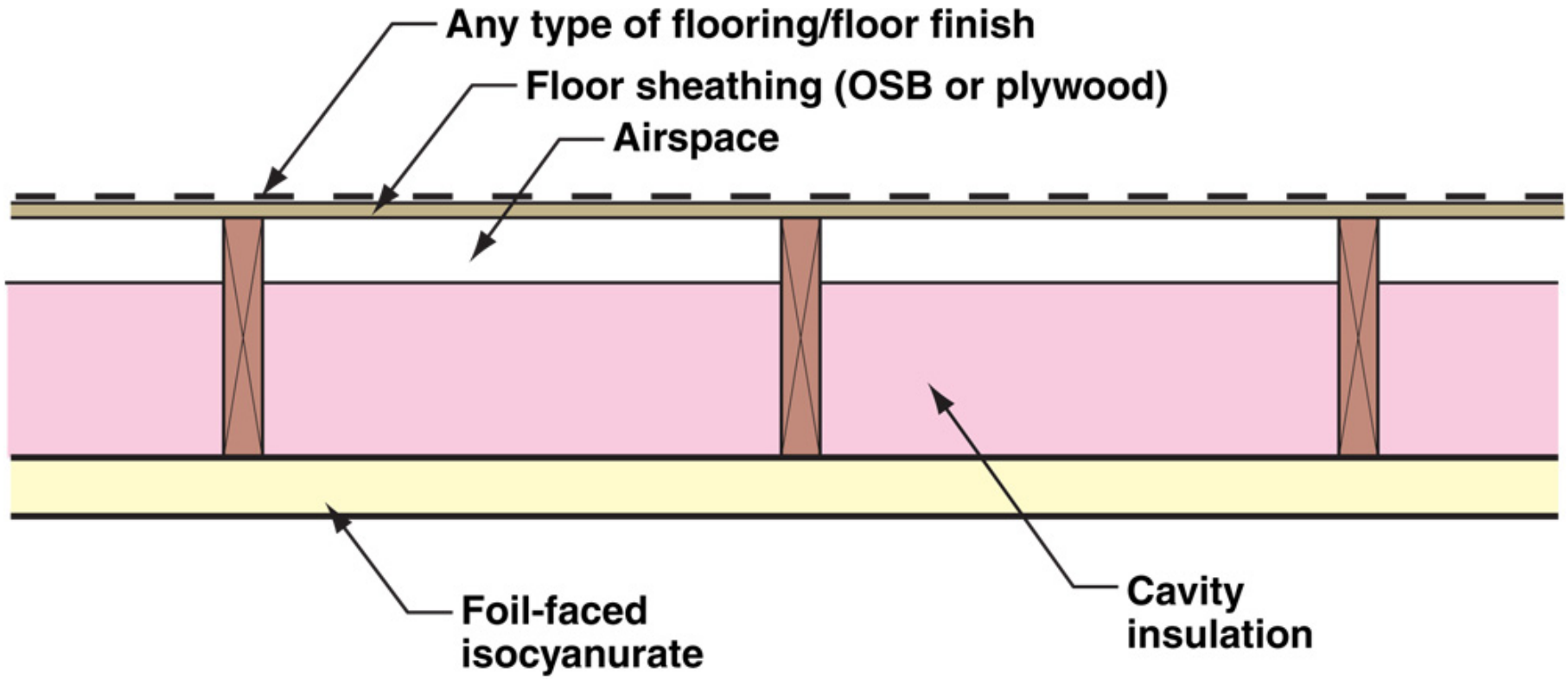
Smart Thing

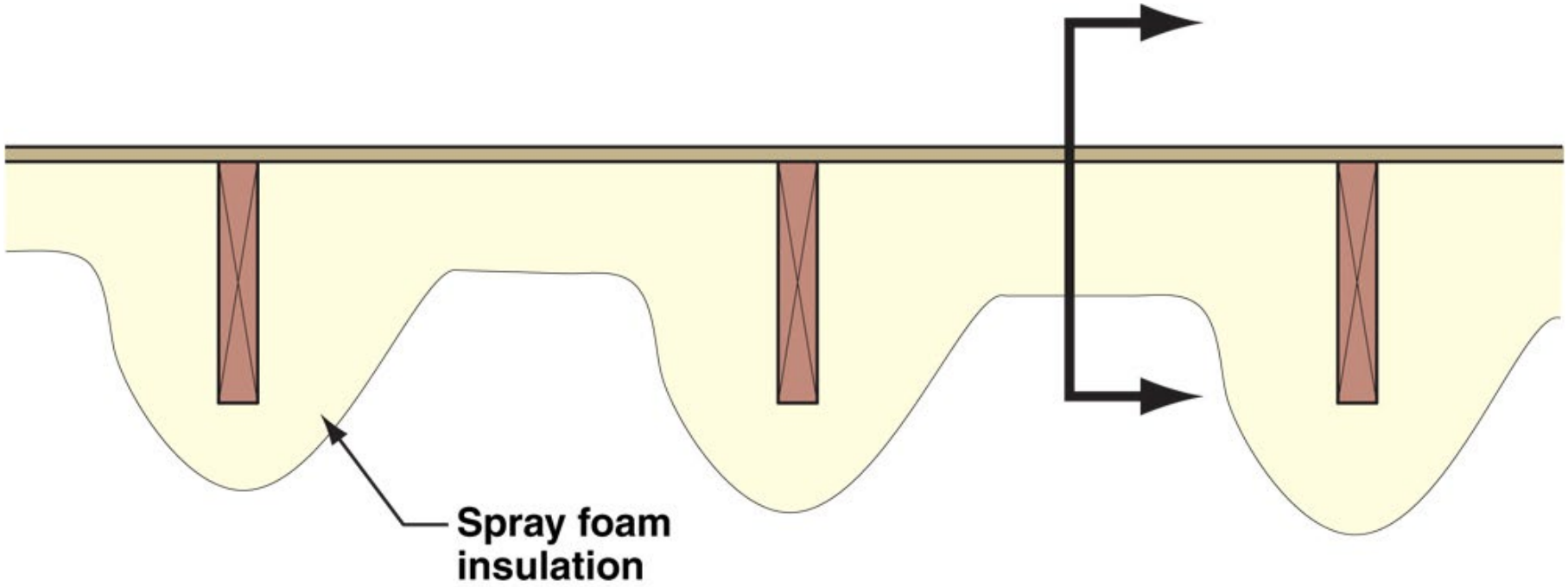

Wood siding
(all surfaces painted)
Air space
1/2" OSB sheathing
Furring
Sealant, adhesive
or gasket
Adhesive
Sealant, adhesive
or gasket
Crawlspace vent at top
of foundation wall
Masonry foundation
wall
Ground sloppes away
from wall at 5%
(6 in. per 10 ft.)
Capillary break
over footing
Dampproofing
Concrete footing
below frost depth
Unfaced cavity insulation,
cellulose or low-density spray-
applied foam insulation
Gypsum board with permeable
(latex) paint
Sealant, adhesive or gasket
Sealant at corner of bottom
plate and subfloor or gasket
under bottom plate
Sealant (typ.)
Rigid insulation
Gasket
Batt insulation
Rigid insulation (fire rated,
taped and sealed joints)
Capillary break
Sealant
Treated wood nailer
Continuous polyethylene
vapor barrier (all joints
overlapped)
Dampproofing

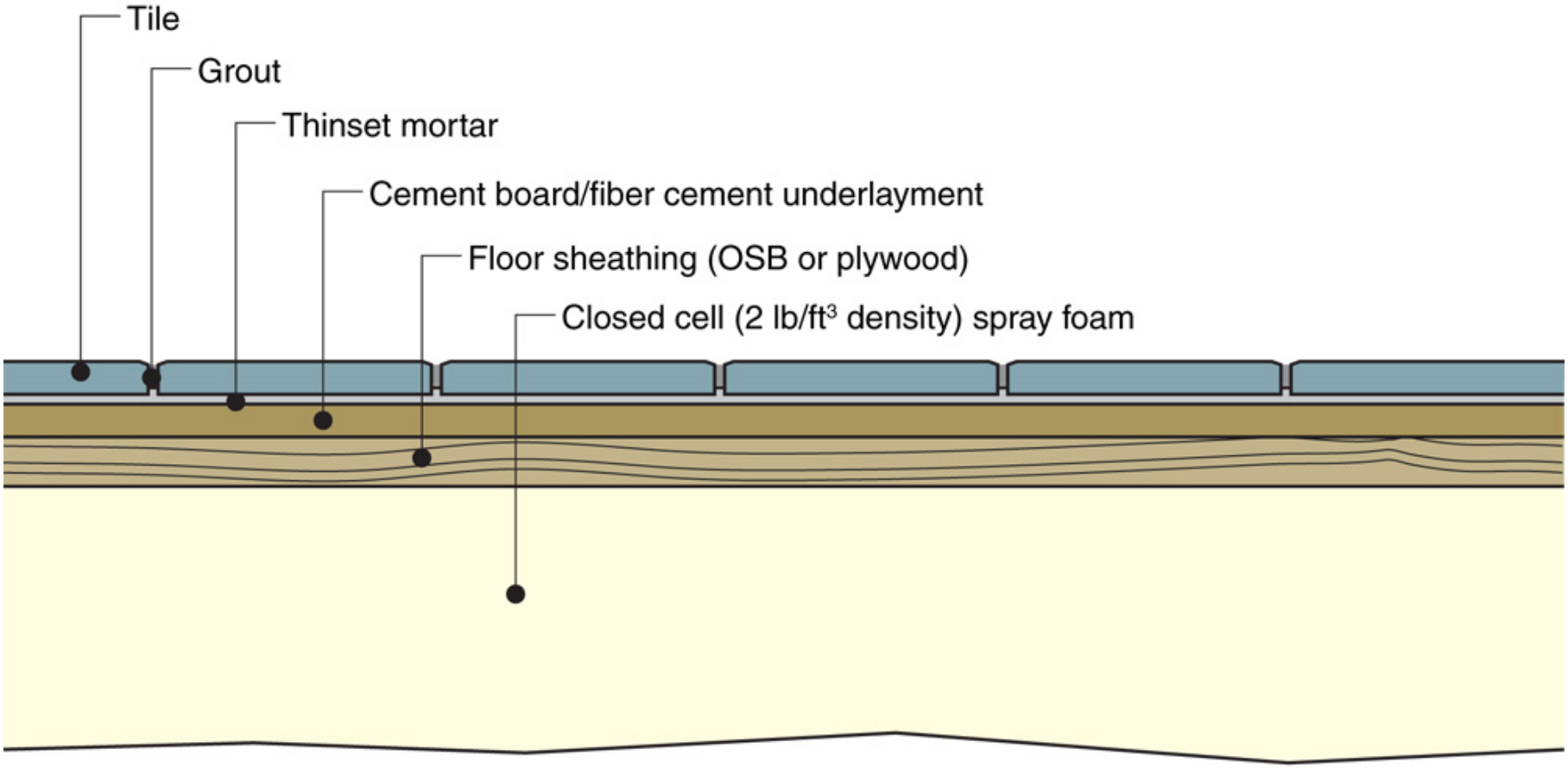

Cladding
Air gap
Wood based sheathing (plywood or OSB)
Water control layer
Spray polyurethane foam (SPF)
Arylic latex paint
Gypsum board
Sealant
High density closed cell spray polyurethane foam
Protection board

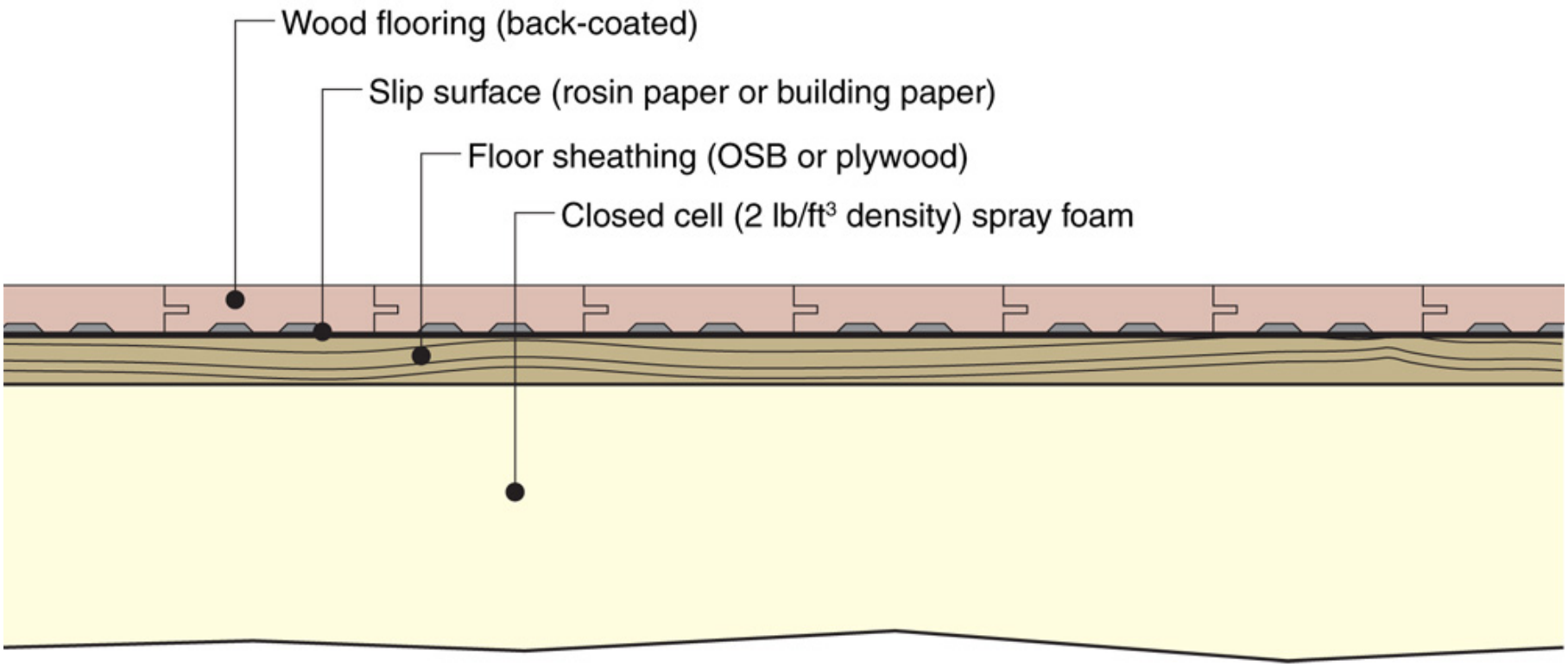

Vinyl or aluminum siding
Rigid insulation (taped or sealed joints)
Sealant, adhesive or gasket
Adhesive
Sealant
Sealant, adhesive or gasket
Capillary break
Unfaced cavity insulation, cellulose or low density spray-applied foam insulation
Gypsum board with (latex) paint
Sealant, adhesive or gasket
Sealant at corner of bottom plate and subfloor or gasket under bottom plate
Rigid insulation (taped or sealed joints)
Protection board
Pier foundation
Sealant
Capillary break
Concrete pads below frost depth

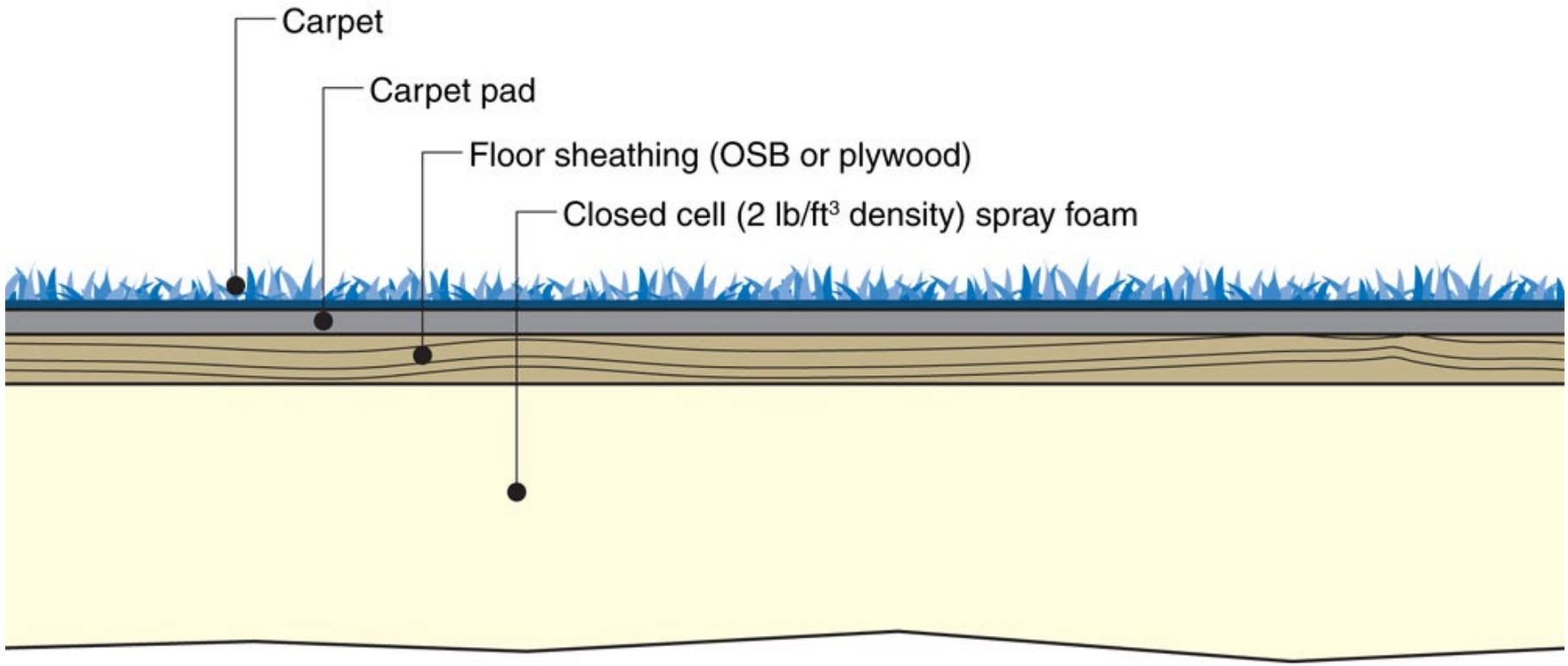

Any type of flooring/floor finish
Floor sheathing (OSB or plywood)
Foil-faced
isocyanurate

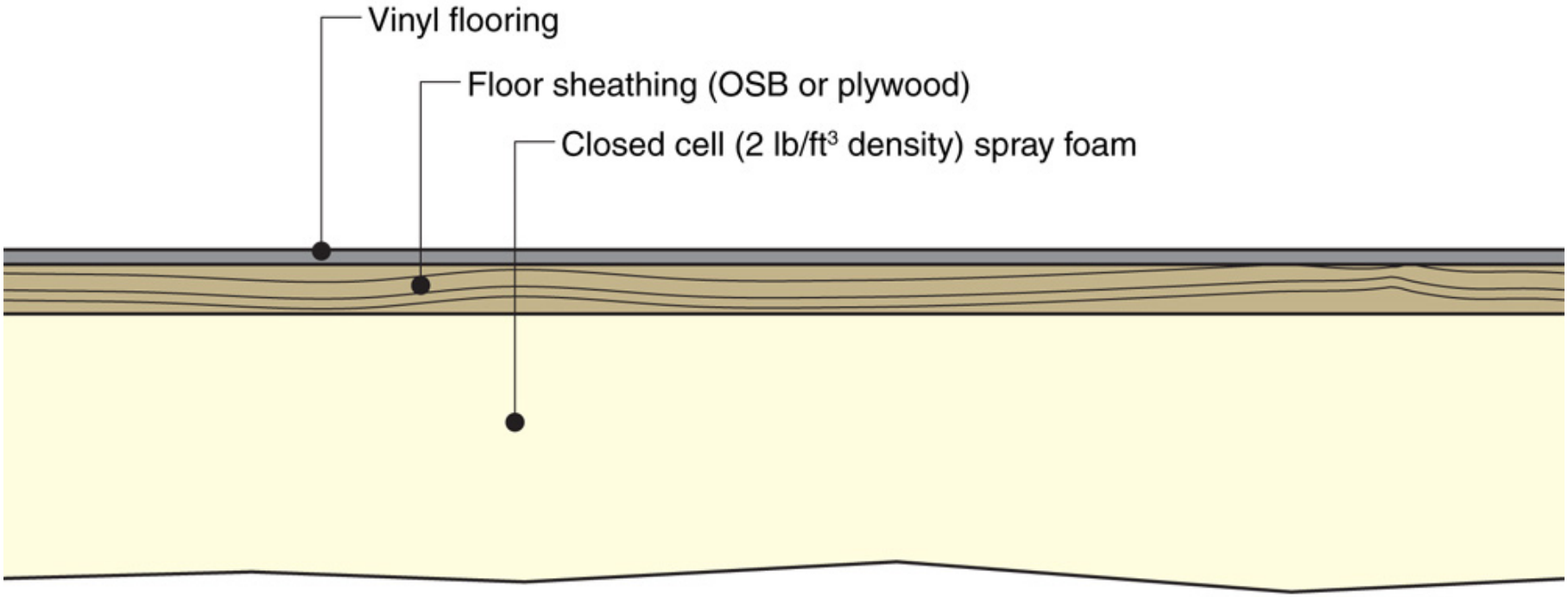

Any type of flooring/floor finish
Floor sheathing (OSB or plywood)
Airspace
Foil-faced isocyanurate
Cavity insulation

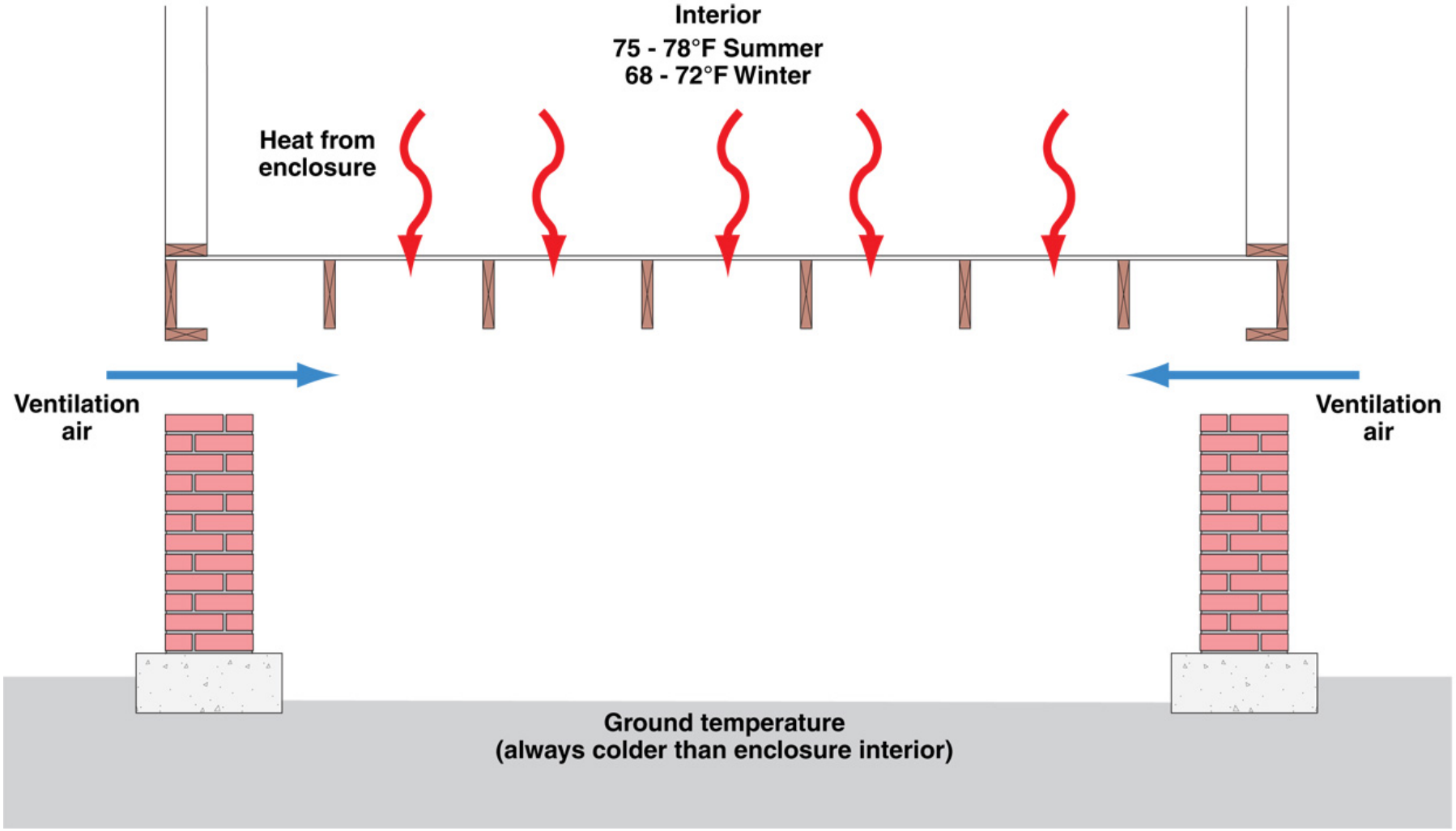

Spray foam
insulation

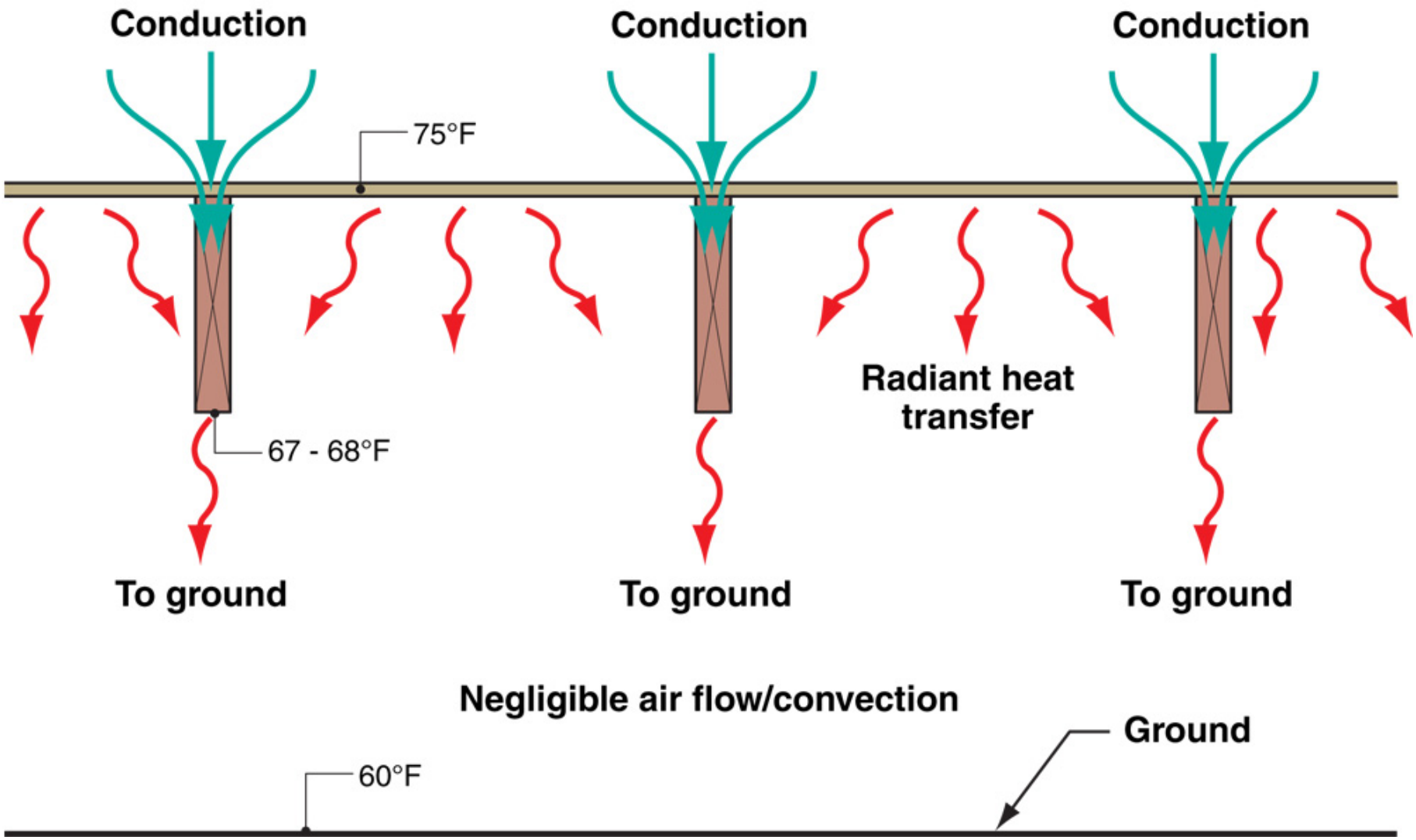

Tile
Grout
Thinset mortar
Cement board/fiber cement underlayment
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft³ density) spray foam

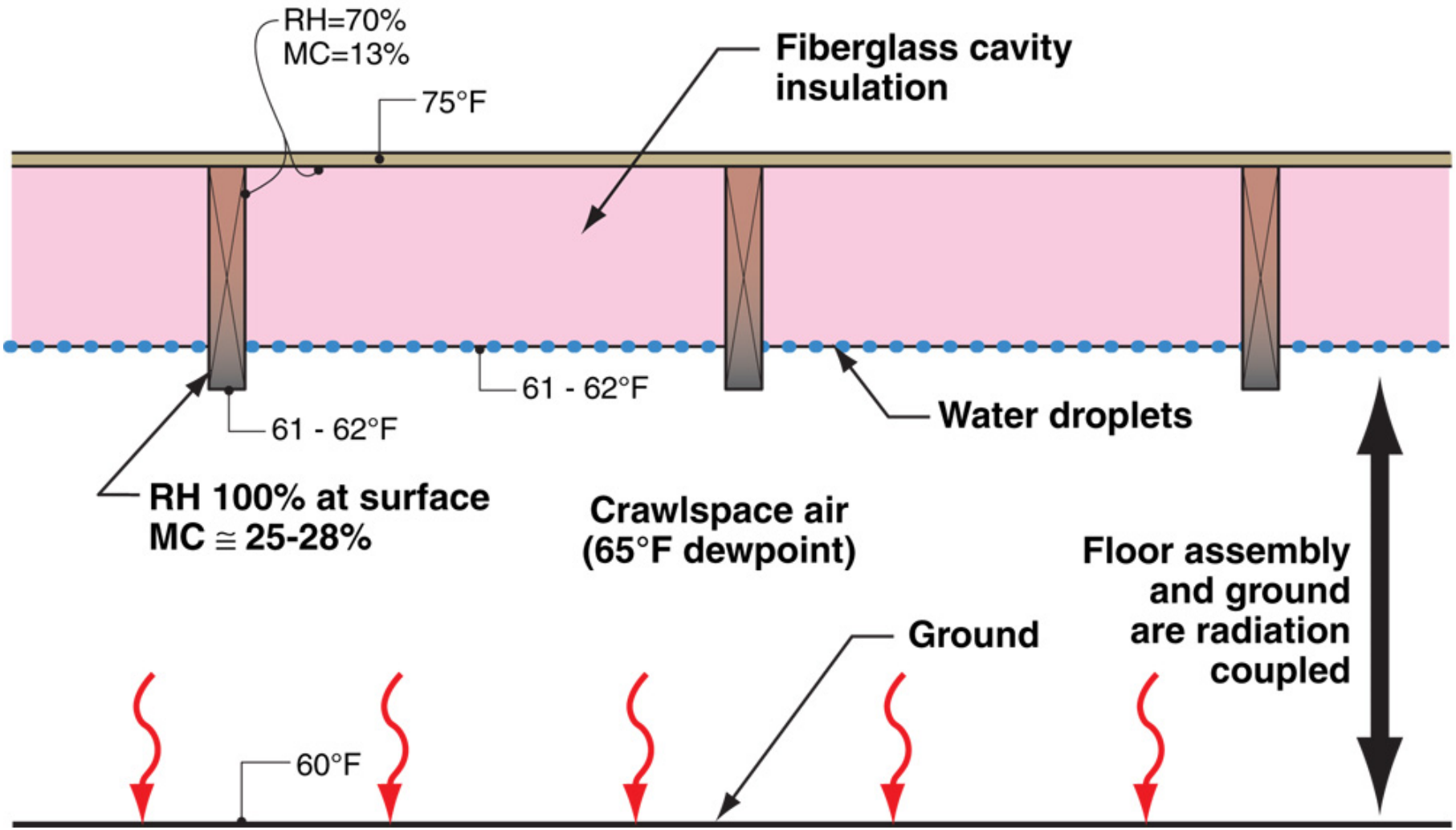

Wood flooring (back-coated)
Slip surface (rosin paper or building paper)
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft3 density) spray foam

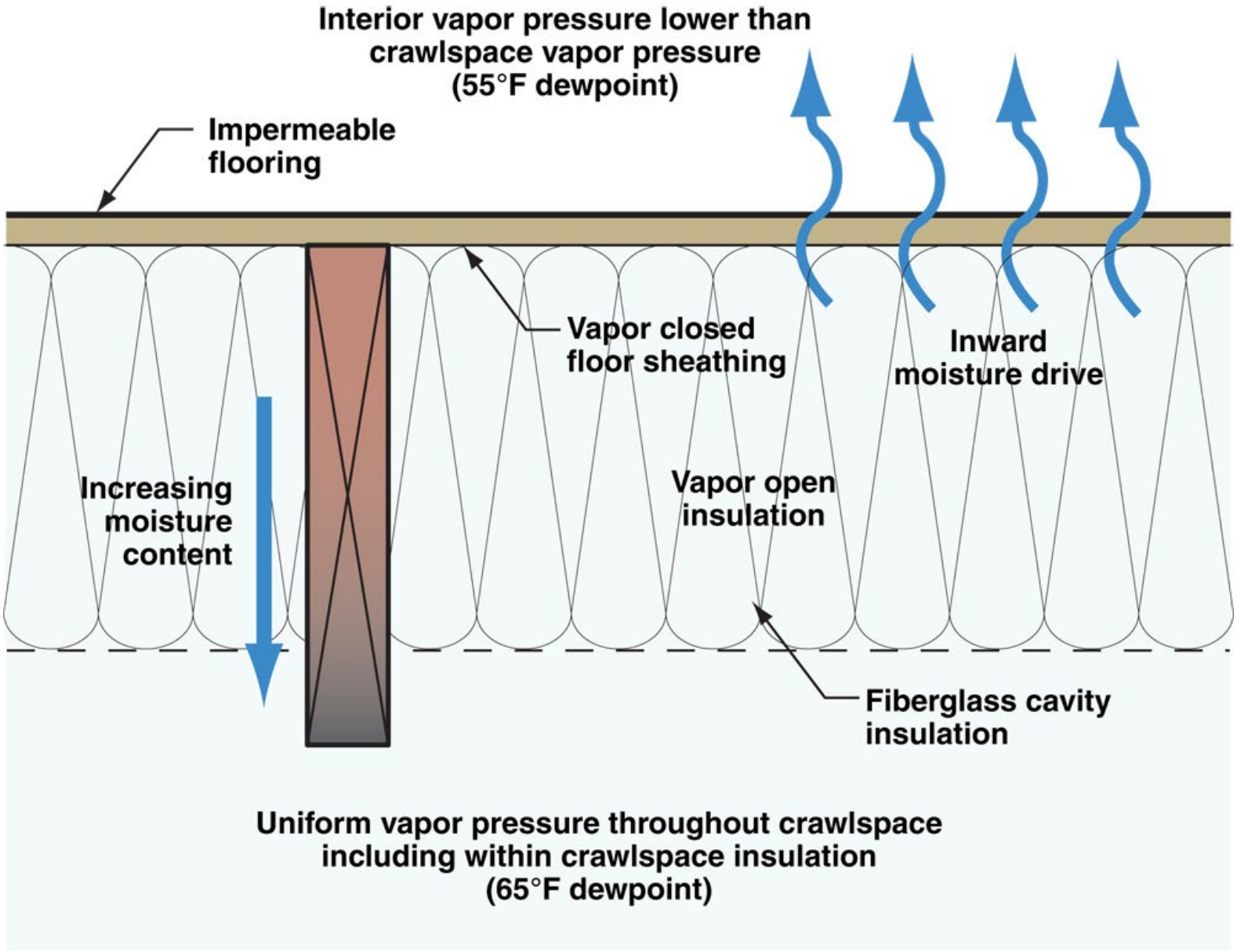

Carpet
Carpet pad
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft³ density) spray foam

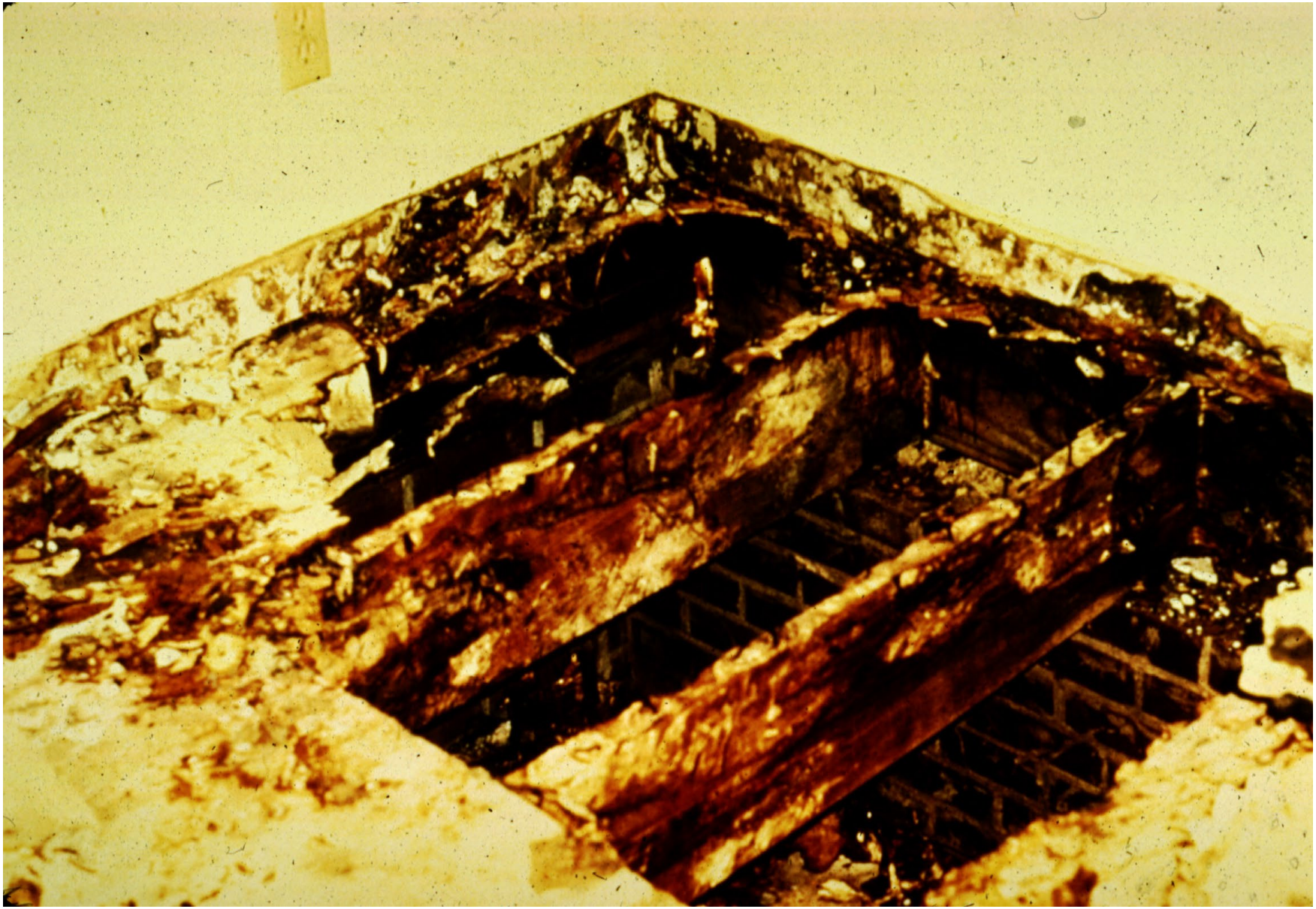

Vinyl flooring
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft³ density) spray foam


Interior
75 - 78°F Summer
68 - 72°F Winter
Heat from enclosure
Ventilation air
Ventilation air
Ground temperature
(always colder than enclosure interior)

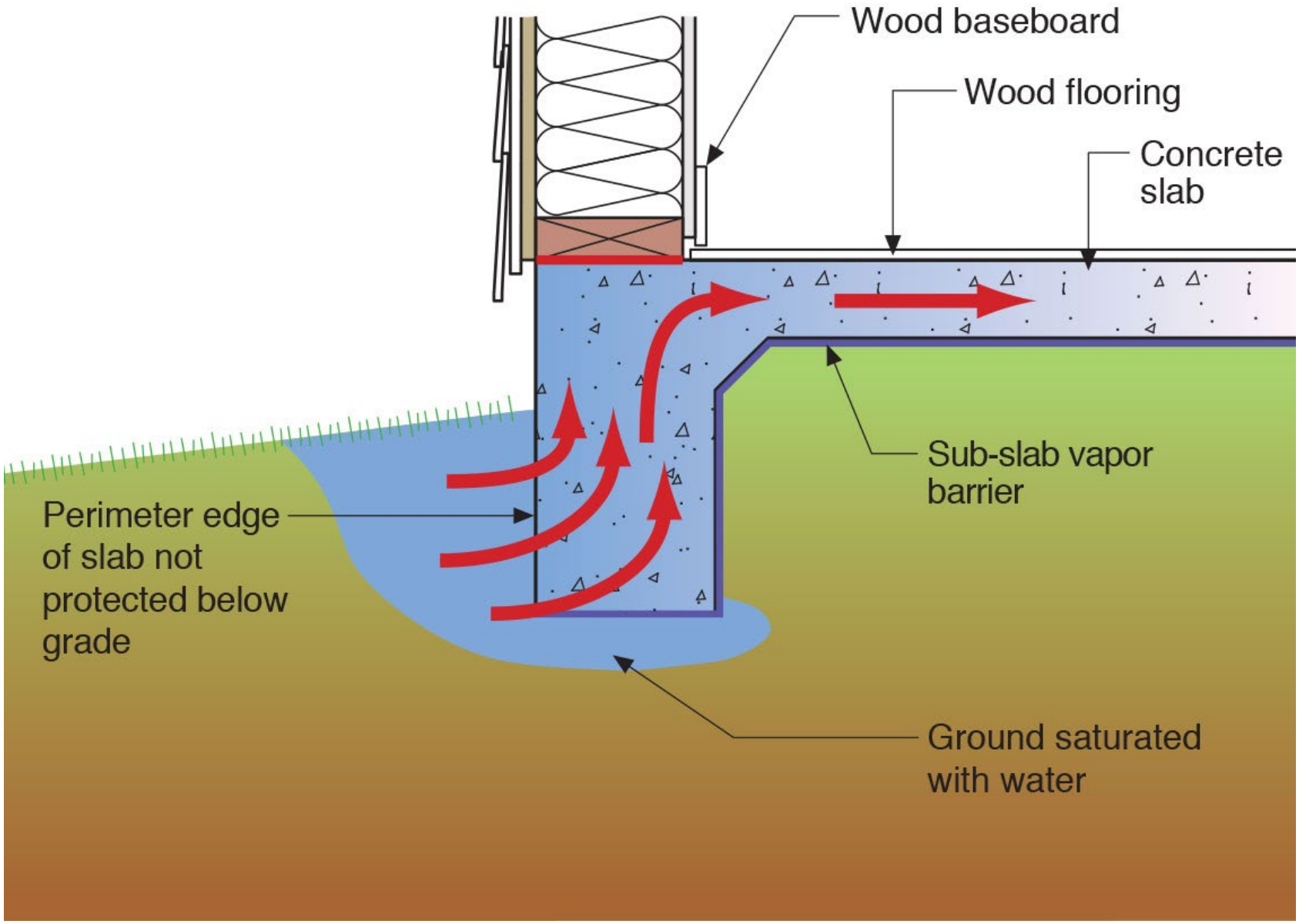

Conduction
Conduction
Conduction
75°F
67 - 68°F
Radiant heat transfer
To ground
To ground
To ground
Negligible air flow/convection
Ground
60°F


RH=70%
MC=13%
75°F
Fiberglass cavity insulation
61 - 62°F
61 - 62°F
Water droplets
RH 100% at surface
MC ≅ 25-28%
Crawlspace air
(65°F dewpoint)
Floor assembly and ground are radiation coupled
Ground
60°F


Interior vapor pressure lower than
crawlspace vapor pressure
(55°F dewpoint)
Impermeable
flooring
Vapor closed
floor sheathing
Inward
moisture drive
Increasing
moisture
content
Vapor open
insulation
Fiberglass cavity
insulation
Uniform vapor pressure throughout crawlspace
including within crawlspace insulation
(65°F dewpoint)

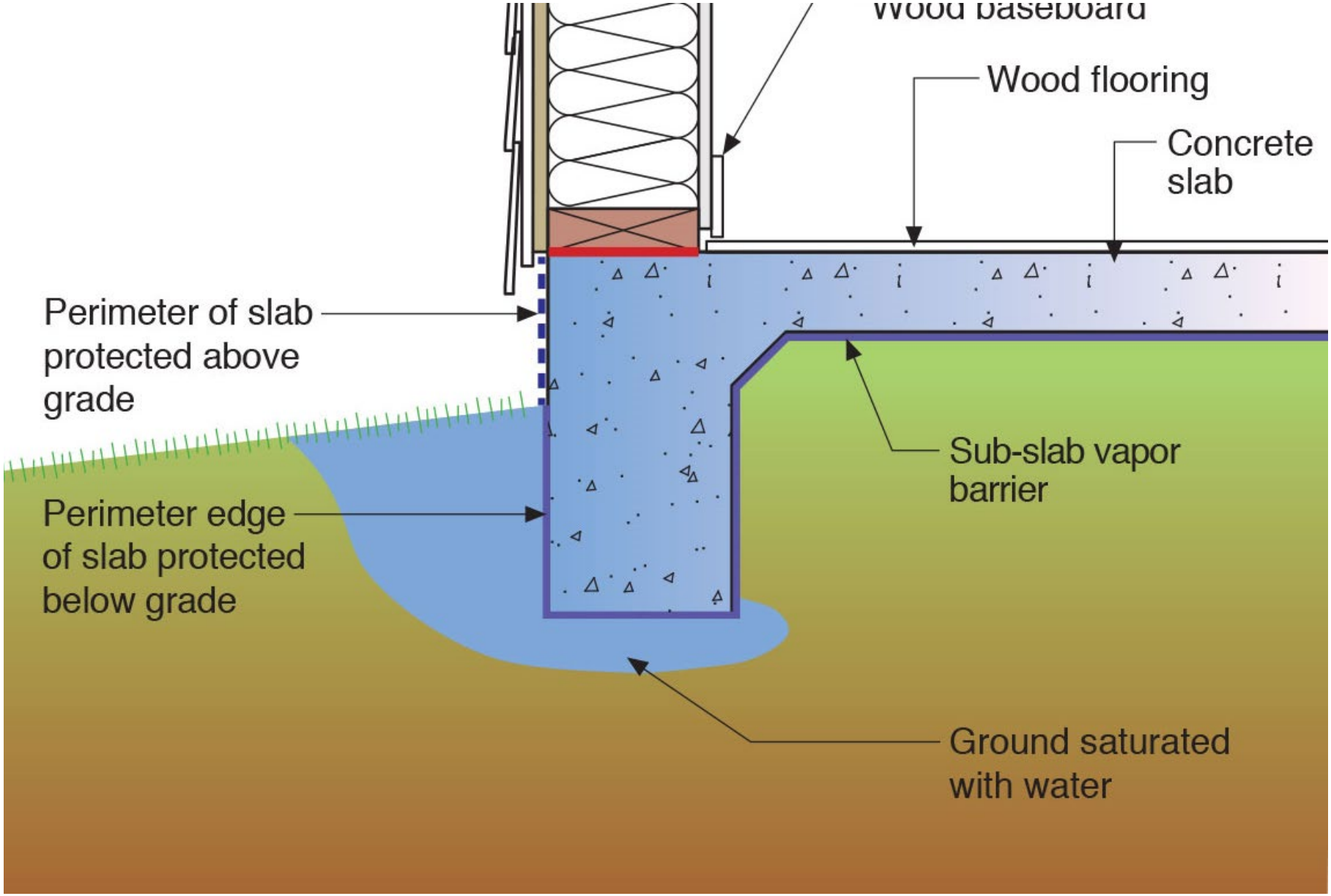


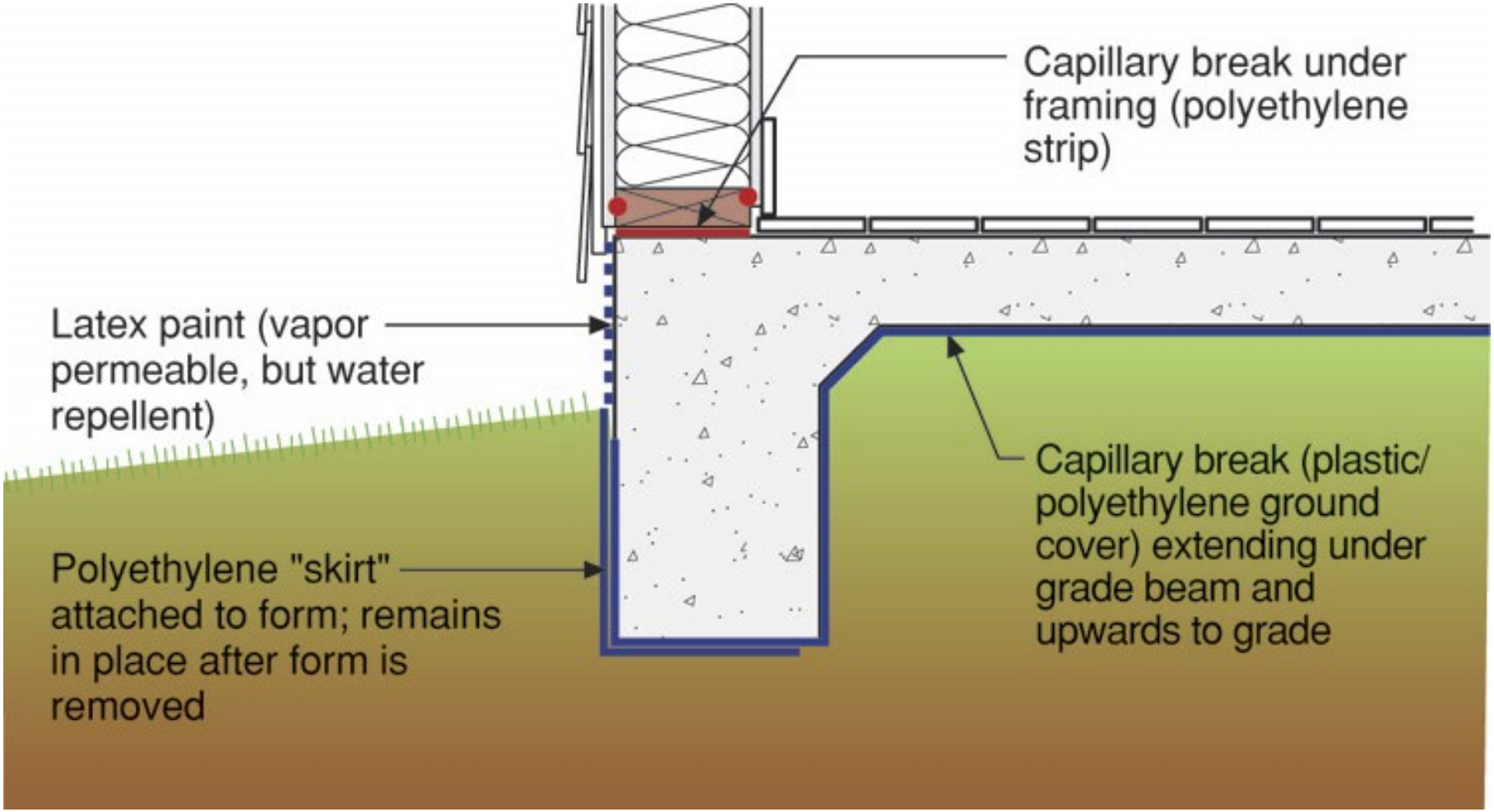
Slabs


Wood baseboard
Wood flooring
Concrete slab
Sub-slab vapor barrier
Perimeter edge of slab not protected below grade
Ground saturated with water


25
U-HAU
MOVE YOURSELF AND

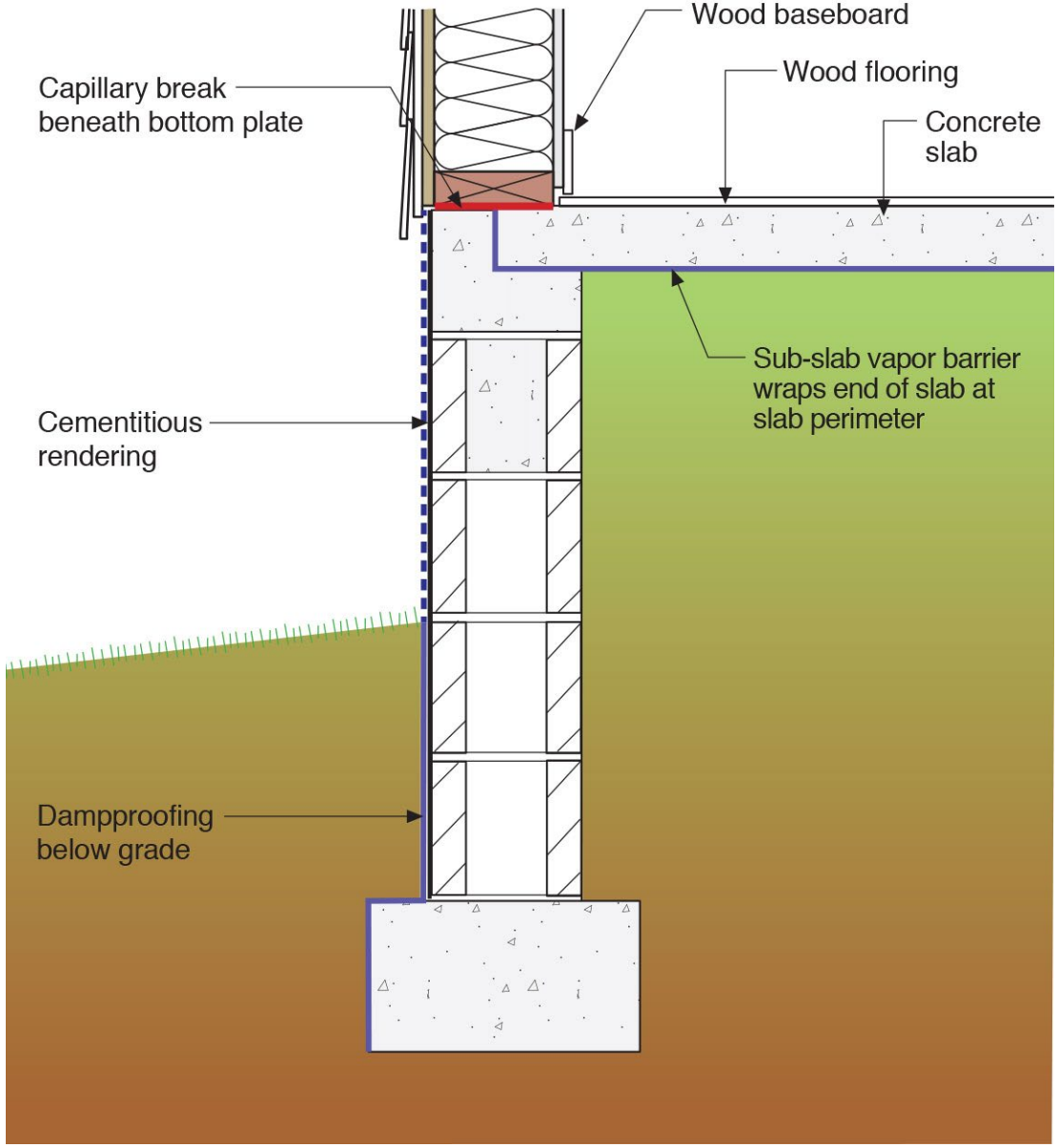

FORD

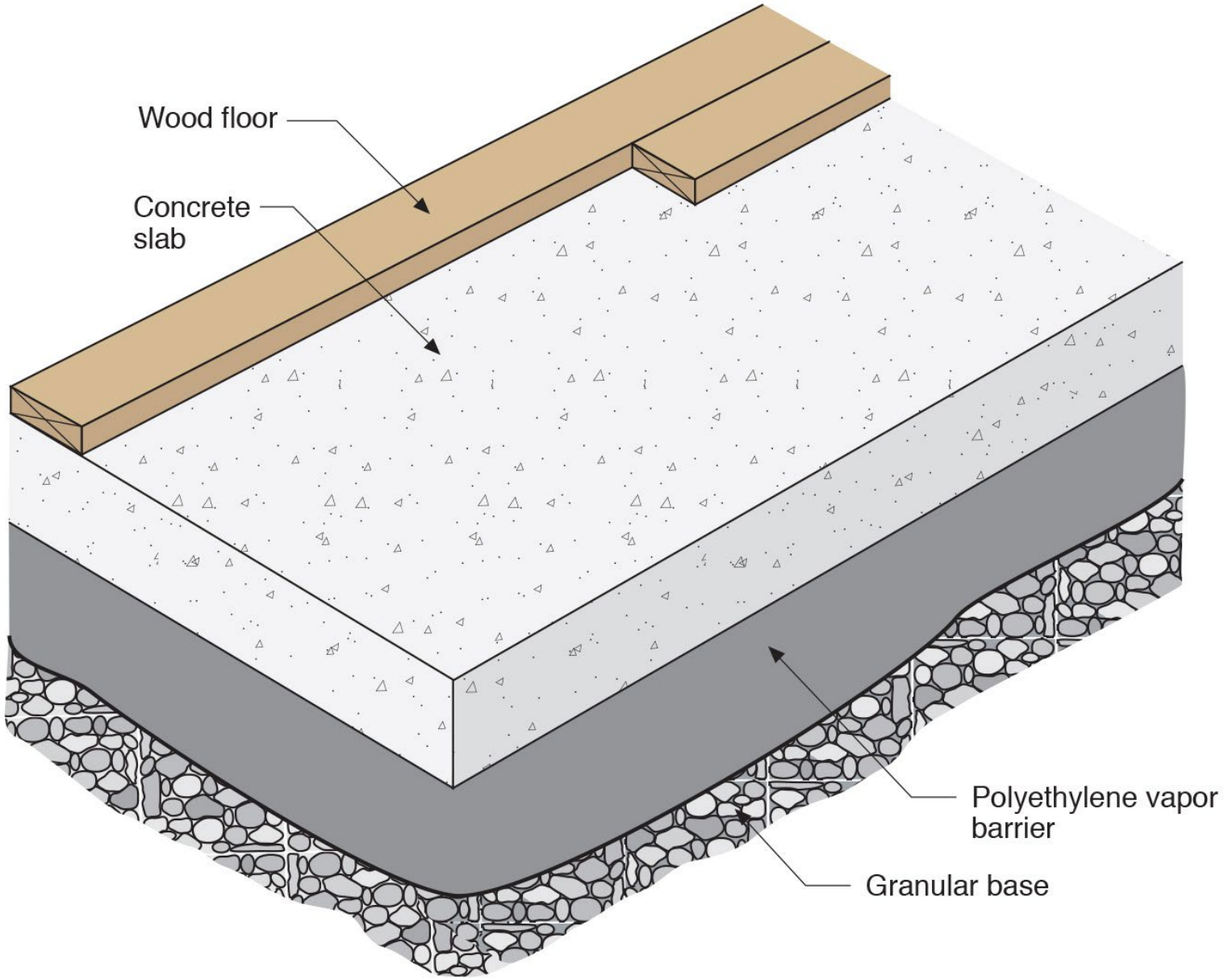

Wood baseboard
Wood flooring
Concrete slab
Perimeter of slab protected above grade
Perimeter edge of slab protected below grade
Sub-slab vapor barrier
Ground saturated with water

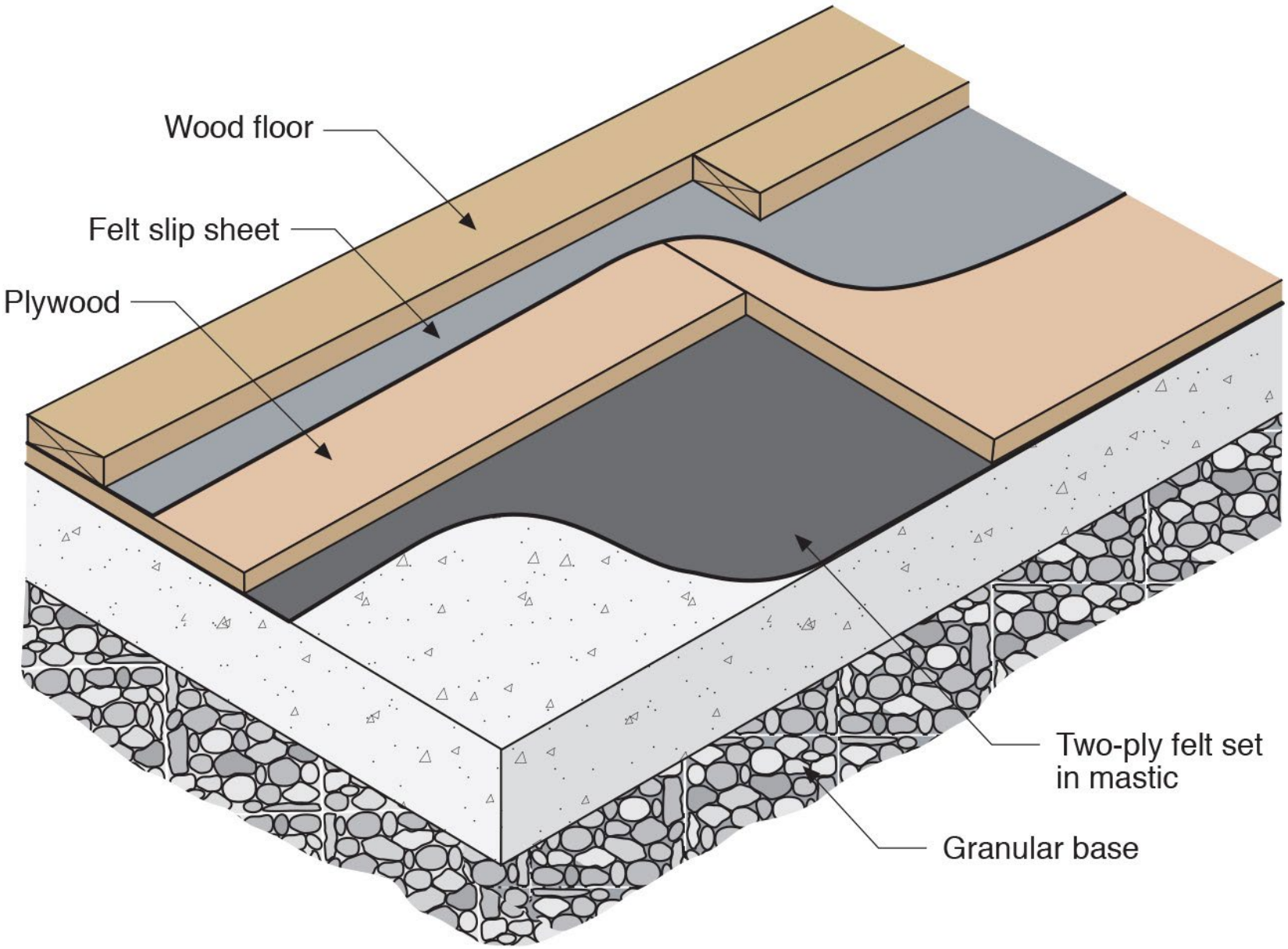

Capillary break under framing (polyethylene strip)
Latex paint (vapor permeable, but water repellent)
Polyethylene "skirt" attached to form; remains in place after form is removed
Capillary break (plastic/ polyethylene ground cover) extending under grade beam and upwards to grade


Cheetos

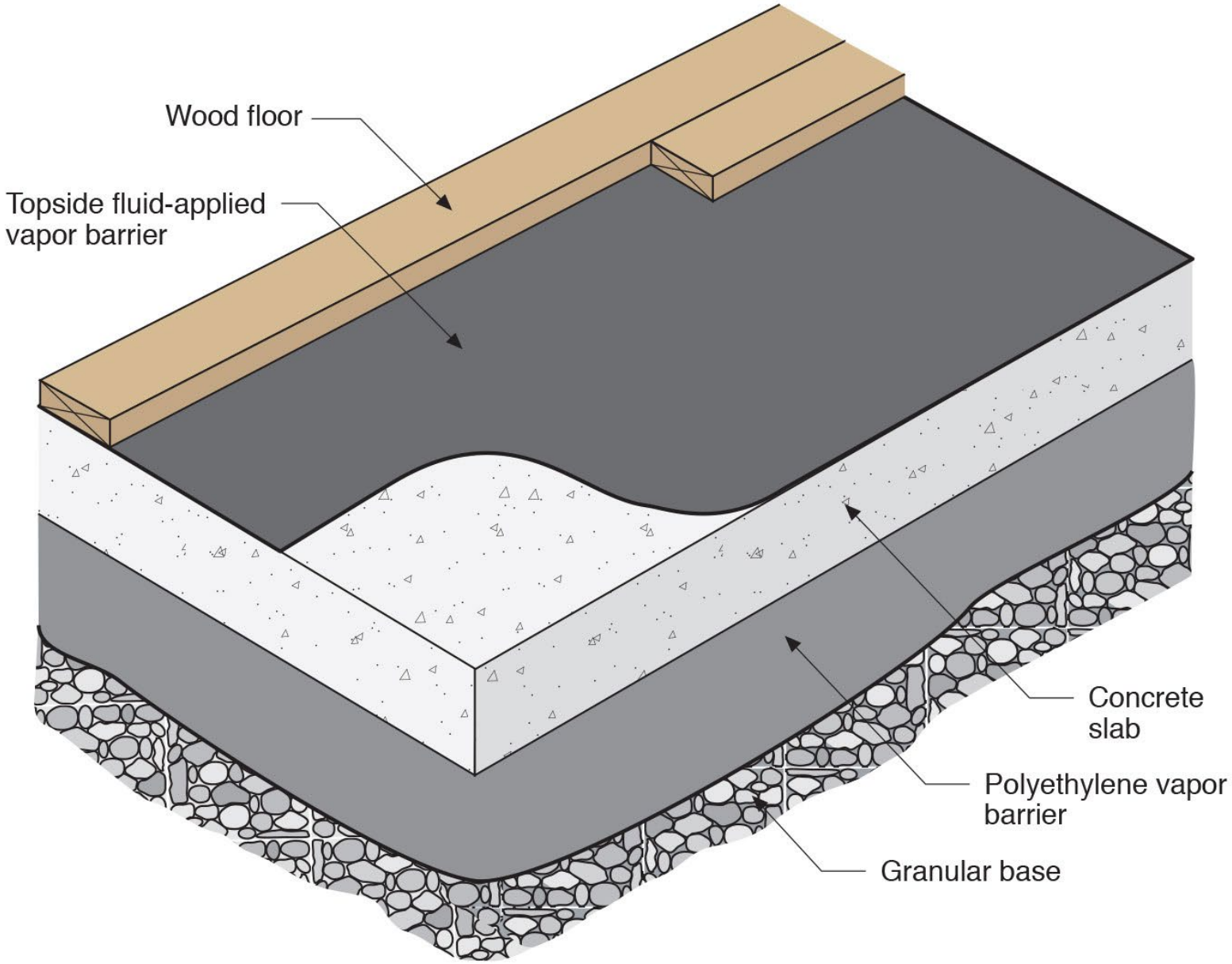

NOW SHREDDING AT
FINER PIZZERIAS.

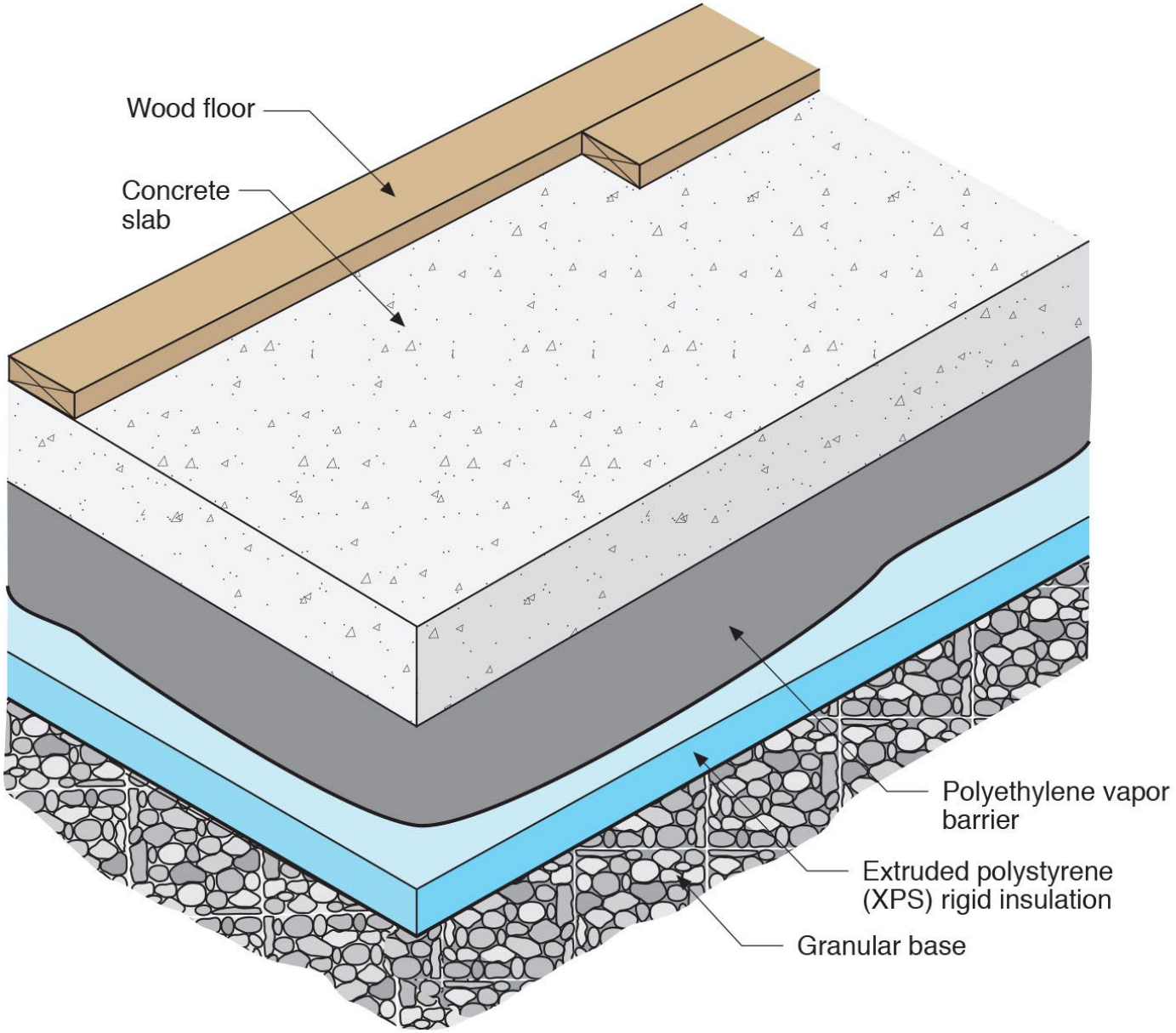

Wood baseboard
Wood flooring
Concrete slab
Capillary break beneath bottom plate
Sub-slab vapor barrier wraps end of slab at slab perimeter
Cementitious rendering
Dampproofing below grade

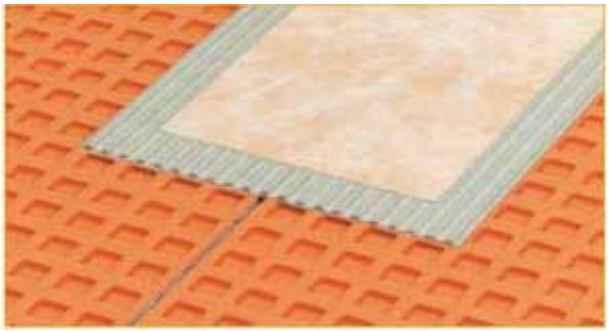

Wood floor
Concrete slab
Polyethylene vapor barrier
Granular base

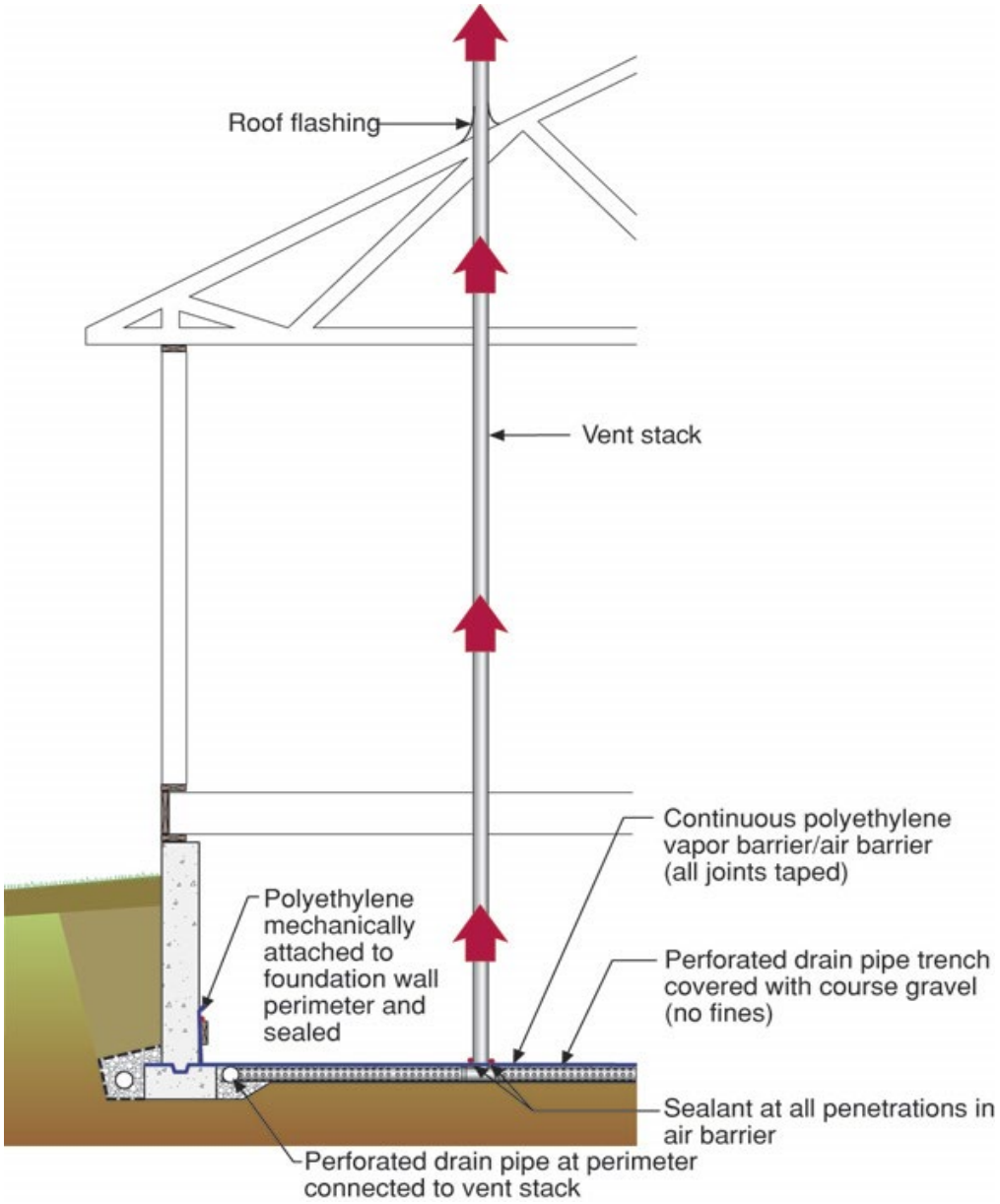

Wood floor
Felt slip sheet
Plywood
Two-ply felt set
in mastic
Granular base

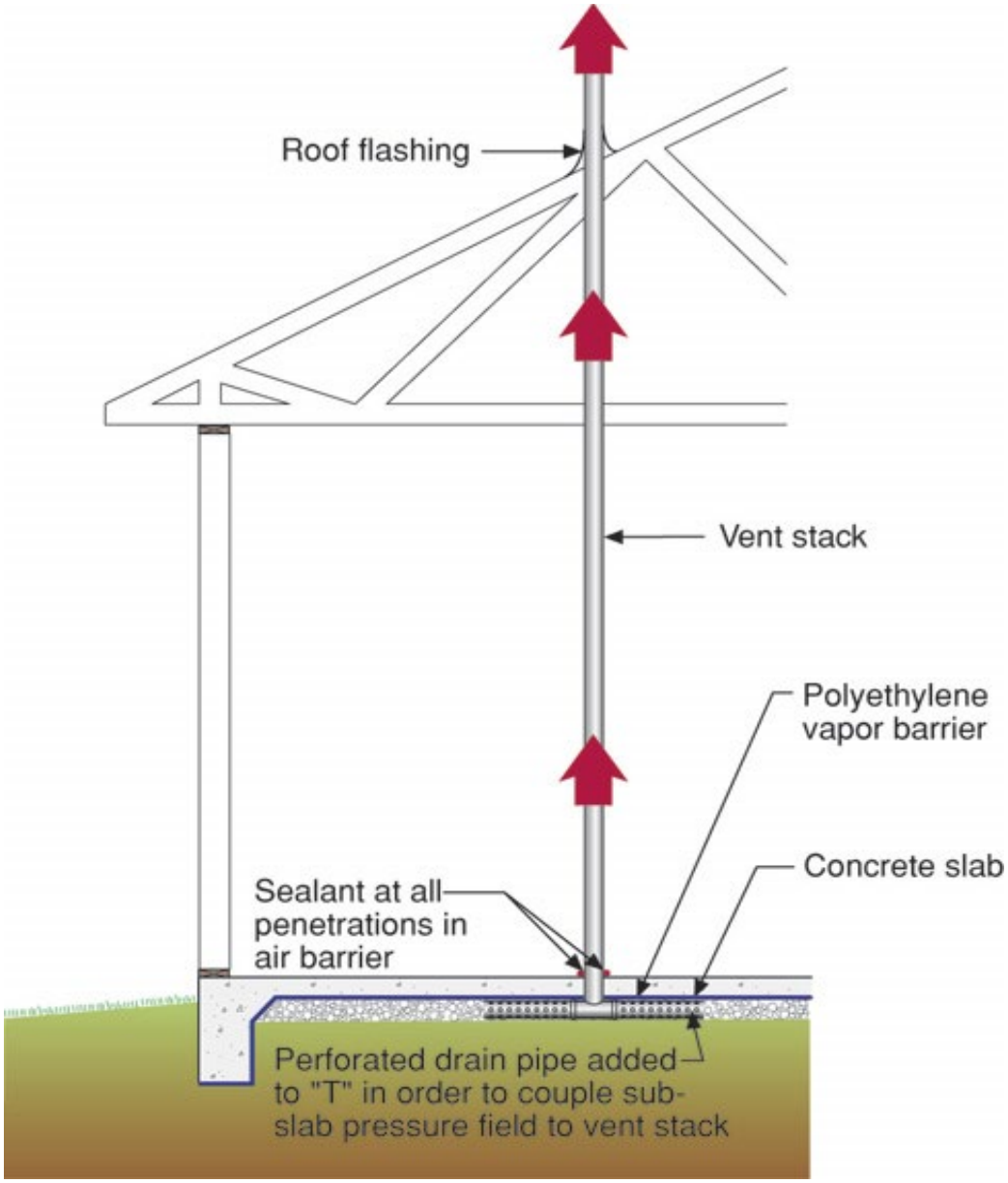

Shop-vac

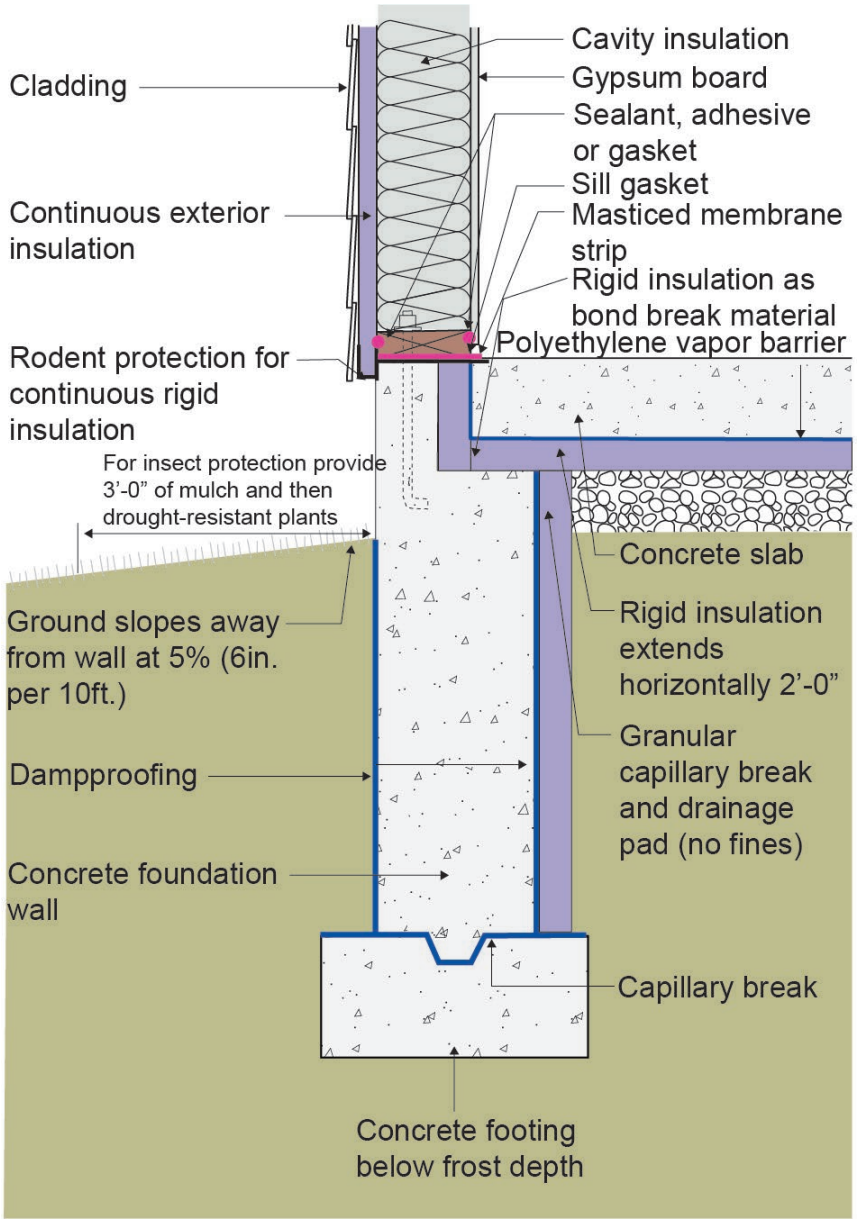

Wood floor
Topside fluid-applied vapor barrier
Concrete slab
Polyethylene vapor barrier
Granular base

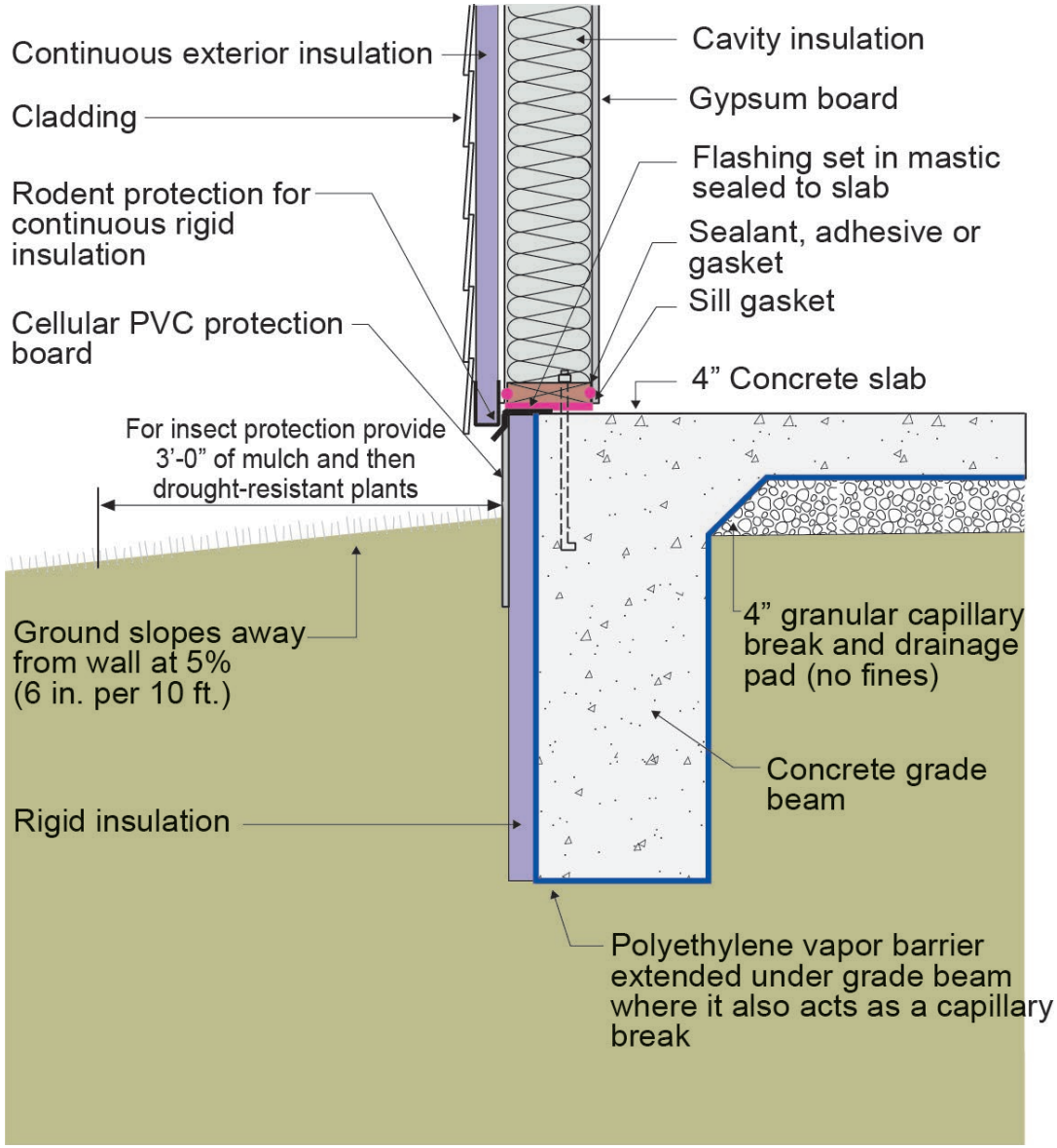

Wood floor
Concrete slab
Polyethylene vapor barrier
Extruded polystyrene (XPS) rigid insulation
Granular base

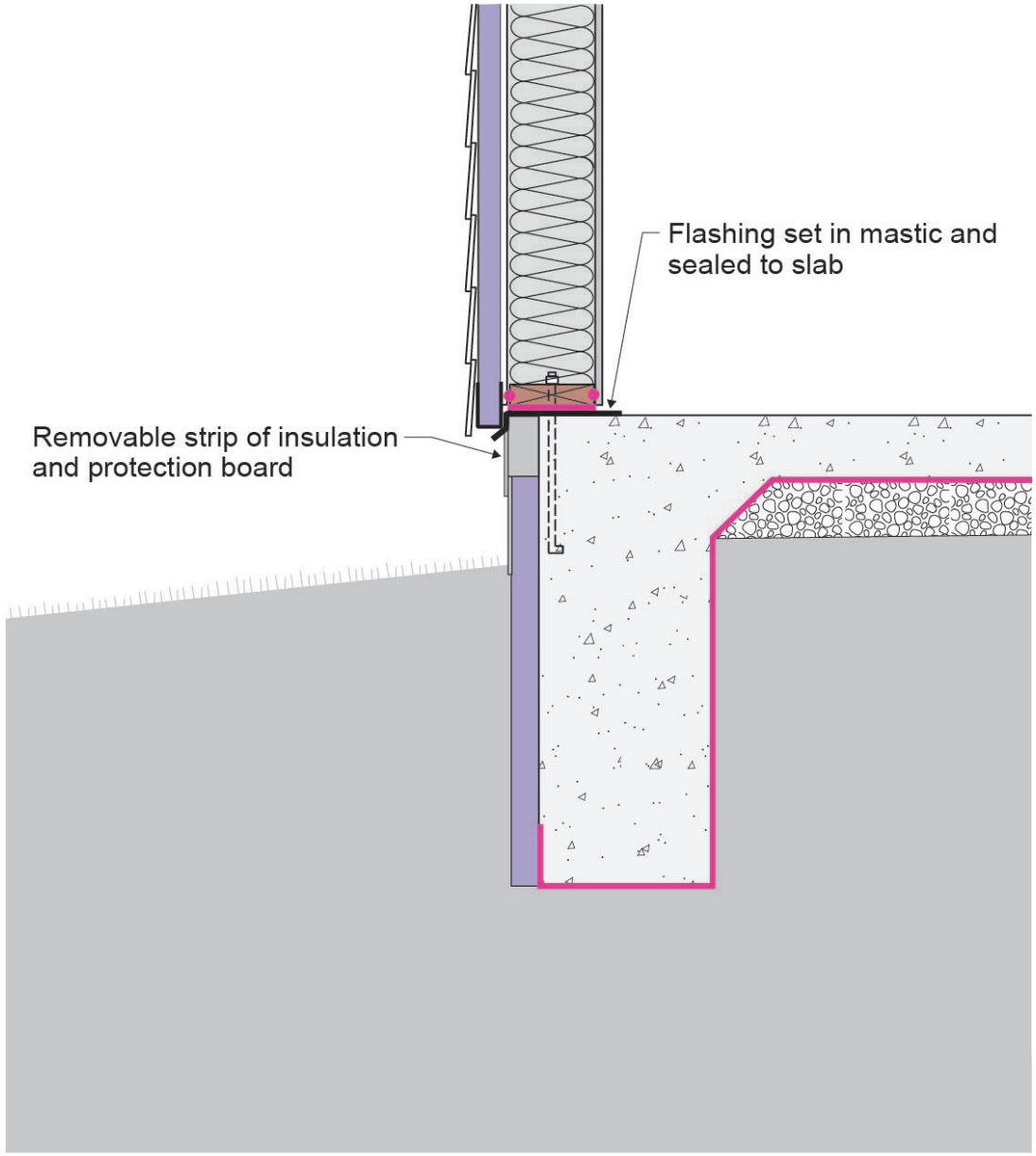


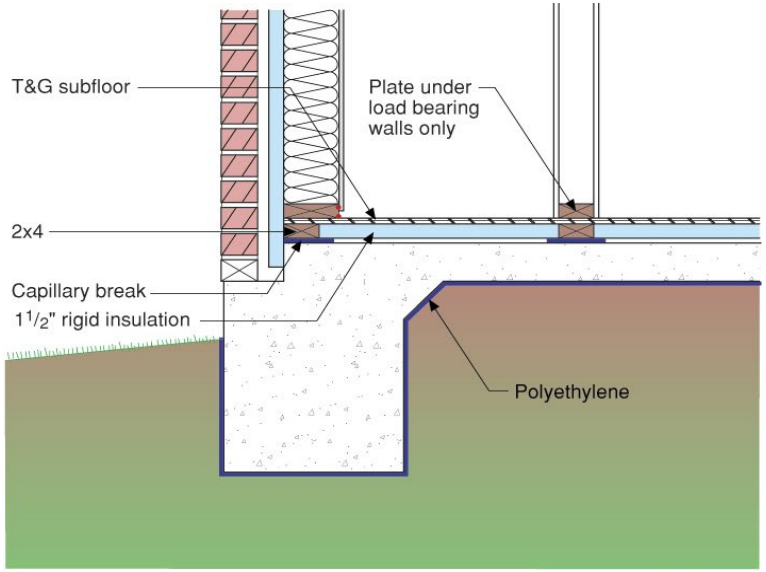

Roof flashing
Vent stack
Continuous polyethylene vapor barrier/air barrier (all joints taped)
Polyethylene mechanically attached to foundation wall perimeter and sealed
Perforated drain pipe trench covered with course gravel (no fines)
Sealant at all penetrations in air barrier
Perforated drain pipe at perimeter connected to vent stack

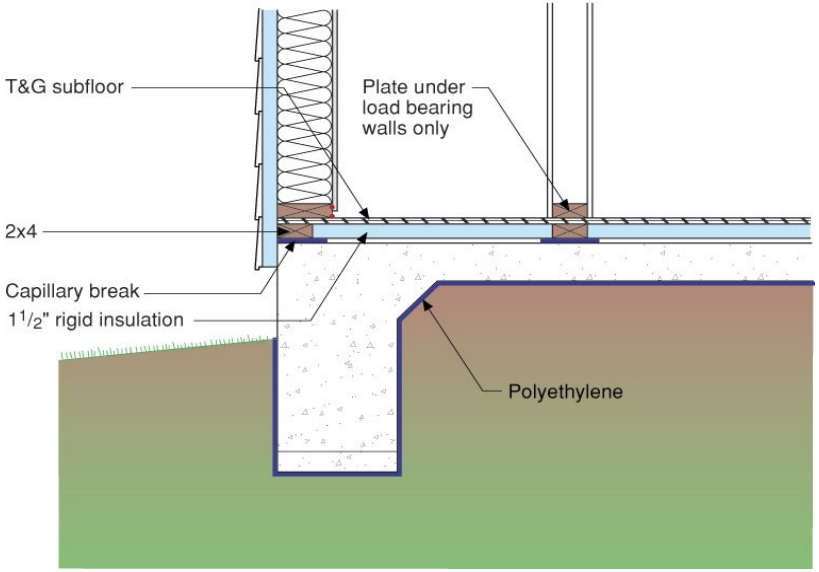

Roof flashing
Vent stack
Polyethylene
vapor barrier
Concrete slab
Sealant at all
penetrations in
air barrier
Perforated drain pipe added
to "T" in order to couple sub-
slab pressure field to vent stack

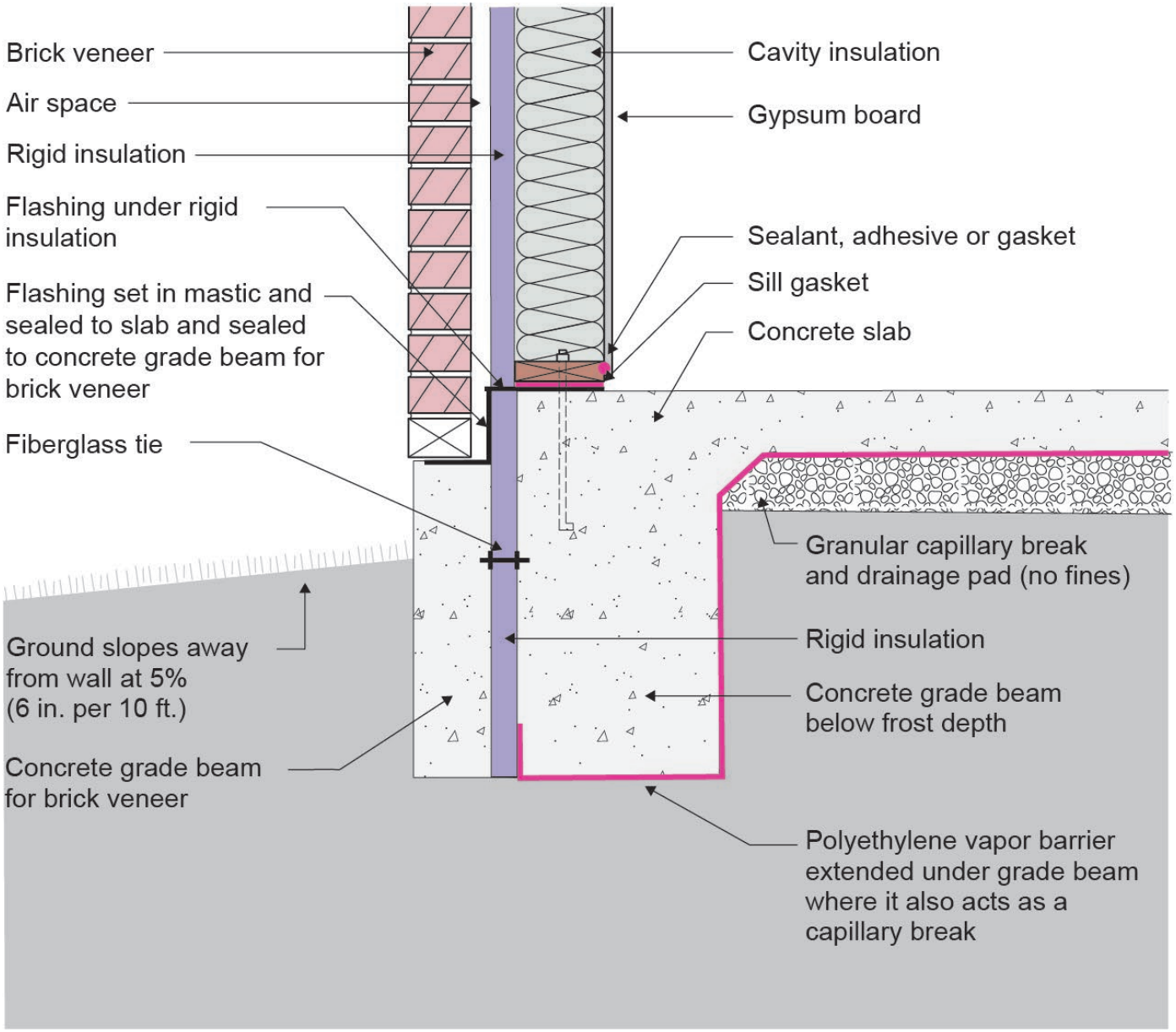

Cladding
Continuous exterior insulation
Rodent protection for continuous rigid insulation
For insect protection provide 3'-0" of mulch and then drought-resistant plants
Ground slopes away from wall at 5% (6in. per 10ft.)
Dampproofing
Concrete foundation wall
Concrete footing below frost depth
Capillary break
Granular capillary break and drainage pad (no fines)
Rigid insulation extends horizontally 2'-0"
Concrete slab
Polyethylene vapor barrier
Rigid insulation as bond break material
Masticed membrane strip
Sill gasket
Sealant, adhesive or gasket
Gypsum board
Cavity insulation

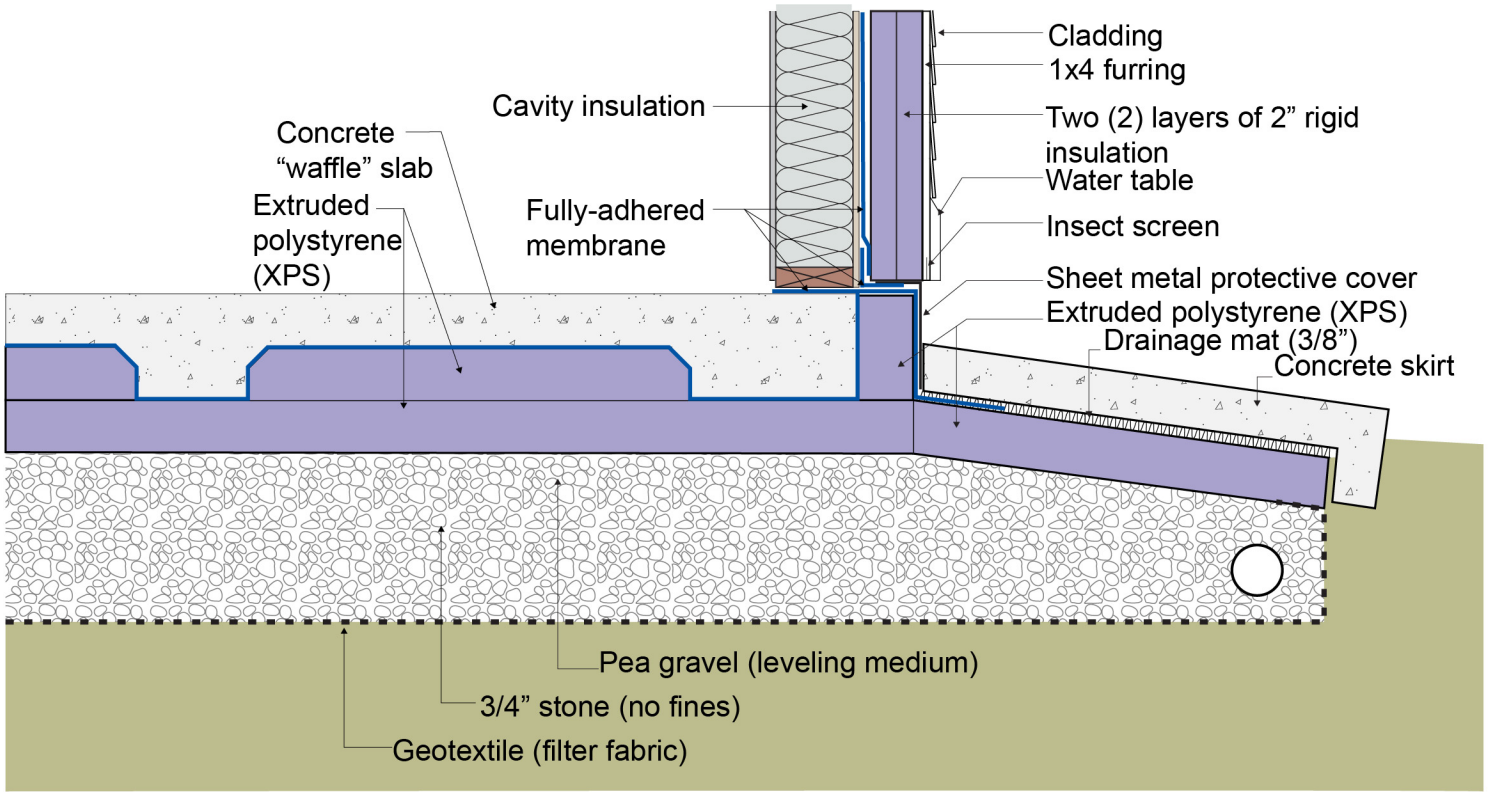

Continuous exterior insulation
Cladding
Rodent protection for continuous rigid insulation
Cellular PVC protection board
For insect protection provide 3'-0" of mulch and then drought-resistant plants
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Rigid insulation
Cavity insulation
Gypsum board
Flashing set in mastic sealed to slab
Sealant, adhesive or gasket
Sill gasket
4" Concrete slab
4" granular capillary break and drainage pad (no fines)
Concrete grade beam
Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break

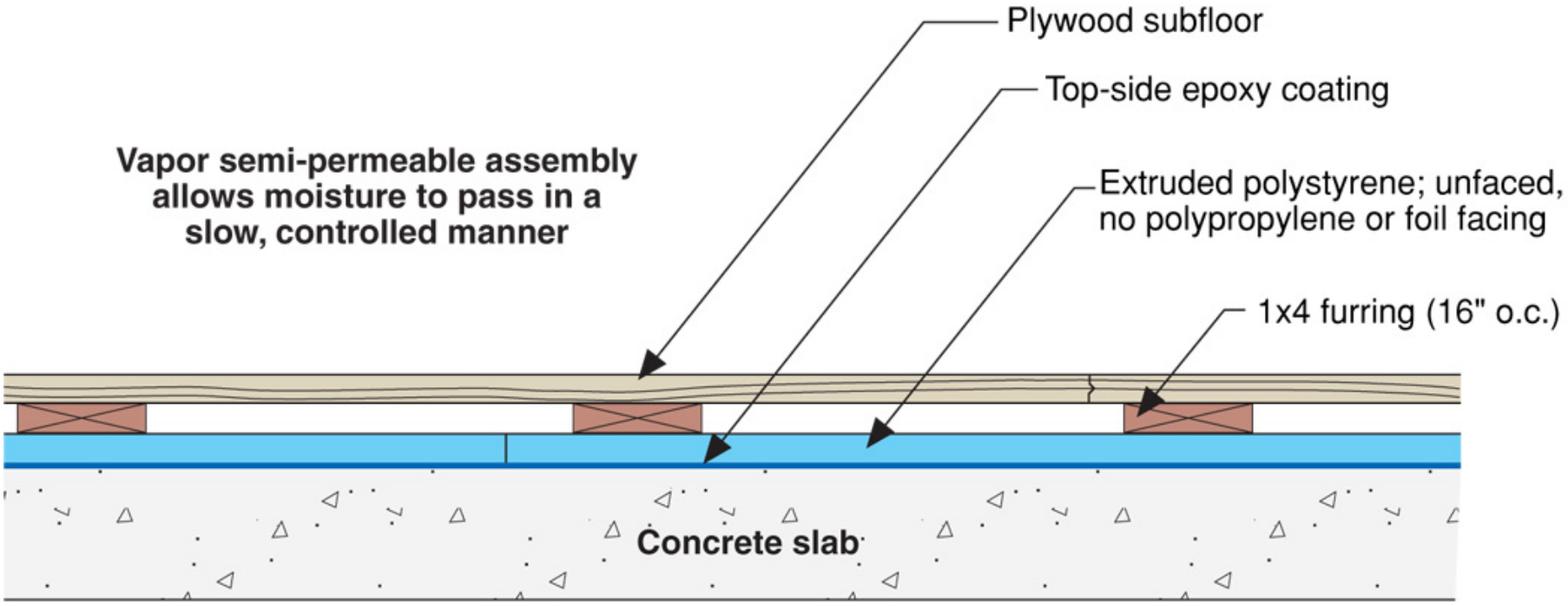

Flashing set in mastic and sealed to slab
Removable strip of insulation and protection board


T&G subfloor
Plate under load bearing walls only
2x4
Capillary break
1 1/2" rigid insulation
Polyethylene

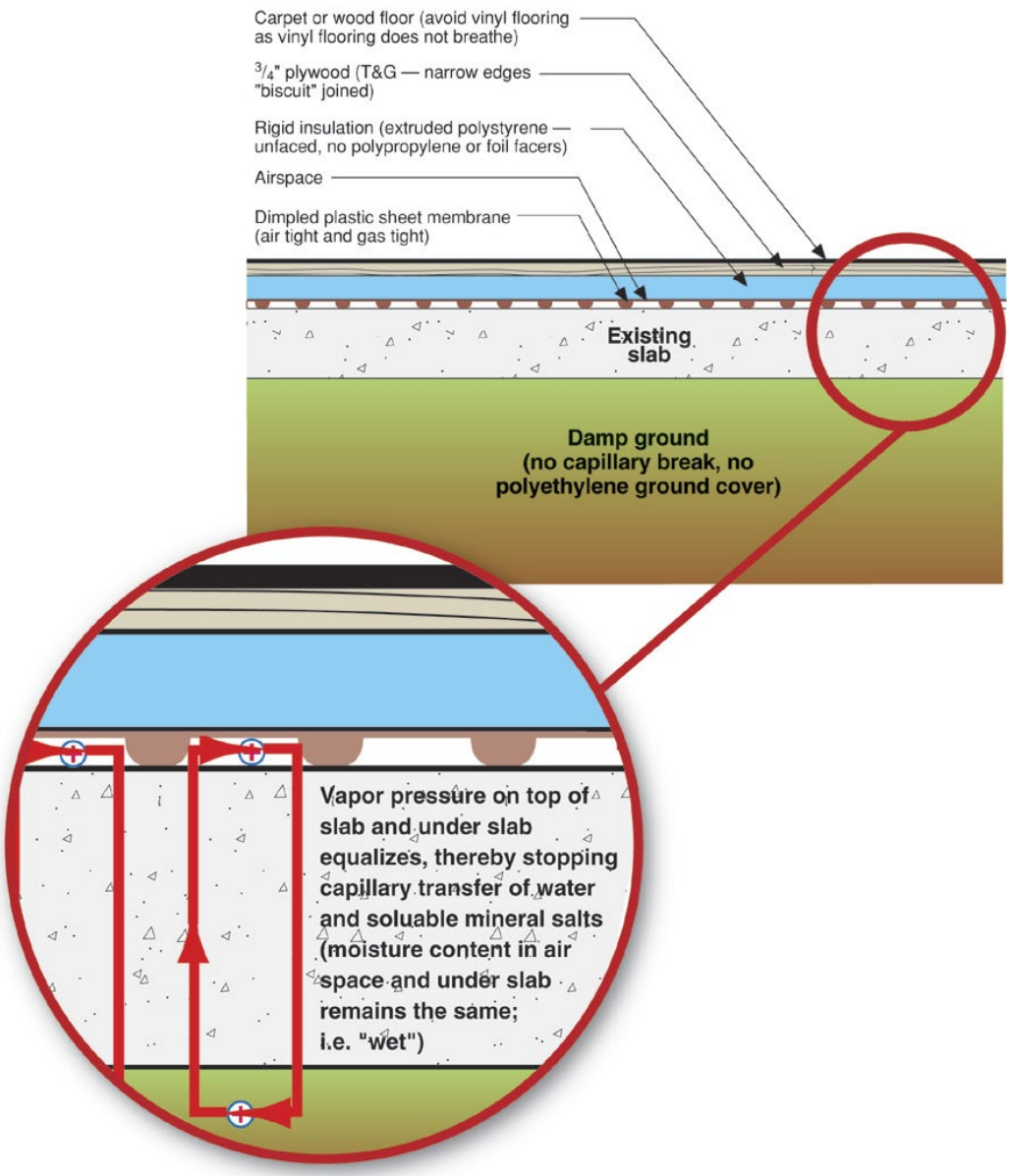

T&G subfloor
Plate under load bearing walls only
2x4
Capillary break
1 1/2" rigid insulation
Polyethylene


Brick veneer
Air space
Rigid insulation
Flashing under rigid insulation
Flashing set in mastic and sealed to slab and sealed to concrete grade beam for brick veneer
Fiberglass tie
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Concrete grade beam for brick veneer
Cavity insulation
Gypsum board
Sealant, adhesive or gasket
Sill gasket
Concrete slab
Granular capillary break and drainage pad (no fines)
Rigid insulation
Concrete grade beam below frost depth
Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break


Cladding
1x4 furring
Cavity insulation
Two (2) layers of 2” rigid insulation
Concrete “waffle” slab
Water table
Extruded polystyrene (XPS)
Fully-adhered membrane
Insect screen
Sheet metal protective cover
Extruded polystyrene (XPS)
Drainage mat (3/8”)
Concrete skirt
Pea gravel (leveling medium)
3/4” stone (no fines)
Geotextile (filter fabric)


Plywood subfloor
Top-side epoxy coating
Vapor semi-permeable assembly allows moisture to pass in a slow, controlled manner
Extruded polystyrene; unfaced, no polypropylene or foil facing
1x4 furring (16" o.c.)
Concrete slab


DELTA-FL


Carpet or wood floor (avoid vinyl flooring as vinyl flooring does not breathe)
3/4" plywood (T&G — narrow edges "biscuit" joined)
Rigid insulation (extruded polystyrene — unfaced, no polypropylene or foil facers)
Airspace
Dimpled plastic sheet membrane (air tight and gas tight)
Existing slab
Damp ground (no capillary break, no polyethylene ground cover)
Vapor pressure on top of slab and under slab equalizes, thereby stopping capillary transfer of water and soluable mineral salts (moisture content in air space and under slab remains the same; i.e. "wet")