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

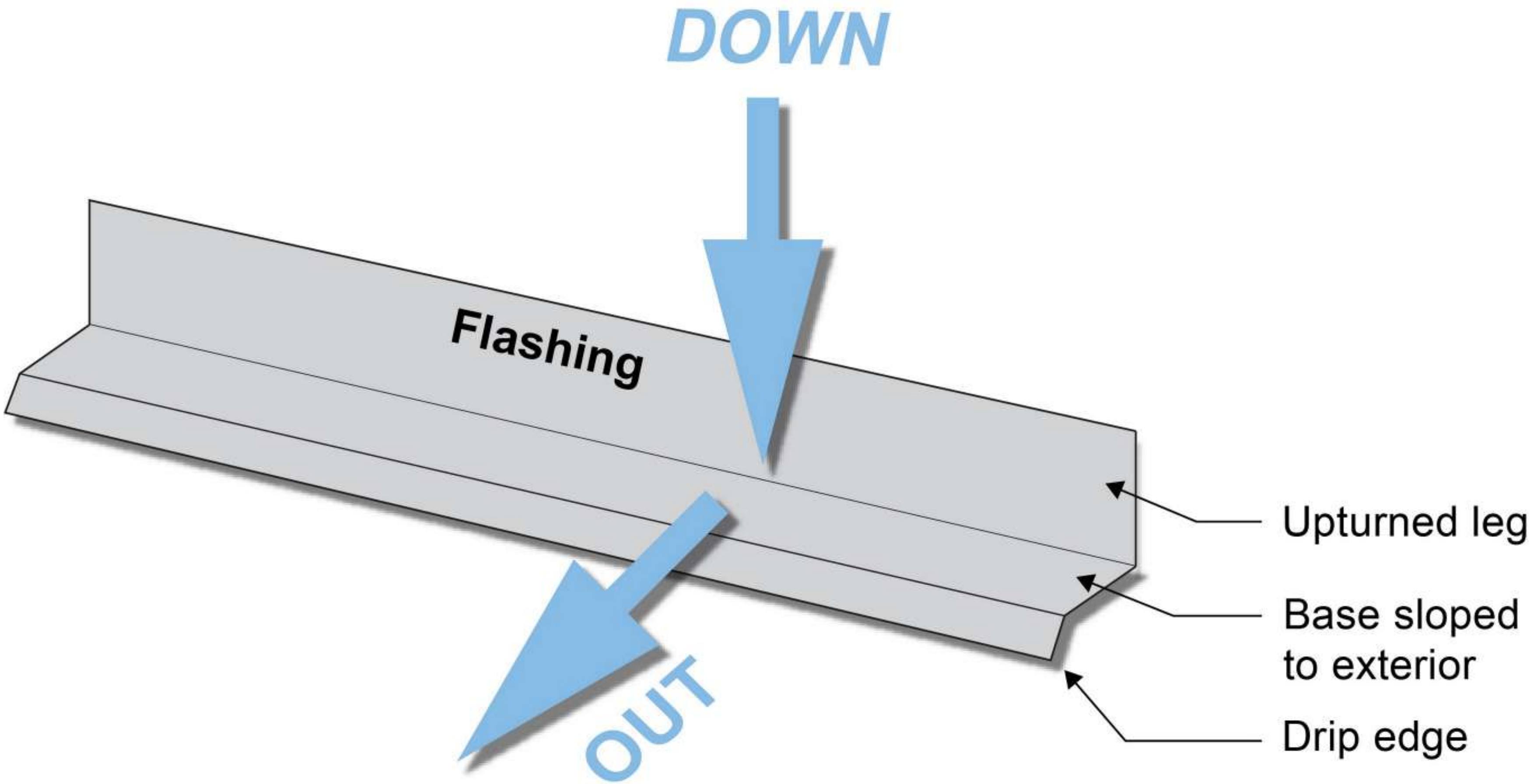
# Building Science

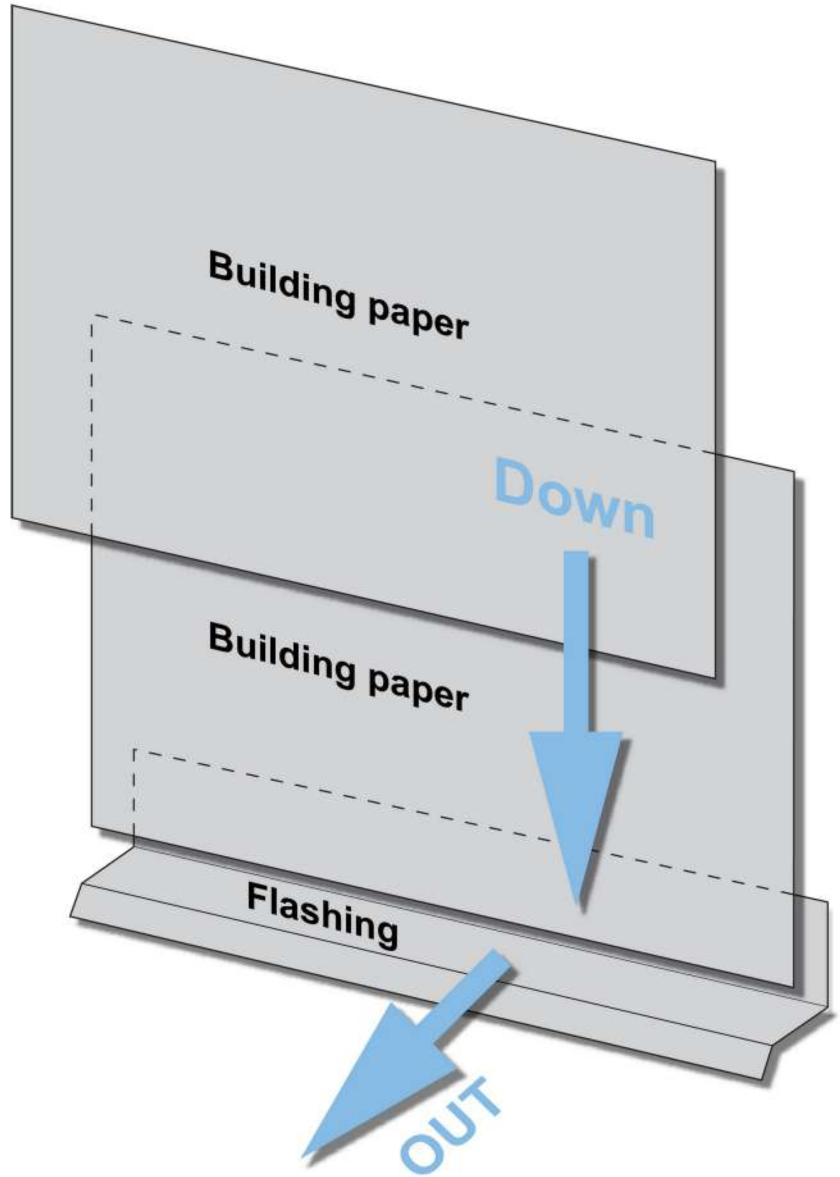
## Adventures In Building Science

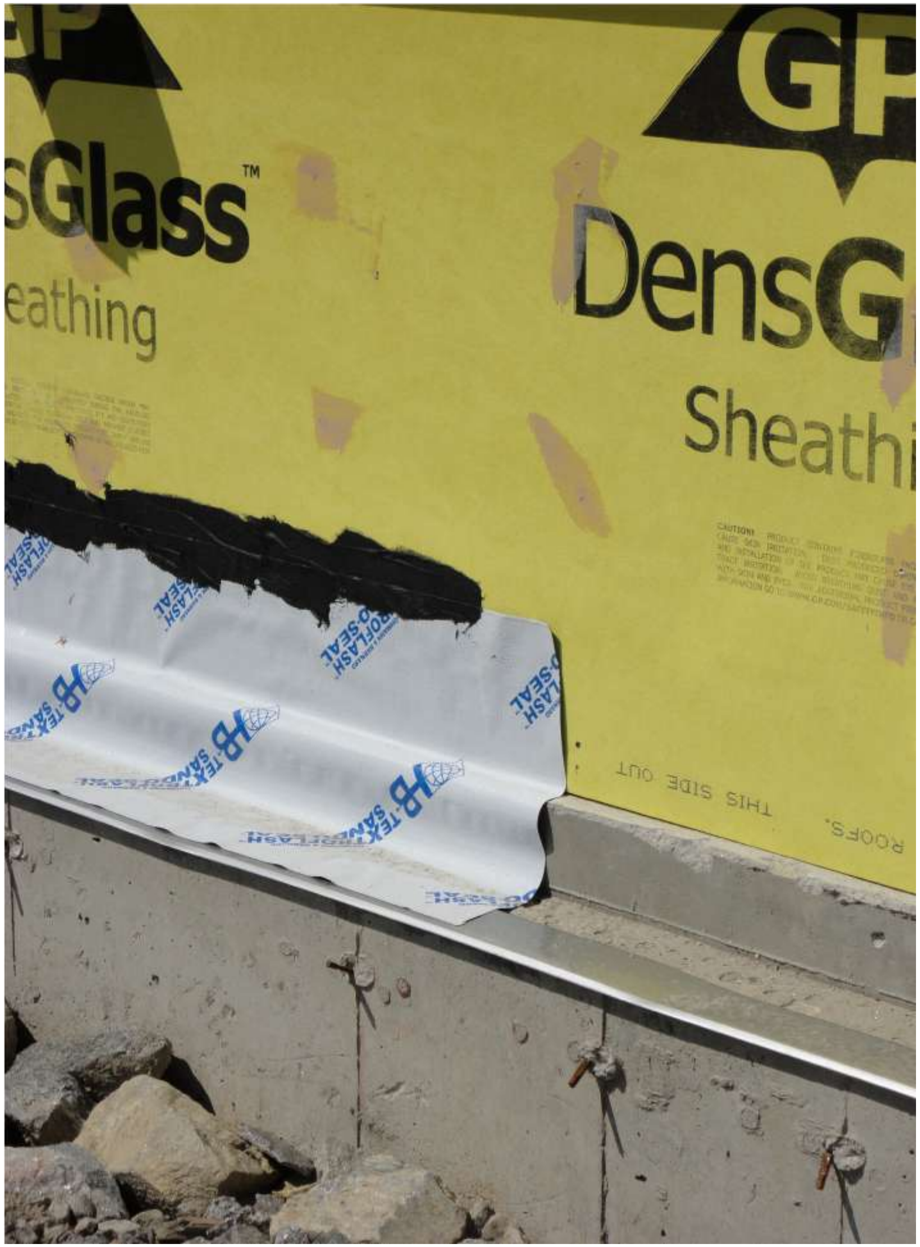
# Rain Screen

Drain the Rain on the Plane

If You Want to Save Cash…Flash

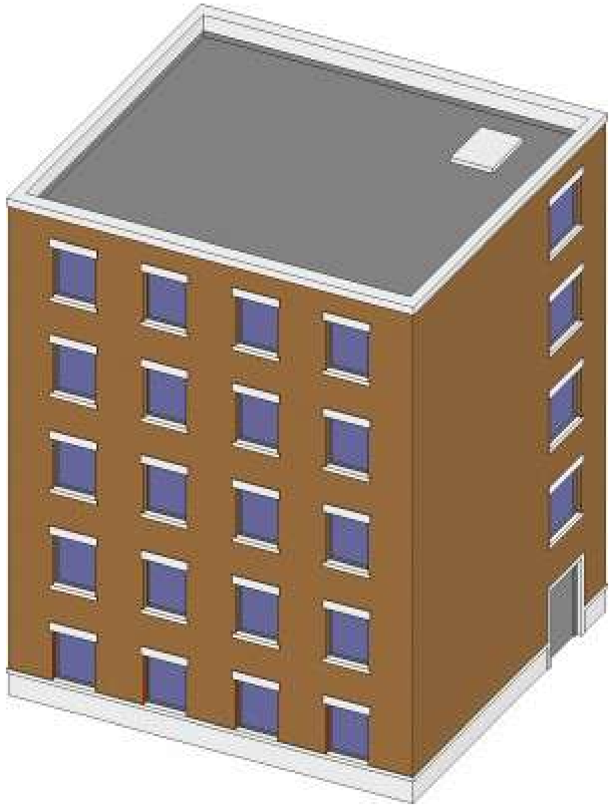

DOWN
Flashing
OUT
Upturned leg
Base sloped to exterior
Drip edge


Building paper
Down
Building paper
Flashing
OUT

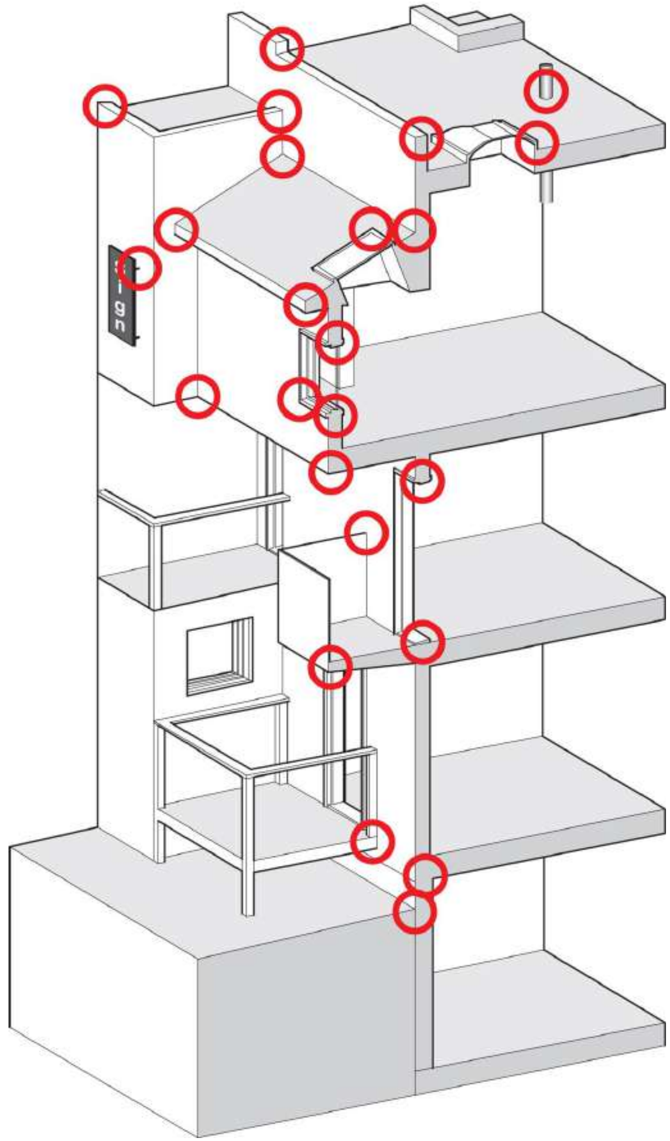

GP
DensGlass™
Sheathing
THIS SIDE OUT


rmax
ci
Isolant extérie
Thermax ci
Aislamiento Ext
THERM X ci

# Commercial Enclosure: Simple Layers



- Structure
- Rain/Air/Vapor
- Insulation
- Finish

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38"


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Sheathing
Polyguard
www.polyguardproducts.com


MEL-ROL


www.polyguard.com
Expect more.


DuPont™ Flashing Systems
COR® PLUS


StraightFlash


aightFlash
StraightFlash
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StraightFlash
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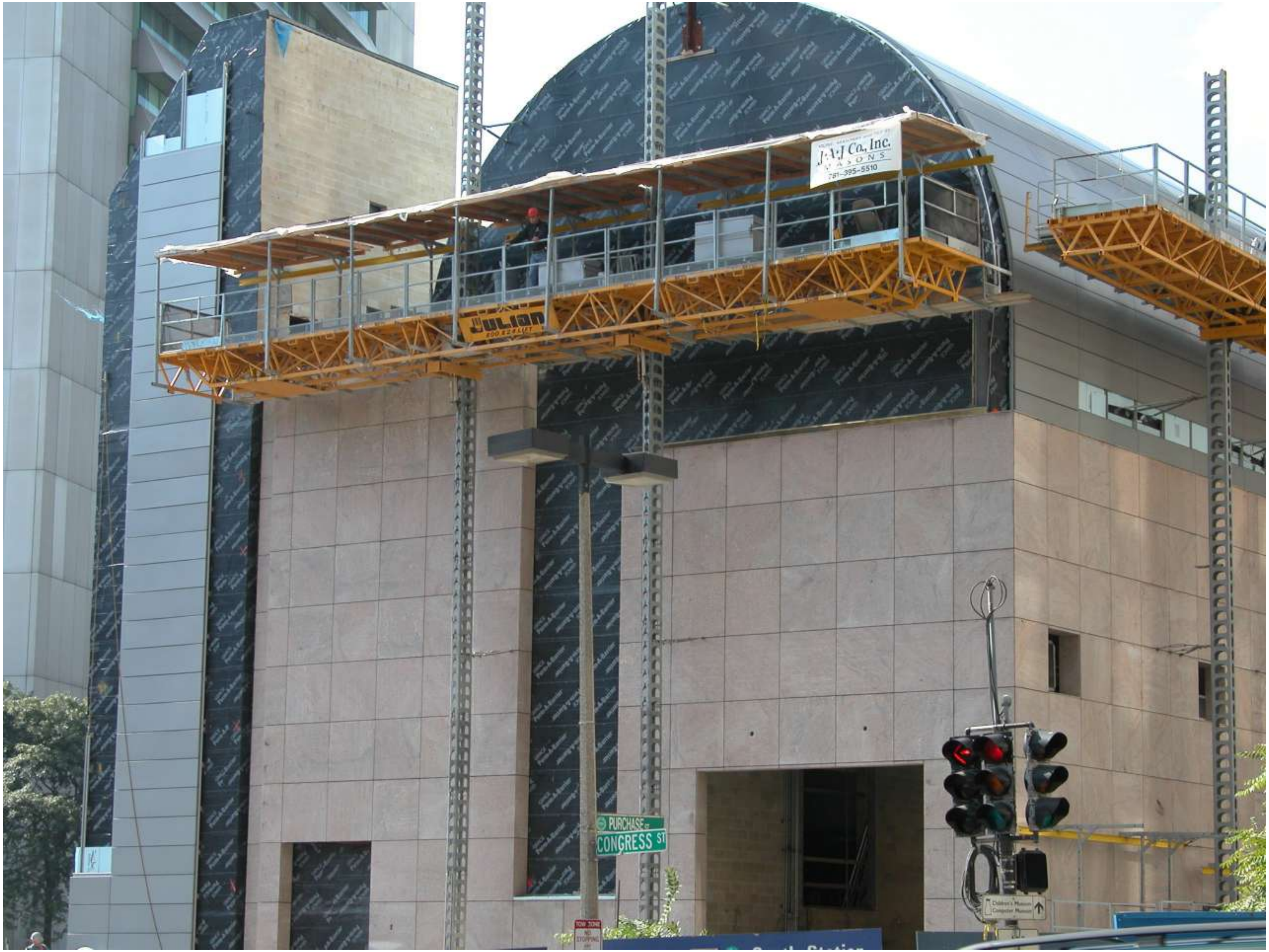
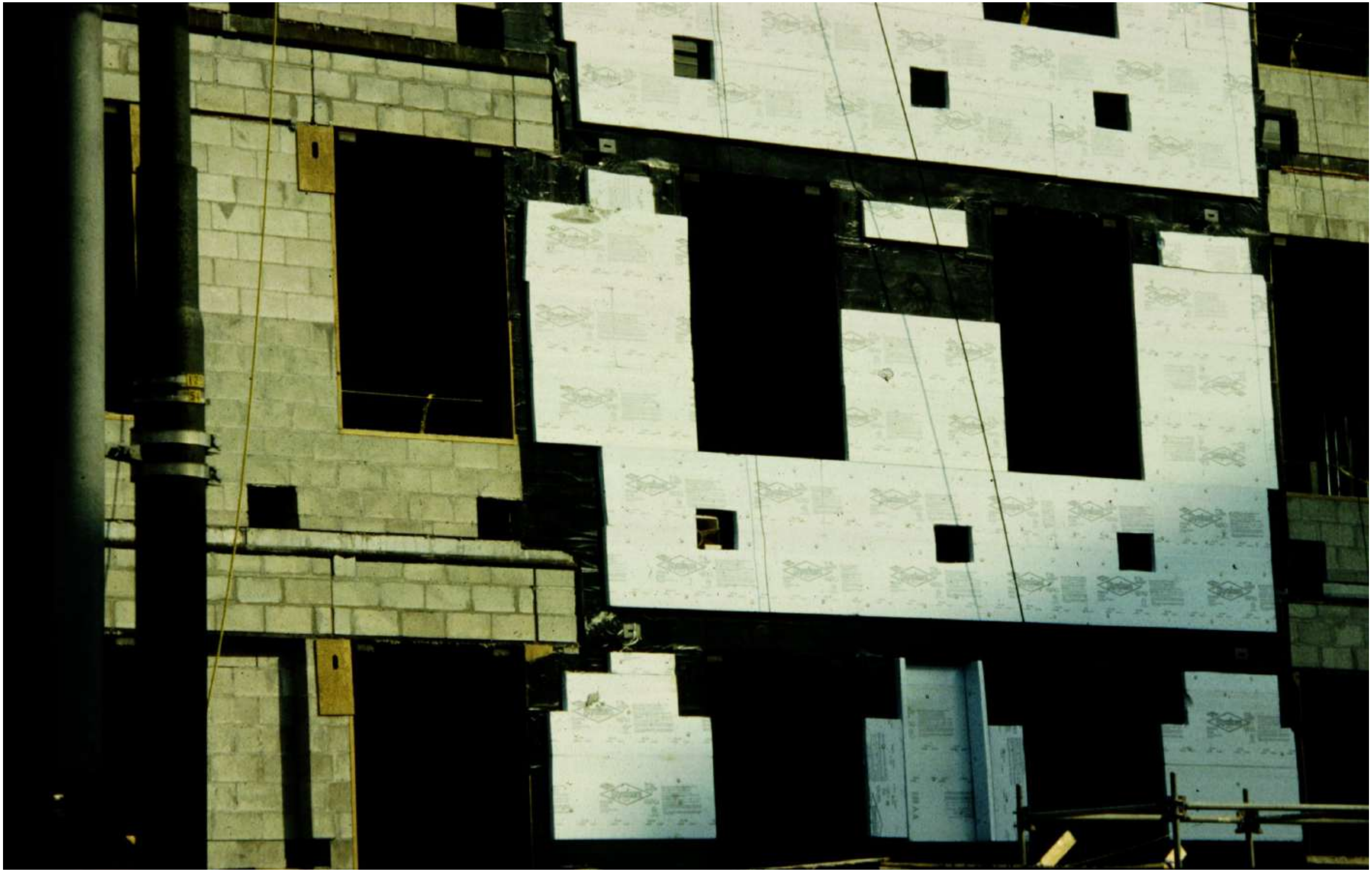

J-A-J Co., Inc.
MASONS
781-395-5510
JULIAN
PURCHASE ST
CONGRESS ST

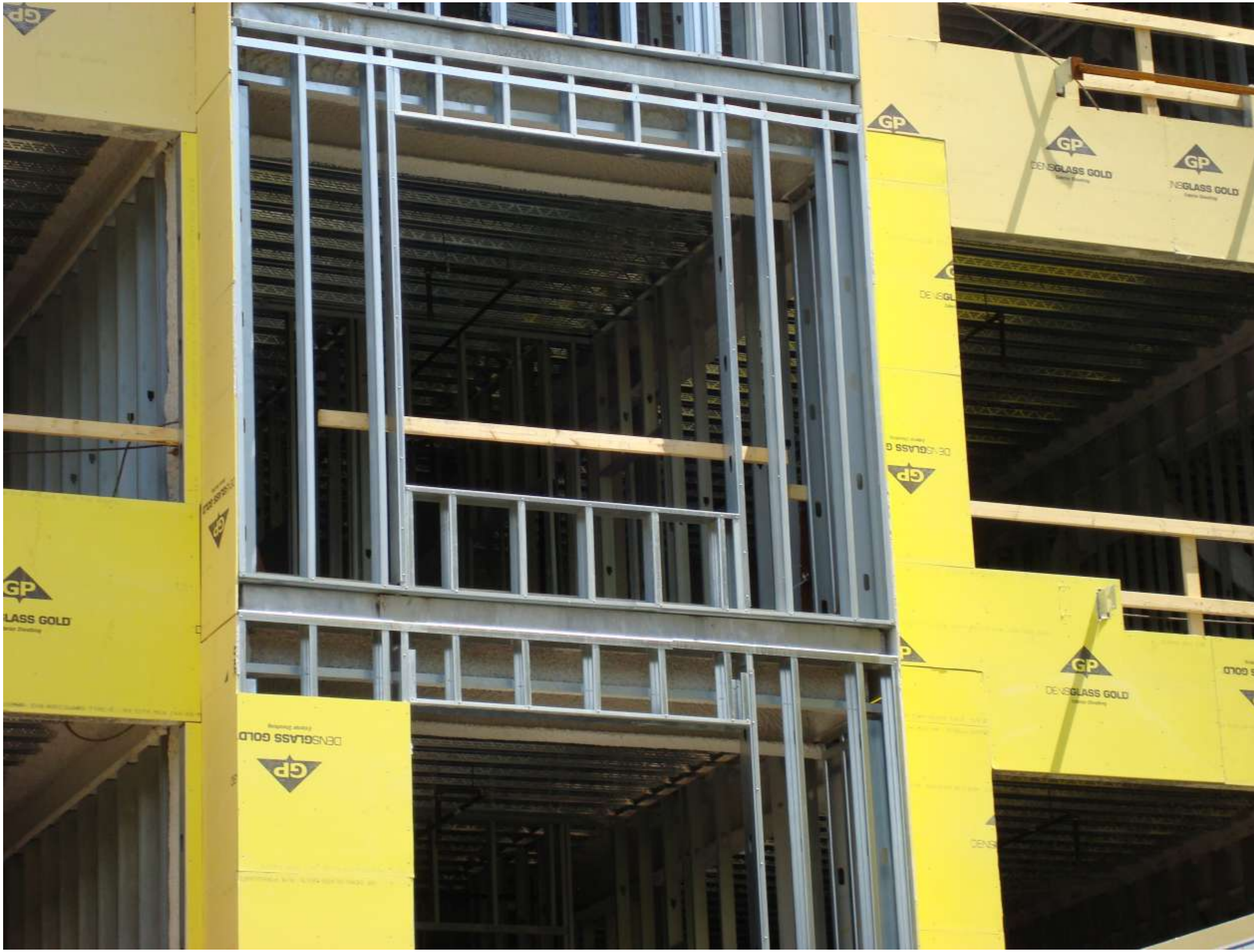

RENTA




HARVARD SCHOOL OF PUBLIC HEALTH


CAVITYMATE


ALL VISITORS
MUST SIGN IN
AT
JOHN MORIARTY
AND ASSOCIATES
FIELD OFFICE
CAUTION
HARD HAT
AREA
WORKSITE


GP
DENSGLASS GOLD


DENSGLASS GOLD
Exterior Sheathing
GP
DENSGLASS GOLD
Exterior Sheathing


Blueskin


Blueskin VP160


REPUBLIC


AVAILAB
978-369-4


GP
DensGlass
Sheathing


MARKET
BASKET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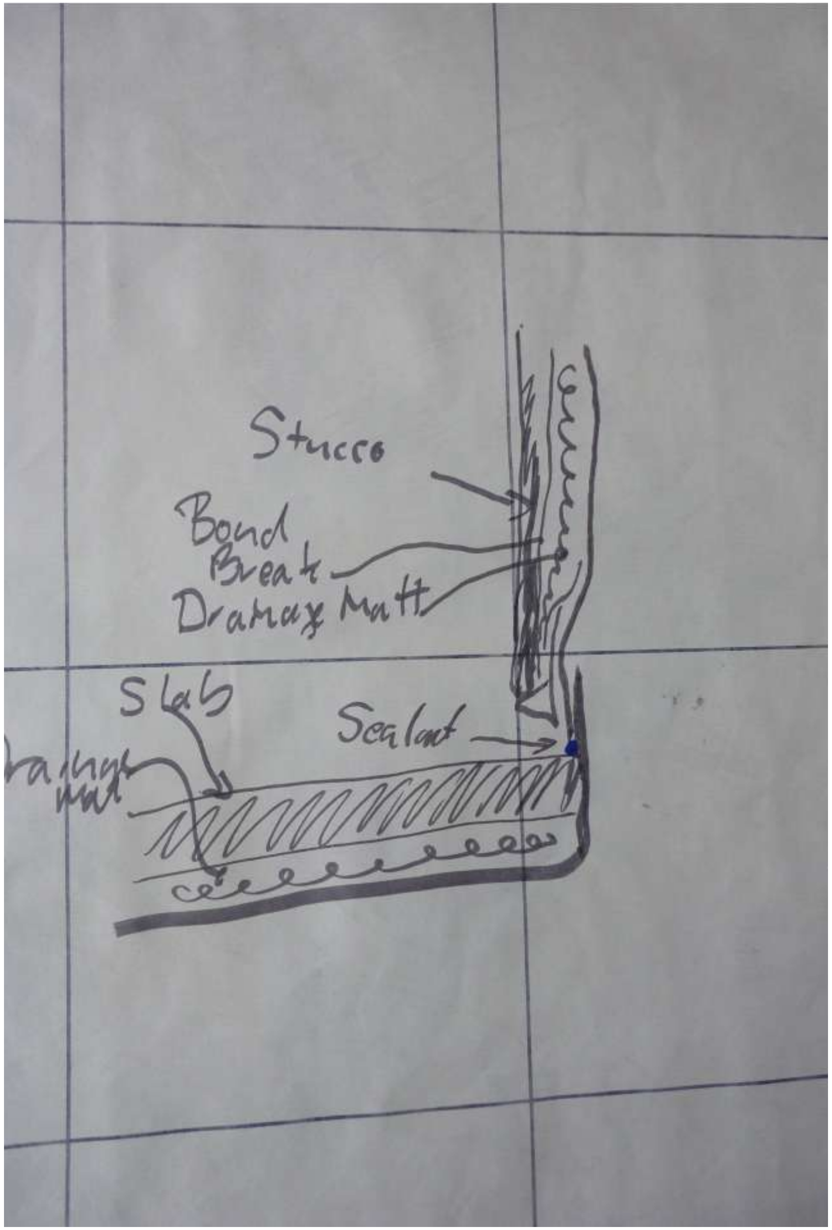
PRIVATE PARKING


Stucco
Bond
Break
Dramag Matt
Slab
Sealant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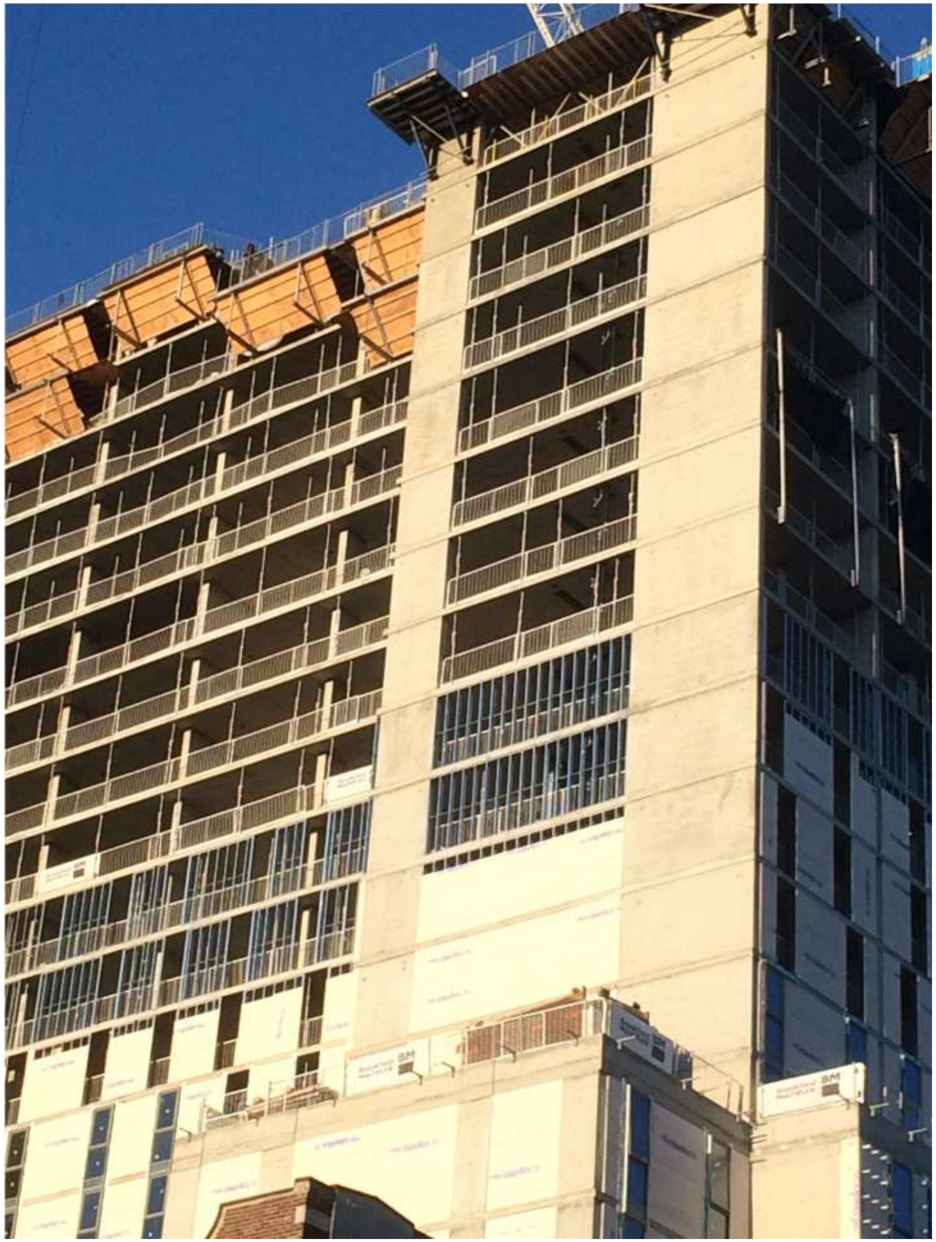
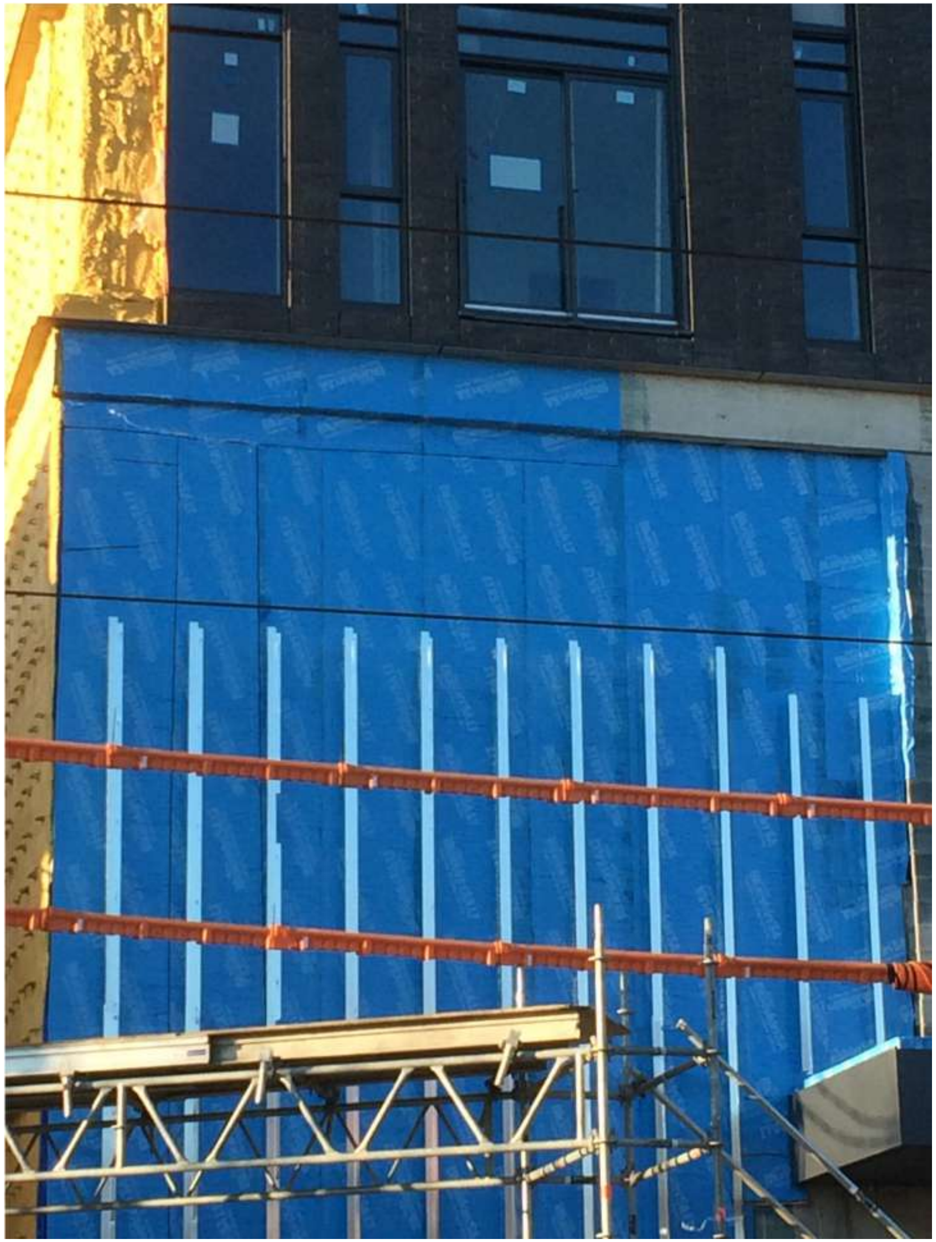
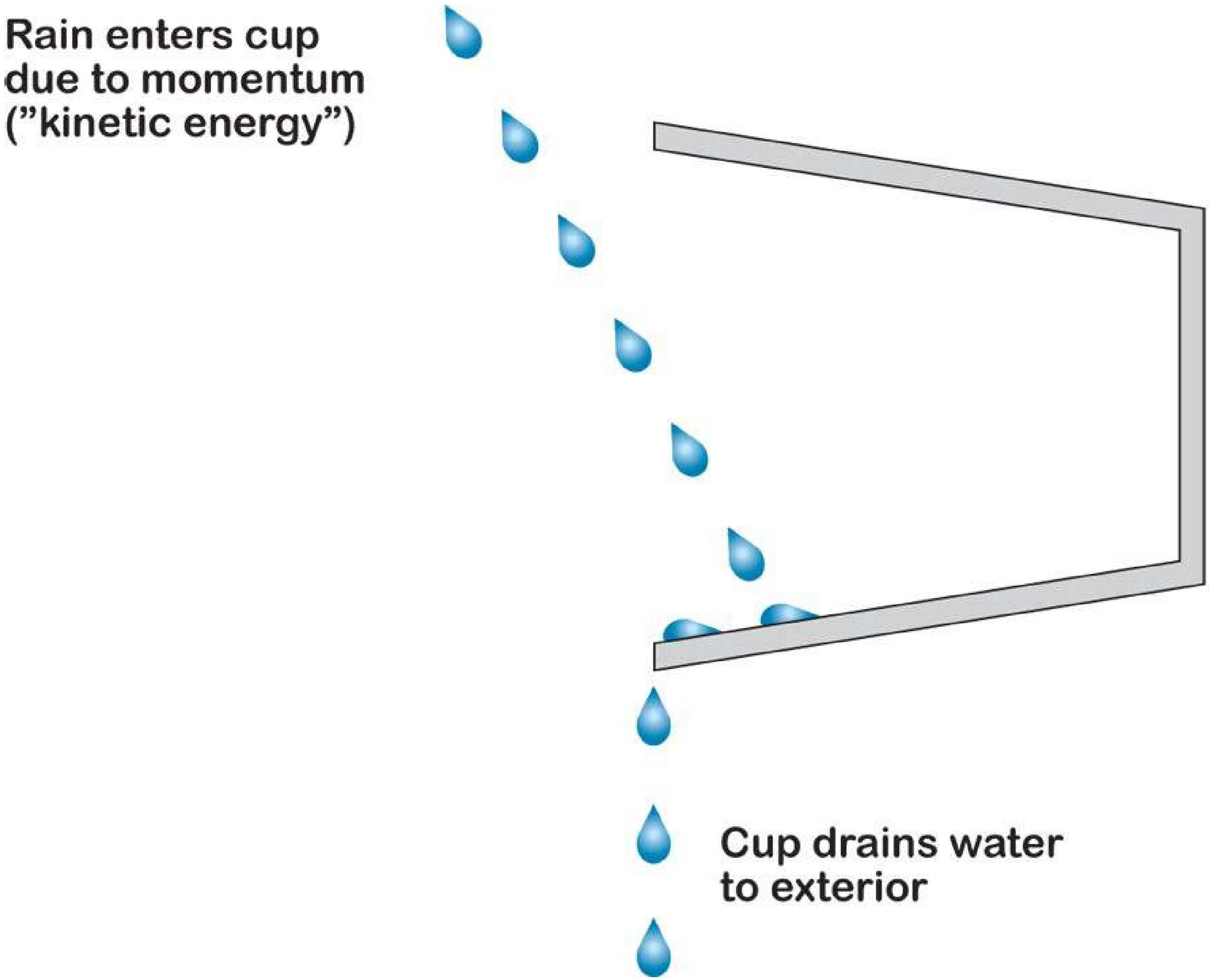


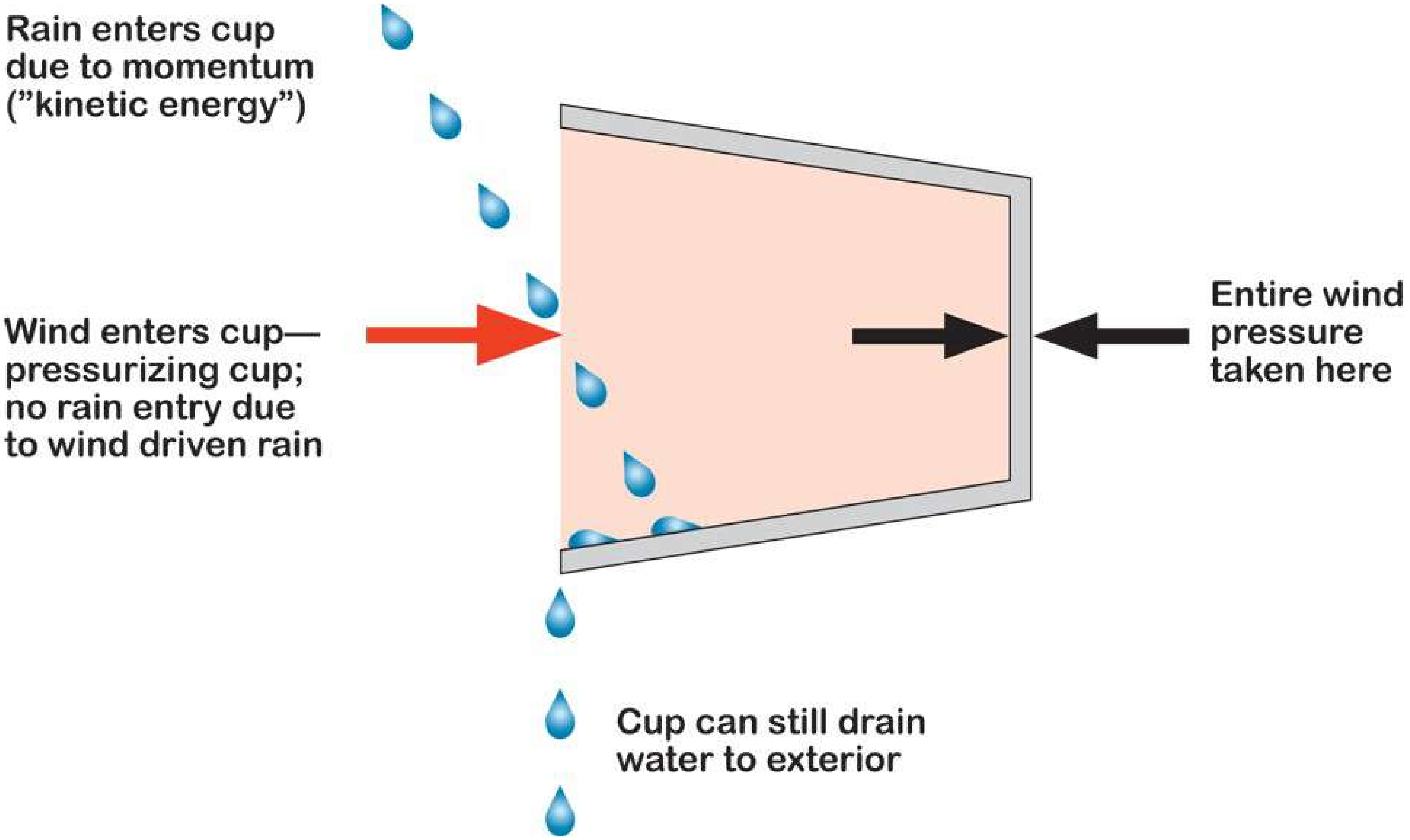

Tribute
Parking
FOR LEASE
WALK-IN CLINIC

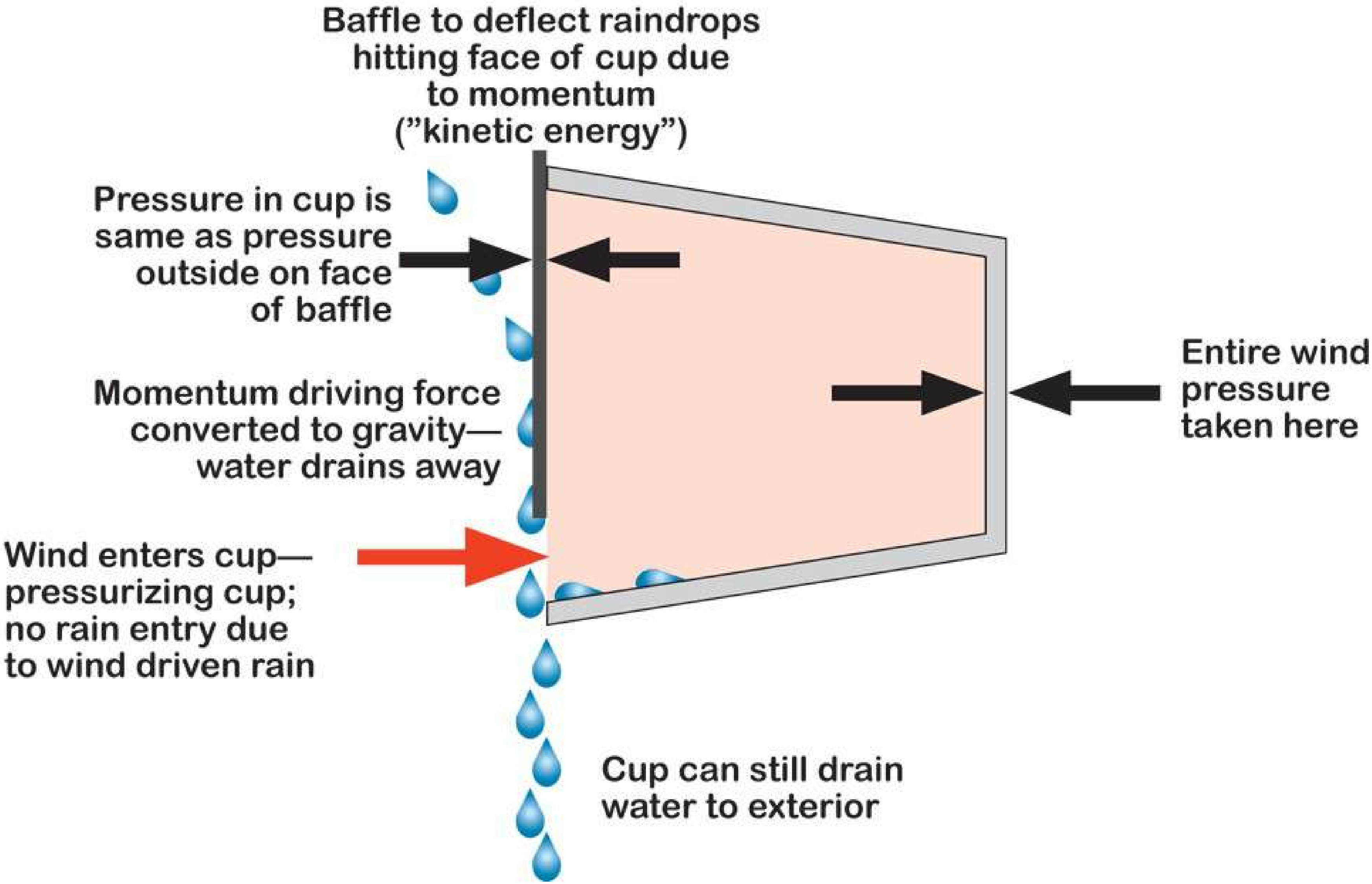

Tribute
Tribute
Tribute

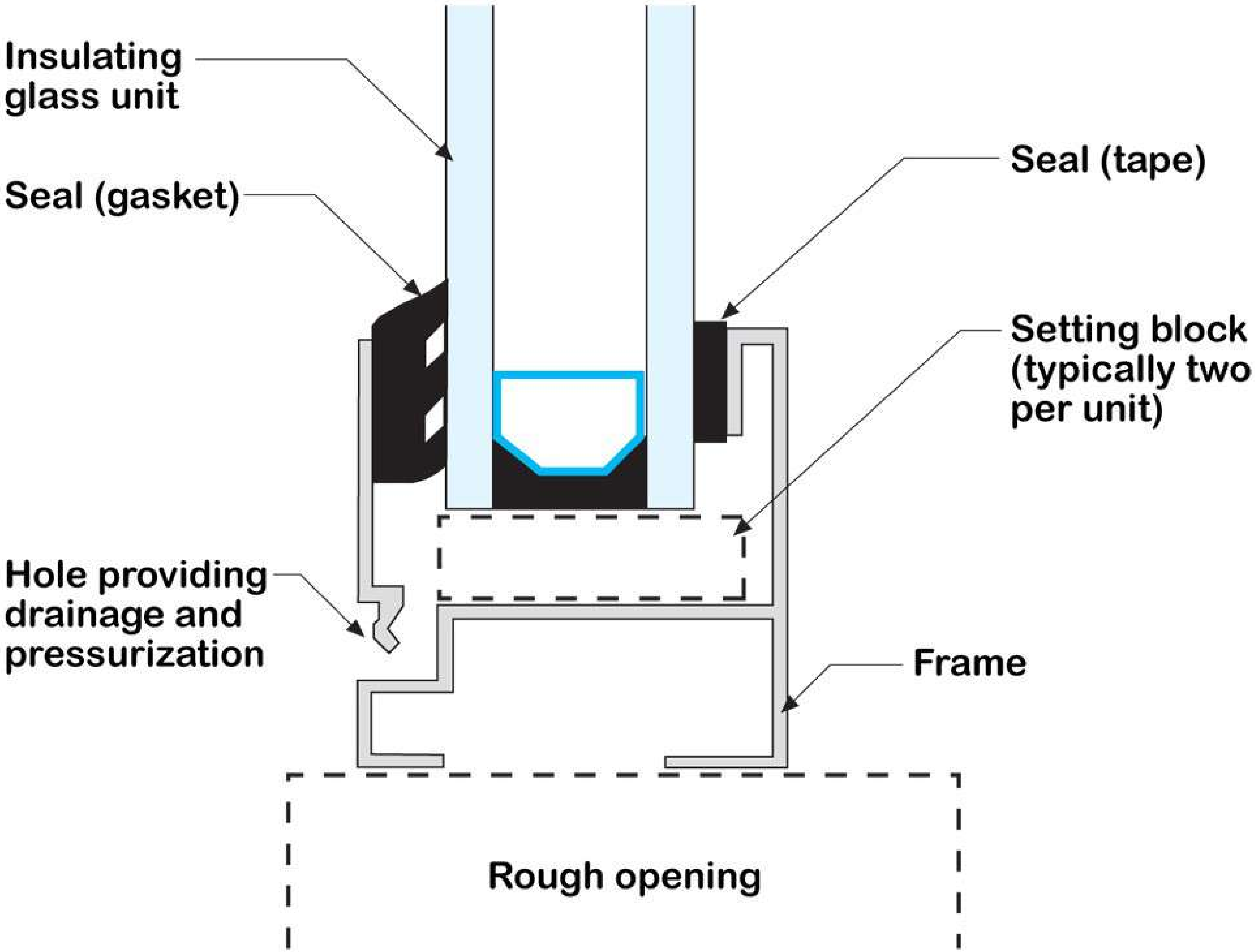


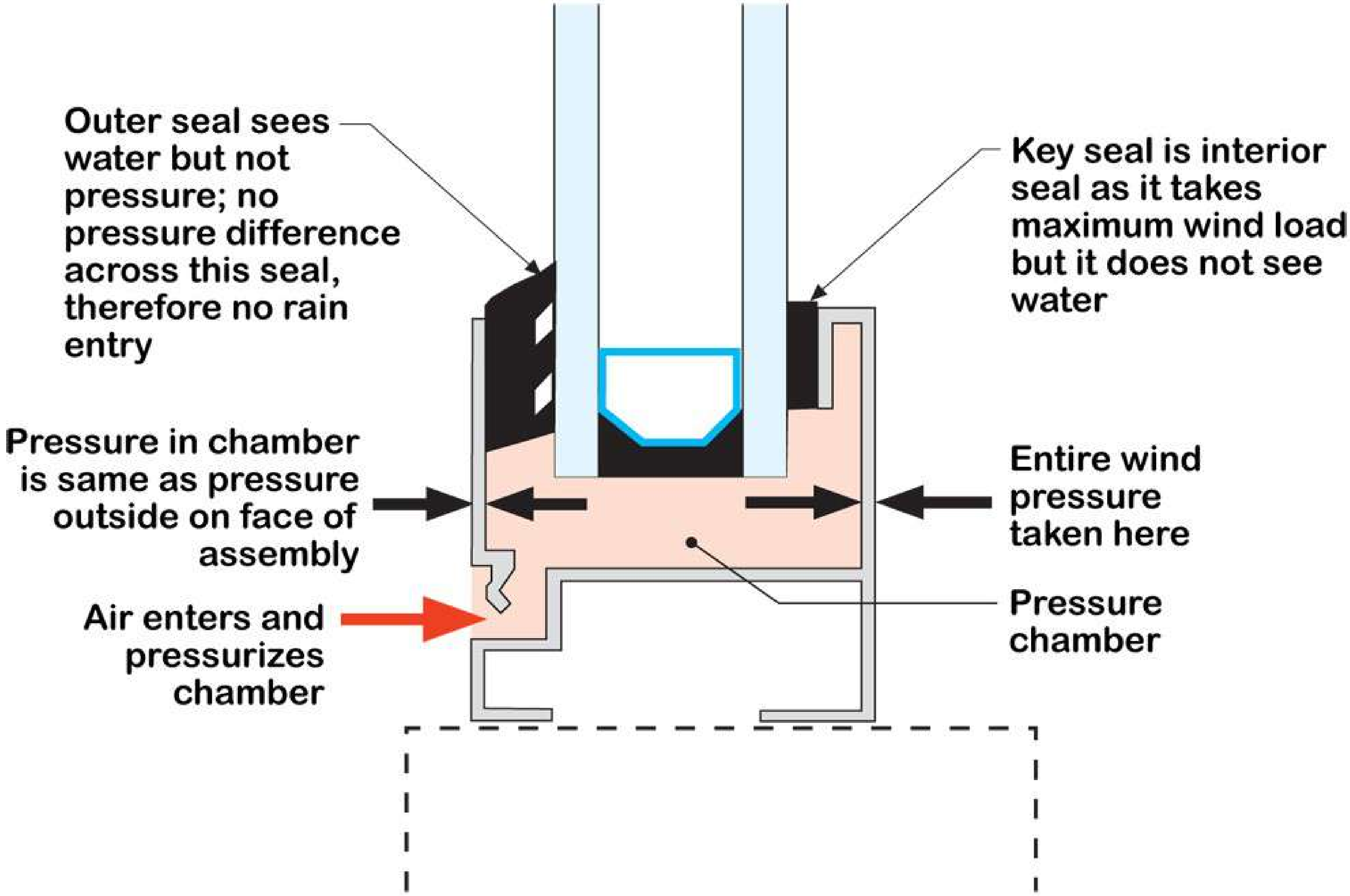

SKYTEC


Rain enters cup
due to momentum
("kinetic energy")
Cup drains water
to exterior

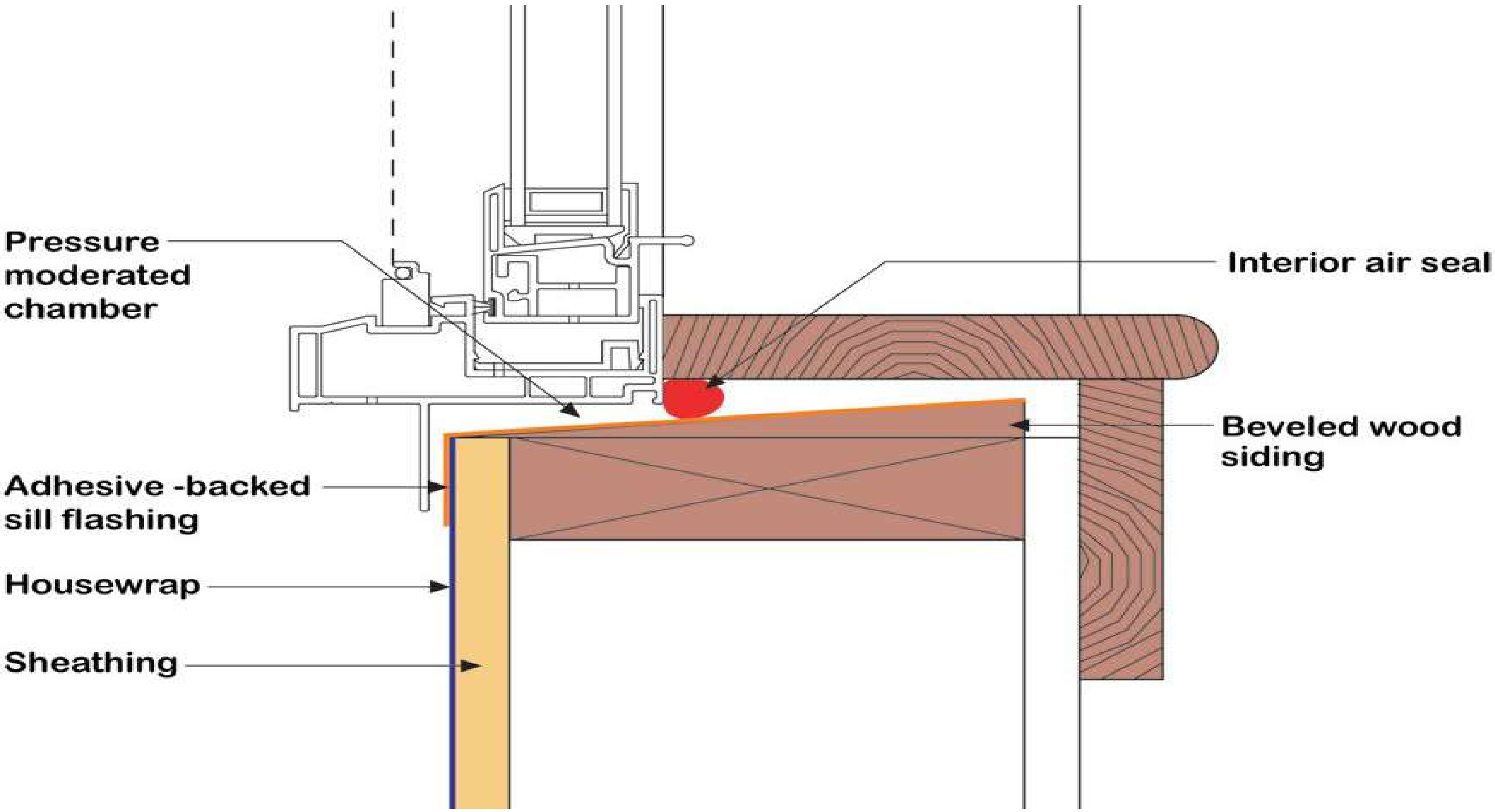

Rain enters cup due to momentum ("kinetic energy")
Wind enters cup—pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior


Baffle to deflect raindrops hitting face of cup due to momentum ("kinetic energy")
Pressure in cup is same as pressure outside on face of baffle
Momentum driving force converted to gravity— water drains away
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

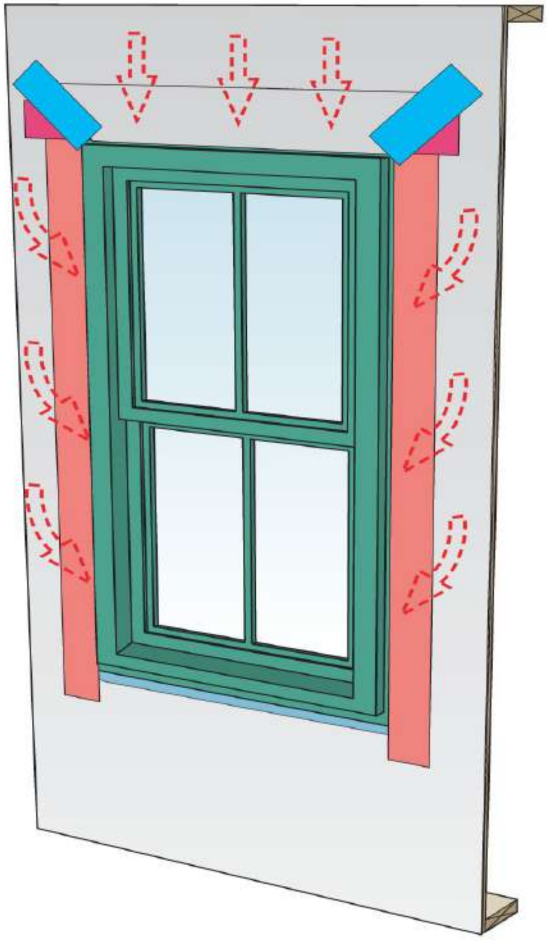

Insulating glass unit
Seal (gasket)
Seal (tape)
Setting block (typically two per unit)
Hole providing drainage and pressurization
Frame
Rough opening

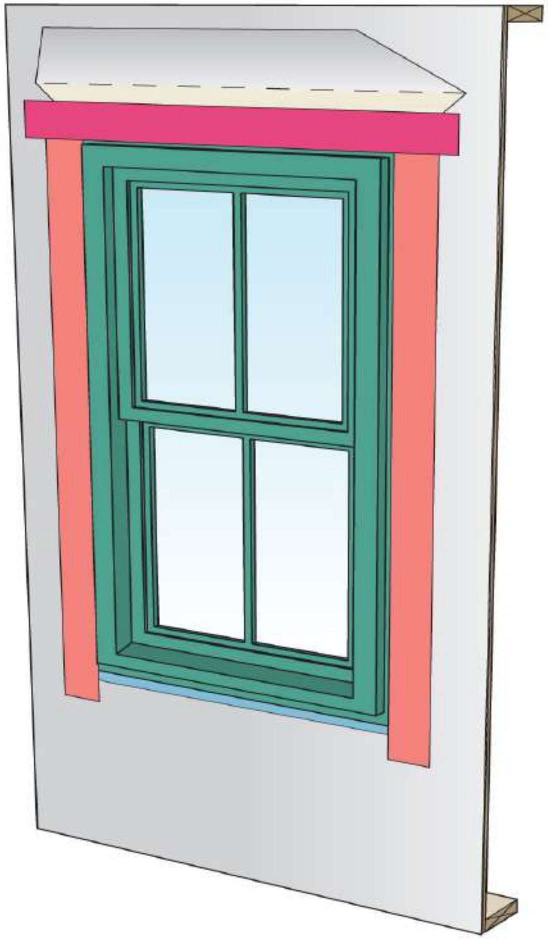


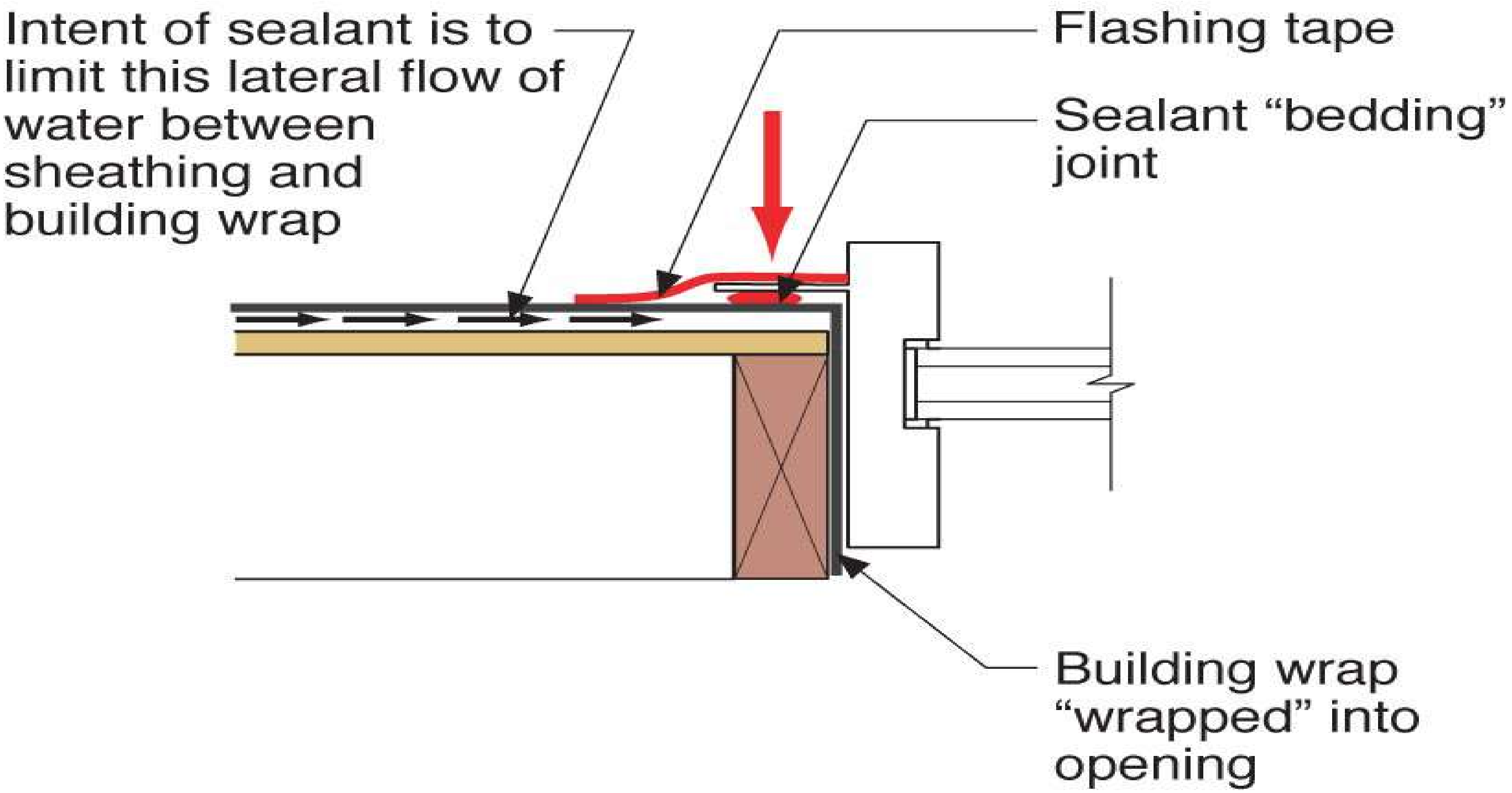
Outer seal sees water but not pressure; no pressure difference across this seal, therefore no rain entry
Key seal is interior seal as it takes maximum wind load but it does not see water
Pressure in chamber is same as pressure outside on face of assembly
Entire wind pressure taken here
Air enters and pressurizes chamber
Pressure chamber

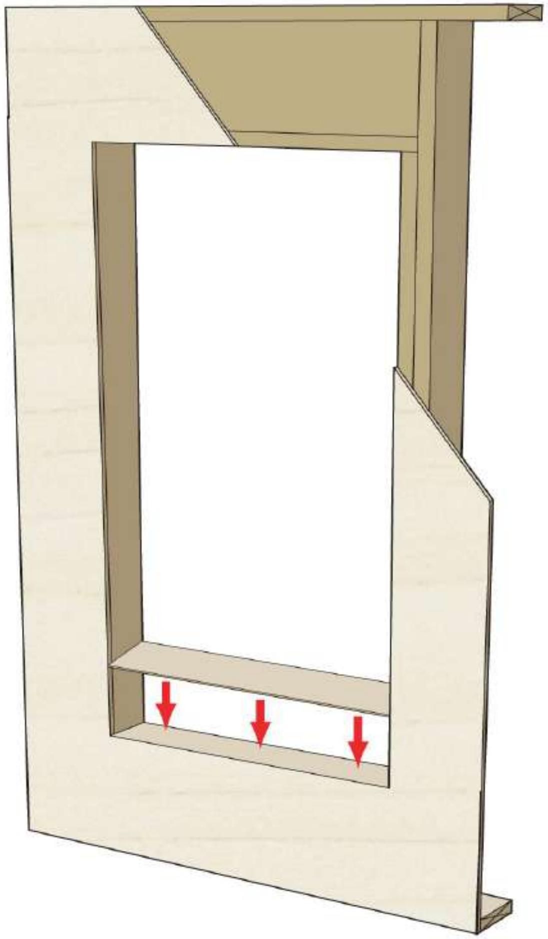

Pressure moderated chamber
Interior air seal
Beveled wood siding
Adhesive -backed sill flashing
Housewrap
Sheathing

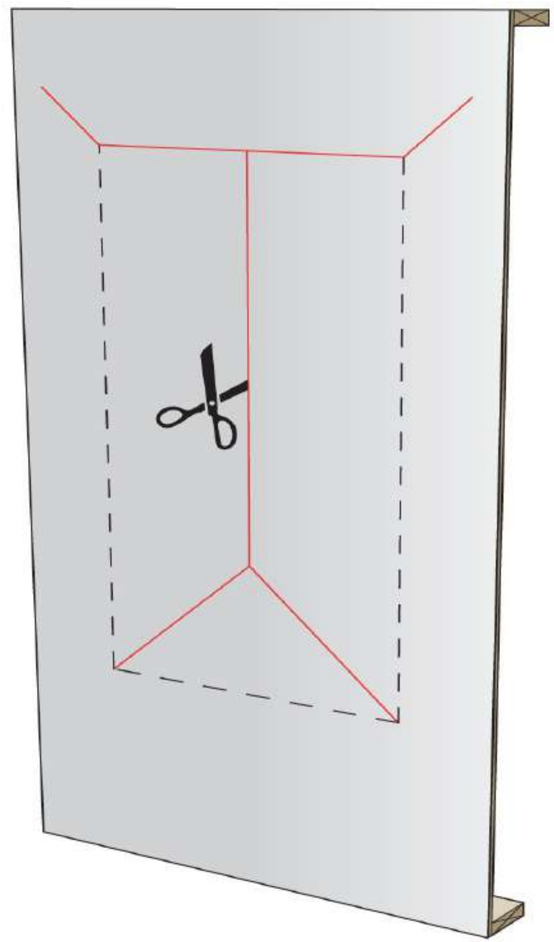

DOW
Styrofoam

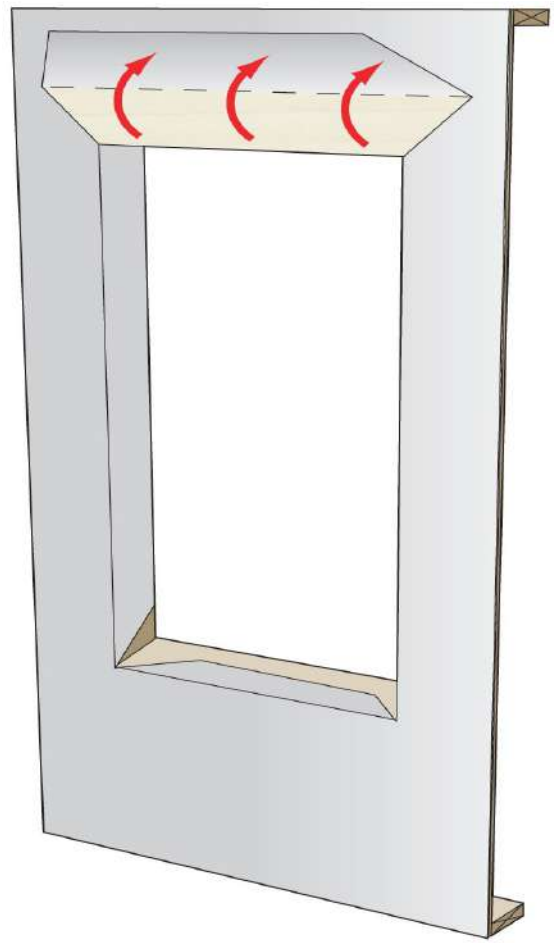


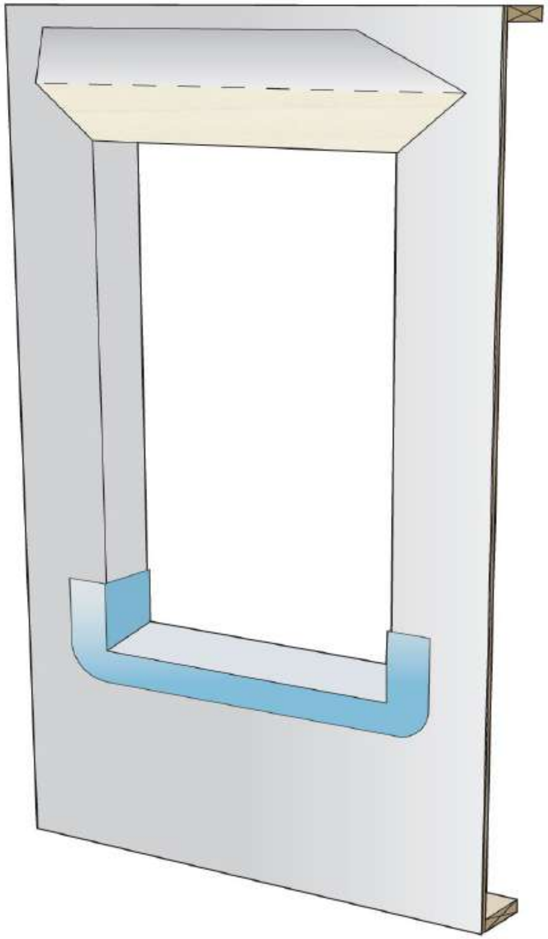


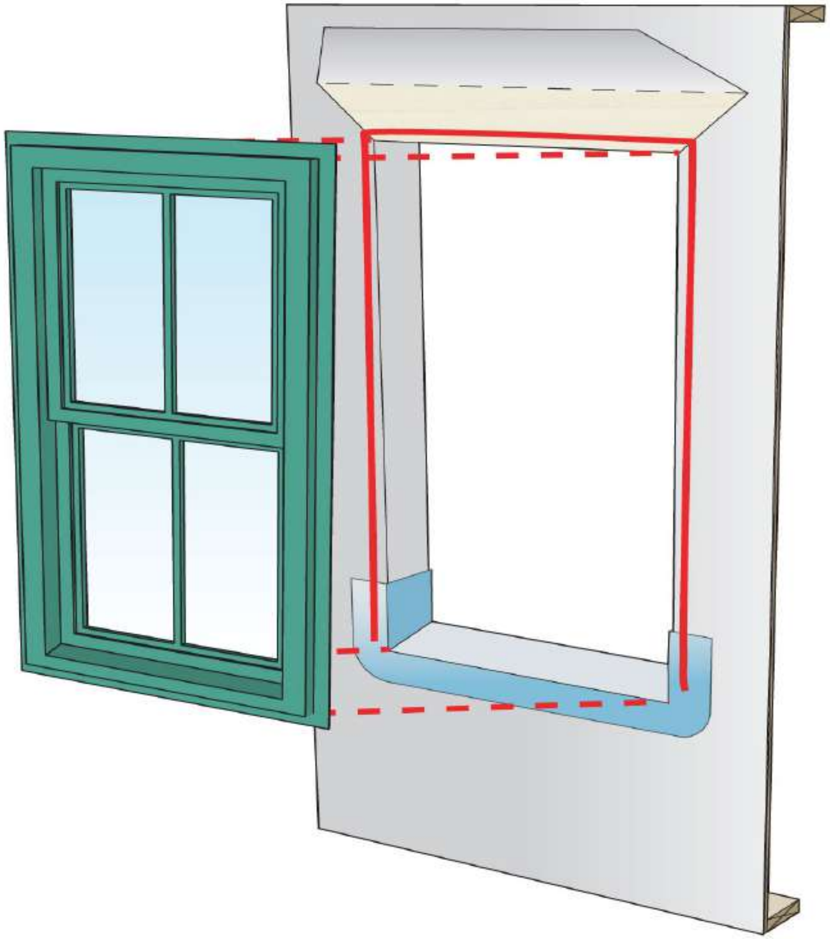

Intent of sealant is to limit this lateral flow of water between sheathing and building wrap
Flashing tape
Sealant "bedding" joint
Building wrap "wrapped" into opening

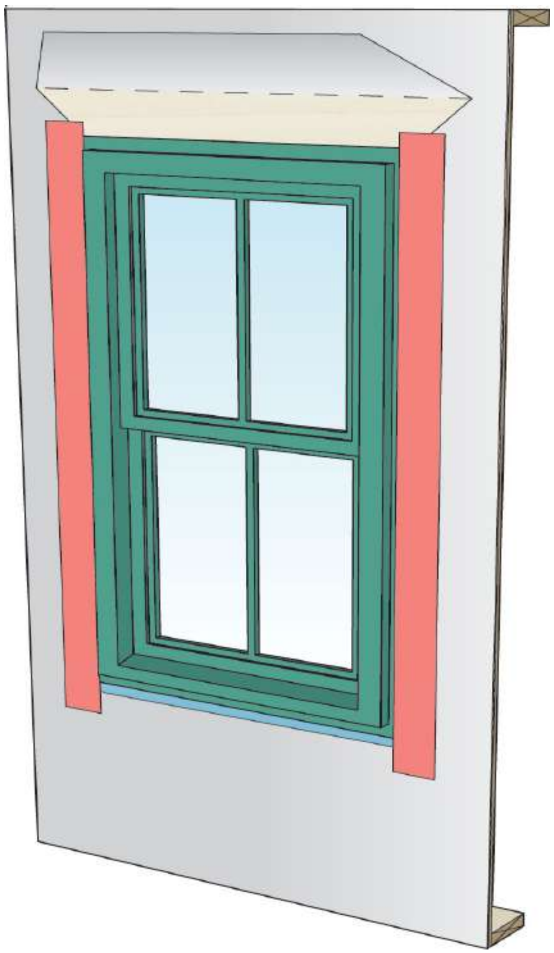


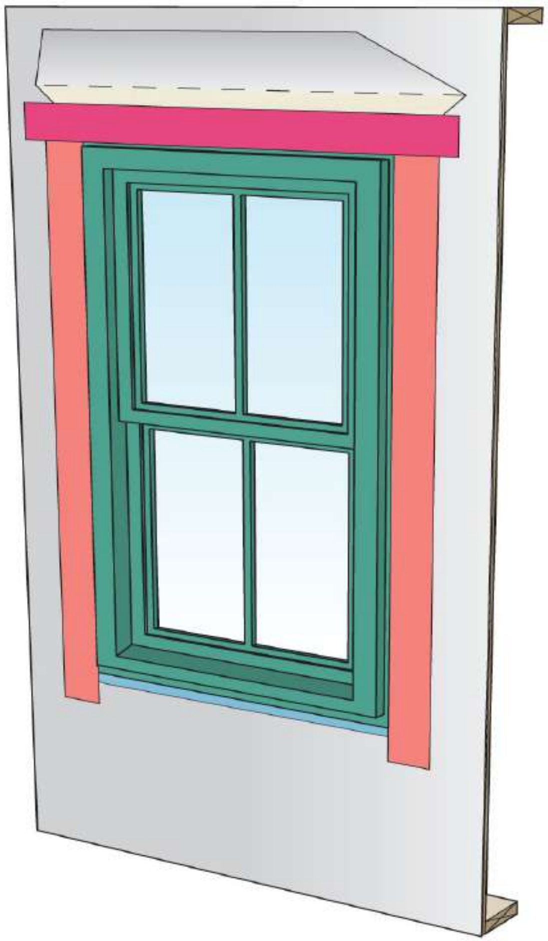


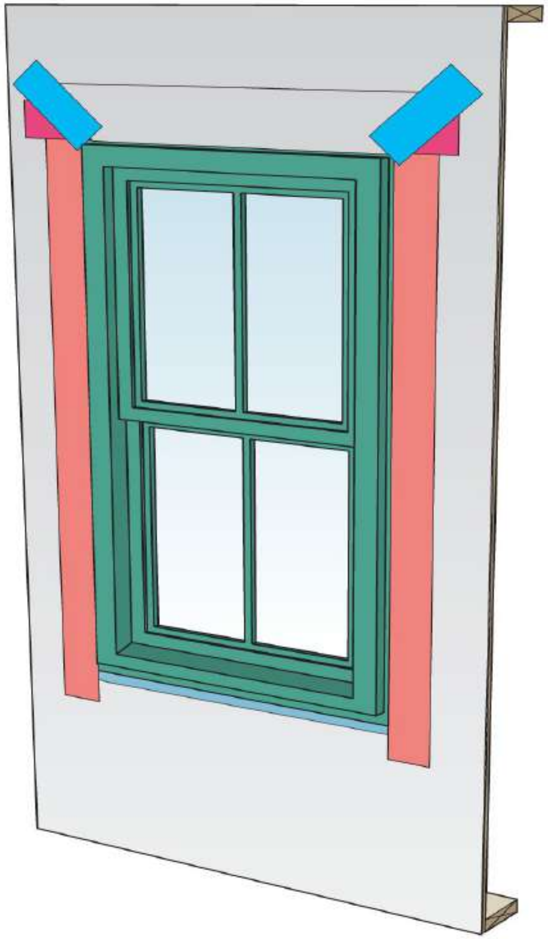


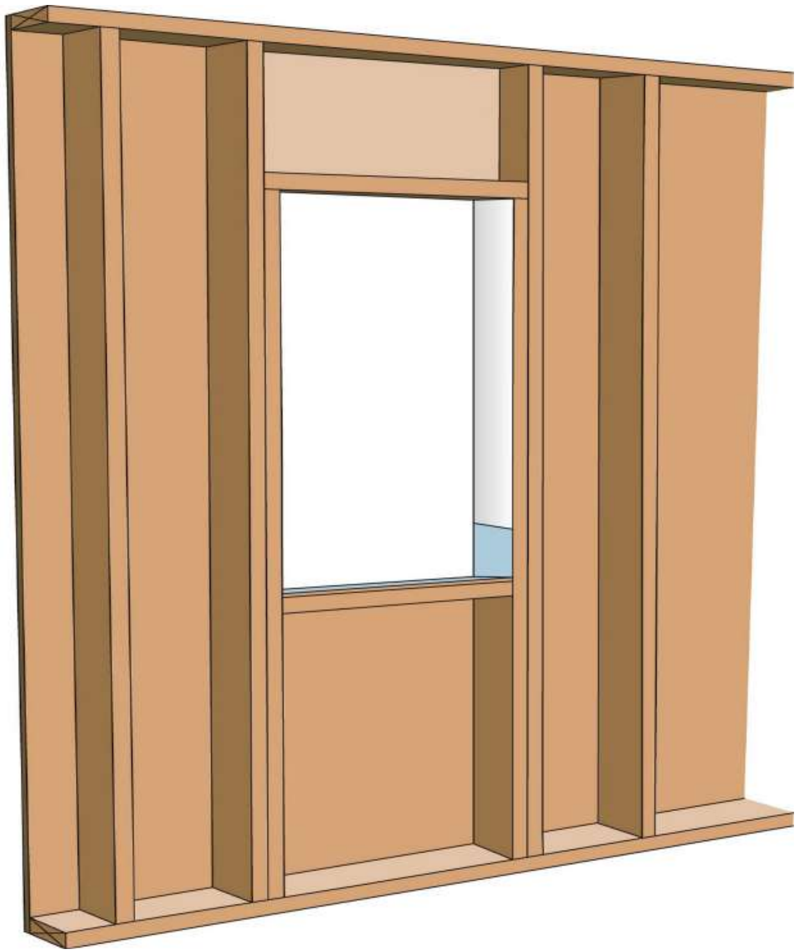


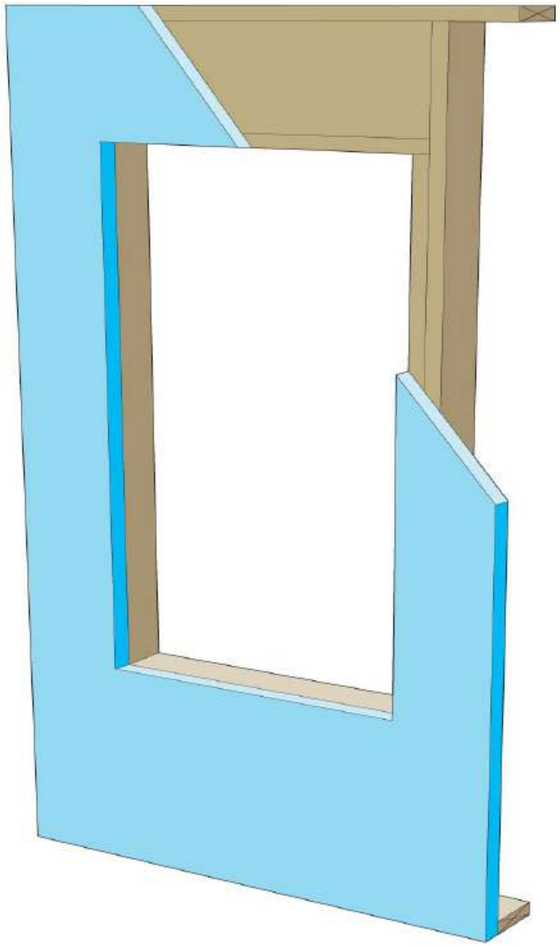


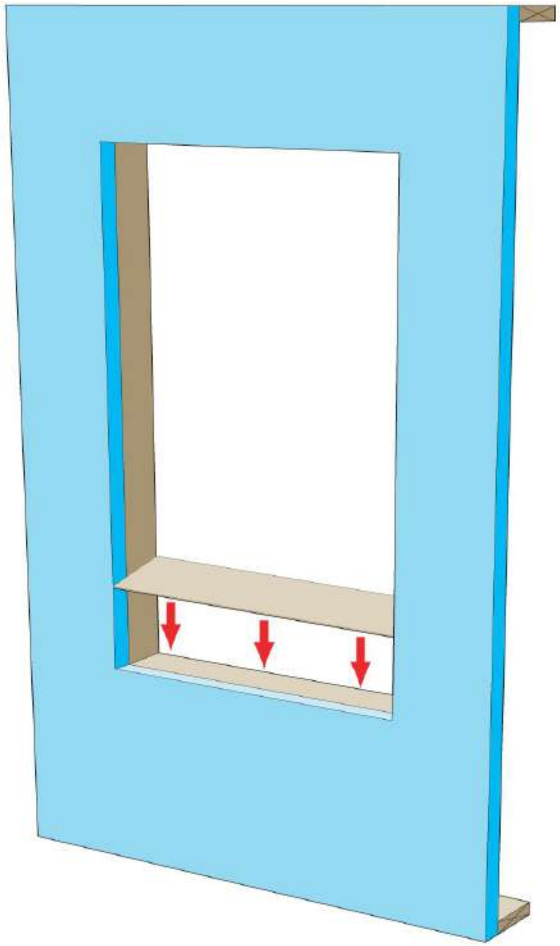


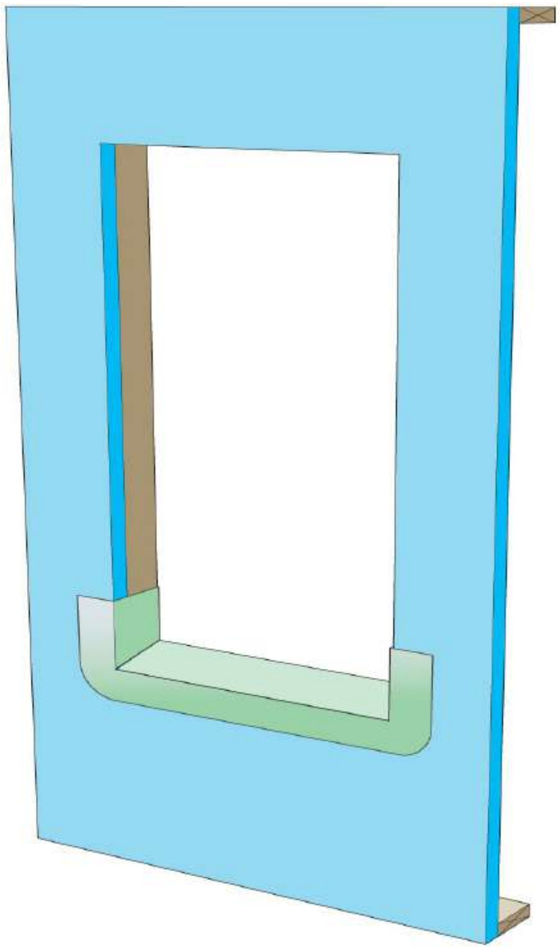


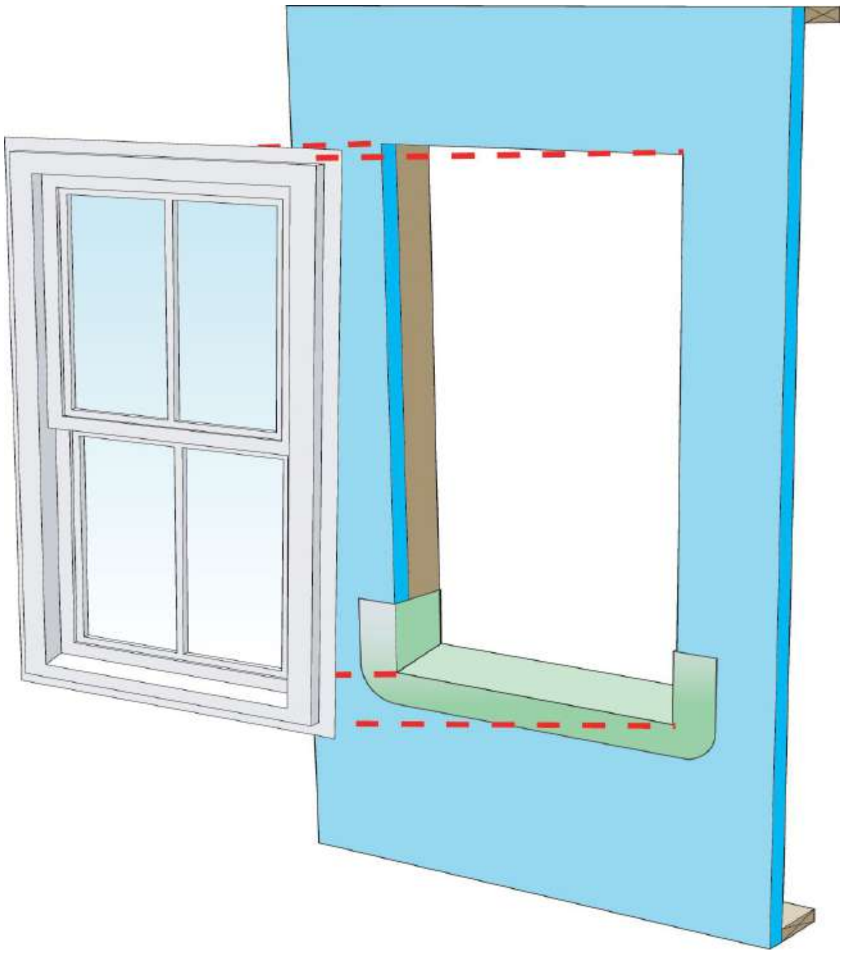


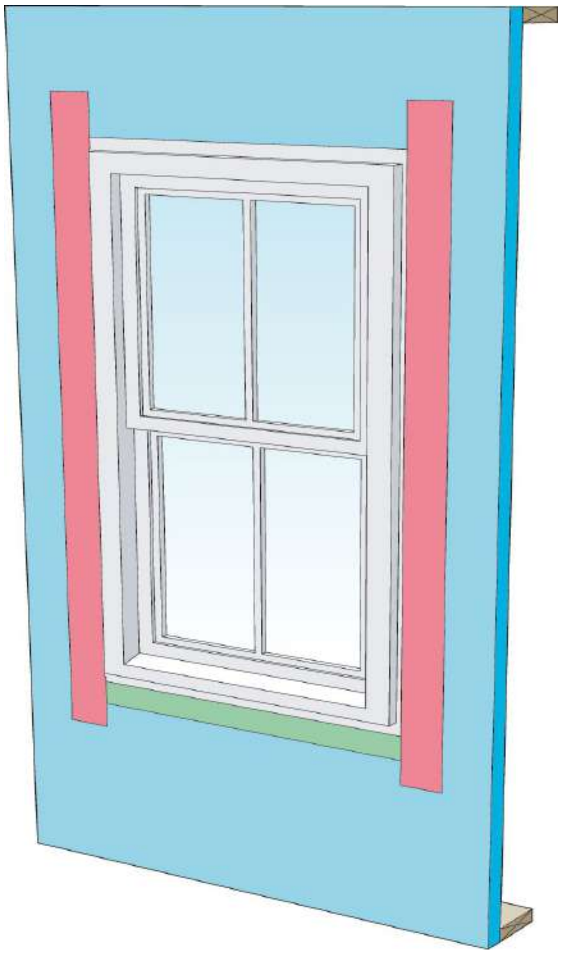


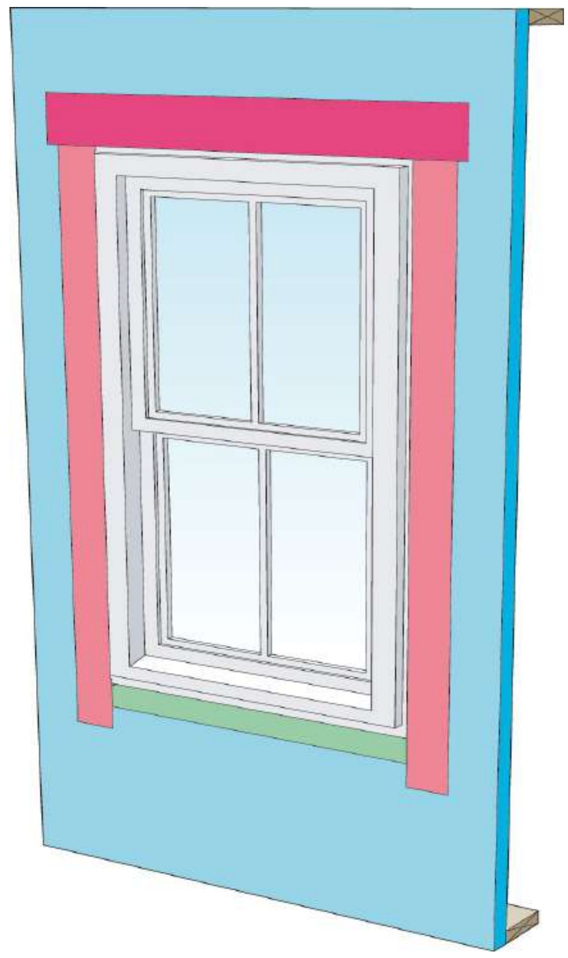


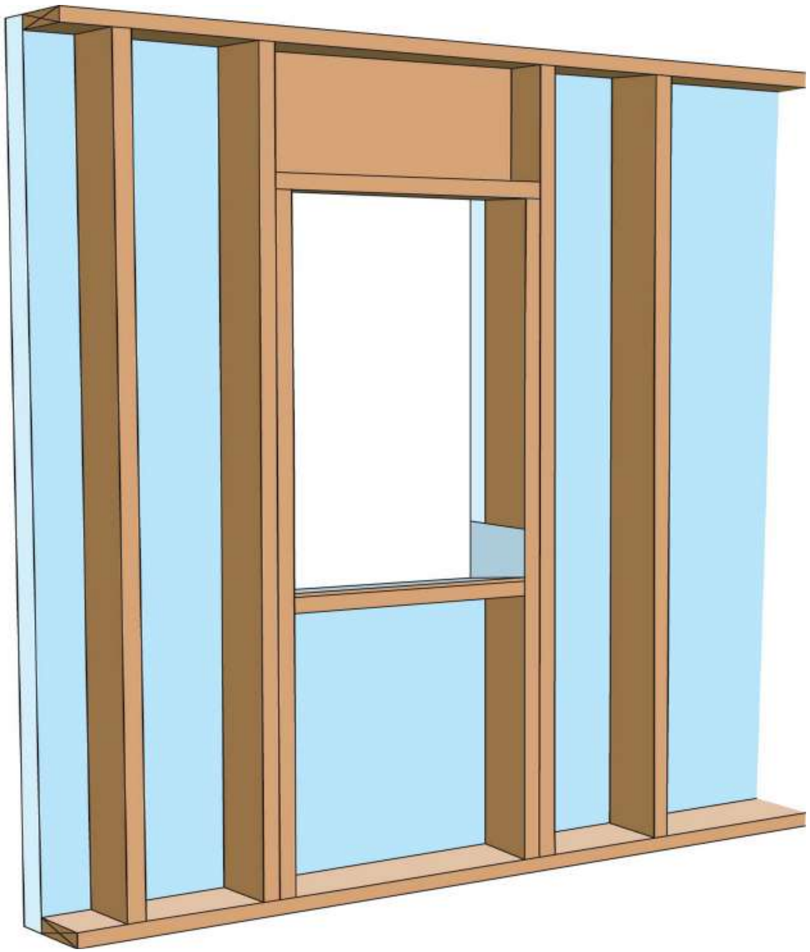


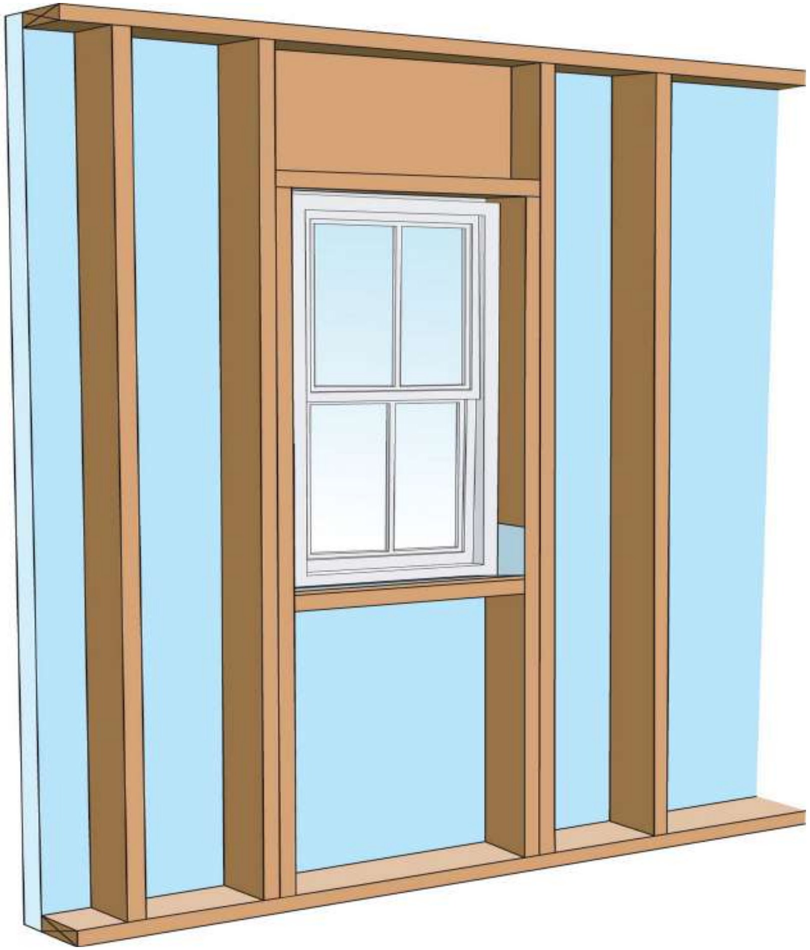


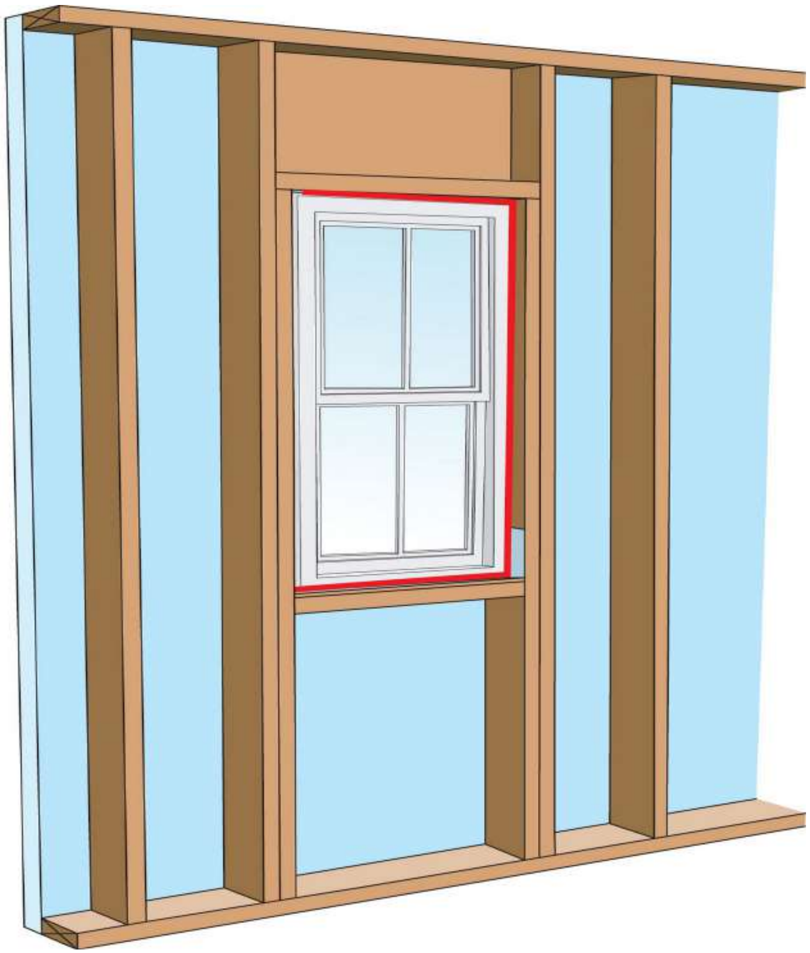


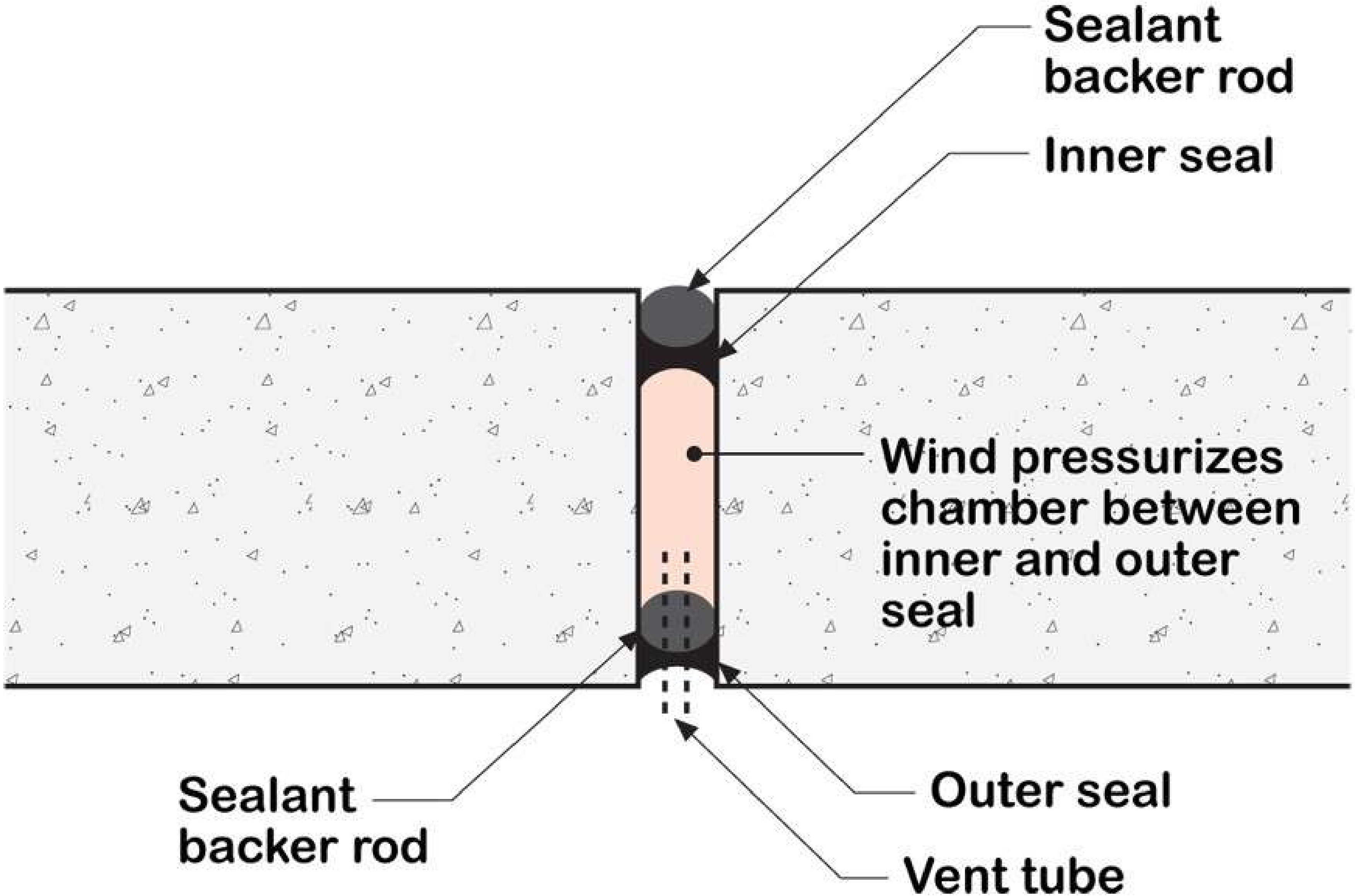


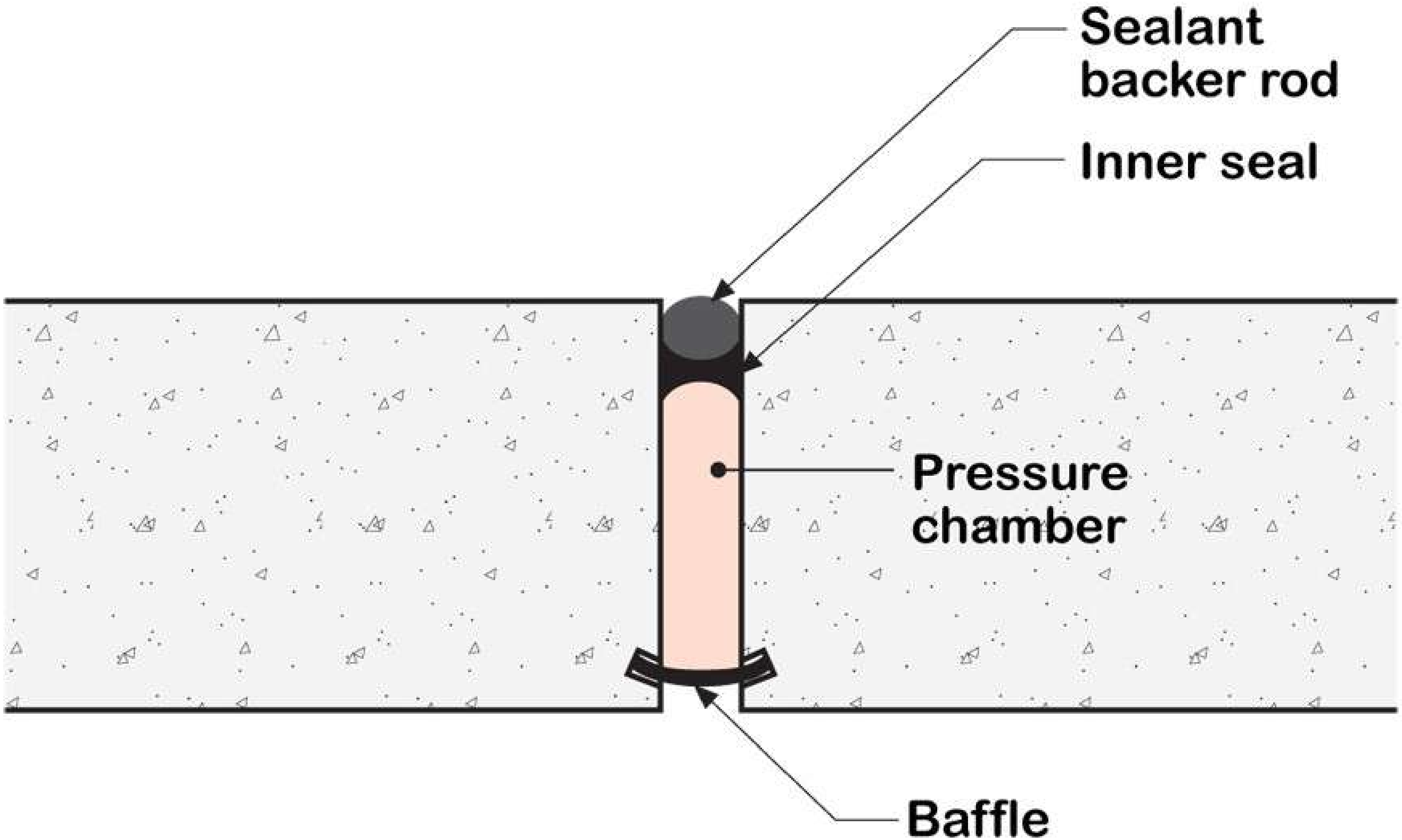


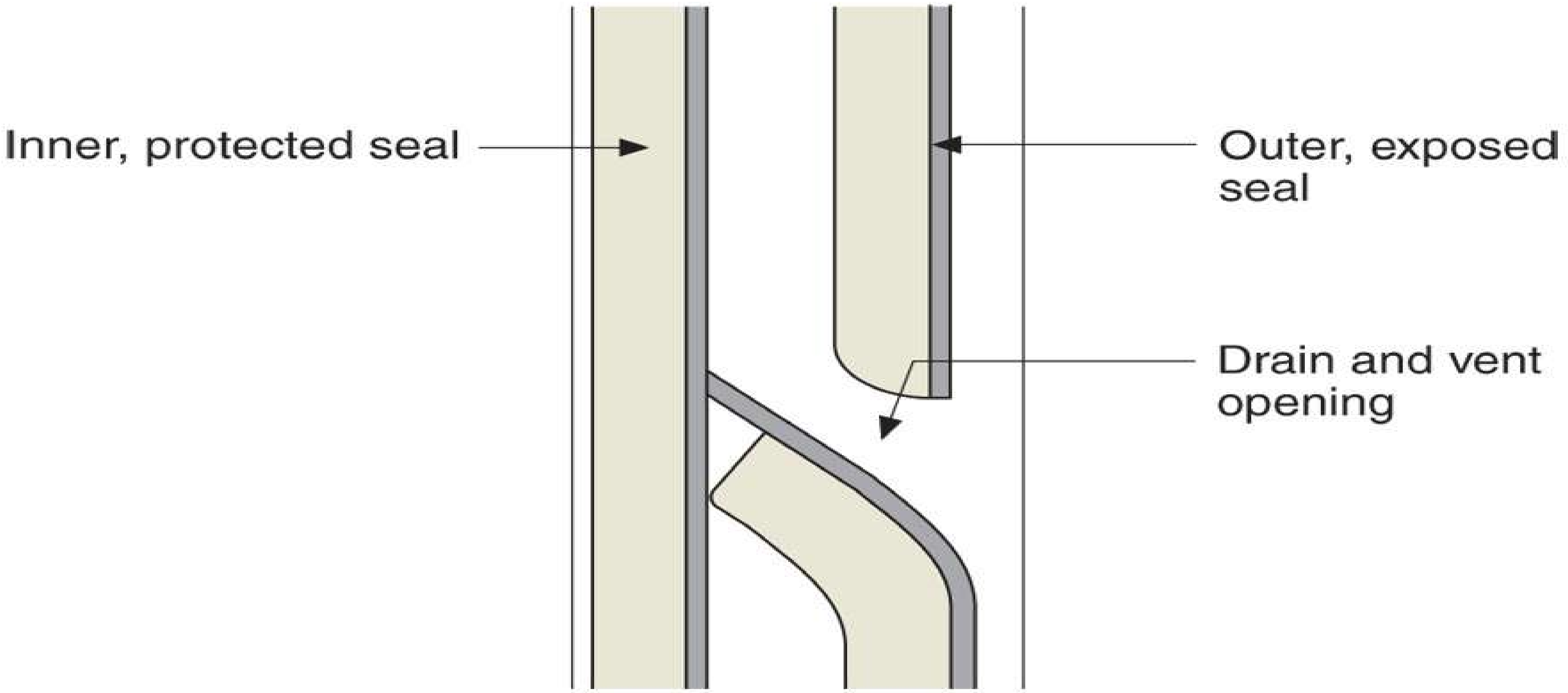


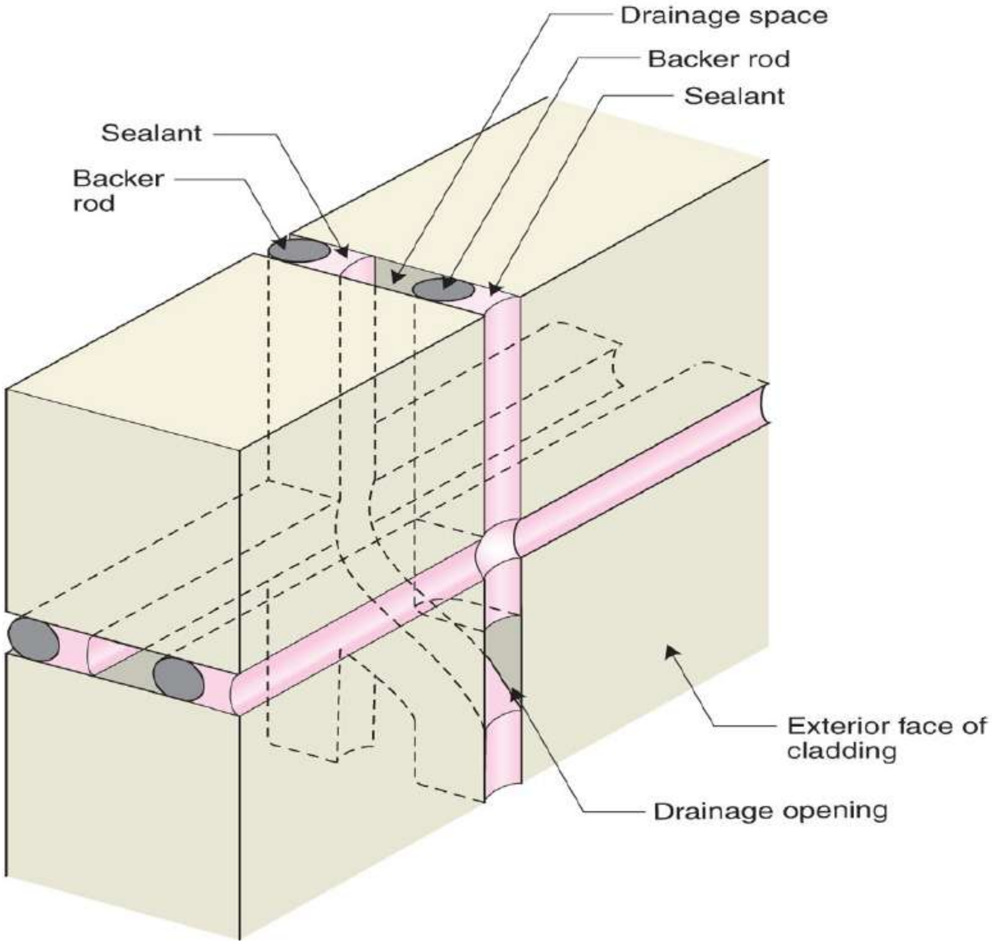





Sealant
backer rod
Inner seal
Wind pressurizes
chamber between
inner and outer
seal
Sealant
backer rod
Outer seal
Vent tube


Sealant
backer rod
Inner seal
Pressure
chamber
Baffle

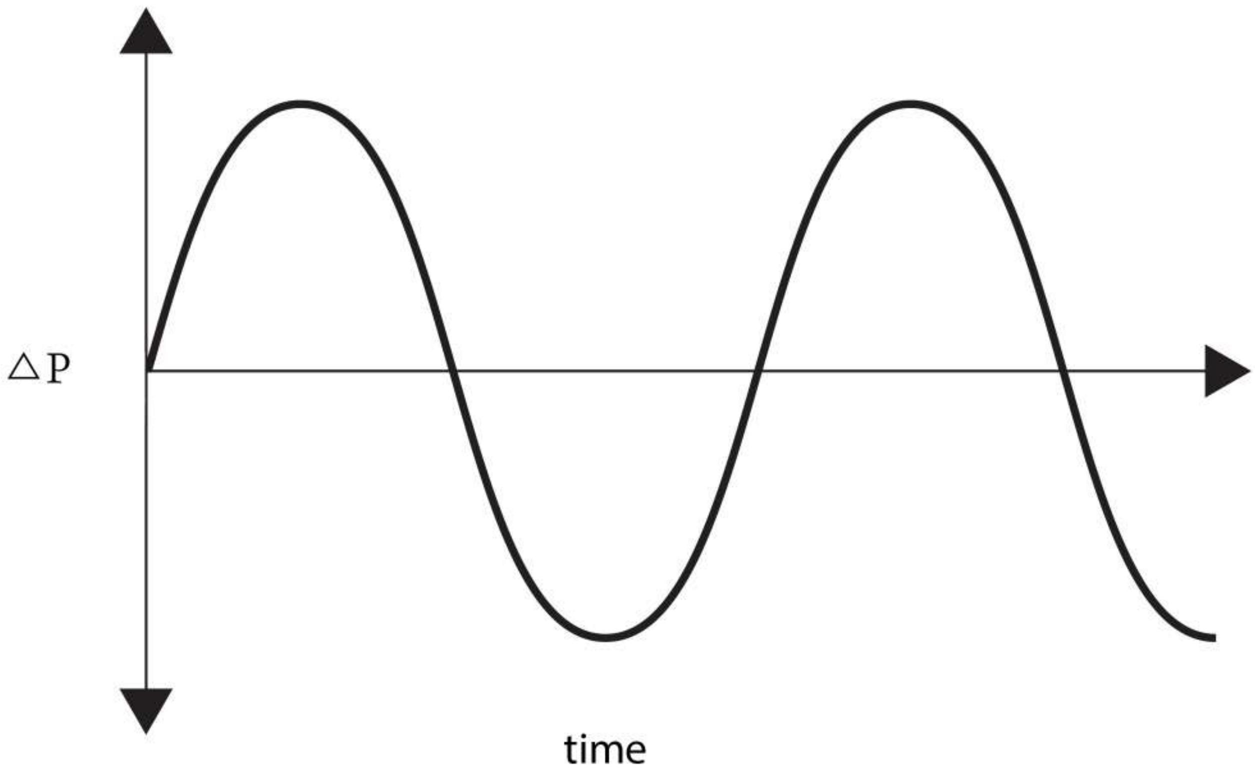

Inner, protected seal
Outer, exposed seal
Drain and vent opening


Drainage space
Backer rod
Sealant
Sealant
Backer rod
Exterior face of cladding
Drainage opening

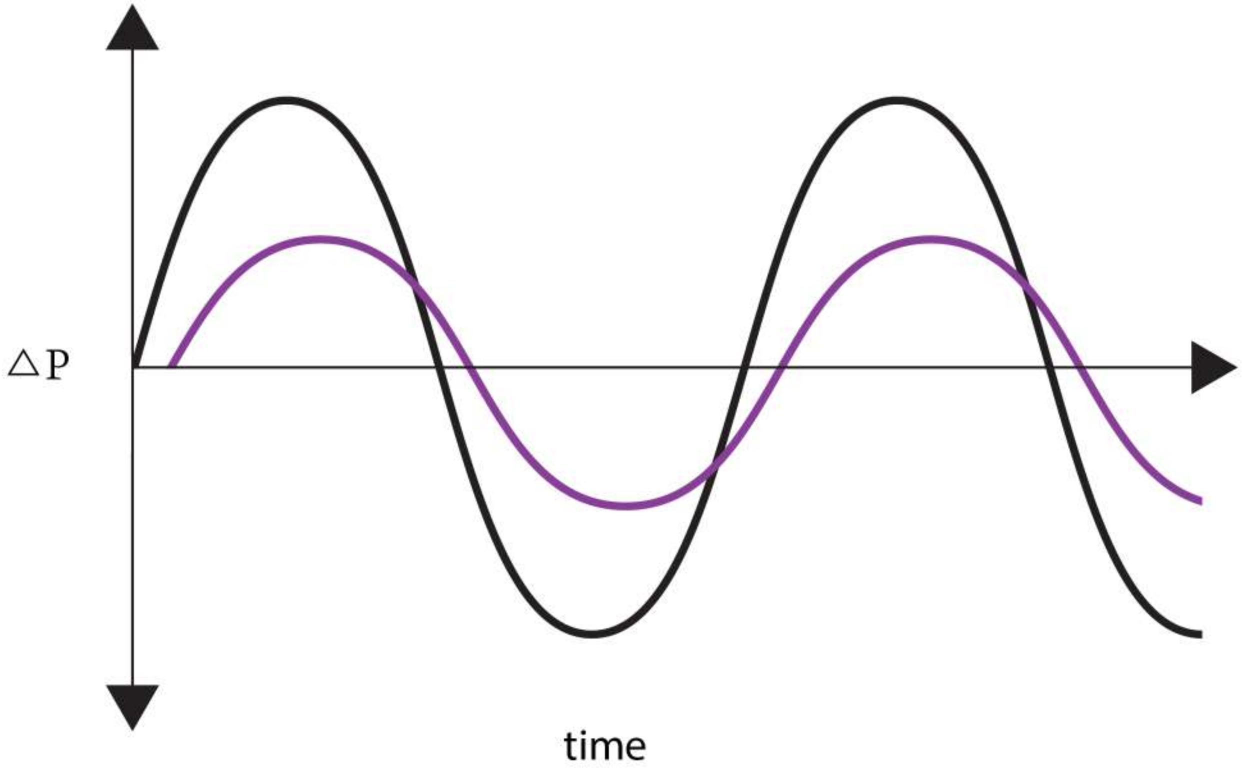
# Open Joints vs Closed Joints

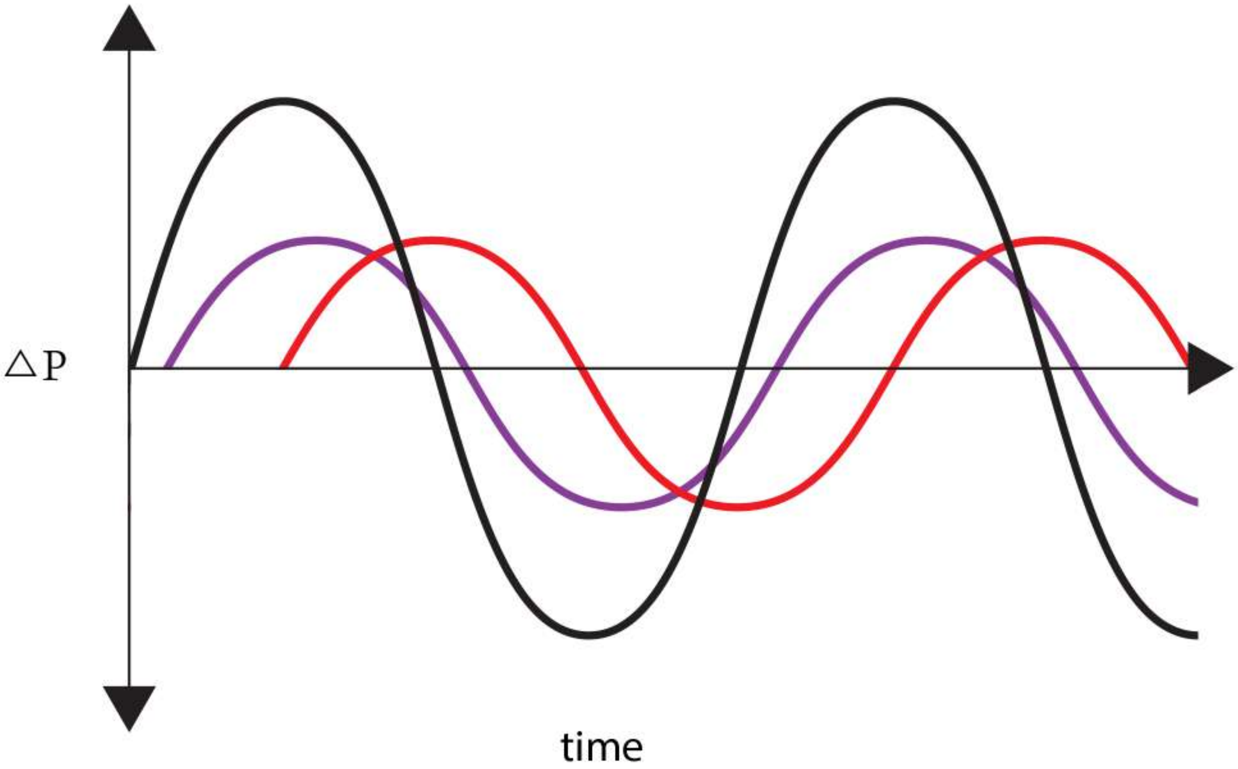
Open Joints vs Closed Joints

Limits of Pressure Equalization



△P
time


△P
time


△P
time

Pressure Equalization Needs to be Perfect

Pressure Equalization Reduces Drying

Prevention of Wetting Is Not As Important As Drying

Assume Things Get Wet…Design Them to Dry

Ventilated Claddings Promote Drying

# Capillarity

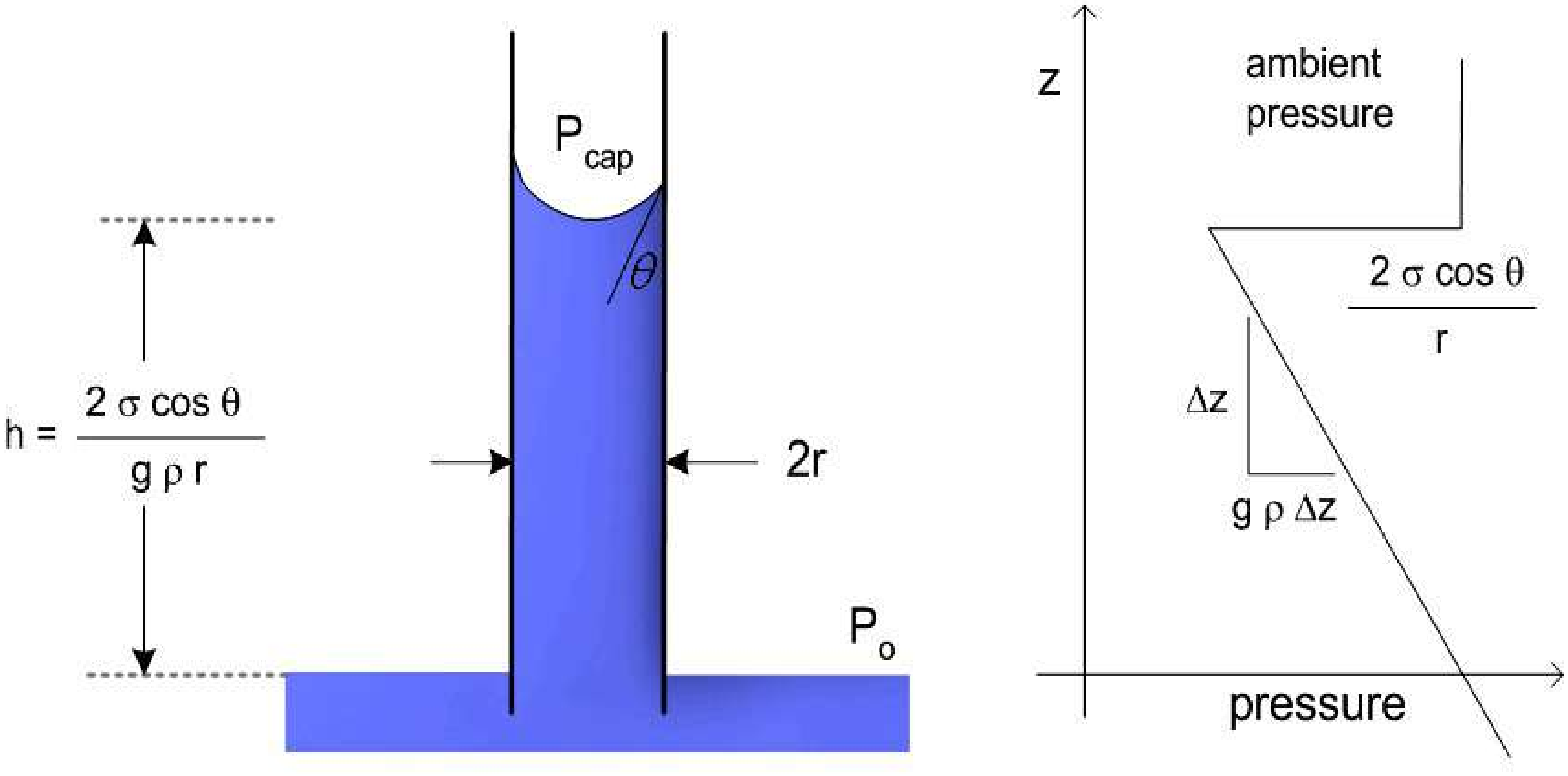
# William Thomson

# William Thomson – Lord Kelvin

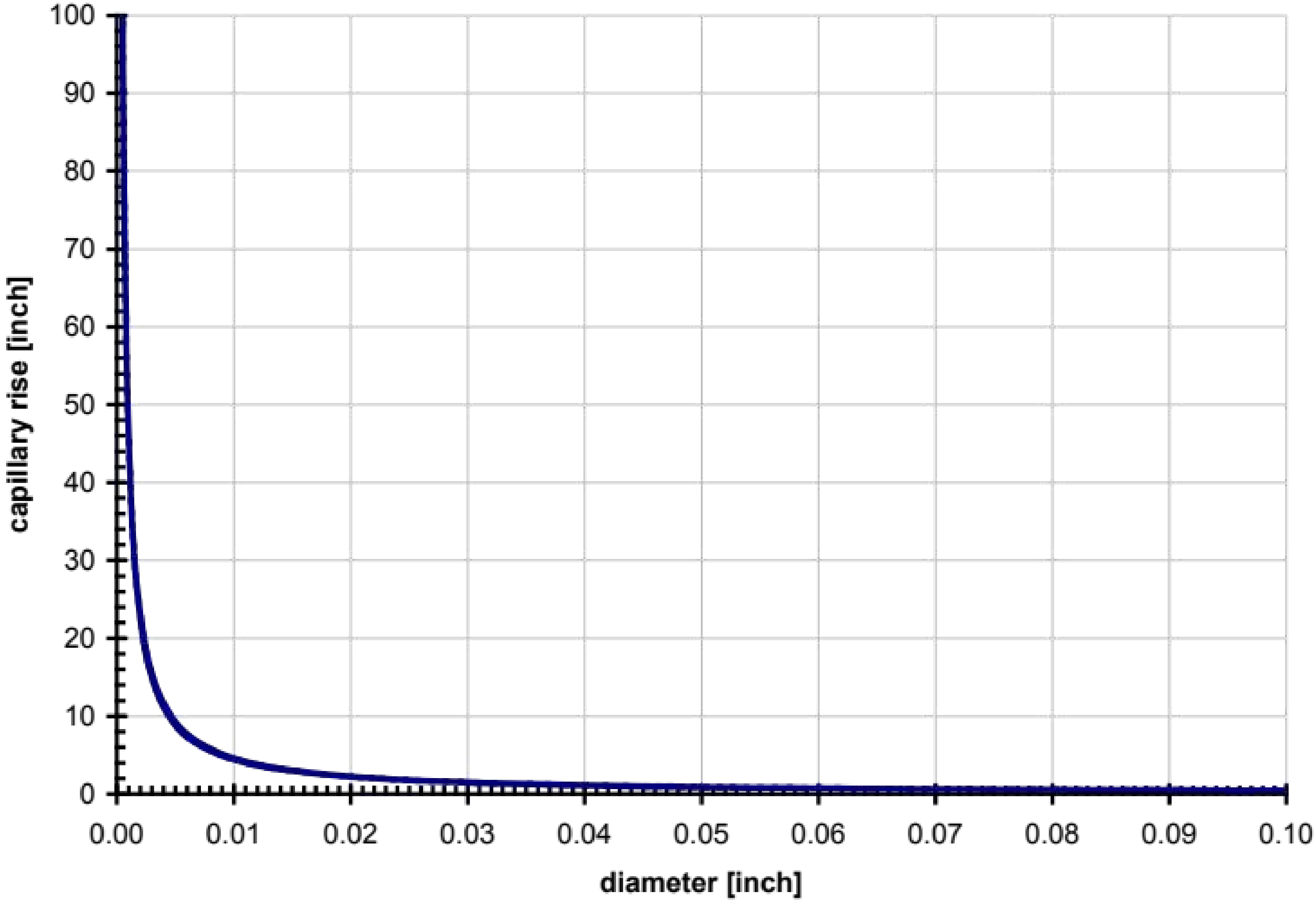
# Kelvin Equation

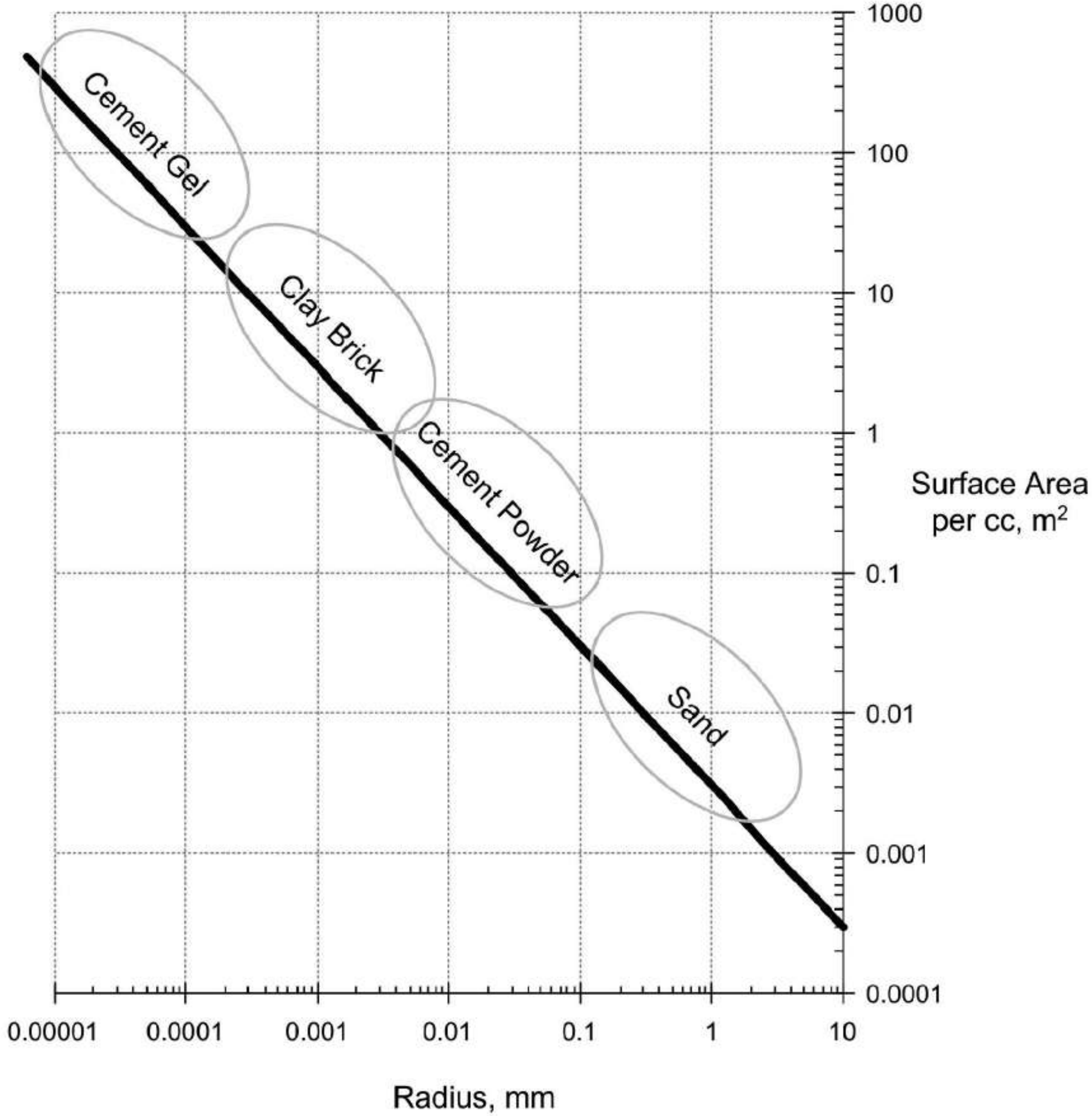
$$\ln \frac{p}{p_0} = \frac{2\gamma V_{\mathrm{m}}}{rRT}$$

# Calculating capillary rise



# Capillary rise versus diameter






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

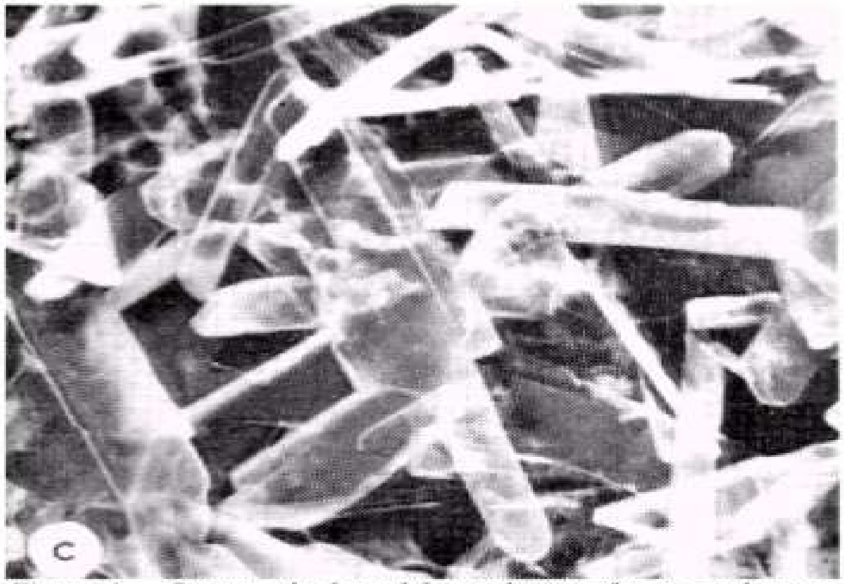



*Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.*

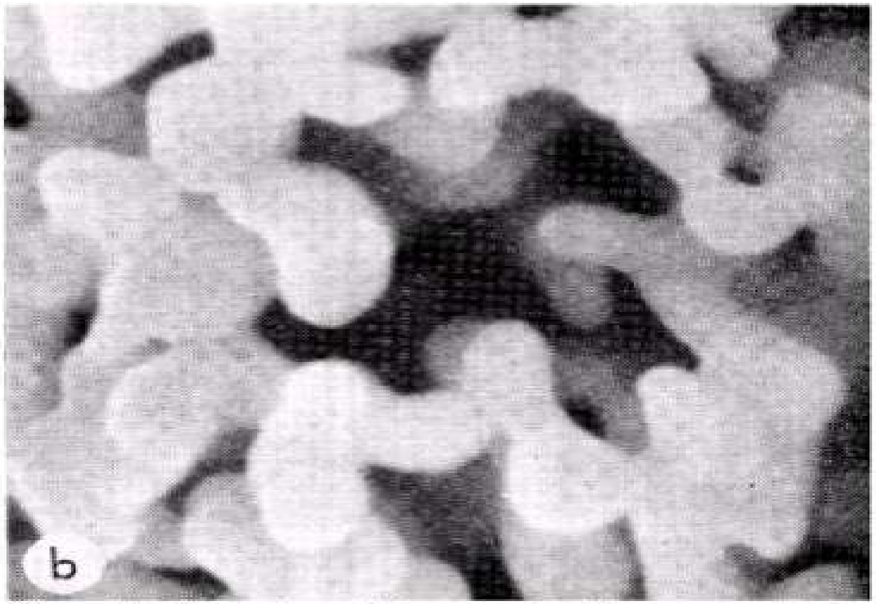
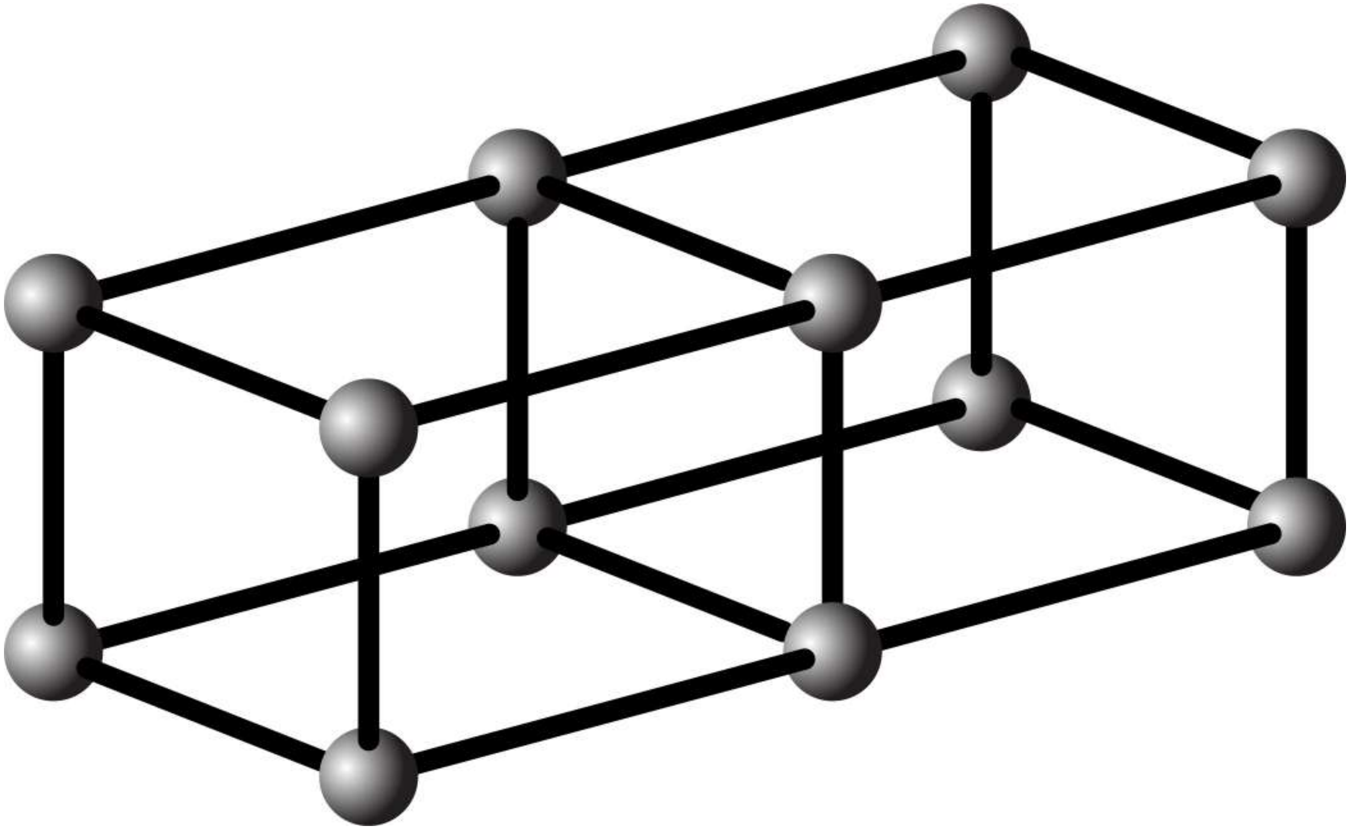
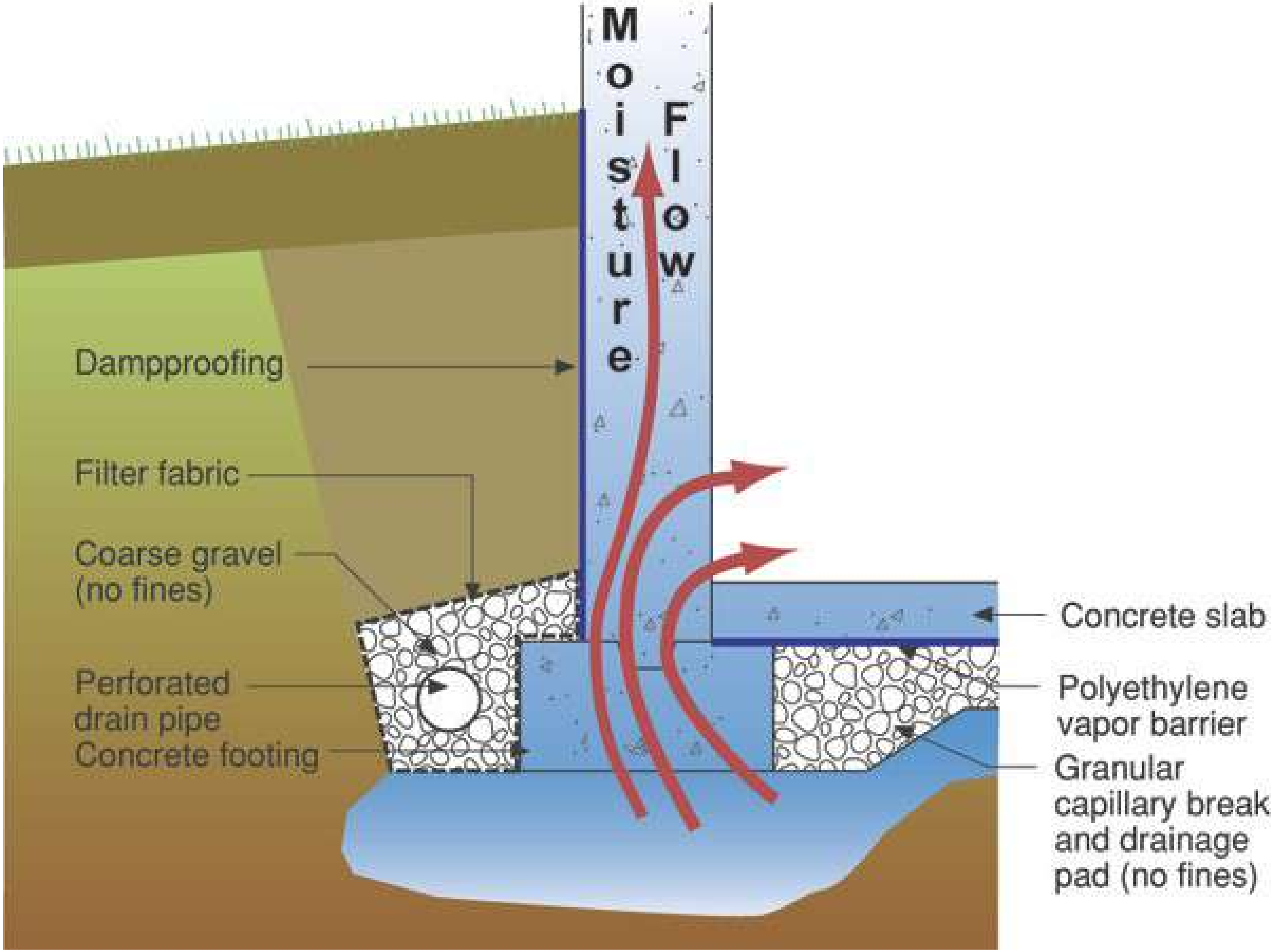
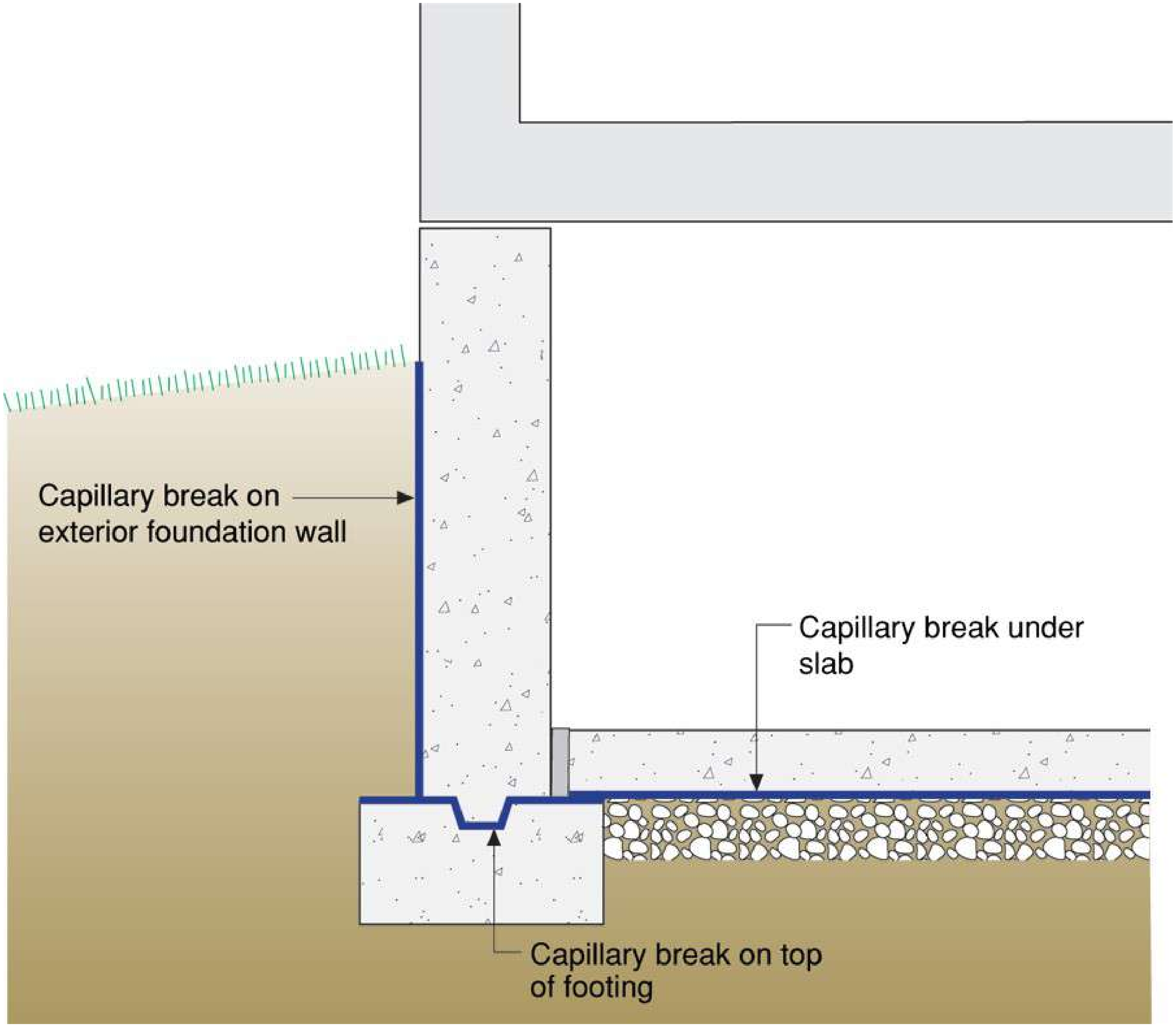


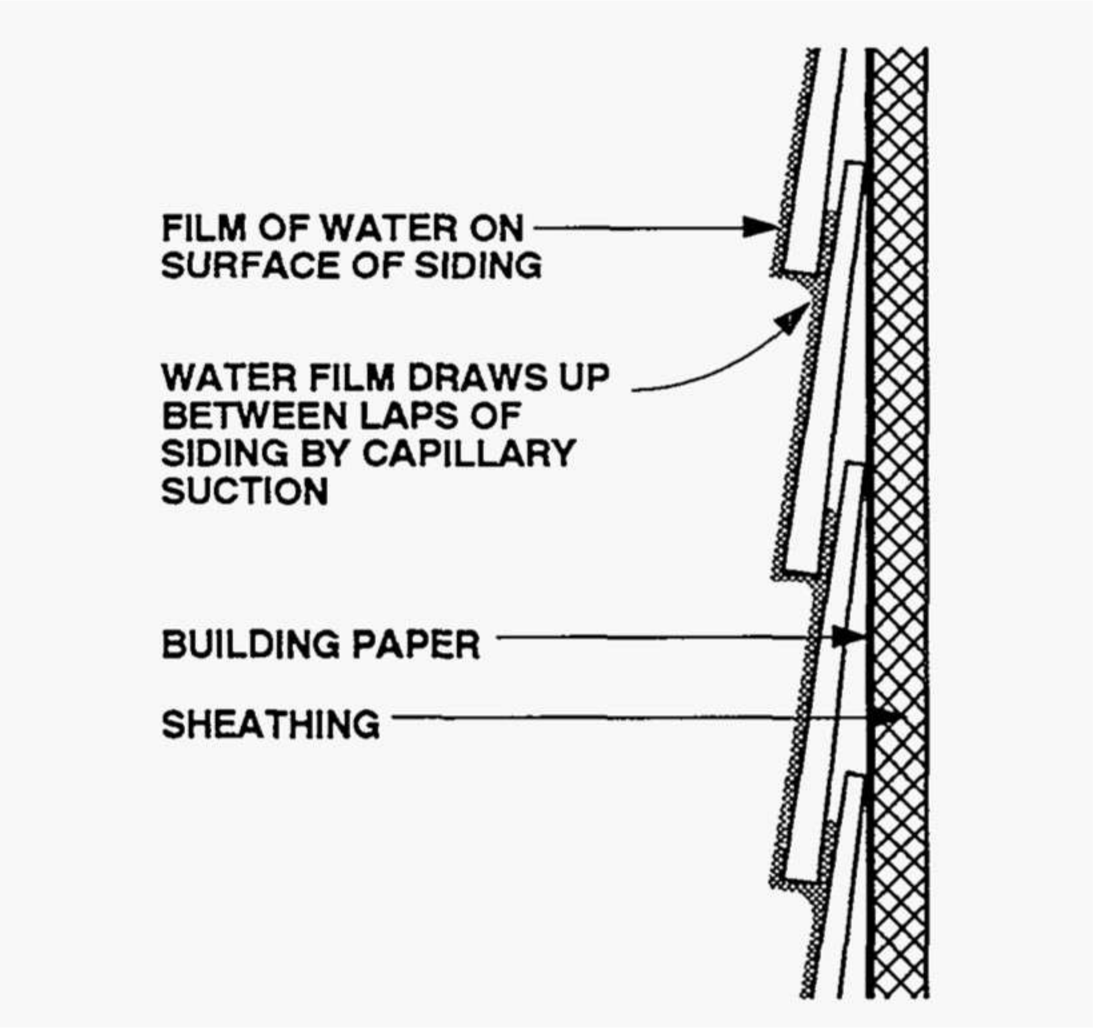

*Figure 1b. Brick, sintered clay, porosity 40 per cent.*

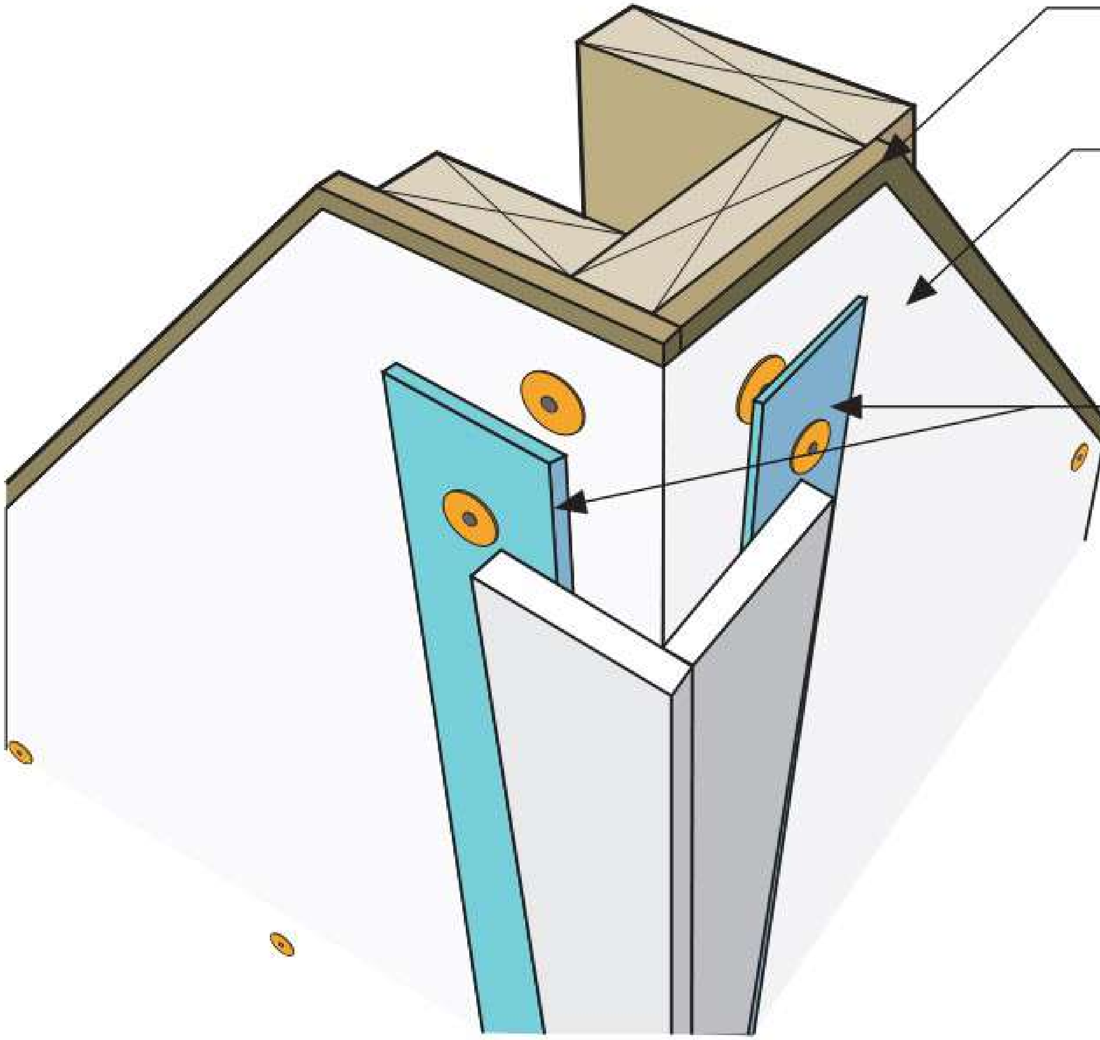


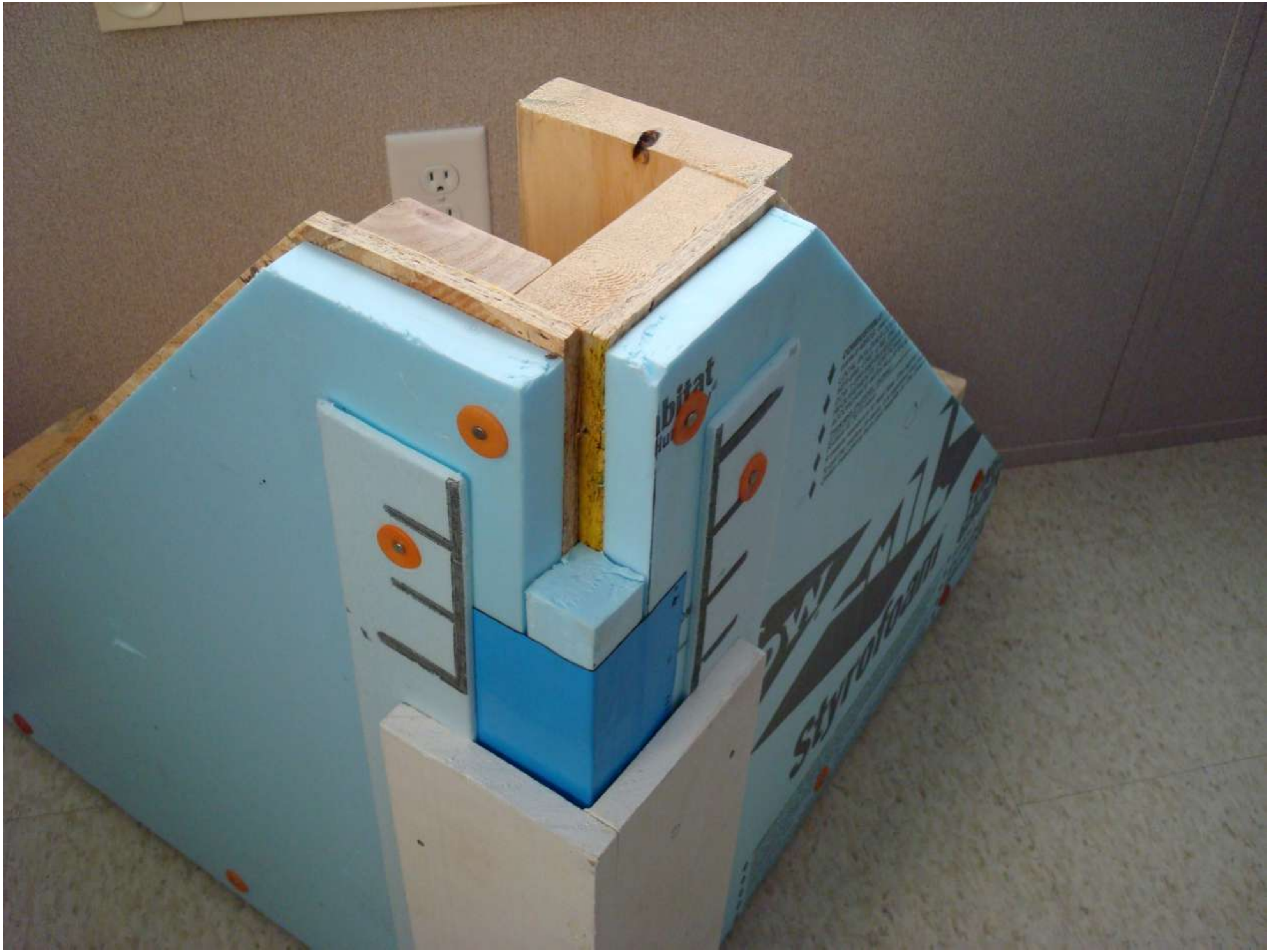

Moisture Flow
Dampproofing
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Concrete footing
Concrete slab
Polyethylene vapor barrier
Granular capillary break and drainage pad (no fines)


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

# Siding Laps

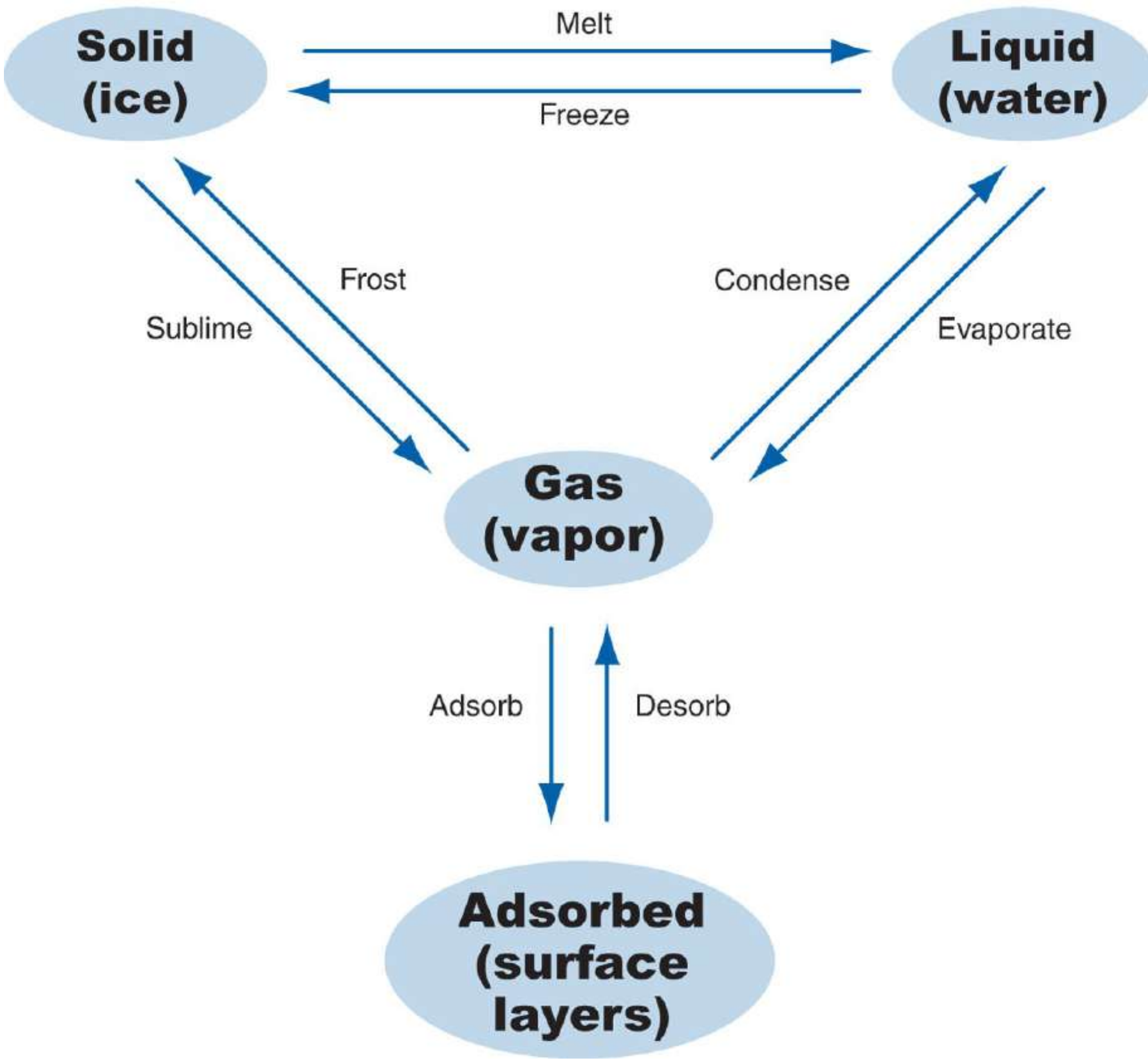

FILM OF WATER ON SURFACE OF SIDING
WATER FILM DRAWS UP BETWEEN LAPS OF SIDING BY CAPILLARY SUCTION
BUILDING PAPER
SHEATHING

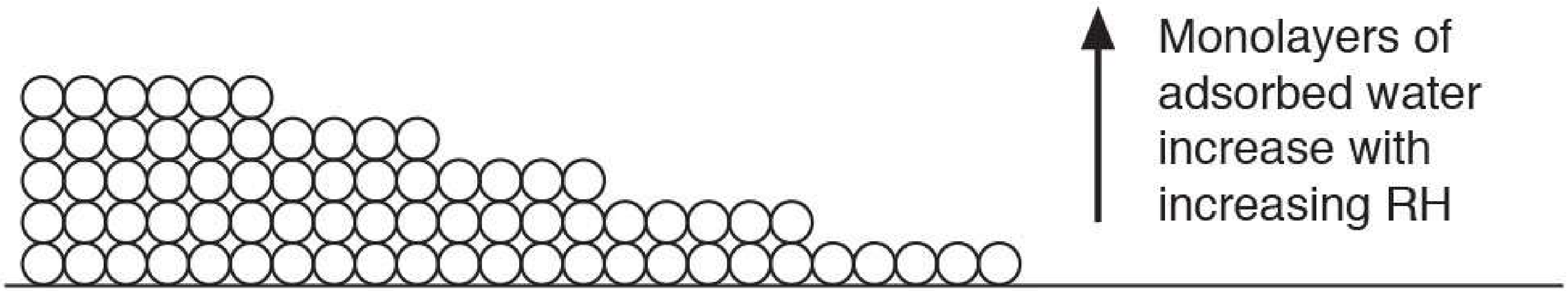

Plywood/OSB sheathing
Water control layer
$^3/_8$" spacer strip

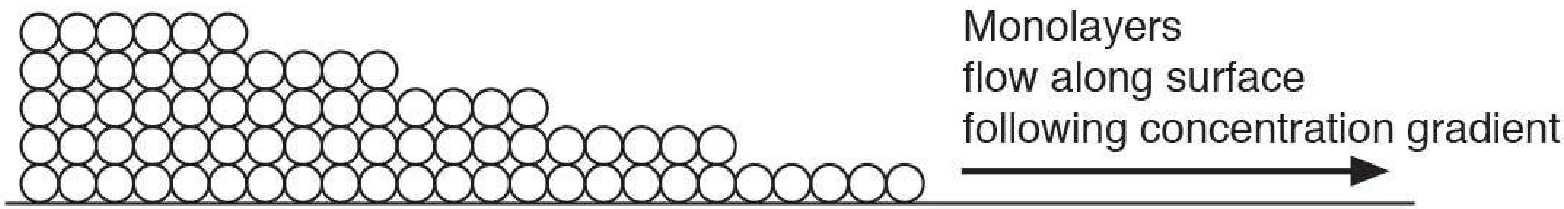


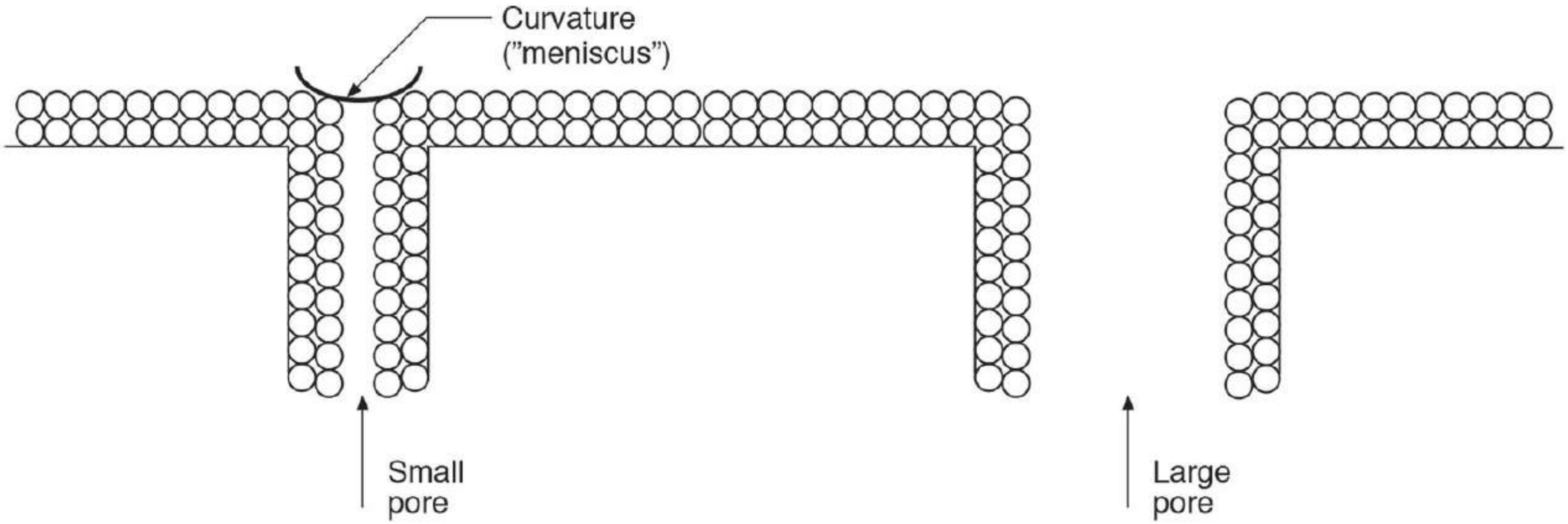
# Kelvin Equation Again….

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

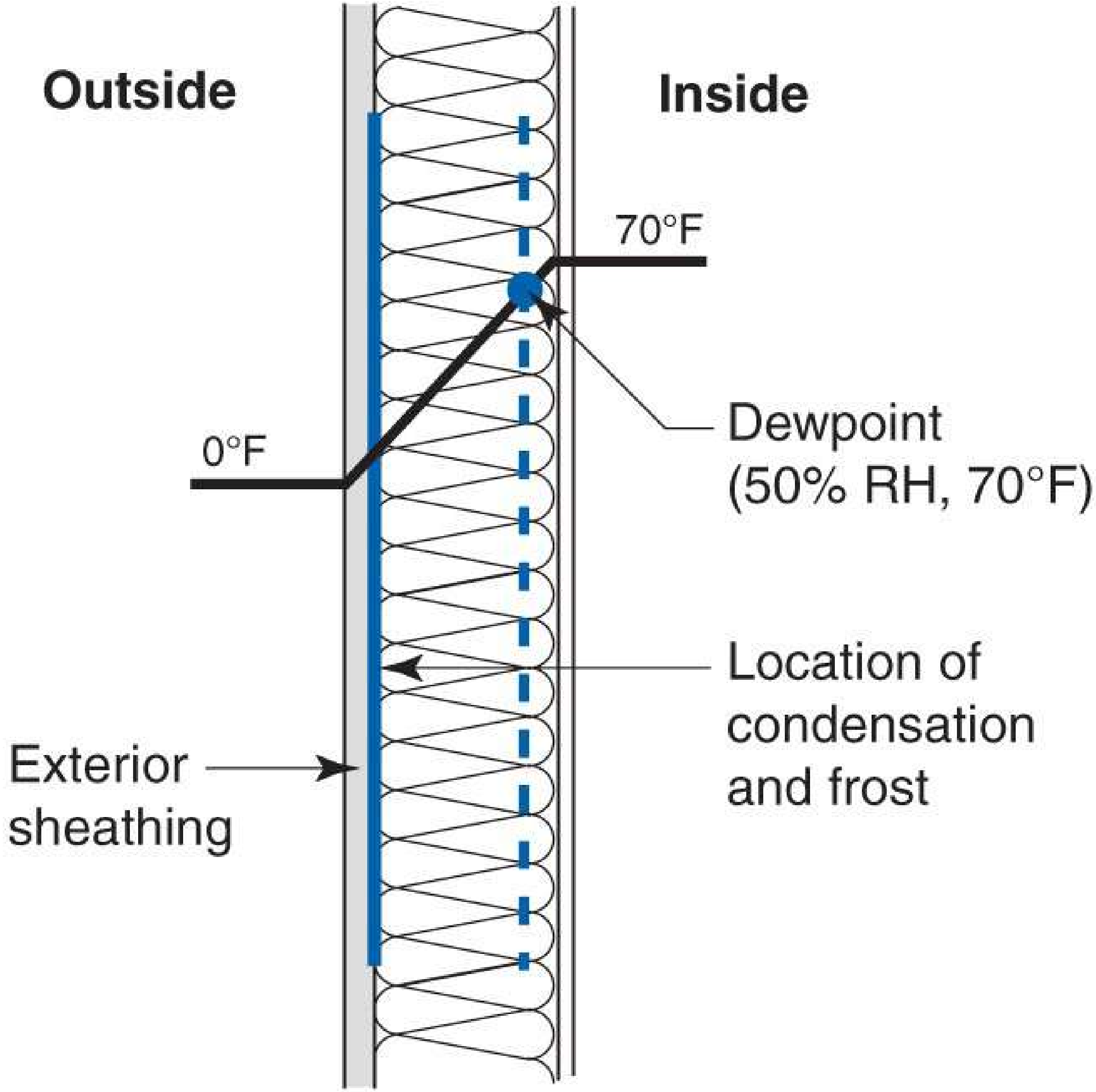

Solid
(ice)
Melt
Freeze
Liquid
(water)
Frost
Sublime
Condense
Evaporate
Gas
(vapor)
Adsorb
Desorb
Adsorbed
(surface
layers)

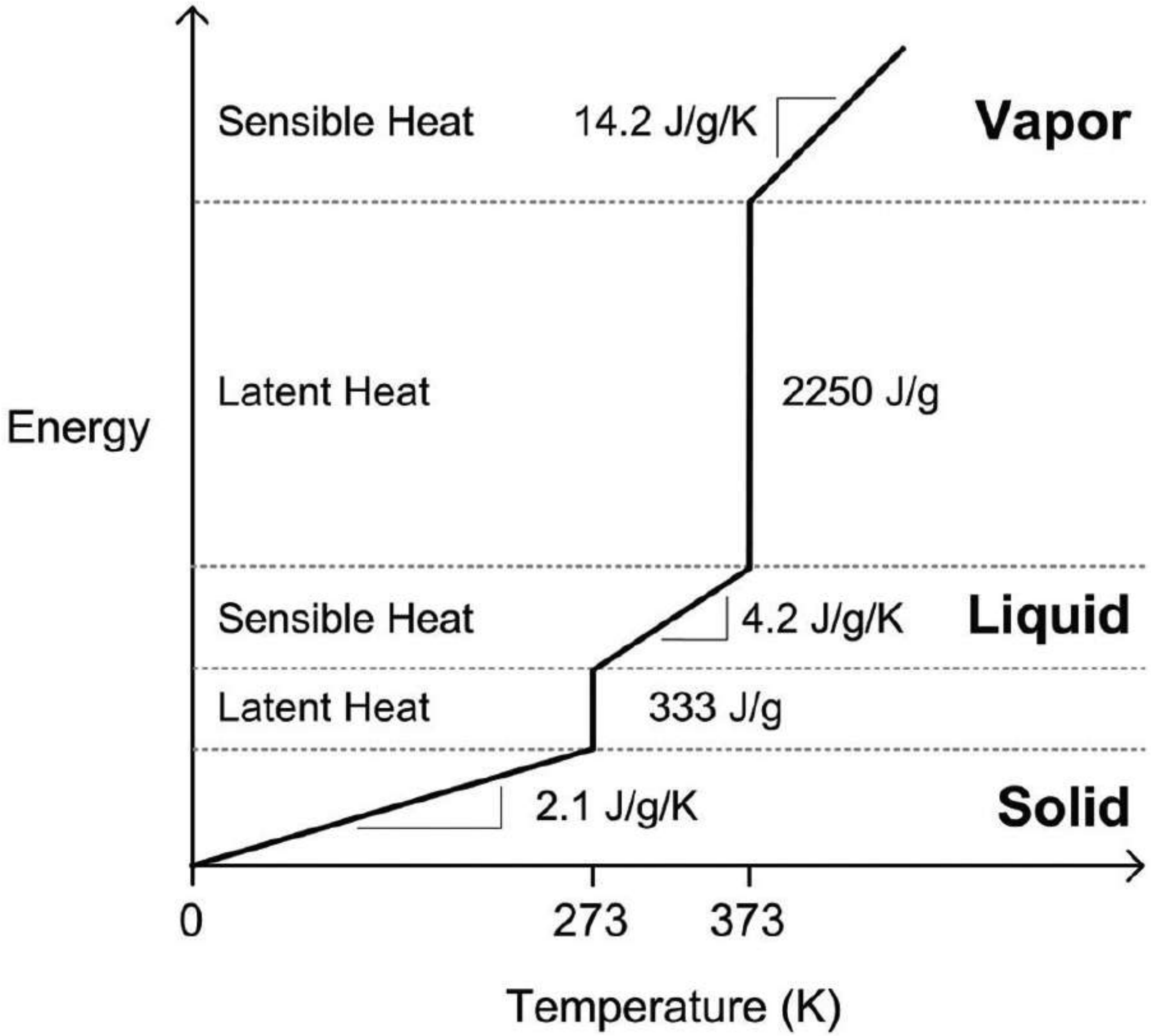

Monolayers of
adsorbed water
increase with
increasing RH


Monolayers
flow along surface
following concentration gradient


Curvature
("meniscus")
Small
pore
Large
pore

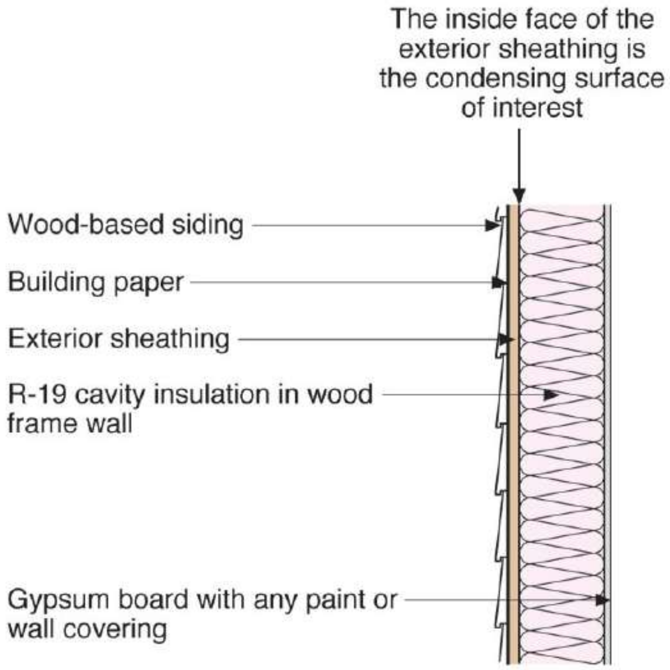
# The Myth of the Dew Point

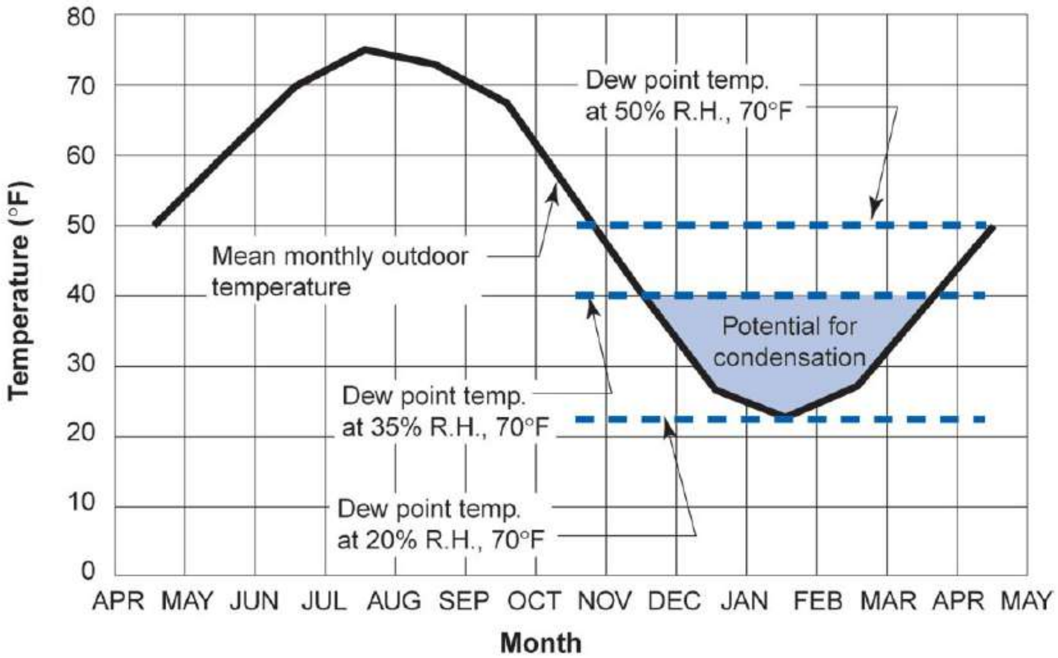

Outside
Inside
70°F
0°F
Dewpoint
(50% RH, 70°F)
Location of
condensation
and frost
Exterior
sheathing

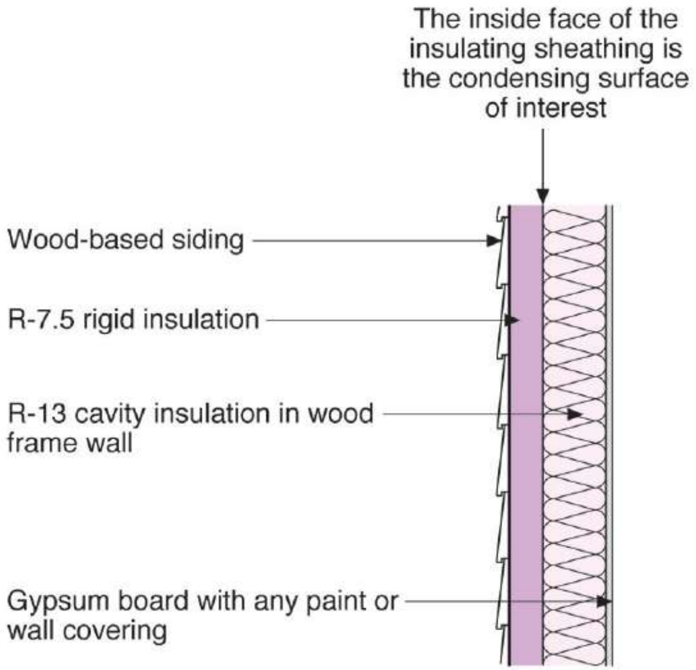



**Simple linearized energy-temperature relation for water**

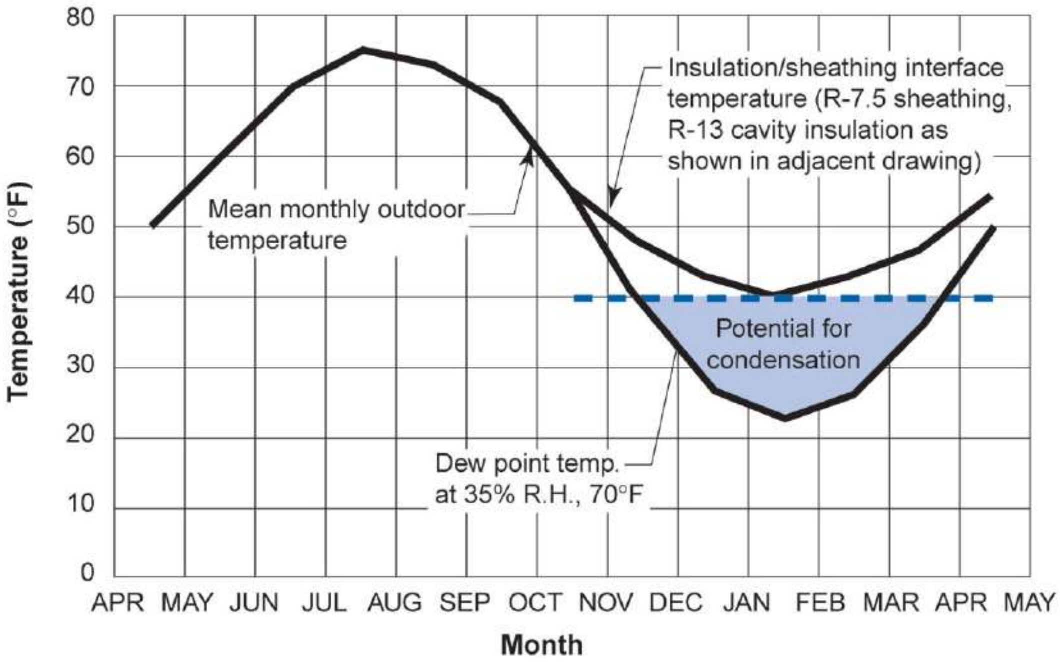
From Straube & Burnett, 2005


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
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
APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
Month



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

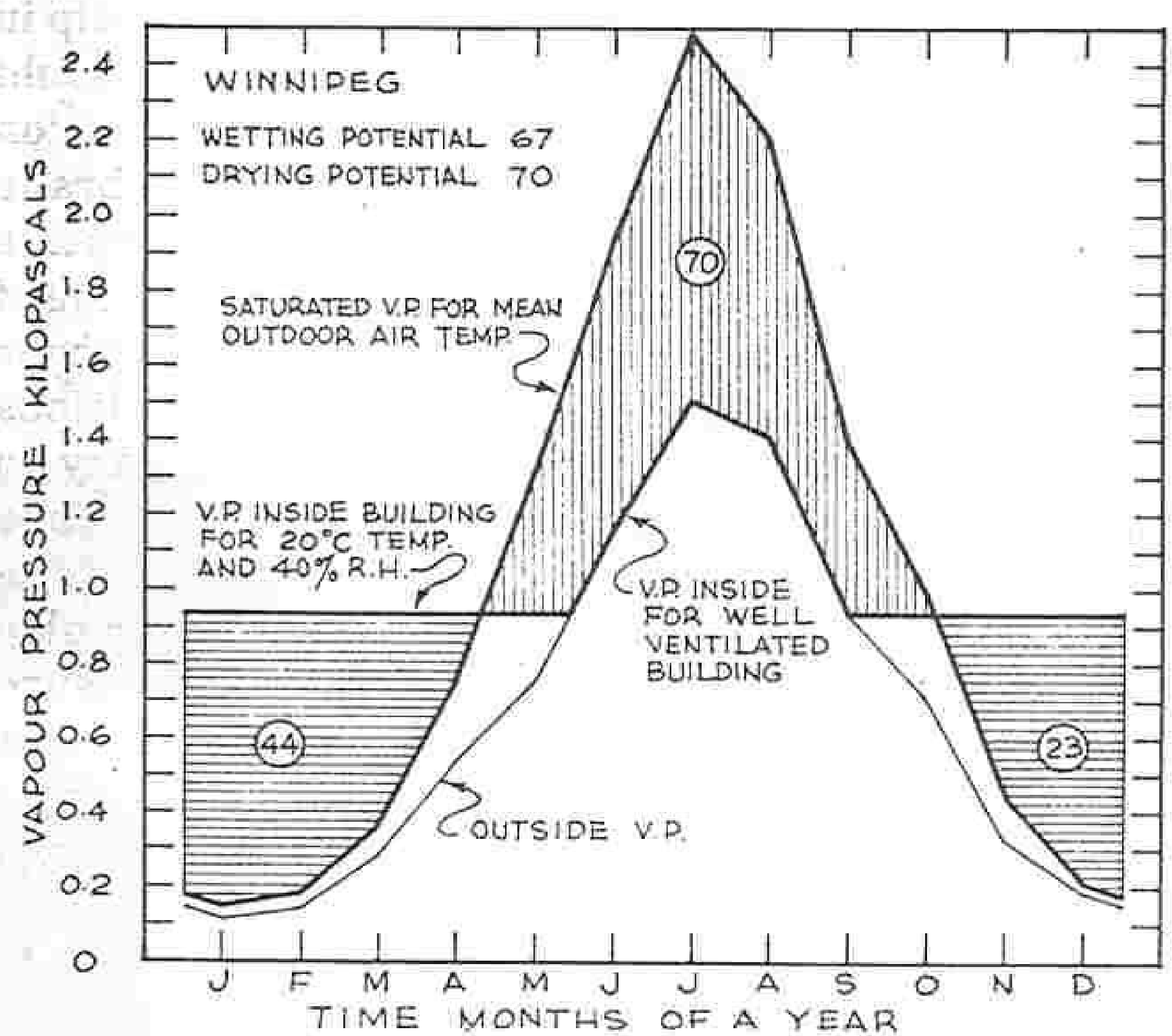
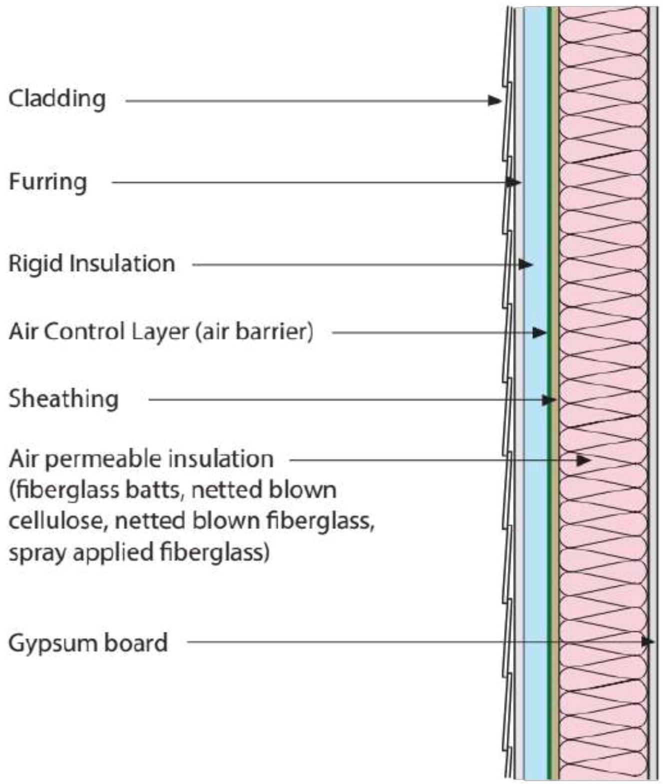


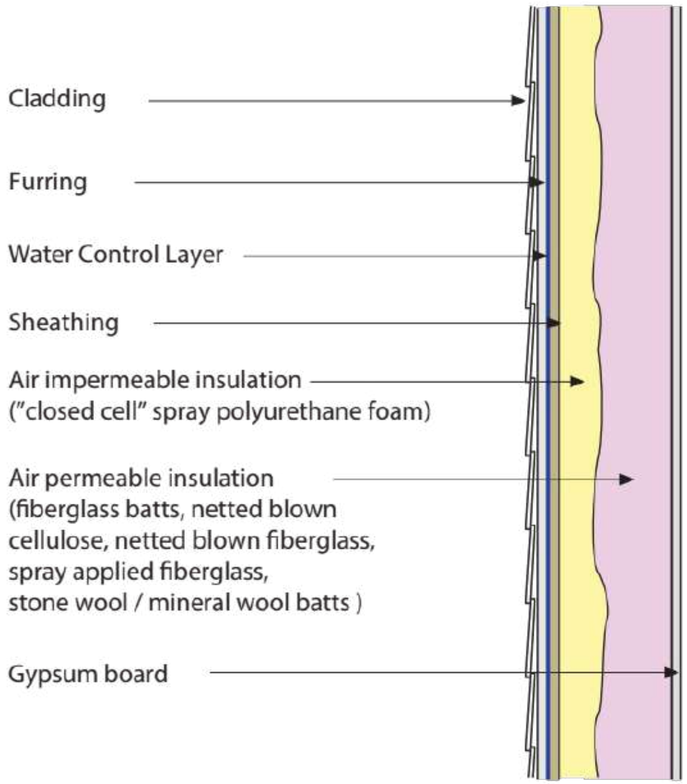

Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.

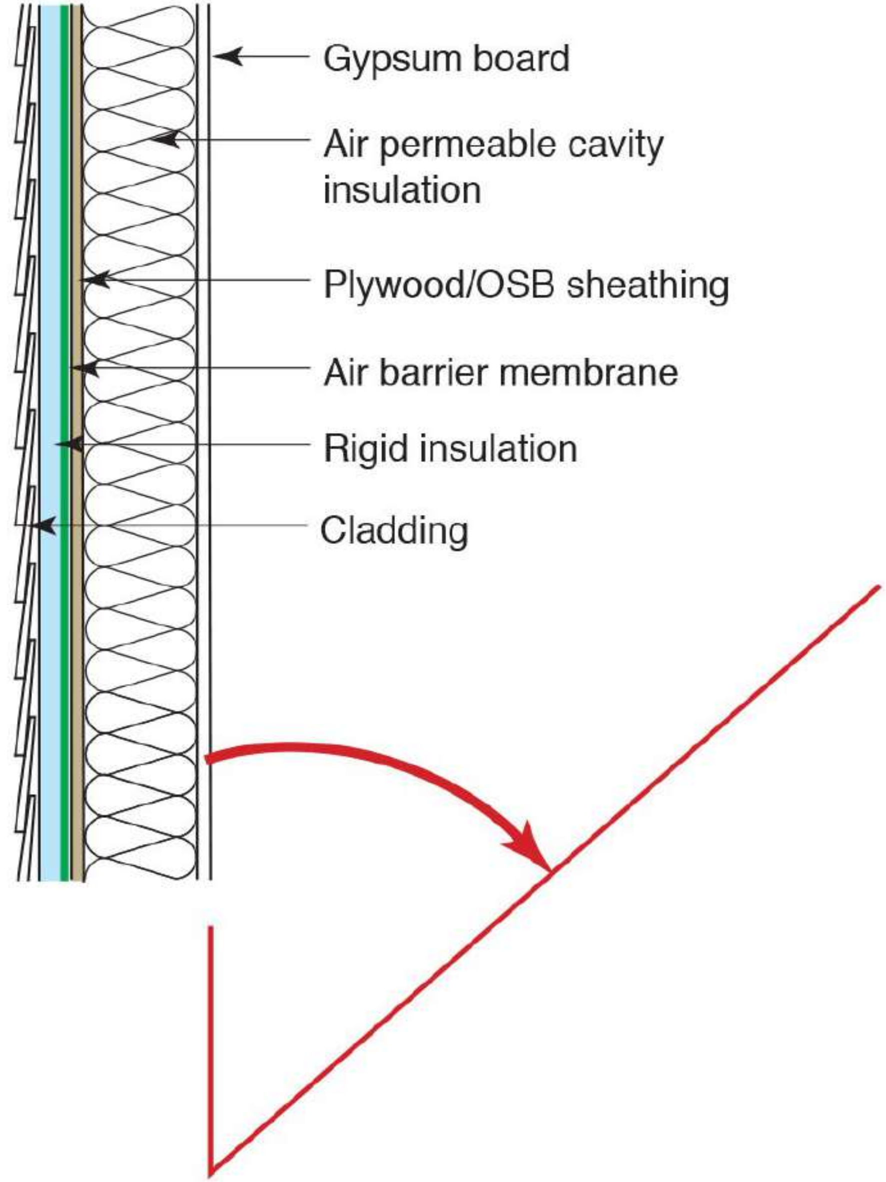
Insulation for Condensation Control*

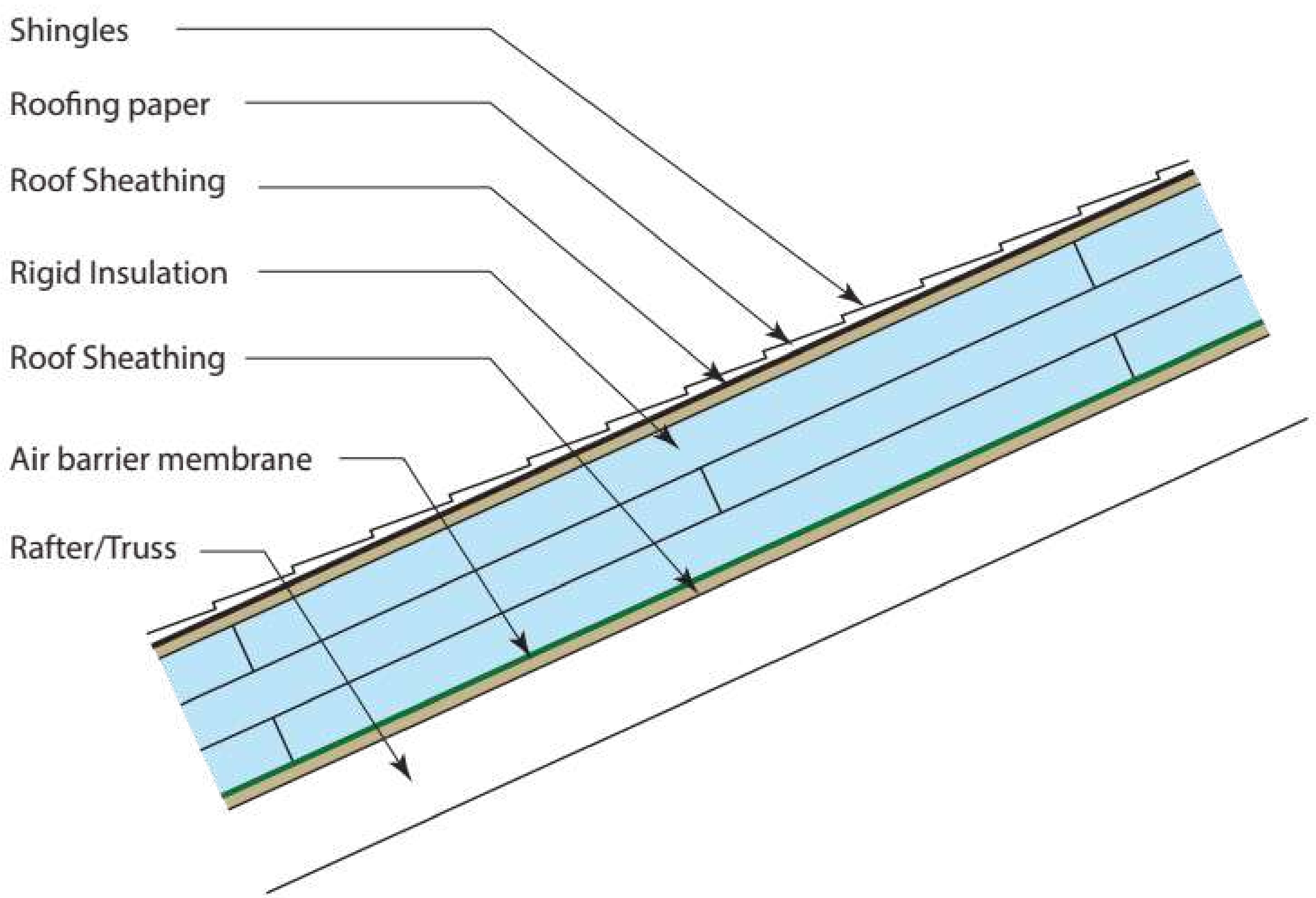
| Climate Zone | Rigid Board or Air Impermeable Insulation | Total Cavity Insulation | Total Wall Assembly Insulation | Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value |
|---|---|---|---|---|
| 4C | R-2.5 | R-13 | R-15.5 | 15% |
| | R-3.75 | R-20 | R-23.75 | 15% |
| 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% |

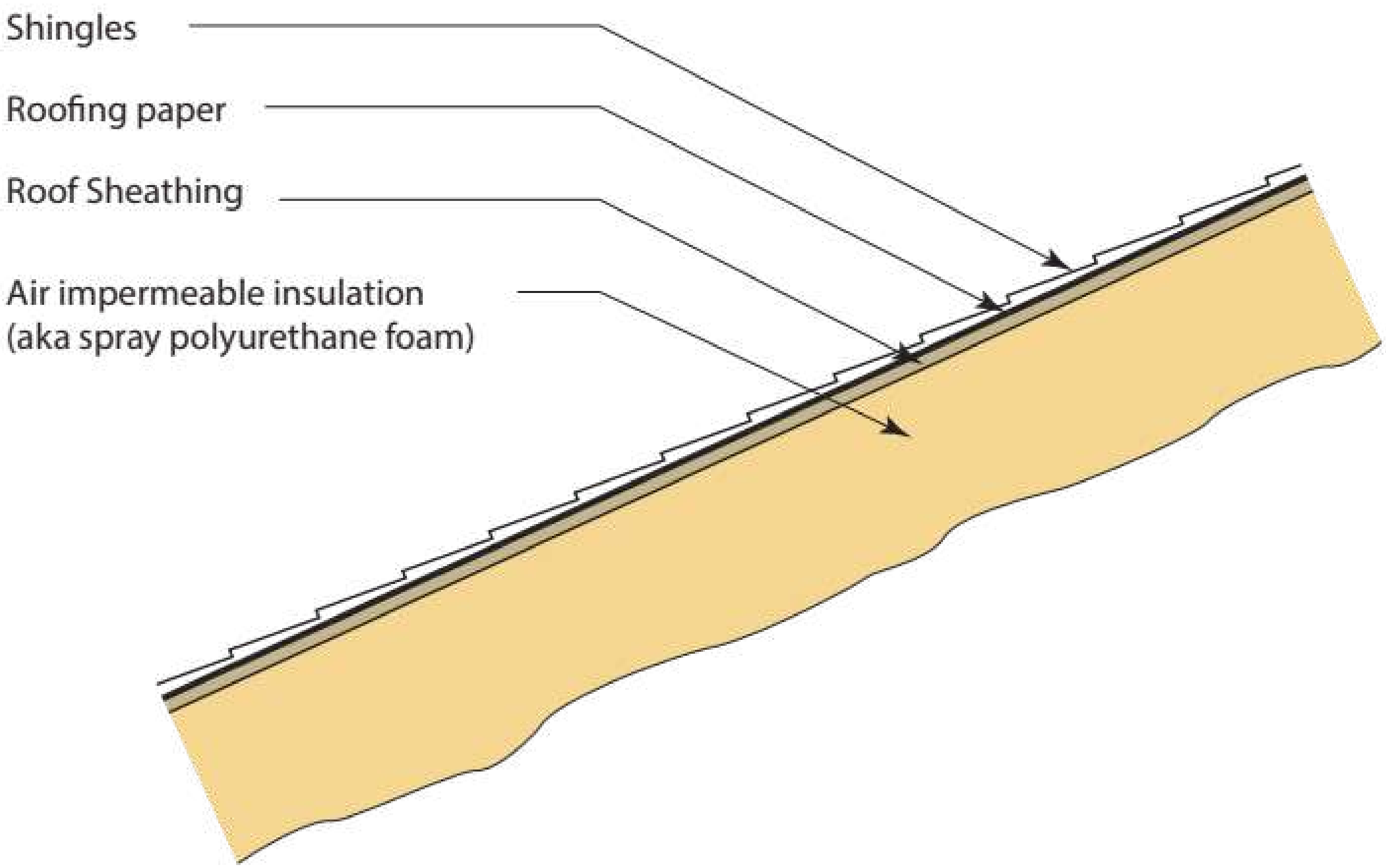
*Adapted from Table R 702.1 2015 International Residential Code

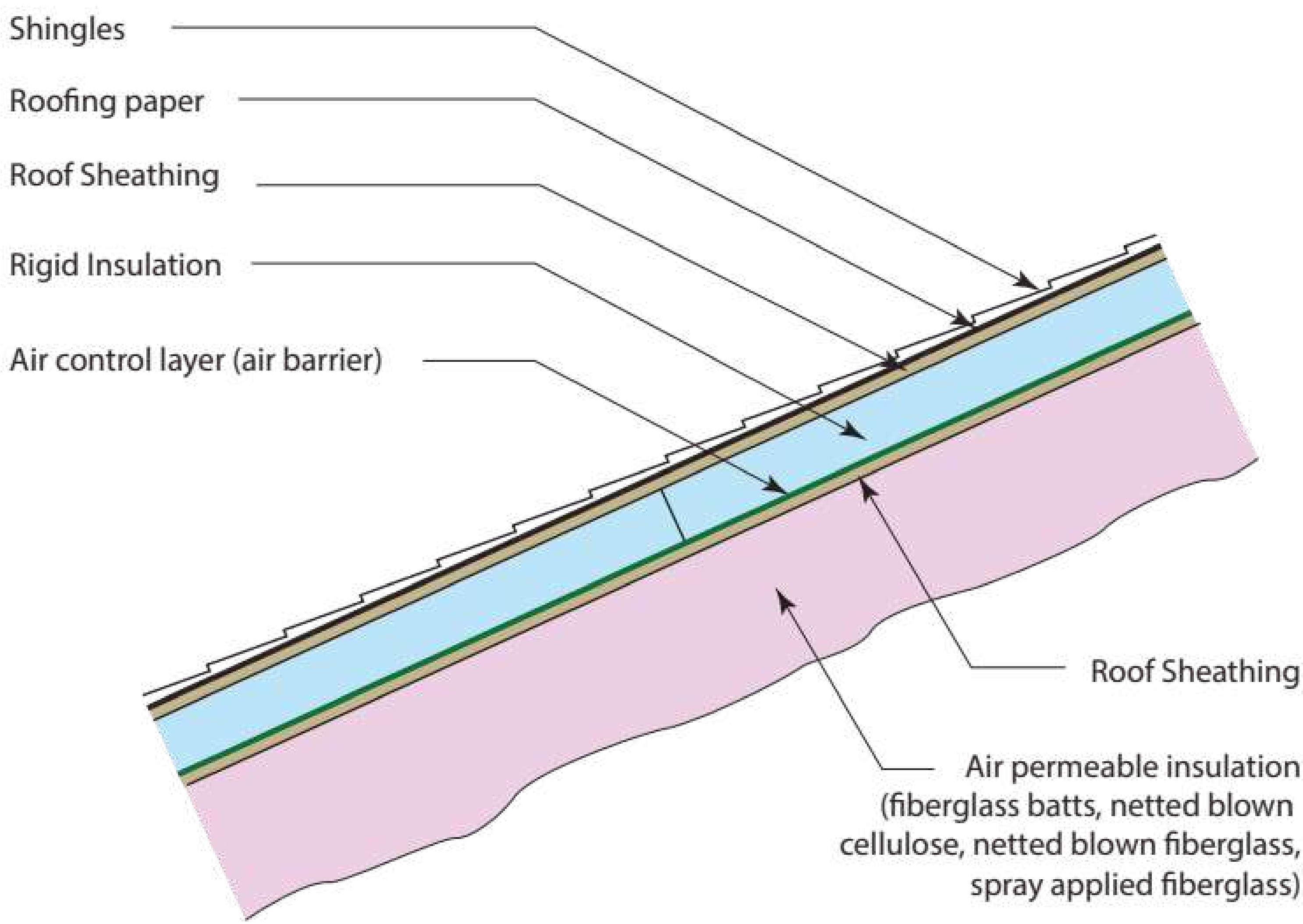

Cladding
Furring
Rigid Insulation
Air Control Layer (air barrier)
Sheathing
Air permeable insulation (fiberglass batts, netted blown cellulose, netted blown fiberglass, spray applied fiberglass)
Gypsum board

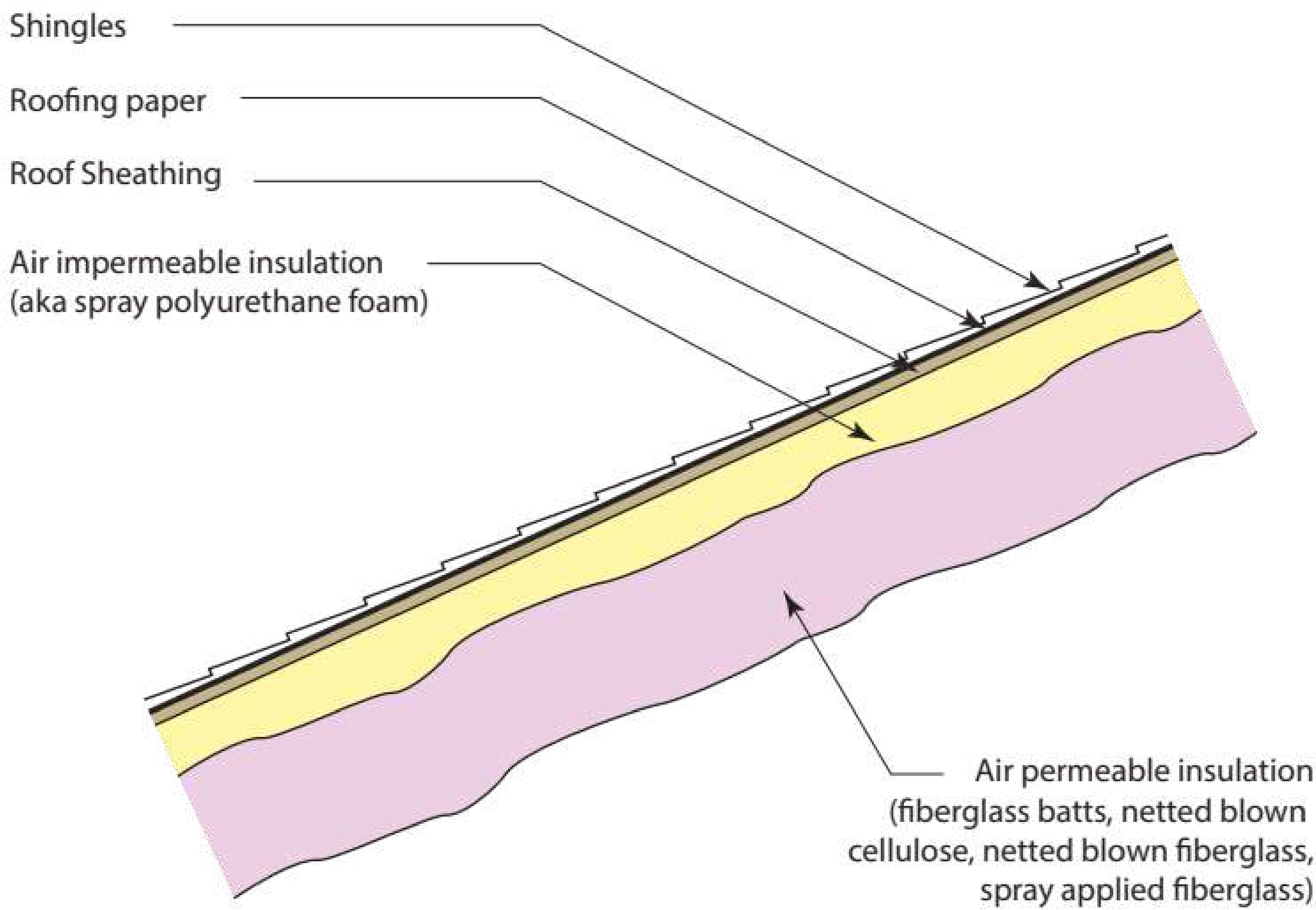

Cladding
Furring
Water Control Layer
Sheathing
Air impermeable insulation
("closed cell" spray polyurethane foam)
Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass,
stone wool / mineral wool batts )
Gypsum board

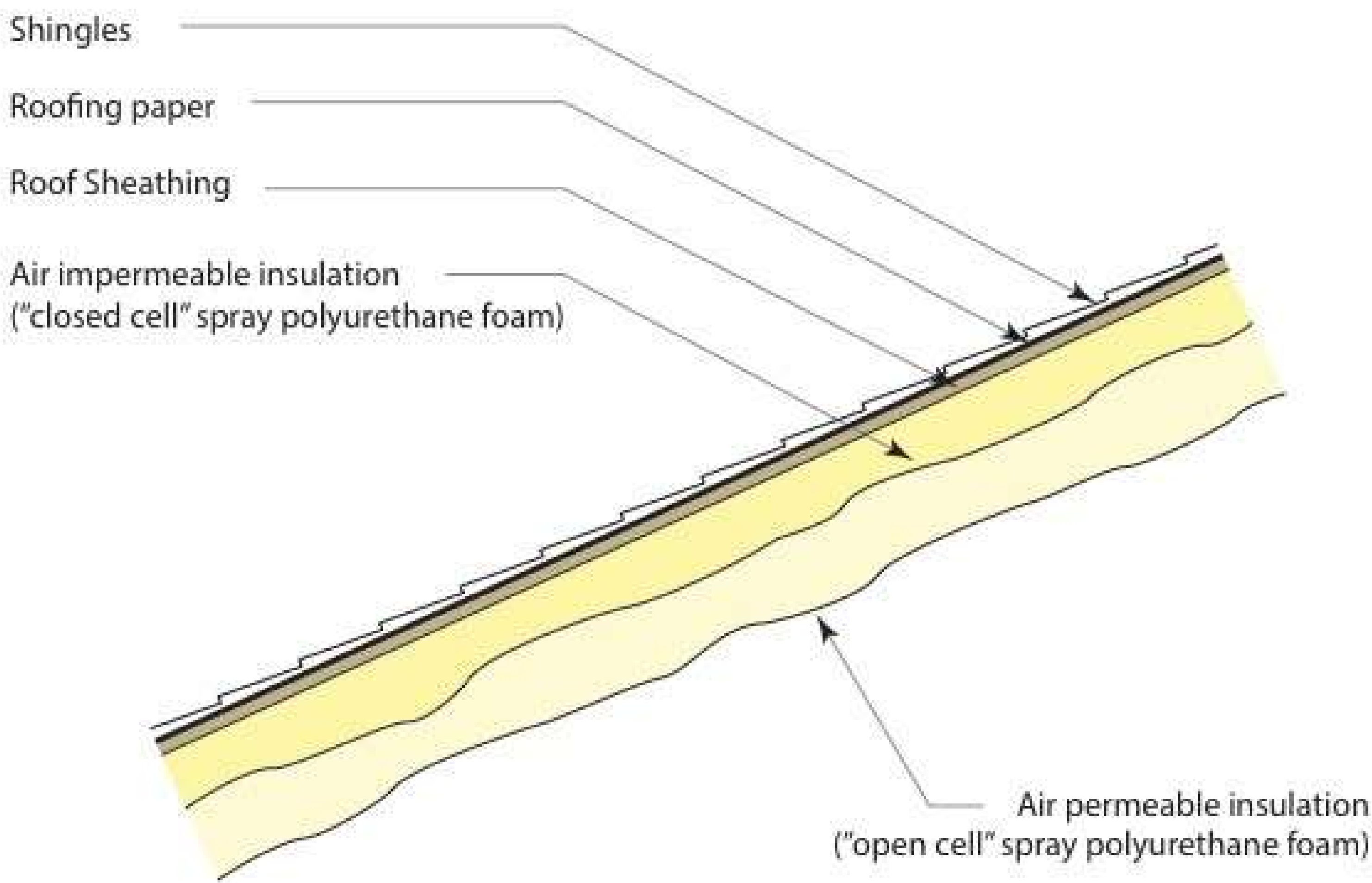

Gypsum board
Air permeable cavity insulation
Plywood/OSB sheathing
Air barrier membrane
Rigid insulation
Cladding


Shingles
Roofing paper
Roof Sheathing
Rigid Insulation
Roof Sheathing
Air barrier membrane
Rafter/Truss


Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation
(aka spray polyurethane foam)


Shingles
Roofing paper
Roof Sheathing
Rigid Insulation
Air control layer (air barrier)
Roof Sheathing
Air permeable insulation (fiberglass batts, netted blown cellulose, netted blown fiberglass, spray applied fiberglass)


Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation
(aka spray polyurethane foam)
Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass)

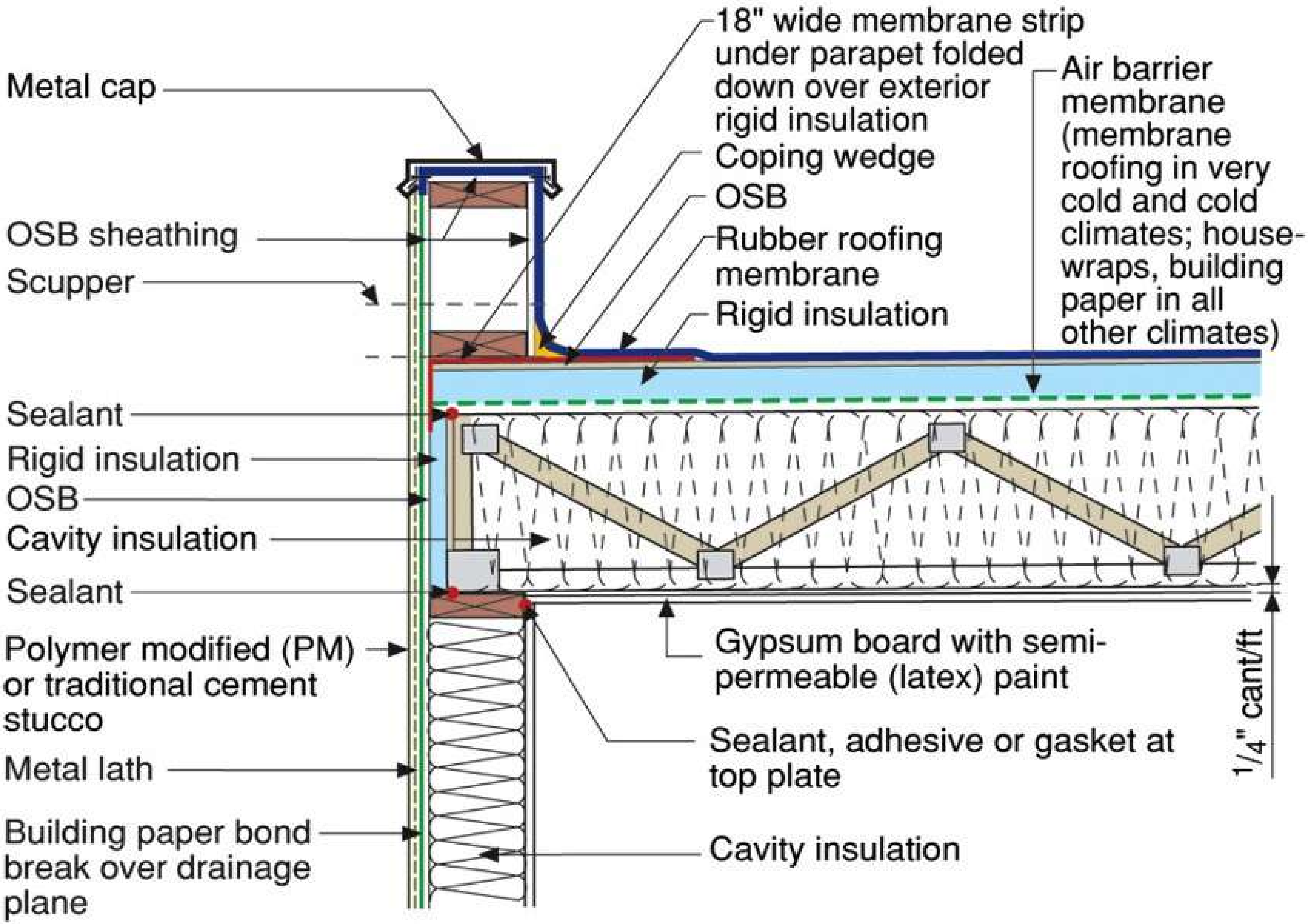

Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation
("closed cell" spray polyurethane foam)
Air permeable insulation
("open cell" spray polyurethane foam)

Insulation for Condensation Control*

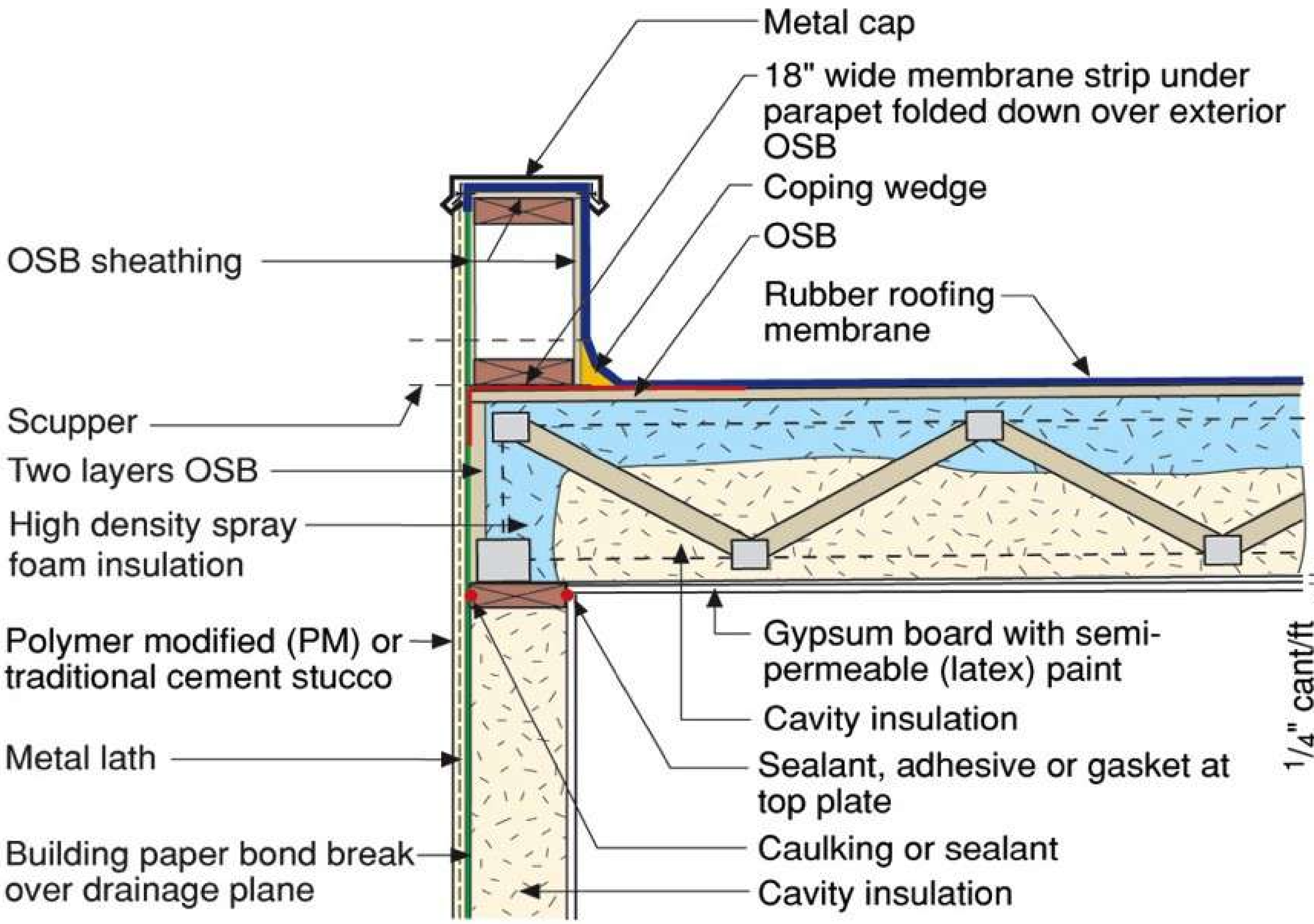
| Climate Zone | Rigid Board or Air Impermeable Insulation | Code Required R-Value | Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value |
|---|---|---|---|
| 1,2,3 | R-5 | R-38 | 10% |
| 4C | R-10 | R-49 | 20% |
| 4A, 4B | R-15 | R-49 | 30% |
| 5 | R-20 | R-49 | 40% |
| 6 | R-25 | R-49 | 50% |
| 7 | R-30 | R-49 | 60% |
| 8 | R-35 | R-49 | 70% |

*Adapted from Table R 806.5 2015 International Residential Code

Table 1



Metal cap
OSB sheathing
Scupper
Sealant
Rigid insulation
OSB
Cavity insulation
Sealant
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
18" wide membrane strip under parapet folded down over exterior rigid insulation
Coping wedge
OSB
Rubber roofing membrane
Rigid insulation
Air barrier membrane (membrane roofing in very cold and cold climates; housewraps, building paper in all other climates)
Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Cavity insulation
1/4" cant/ft


Metal cap
18" wide membrane strip under parapet folded down over exterior OSB
Coping wedge
OSB
Rubber roofing membrane
OSB sheathing
Scupper
Two layers OSB
High density spray foam insulation
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
Gypsum board with semi-permeable (latex) paint
Cavity insulation
Sealant, adhesive or gasket at top plate
Caulking or sealant
Cavity insulation
1/4" cant/ft

# Modeling and Other Lies

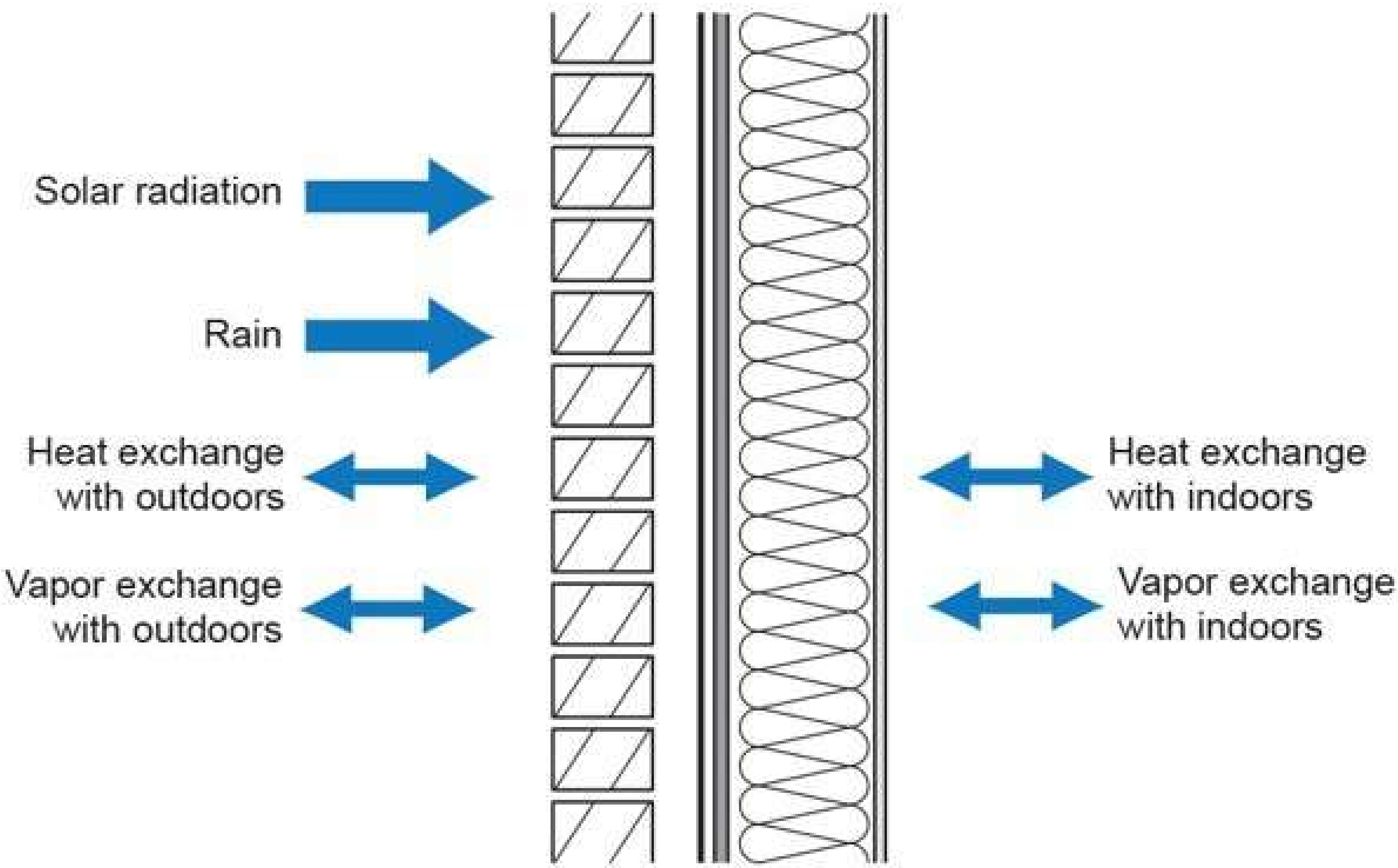
Heat

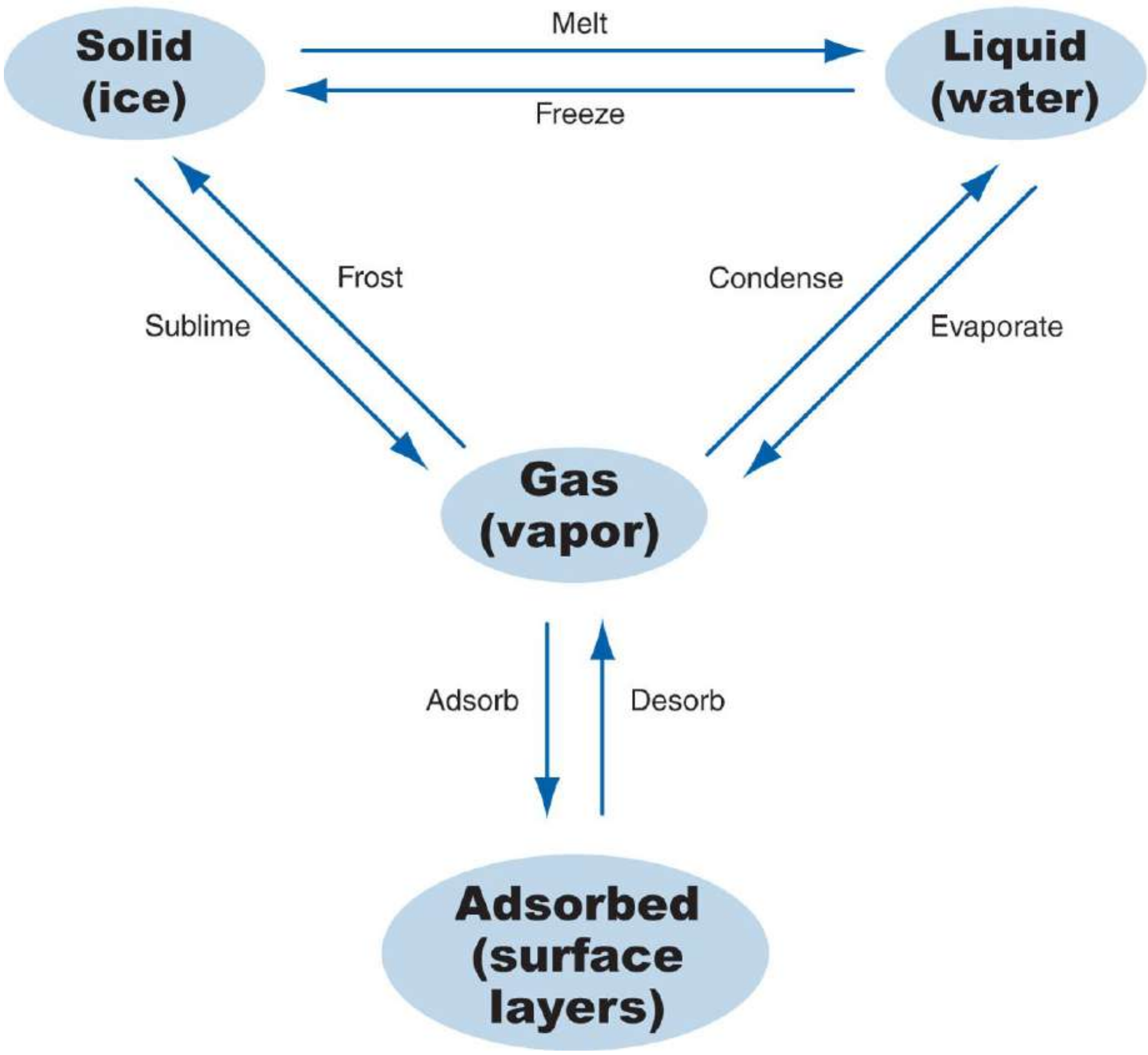
Air

Moisture

# HAM

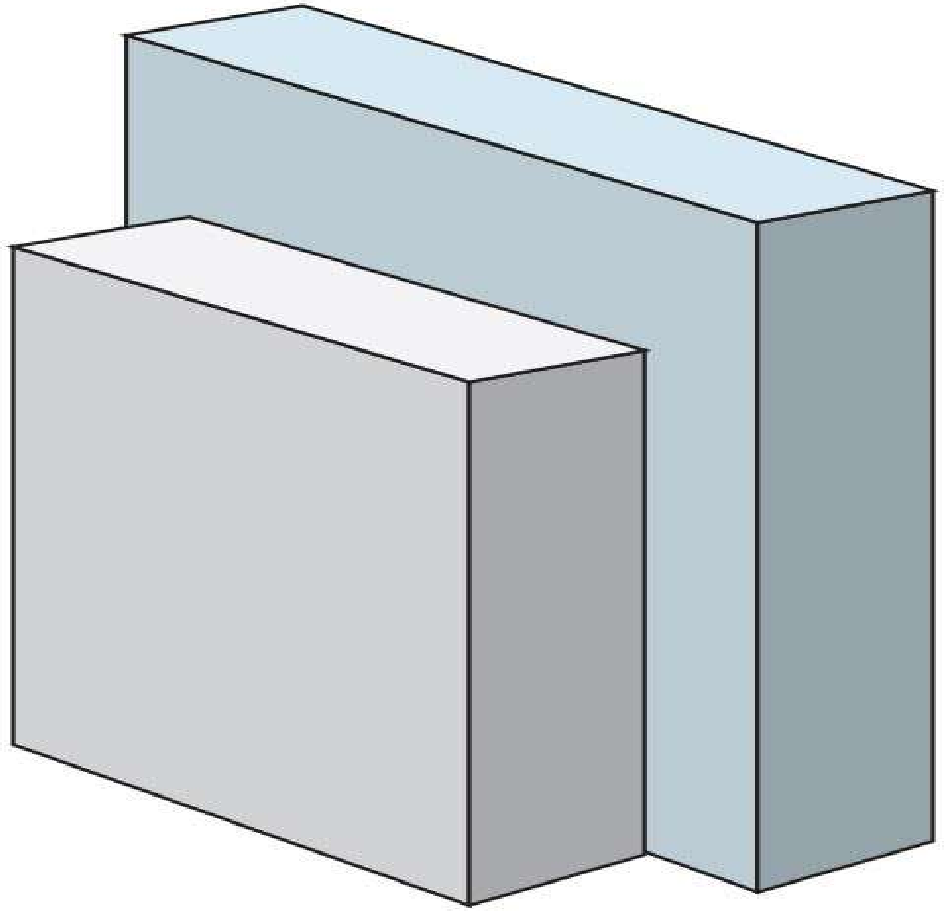
# Hygrothermal Analysis

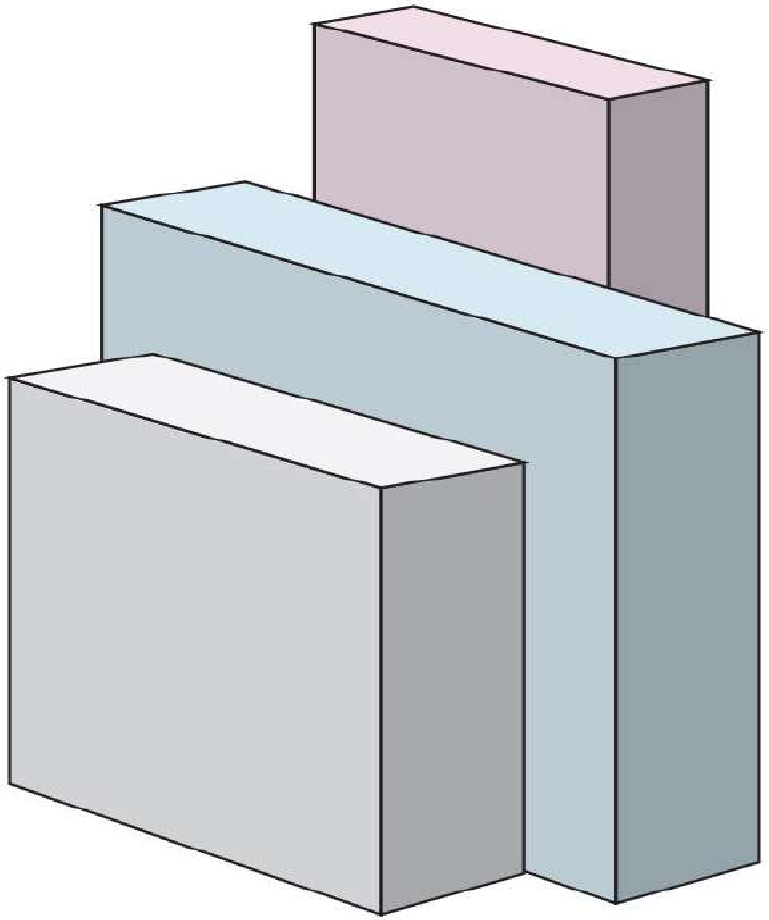

Solar radiation
Rain
Heat exchange
with outdoors
Vapor exchange
with outdoors
Heat exchange
with indoors
Vapor exchange
with indoors

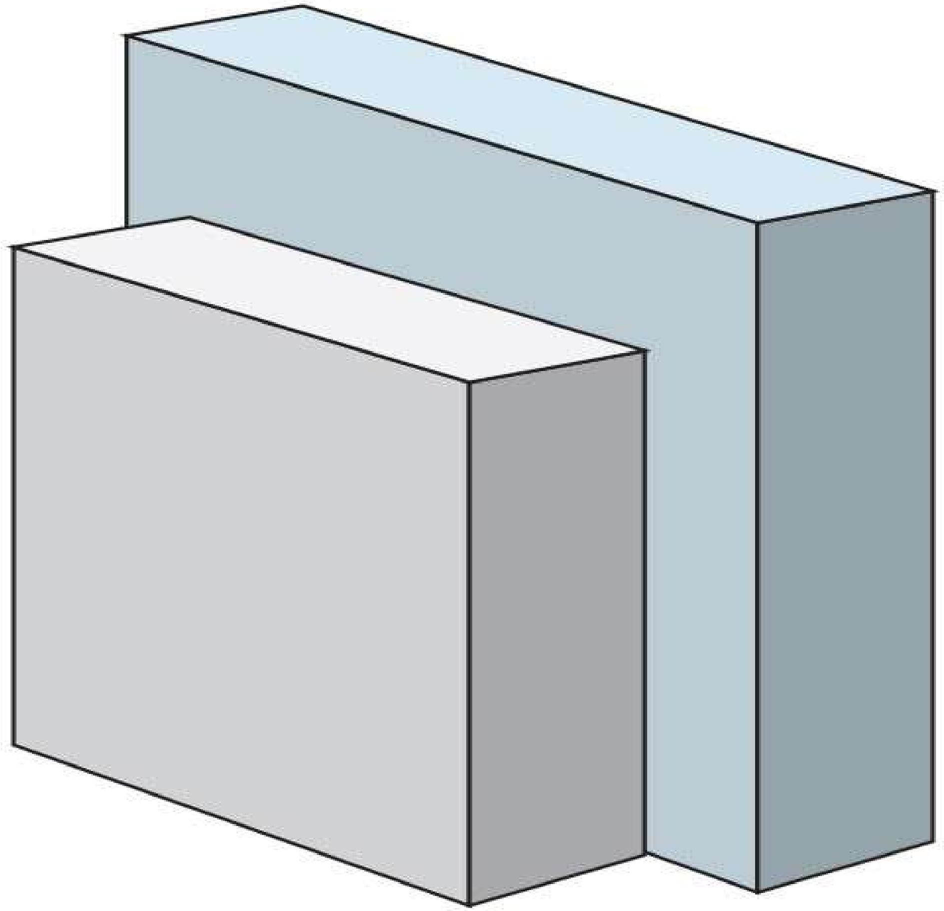

Solid
(ice)
Melt
Freeze
Liquid
(water)
Frost
Sublime
Condense
Evaporate
Gas
(vapor)
Adsorb
Desorb
Adsorbed
(surface
layers)

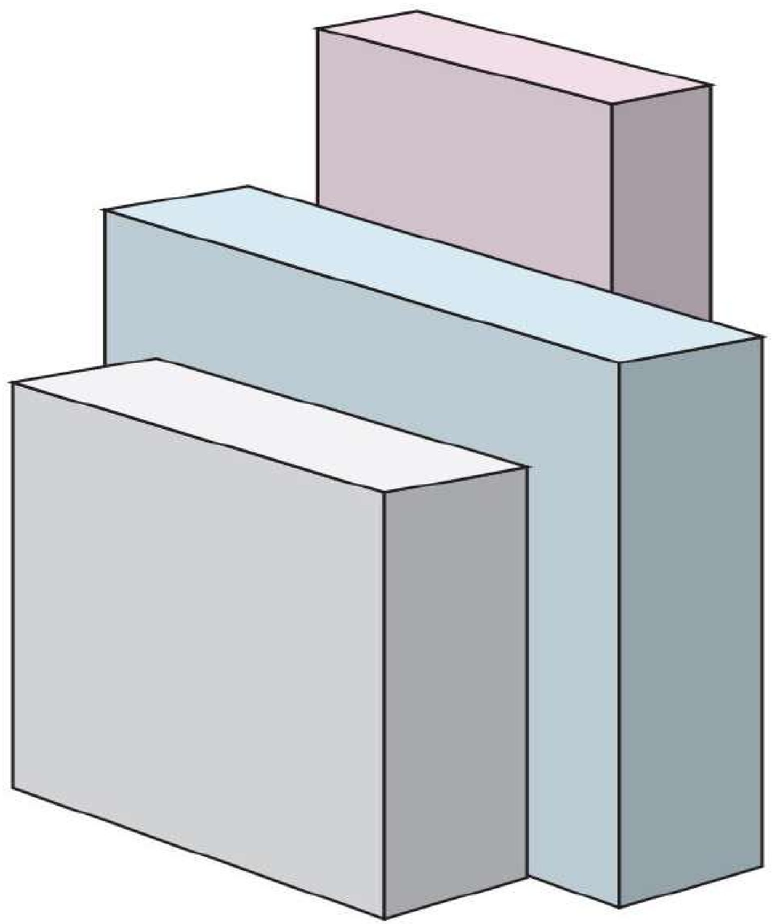
## Moisture Transport in Porous Media

| Phase | Transport Process | Driving Potential |
|---|---|---|
| **Vapor** | Diffusion | Vapor Concentration |
| **Adsorbate** | Surface Diffusion | Concentration |
| **Liquid** | Capillary Flow | Suction Pressure |
| | Osmosis | Solute Concentration |

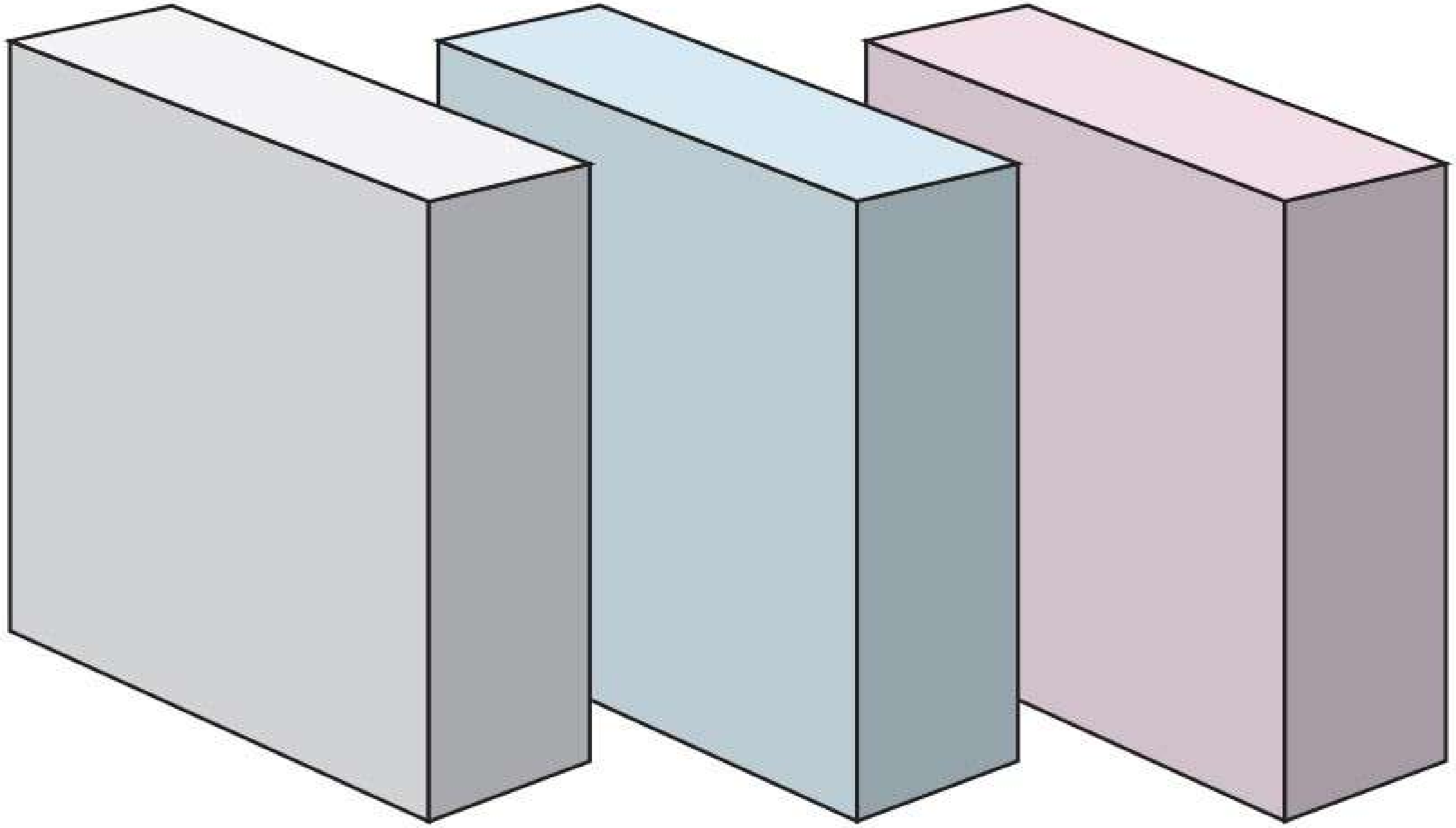








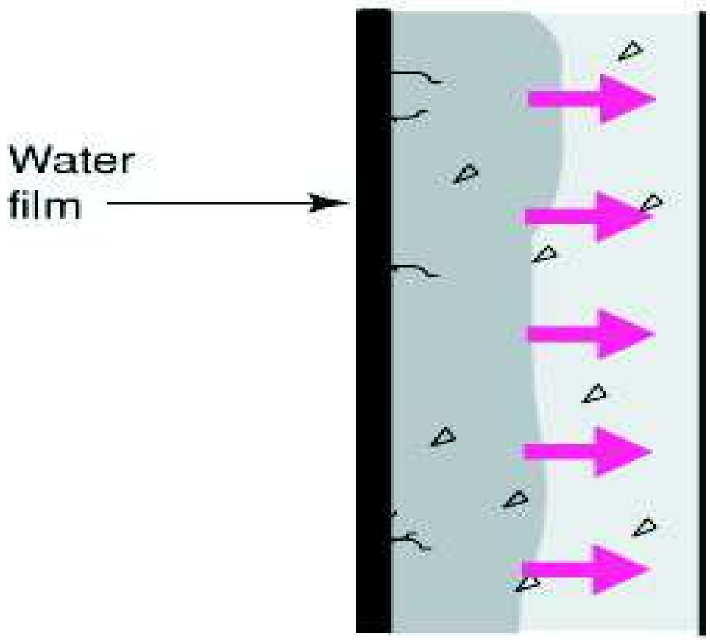
# Rain and Airflow Missing



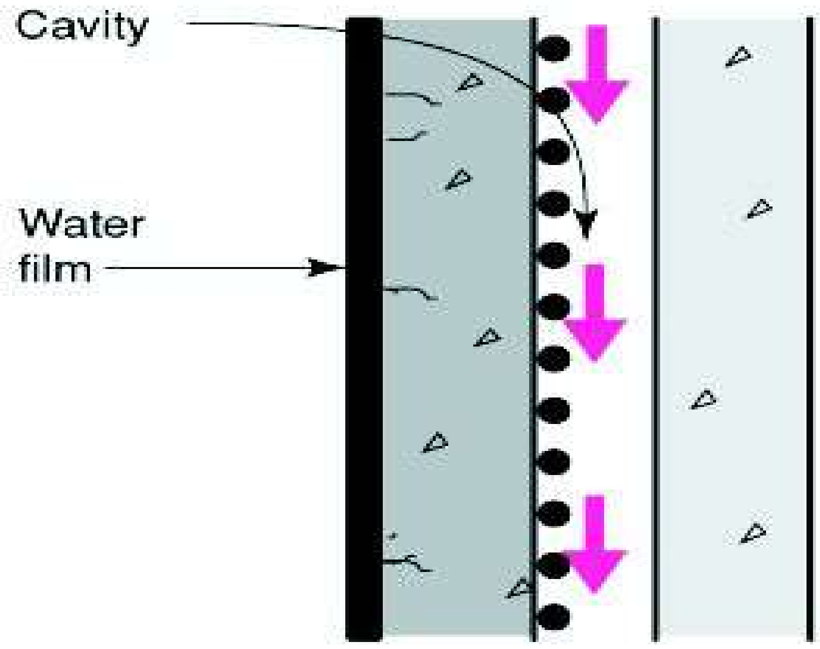
## Moisture Transport in Assemblies

| Phase | Transport Process | Driving Potential |
|---|---|---|
| **Vapor** | Diffusion | Vapor Concentration |
| | Convective Flow | Air Pressure |
| **Adsorbate** | Surface Diffusion | Concentration |
| **Liquid** | Capillary Flow | Suction Pressure |
| | Osmosis | Solute Concentration |
| | Gravitational Flow | Height |
| | Surface Tension | Surface Energy |
| | Momentum | Kinetic Energy |
| | Convective Flow | Air Pressure |

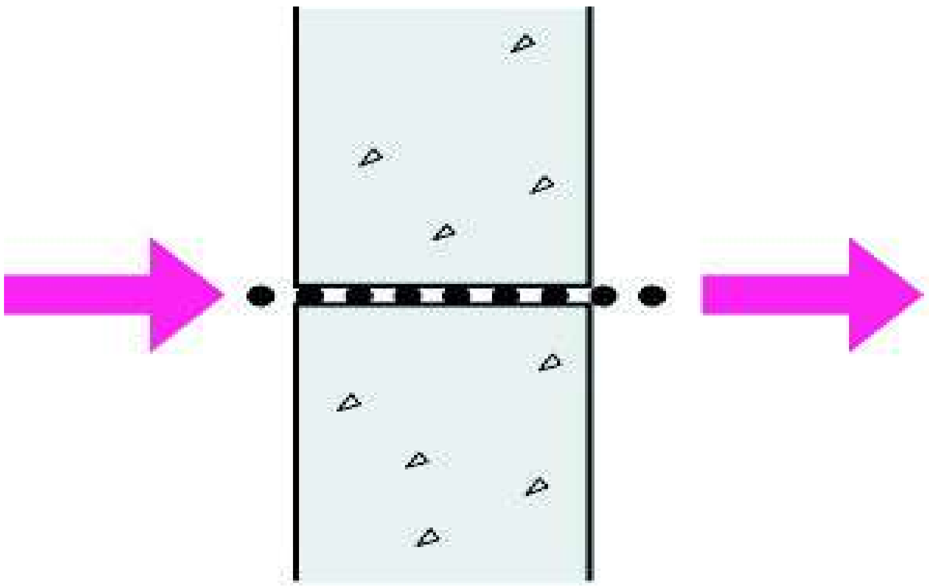
# Rain



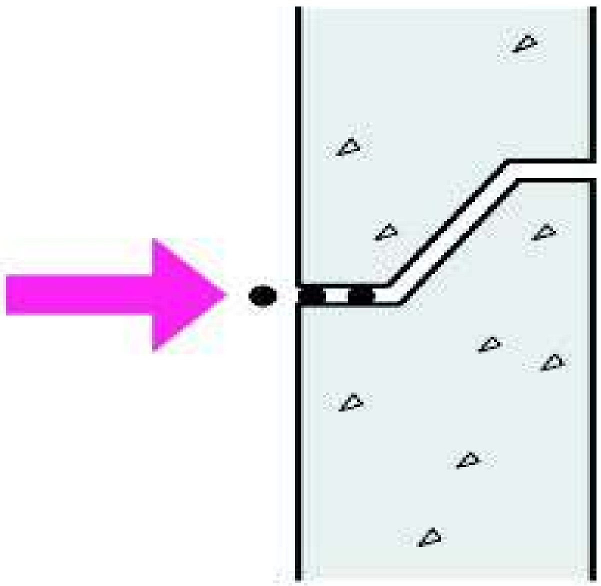

Capillary suction draws water into porous material and tiny cracks



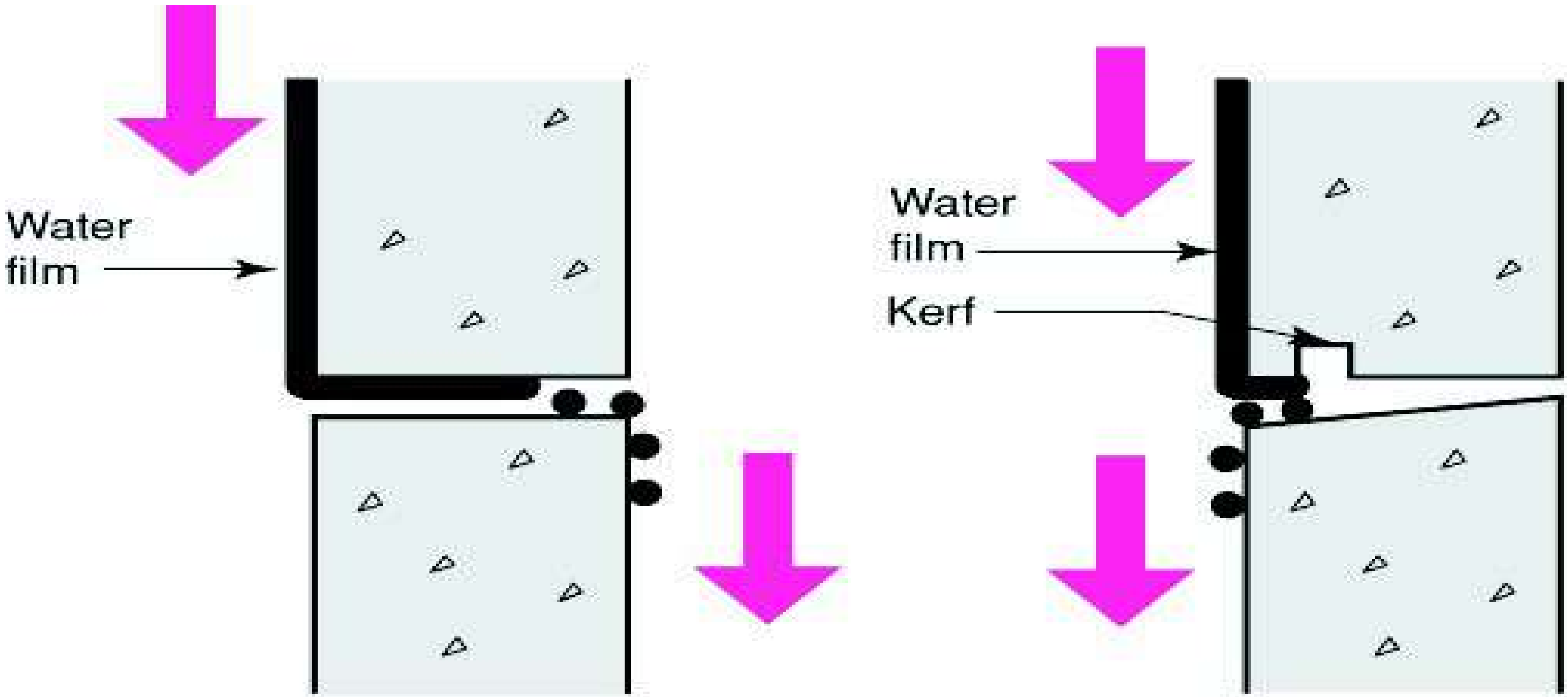

Cavity acts as capillary break and receptor for capillary water interrupting flow



Rain droplets can be carried through a wall by their own momentum

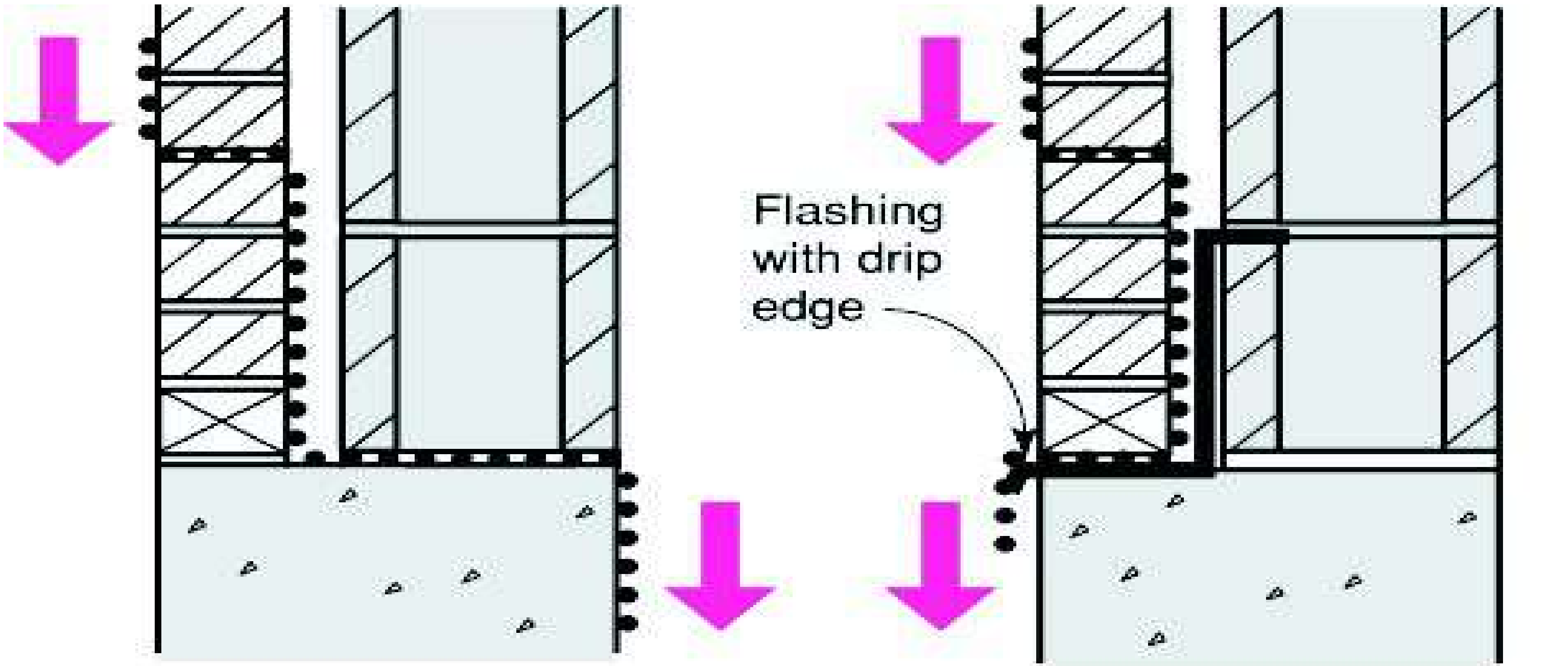


Rain entry by momentum can be prevented by designing wall systems with no straight through openings



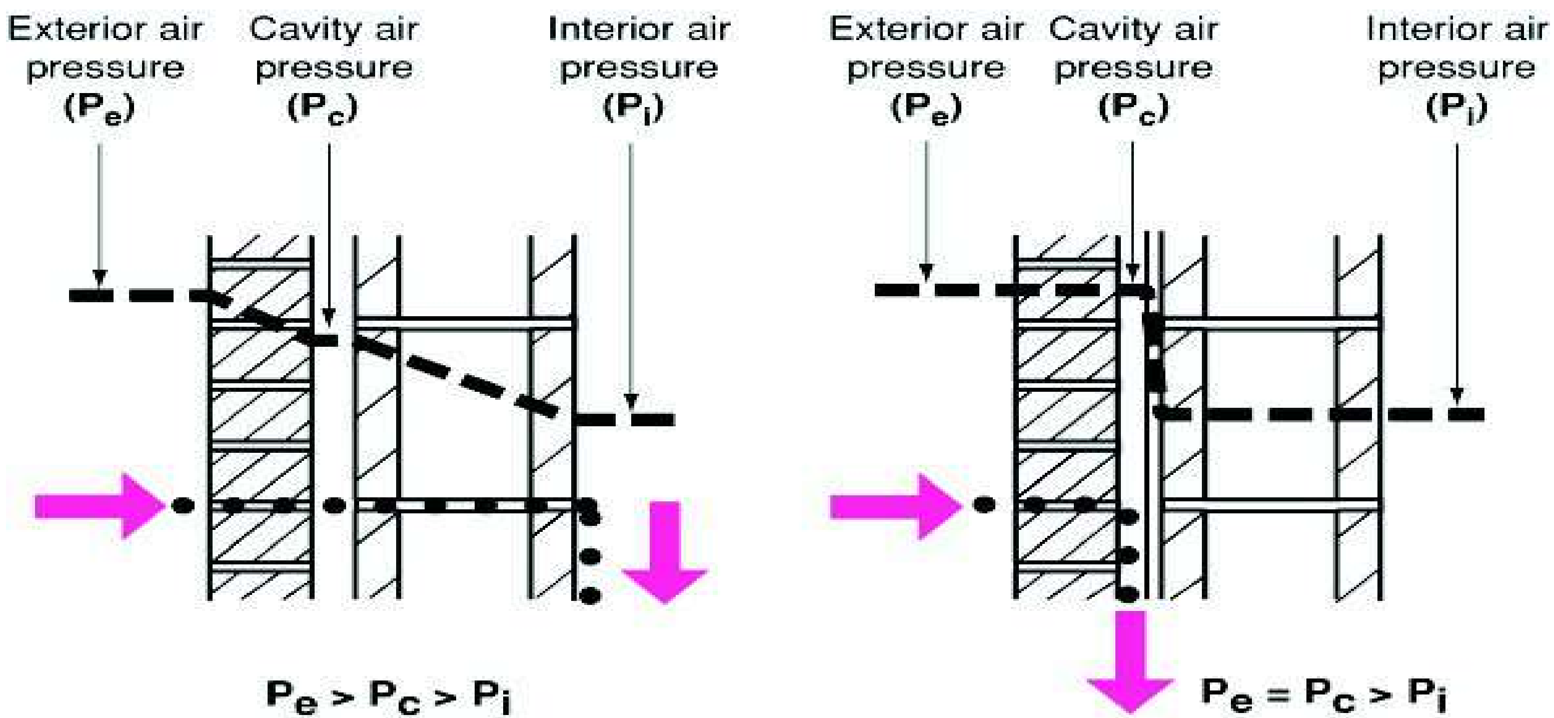

Rainwater can flow around a surface as a result of surface tension

Providing a kerf or drip edge will promote the formation of a water droplet and interrupt flow




Rainwater can flow down surfaces and enter through openings and cavities

Flashings direct gravity flow rainwater back toward the exterior



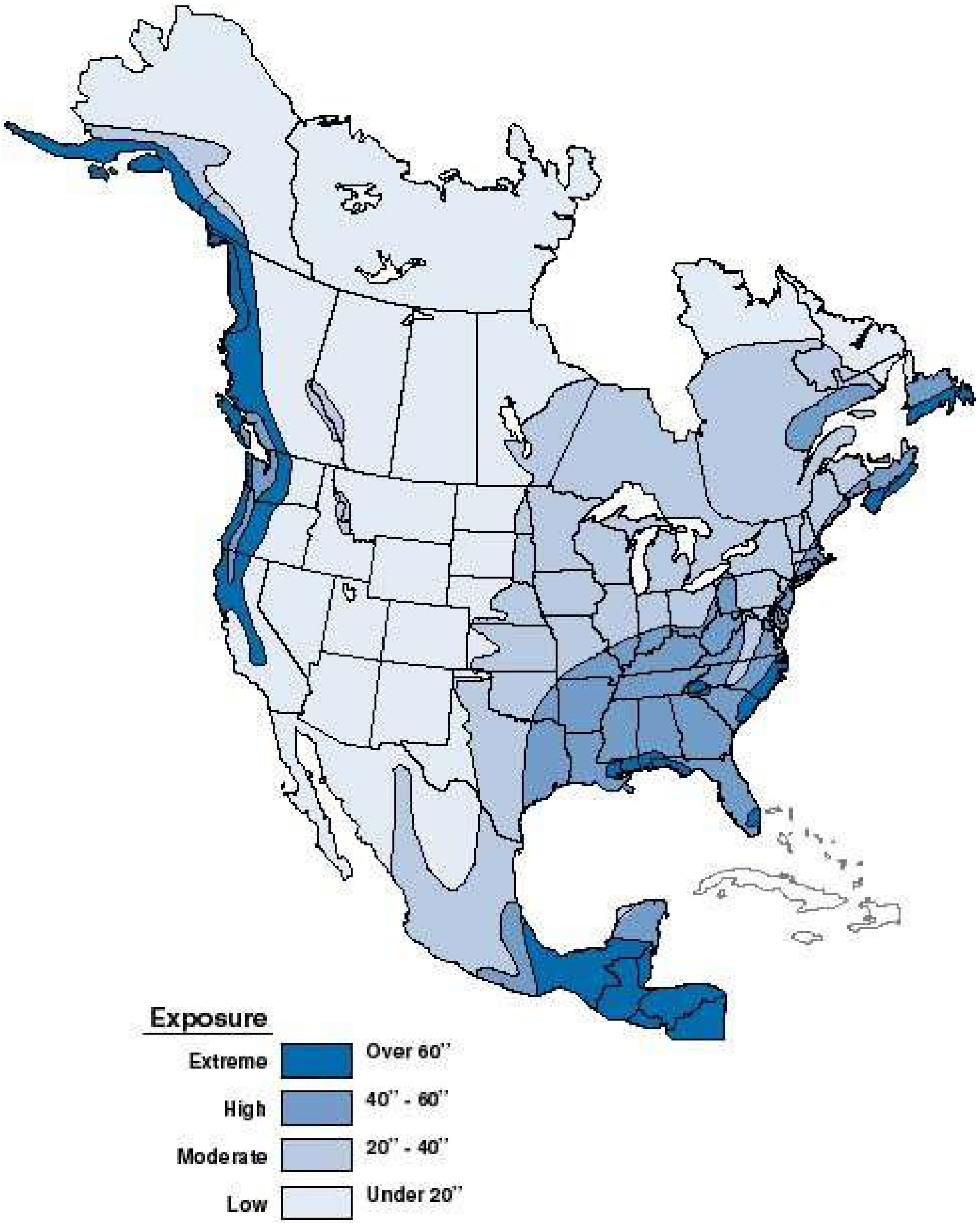

Driven by air pressure differences, rain droplets are drawn through wall openings from the exterior to the interior

By creating pressure equalization or pressure moderation between the exterior and cavity air, air pressure is diminished as a driving force for rain entry

All We Have To Figure Out Is How Much Hits The Wall

All We Have To Figure Out Is How Much Hits The Wall

We Need Straube and Kuenzel


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

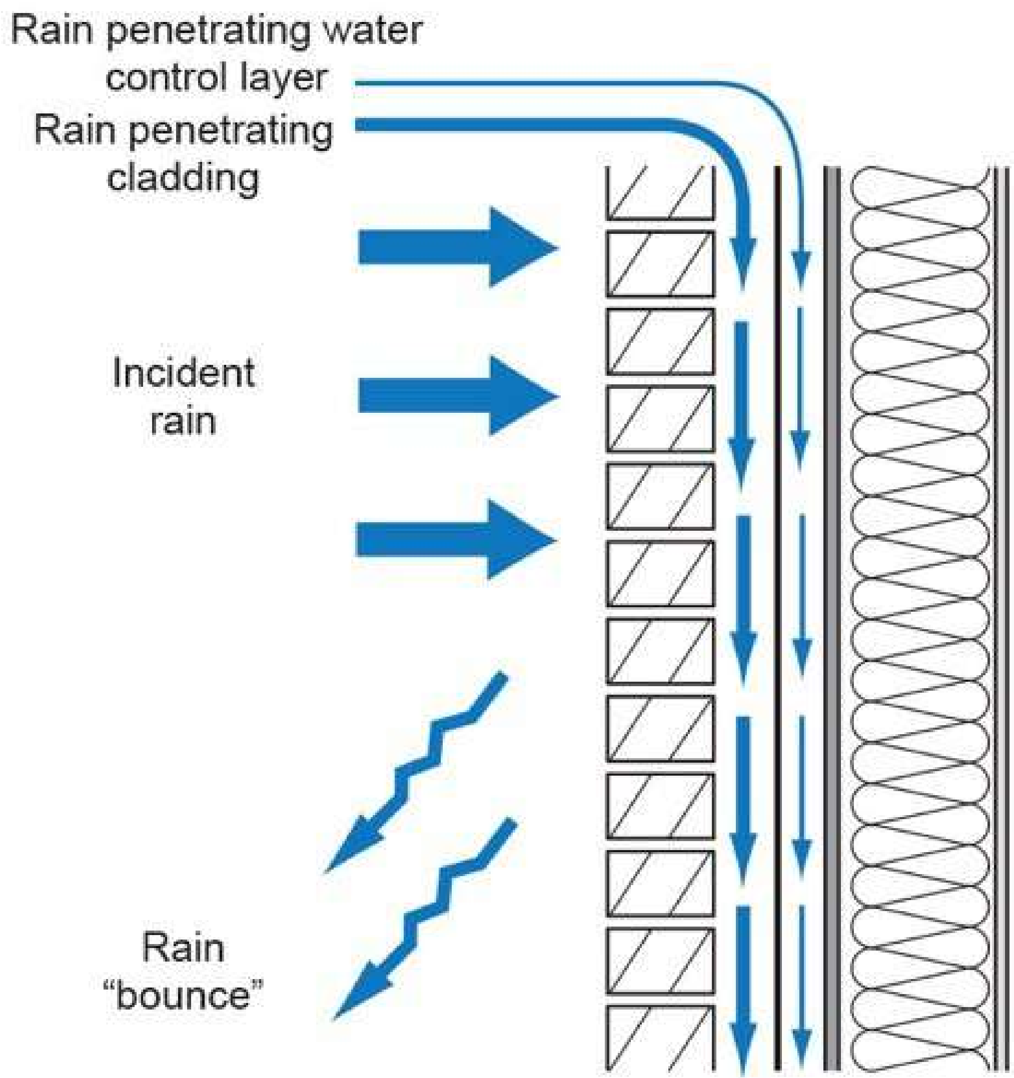
Straube and Kuenzel help us determine how much rain water gets to the wall…we more or less guess.

We assume 30% bounces off.

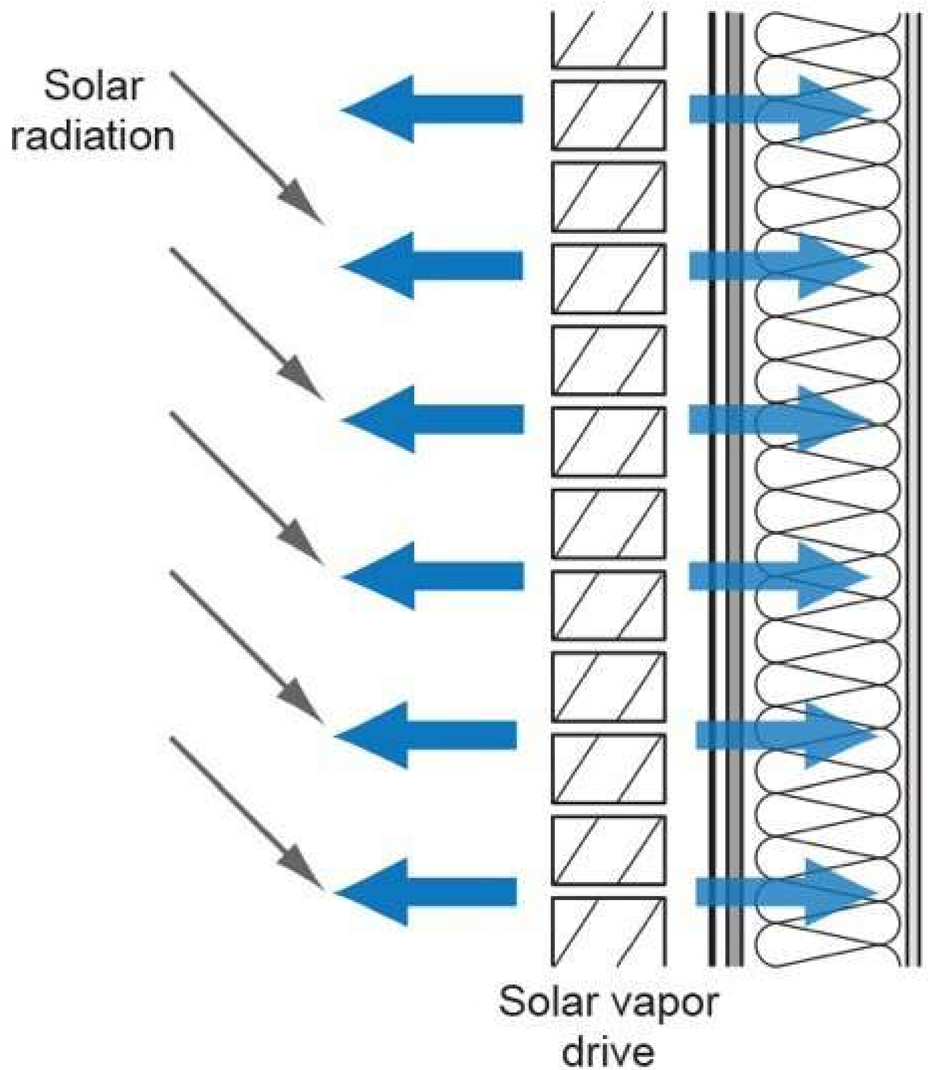
The 70% that stays on the wall is addressed by liquid conductivity (capillary flow) and vapor diffusion.

We further assume 1% penetrates the cladding.

And then assume that 1% of the 1% gets past the water control layer.



Rain penetrating water control layer
Rain penetrating cladding
Incident rain
Rain “bounce”


Solar
radiation
Solar vapor
drive

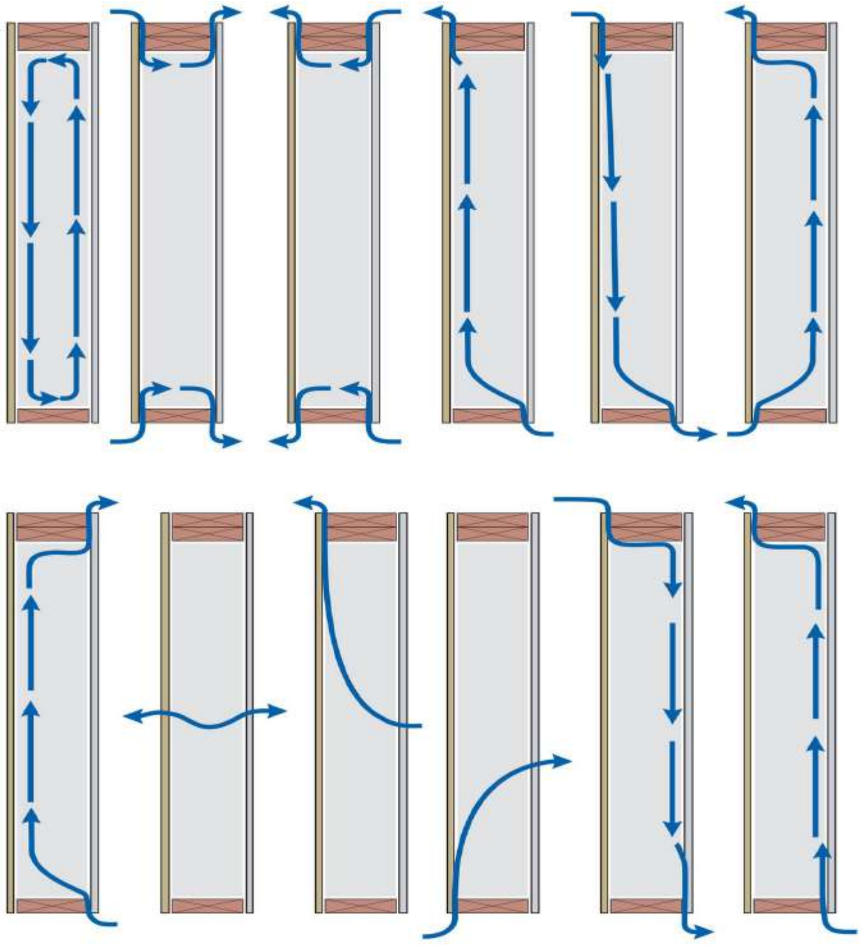
# Airflow

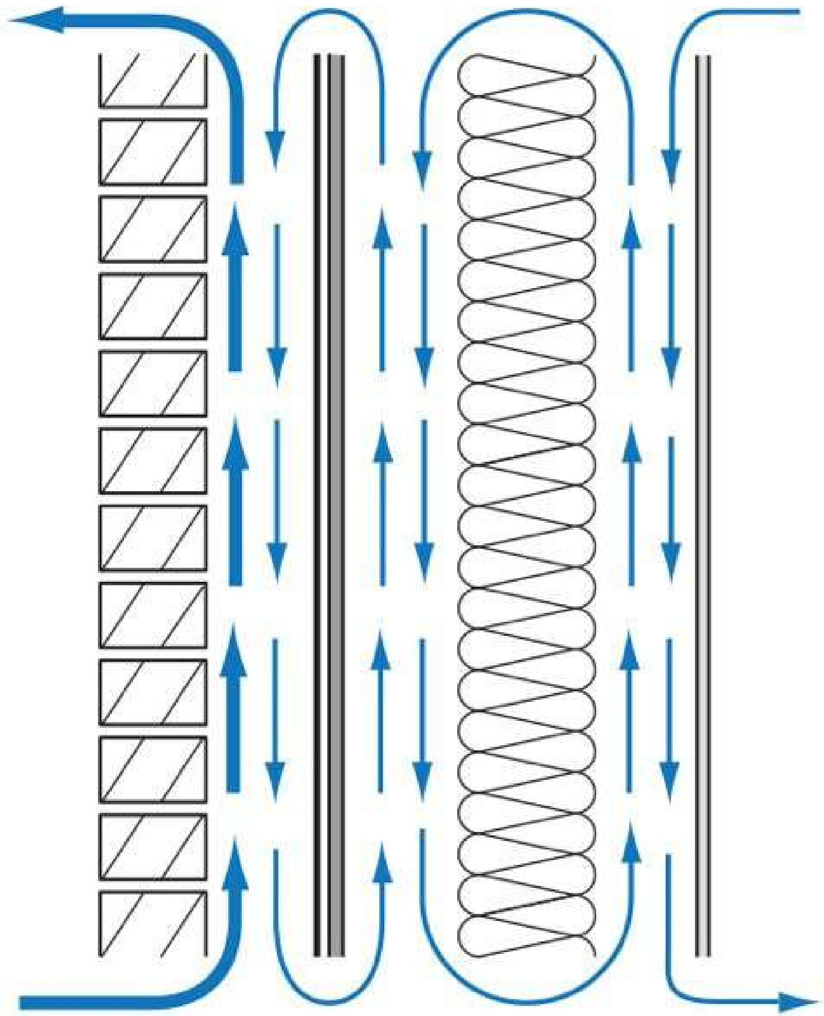
Airflow is 3-Dimensional…

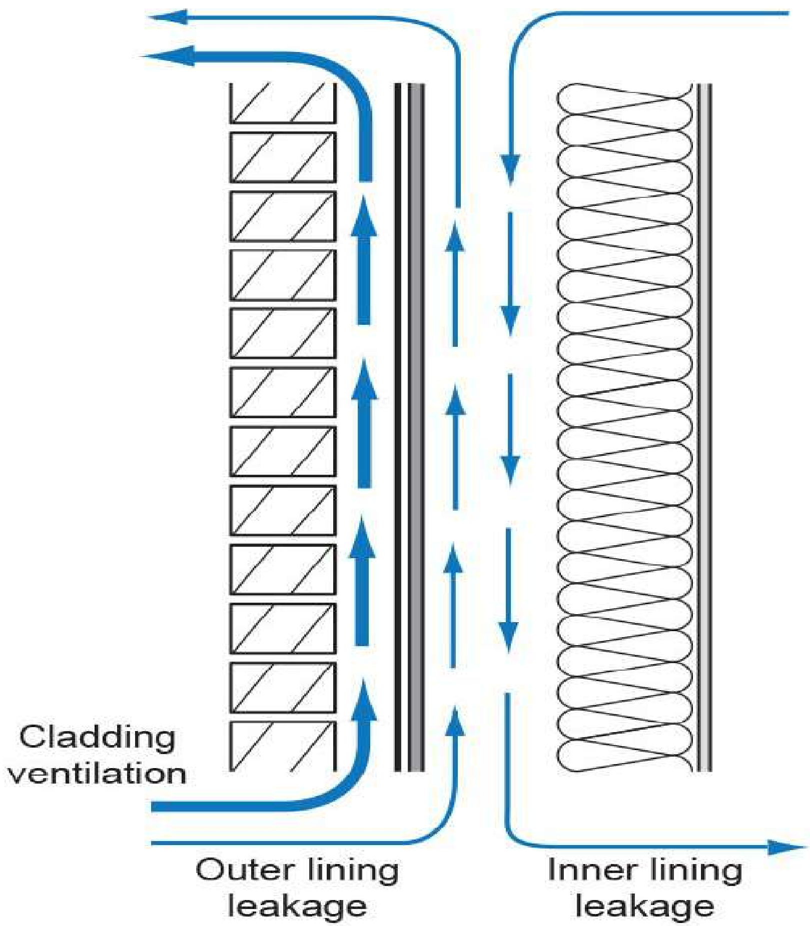
Buildings are Complex 3-Dimensional Multi-Layer Airflow Networks…

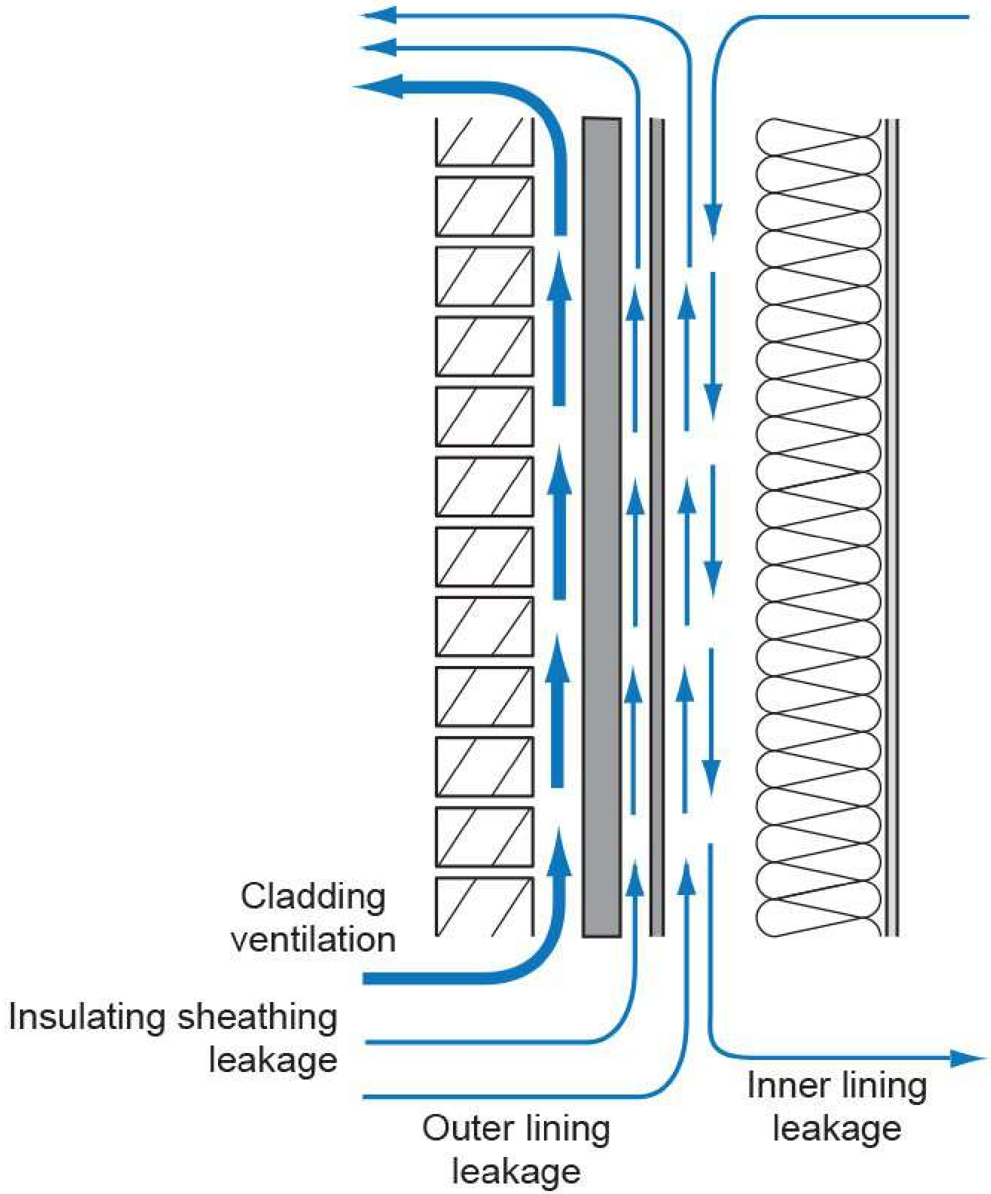
You Can't Model a 3-Dimensional Transport Mechanism with a 1-Dimensional Model…

Unless you make things up….



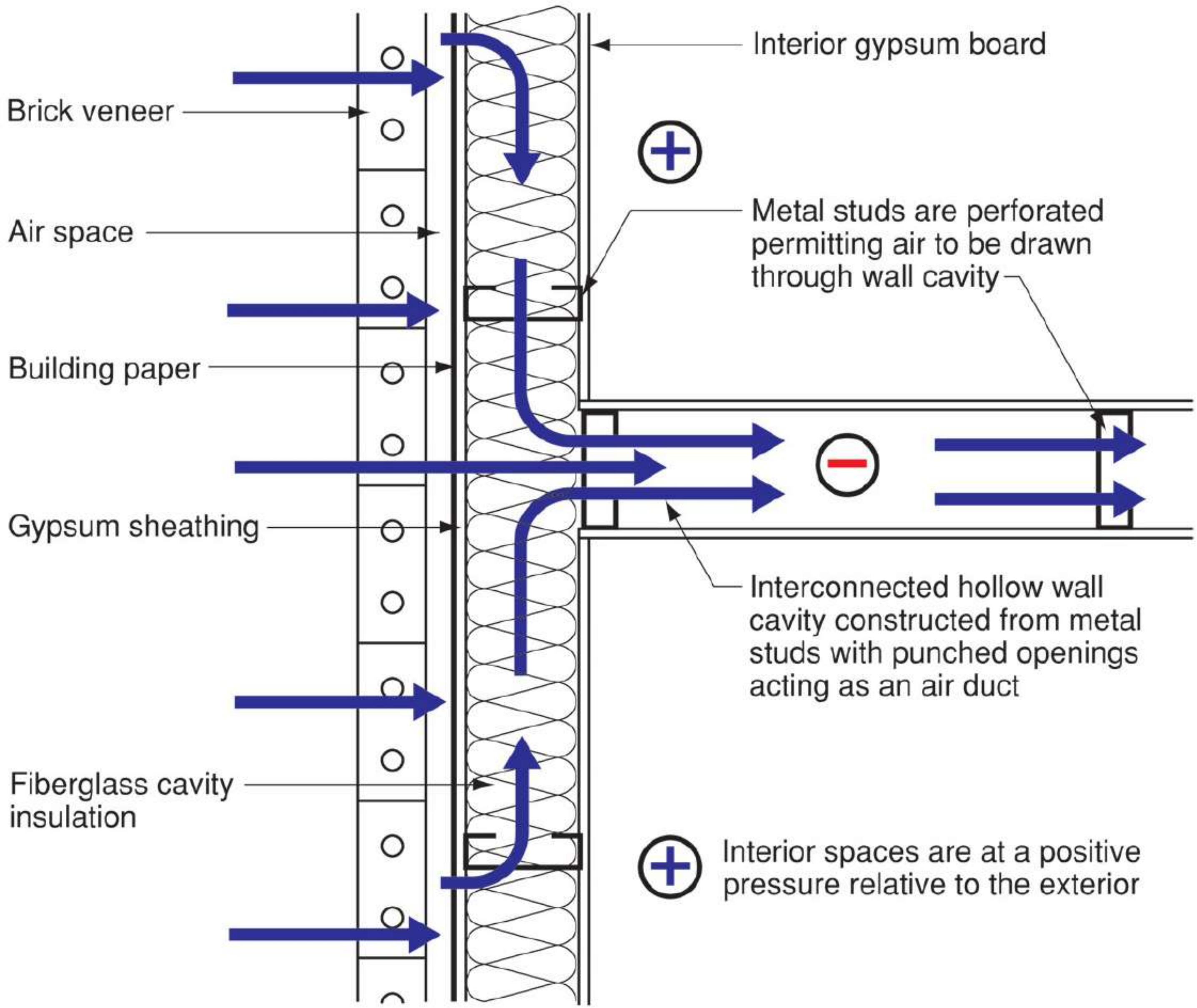



Cladding
ventilation
Outer lining
leakage
Inner lining
leakage


Cladding
ventilation
Insulating sheathing
leakage
Outer lining
leakage
Inner lining
leakage

## Cladding Ventilation/ Sheathing Ventilation

| | Flow Rate | Gap | ACH |
|---|---|---|---|
| **Wood Siding** | 0.1 cfm/sf | 3/16” | 20 |
| **Vinyl Siding** | 0.5 cfm/sf | 3/16” | 200 |
| **Brick Veneer** | 0.15 cfm/sf | 1” | 10 |
| **Stucco (vented)** | 0.1 cfm/sf | 3/8” | 10 |
| **Stucco (direct applied)** | none | none | 0 |
| **Sheathing flanking flow** | 0.05 cfm/sf | 3/16” | 10 |



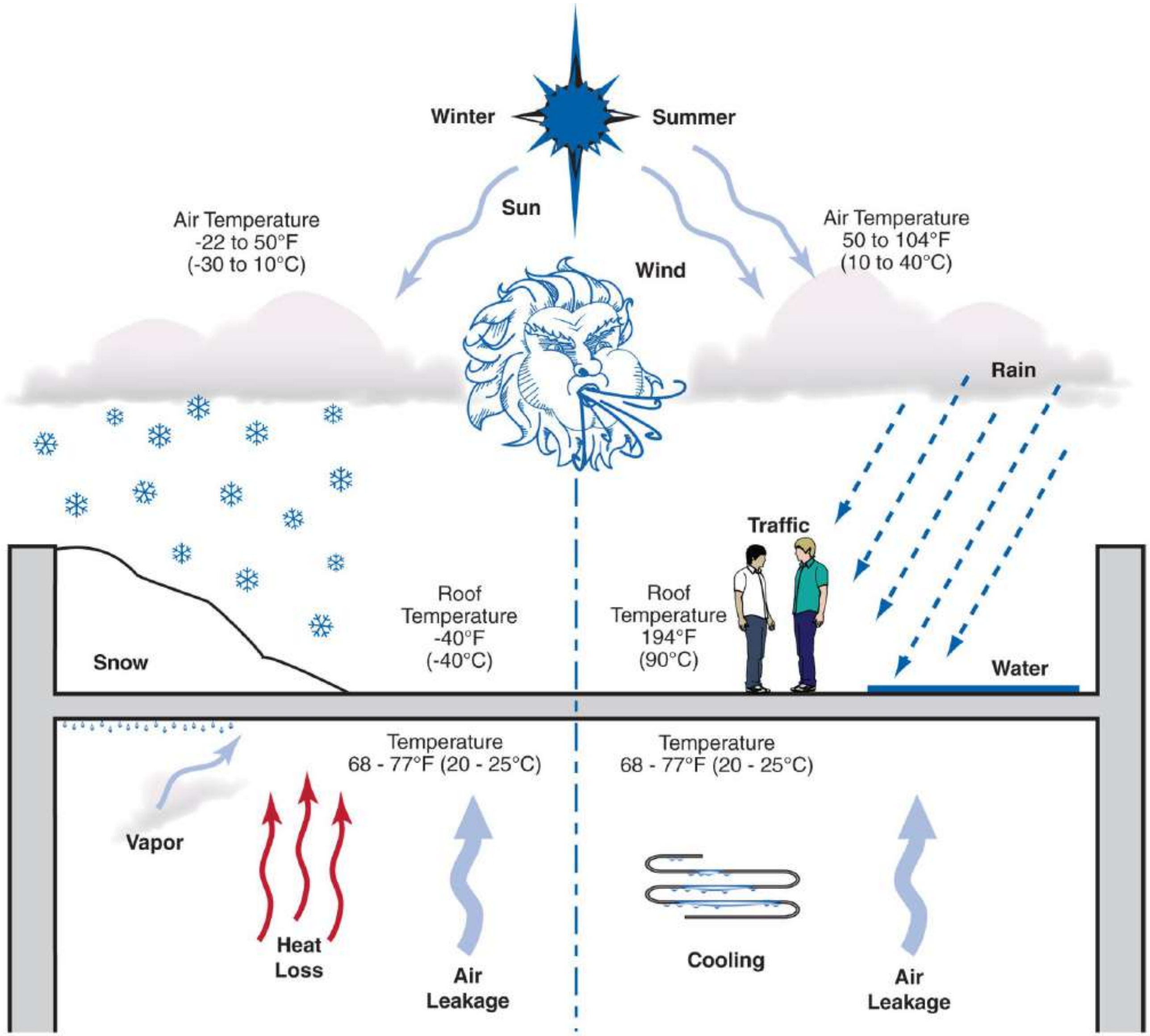
Interior gypsum board
Brick veneer
Air space
Metal studs are perforated permitting air to be drawn through wall cavity
Building paper
Gypsum sheathing
Interconnected hollow wall cavity constructed from metal studs with punched openings acting as an air duct
Fiberglass cavity insulation
Interior spaces are at a positive pressure relative to the exterior

Hygrothermal Analysis

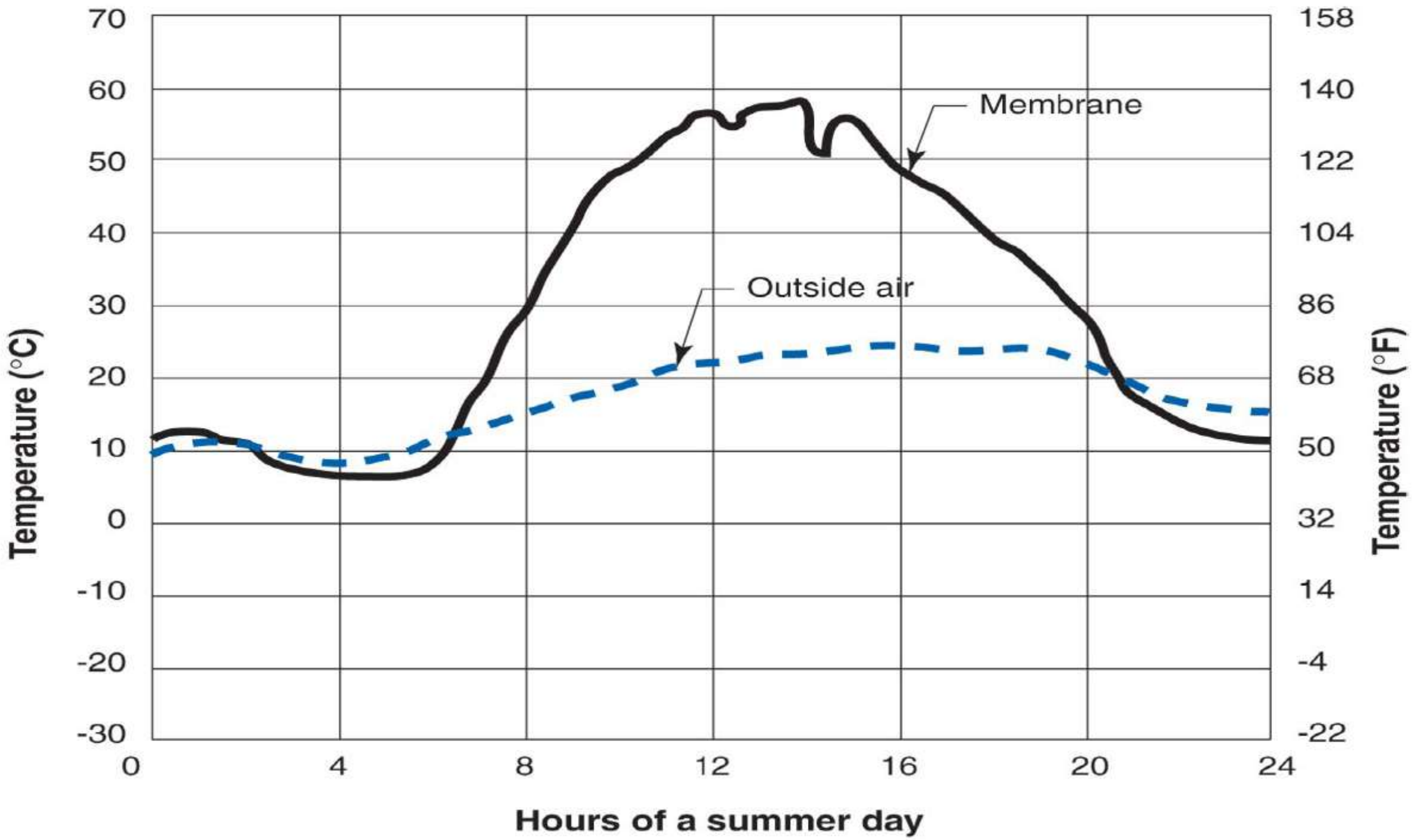
You Can Get Any Answer You Want Based On Your Assumptions….

This is Not Good….But is Often Profitable or Dangerous or Both…

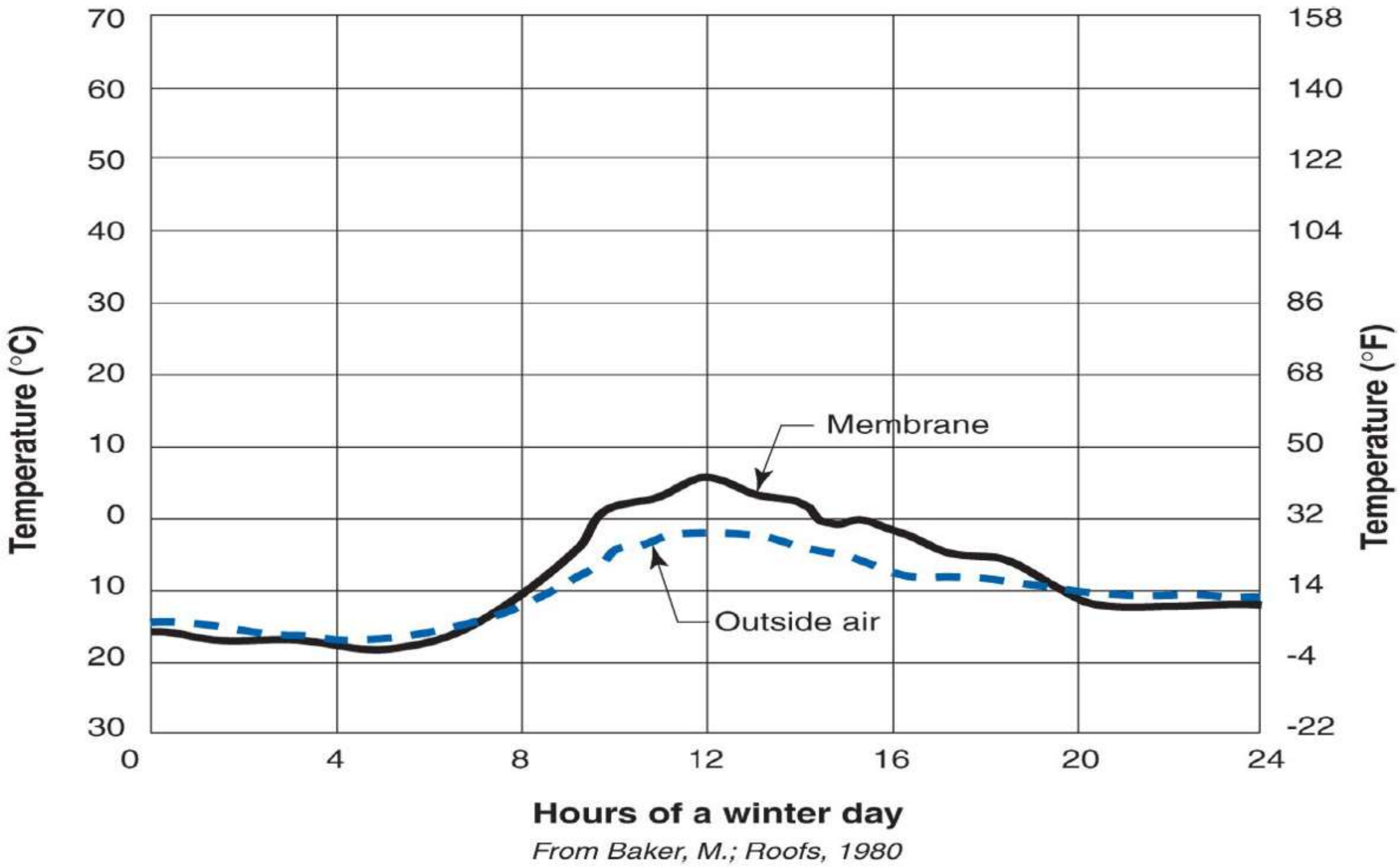
# Roofs and Ice Dams

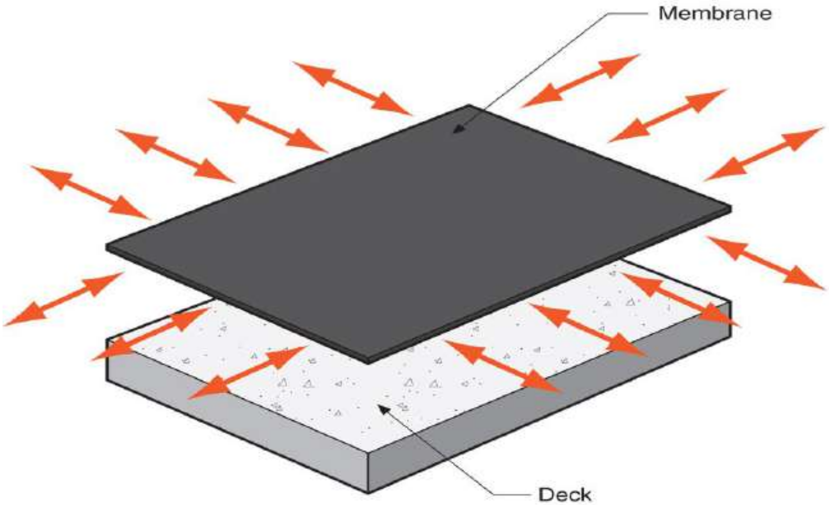


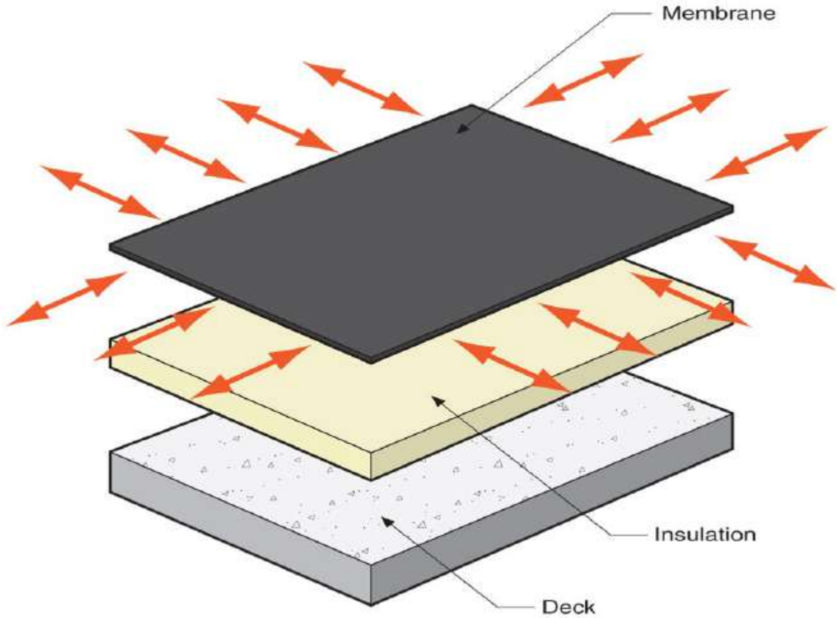

*Adapted from Baker, M.; Roofs, 1980;*
*Courtesy National Research Council of Canada*

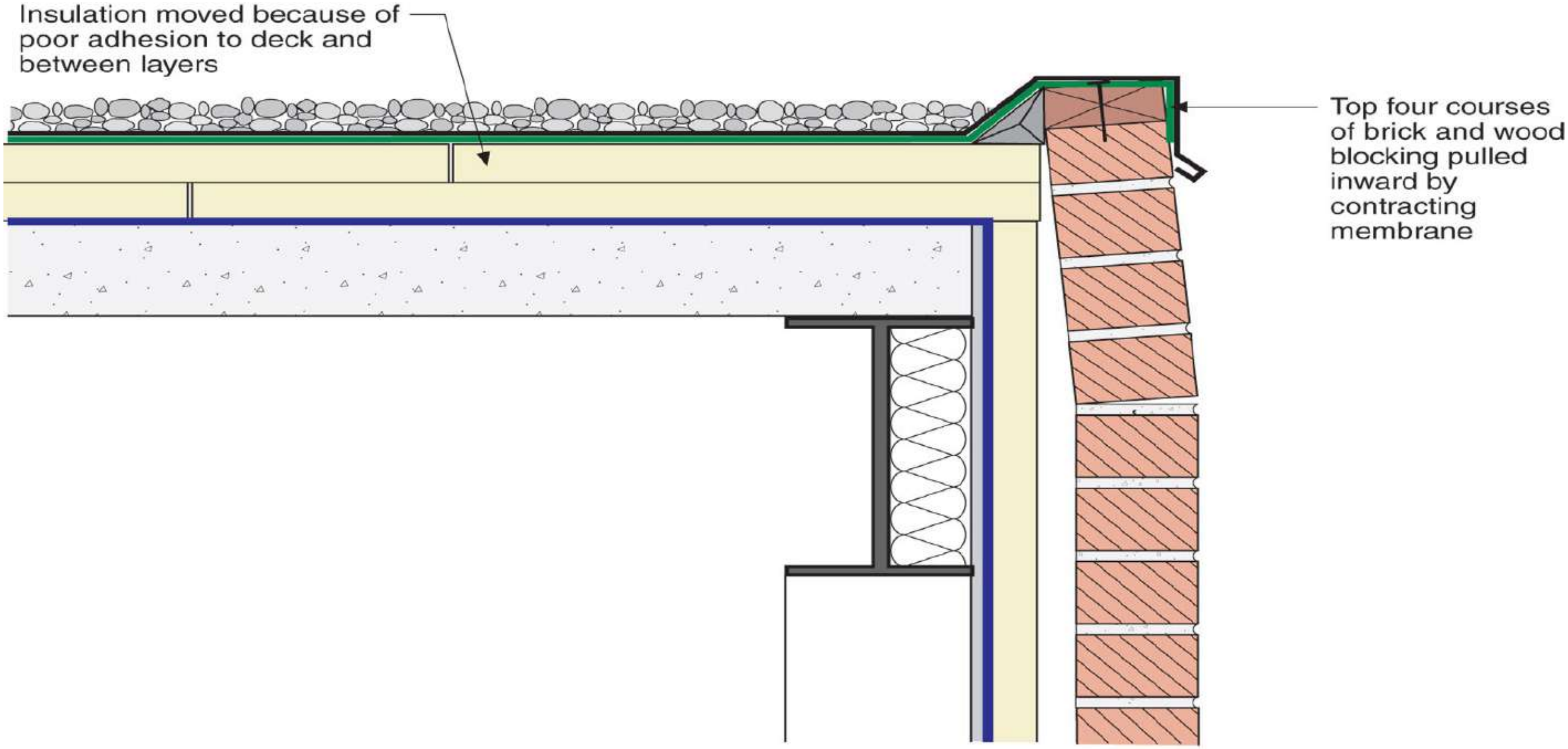



*From Baker, M.; Roofs, 1980*

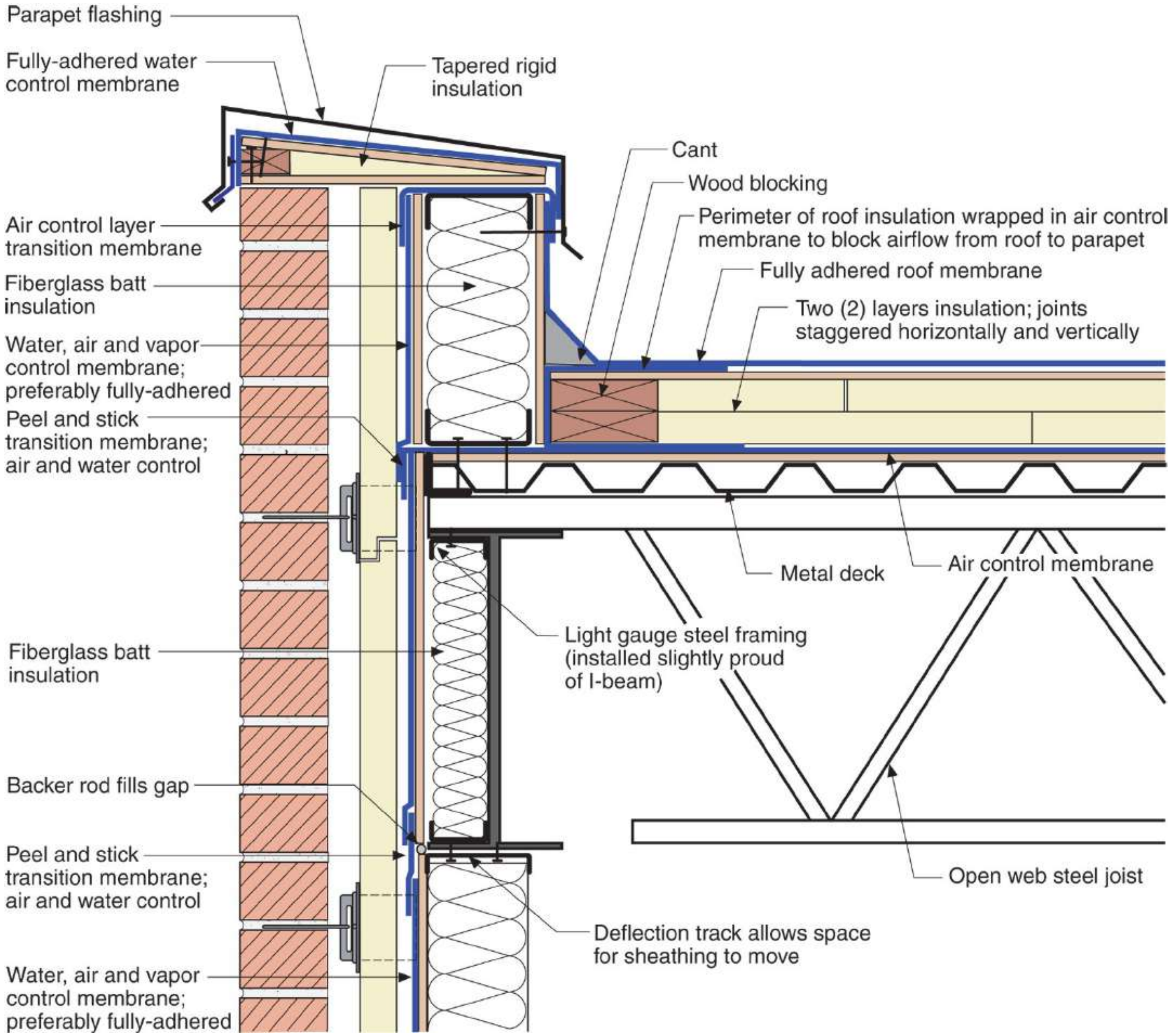

70
60
50
40
30
20
10
0
10
20
30
158
140
122
104
86
68
50
32
14
-4
-22
Temperature (°C)
Temperature (°F)
Membrane
Outside air
0
4
8
12
16
20
24
Hours of a winter day
From Baker, M.; Roofs, 1980


Membrane
Deck

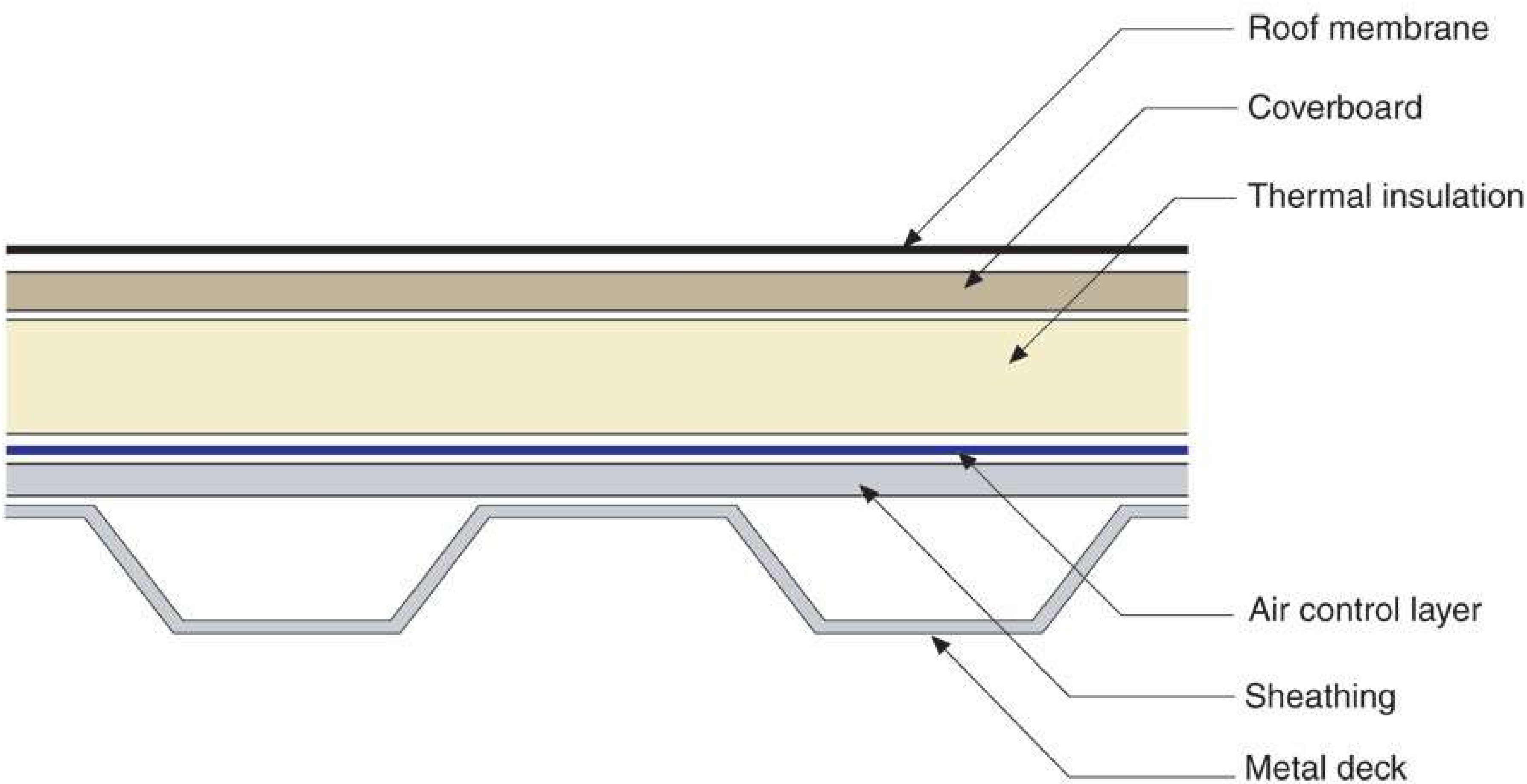

Membrane
Insulation
Deck

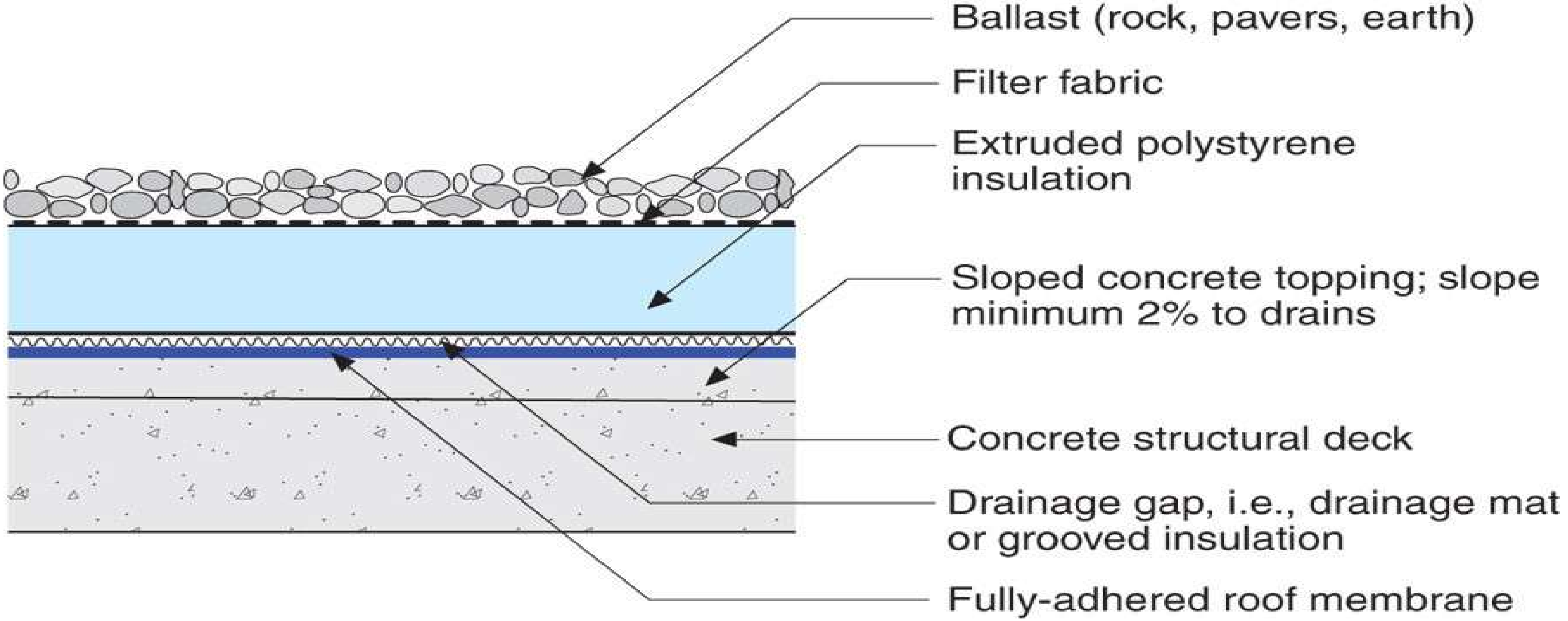


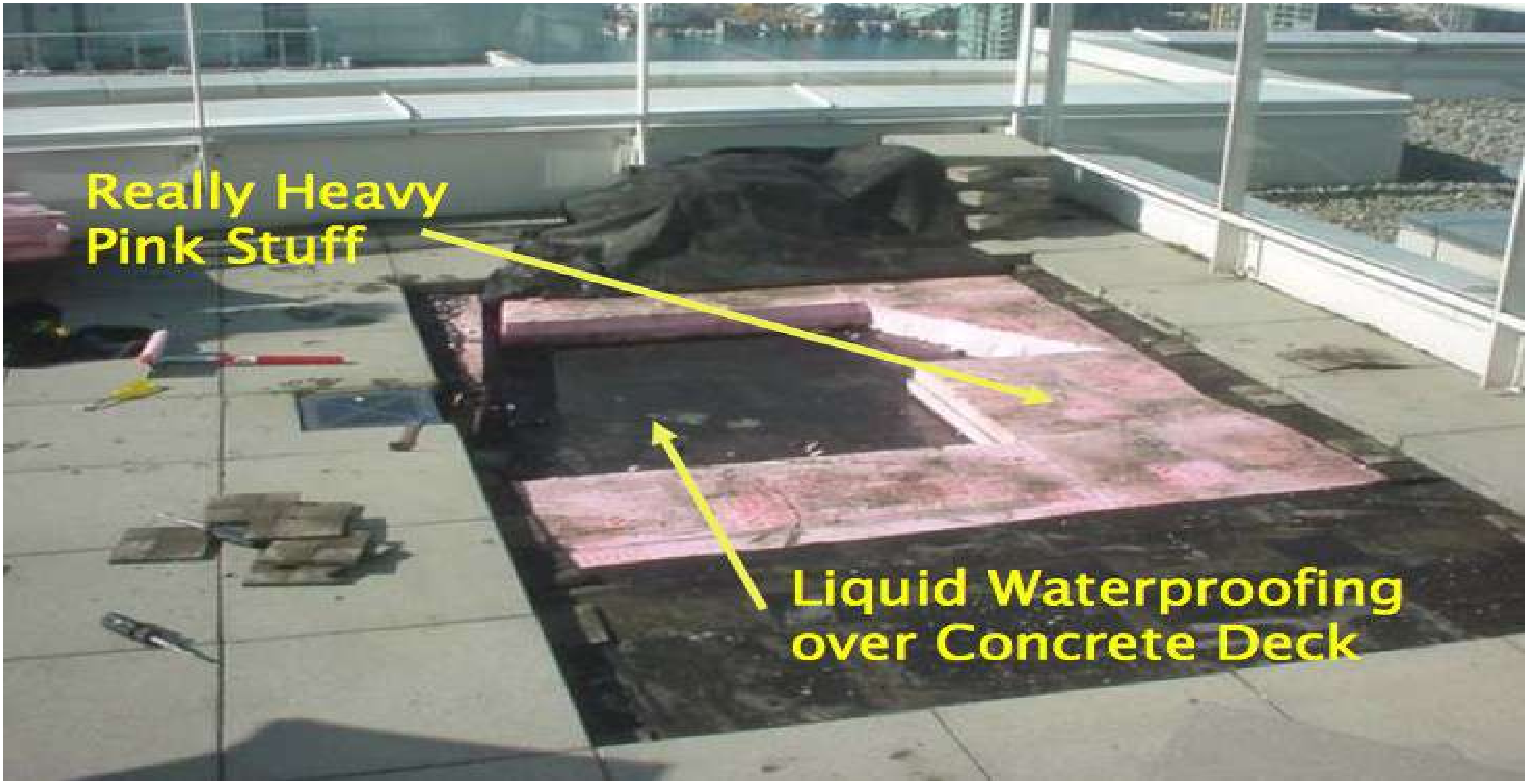

Adapted from Baker, M.; Roofs, 1980; Courtesy National Research Council of Canada

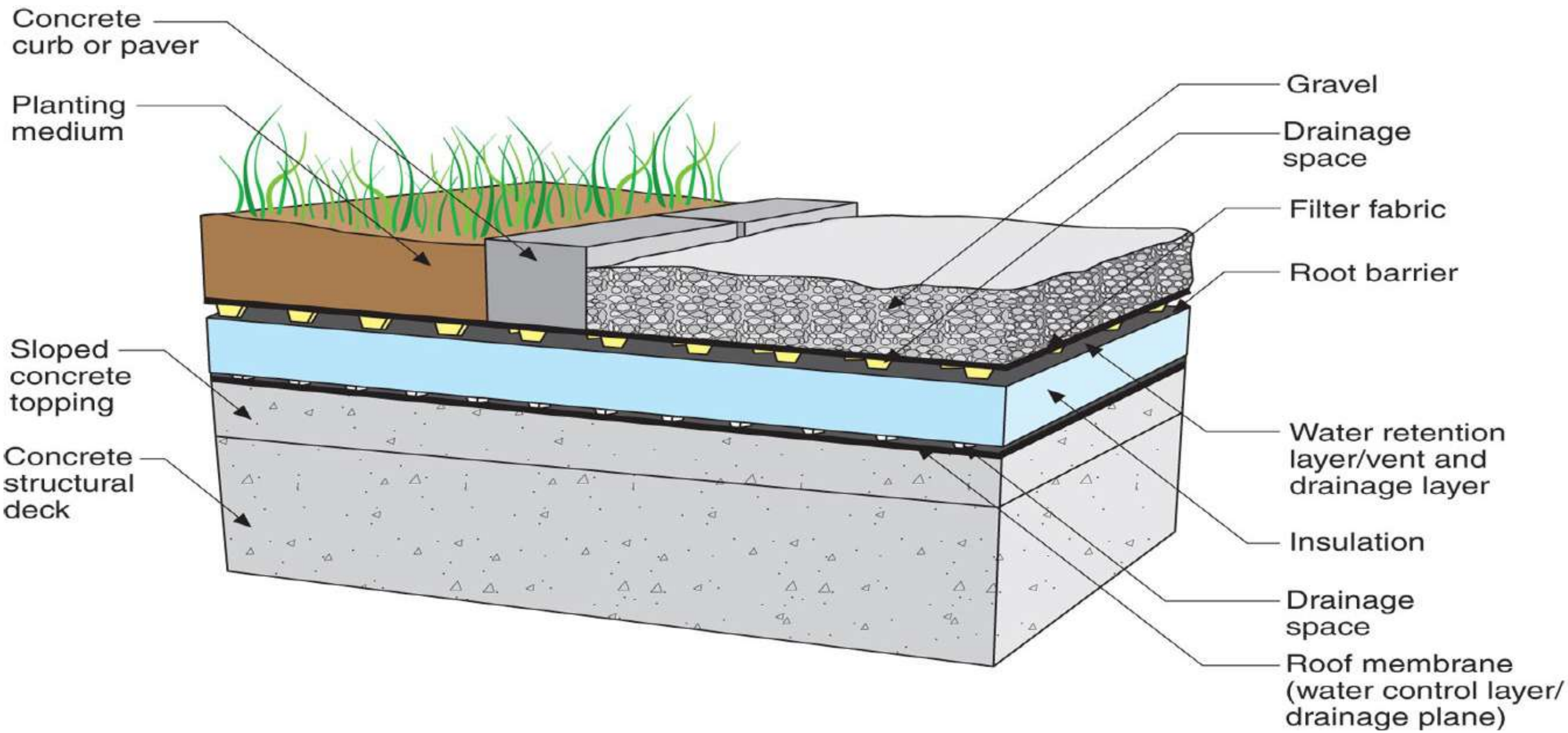


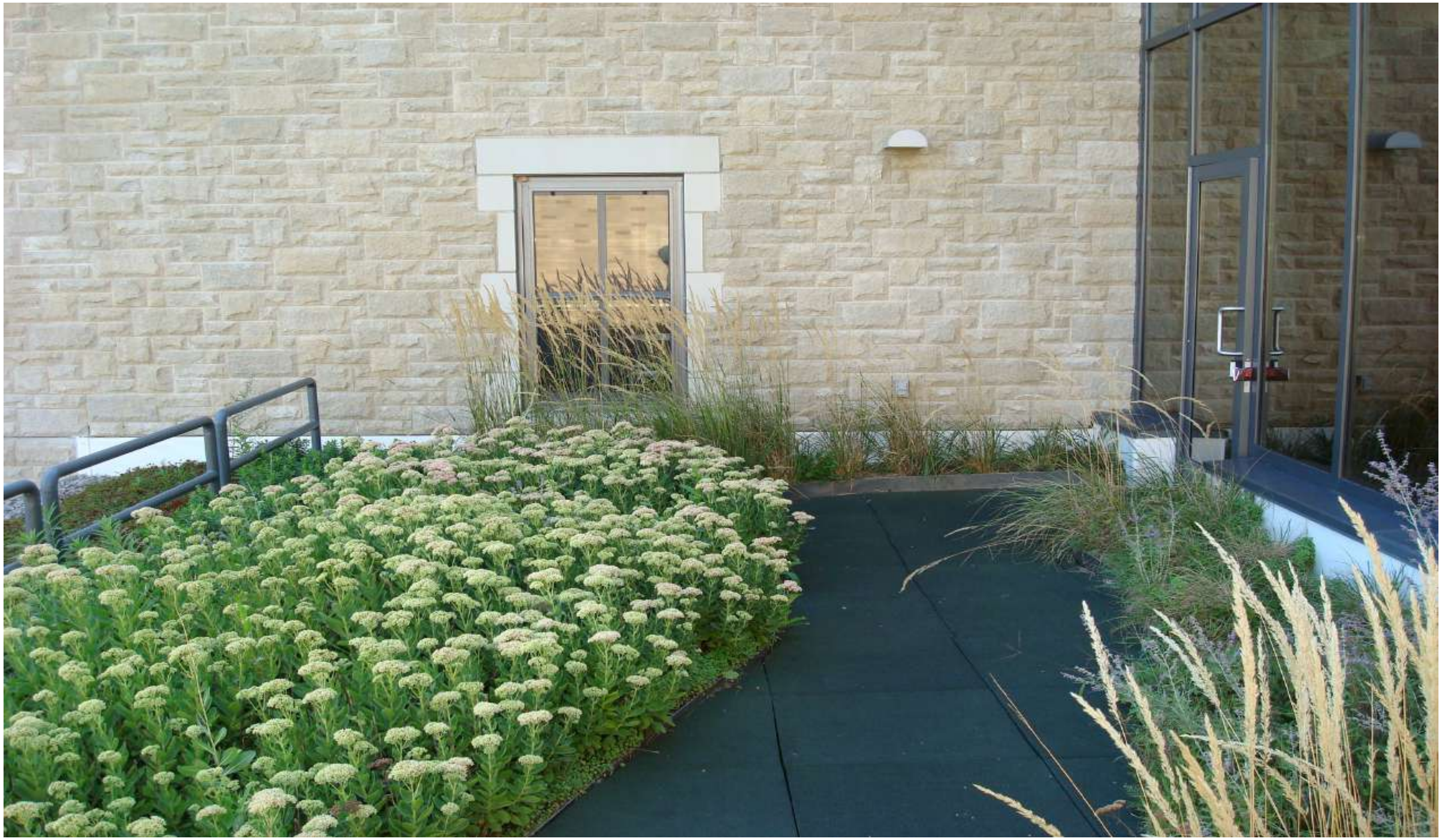
Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Cant
Wood blocking
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Air control layer transition membrane
Fiberglass batt insulation
Water, air and vapor control membrane; preferably fully-adhered
Peel and stick transition membrane; air and water control
Metal deck
Air control membrane
Light gauge steel framing (installed slightly proud of I-beam)
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Open web steel joist
Deflection track allows space for sheathing to move
Water, air and vapor control membrane; preferably fully-adhered

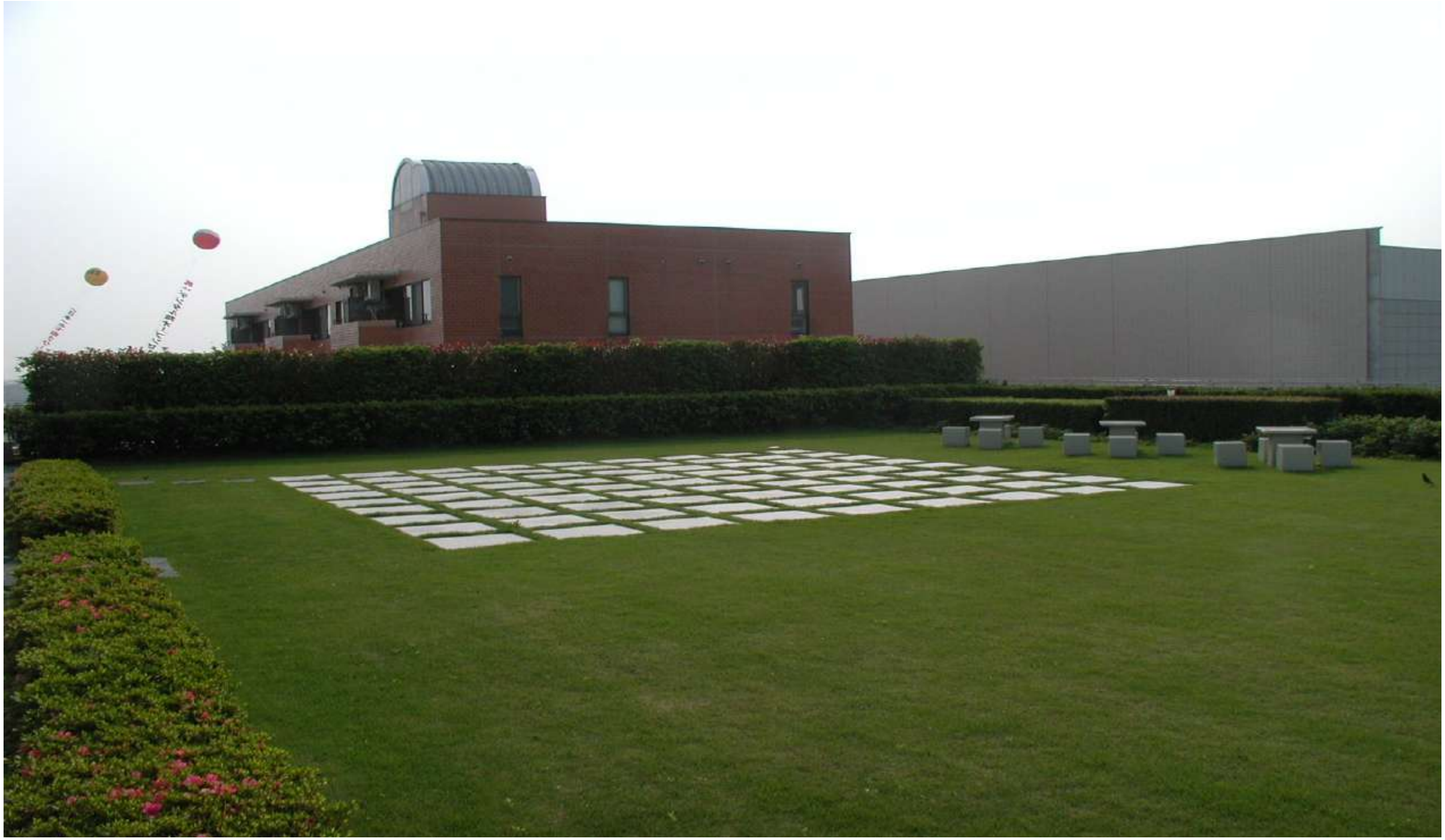

Roof membrane
Coverboard
Thermal insulation
Air control layer
Sheathing
Metal deck

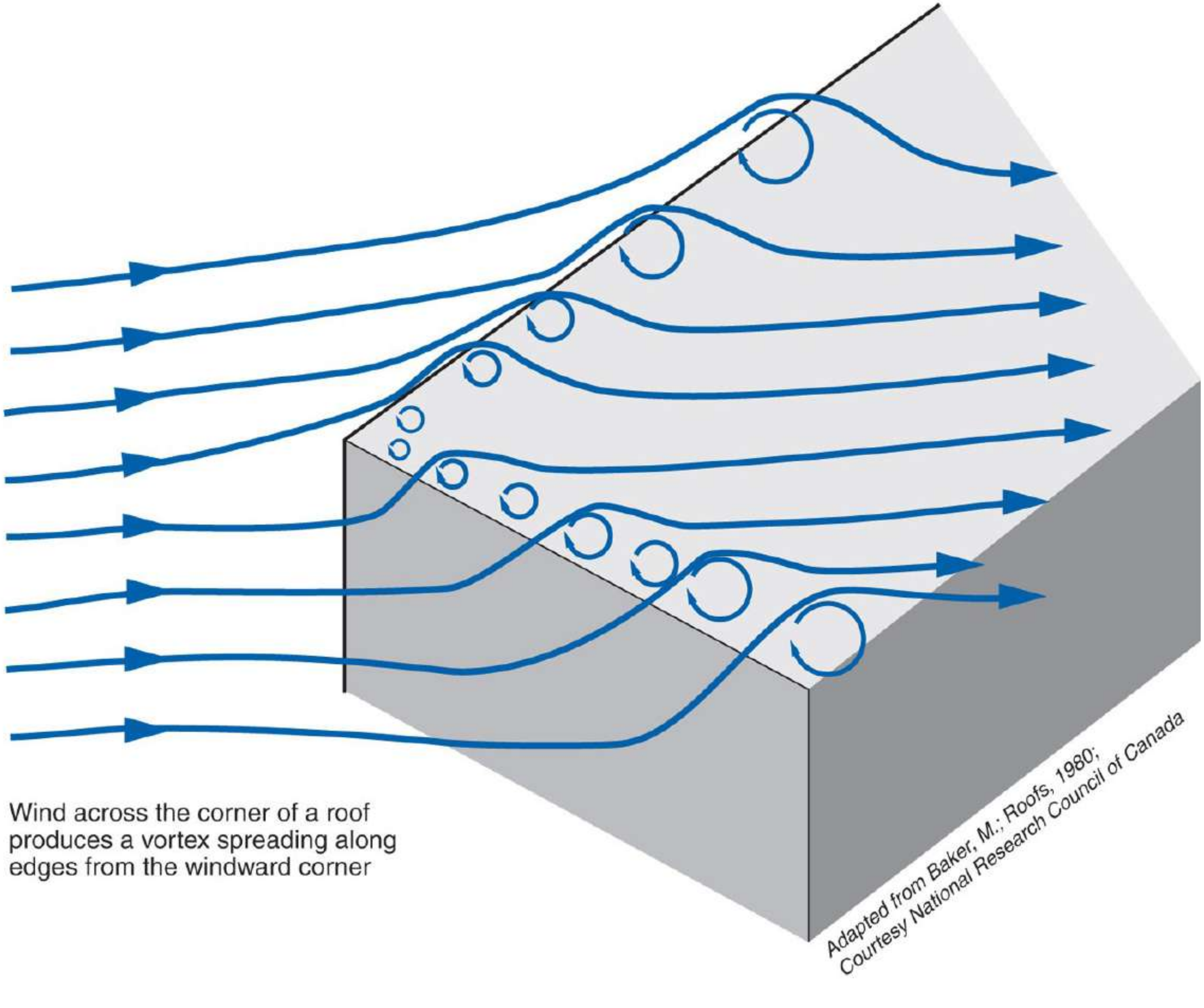

Ballast (rock, pavers, earth)
Filter fabric
Extruded polystyrene insulation
Sloped concrete topping; slope minimum 2% to drains
Concrete structural deck
Drainage gap, i.e., drainage mat or grooved insulation
Fully-adhered roof membrane


Really Heavy
Pink Stuff
Liquid Waterproofing
over Concrete Deck

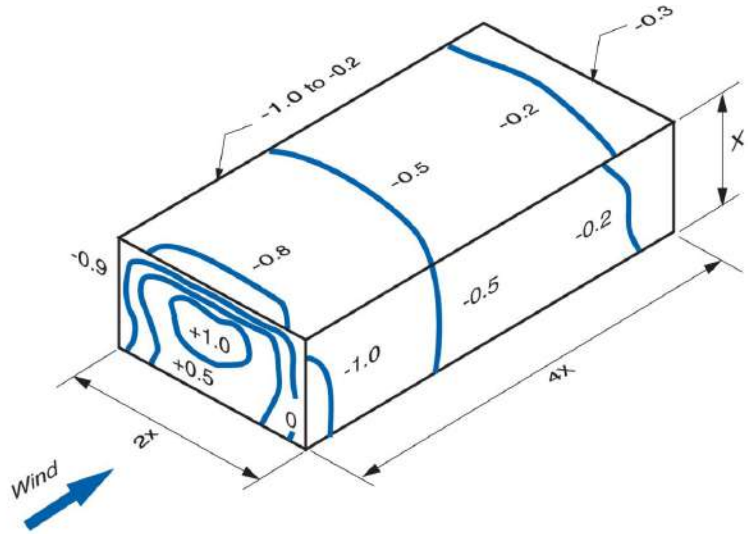

Concrete curb or paver
Planting medium
Sloped concrete topping
Concrete structural deck
Gravel
Drainage space
Filter fabric
Root barrier
Water retention layer/vent and drainage layer
Insulation
Drainage space
Roof membrane (water control layer/ drainage plane)



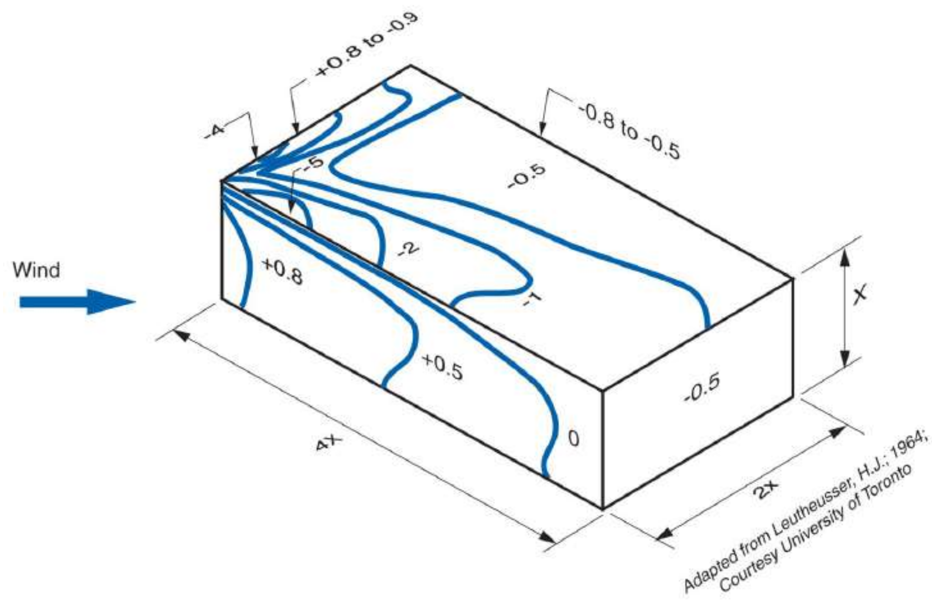




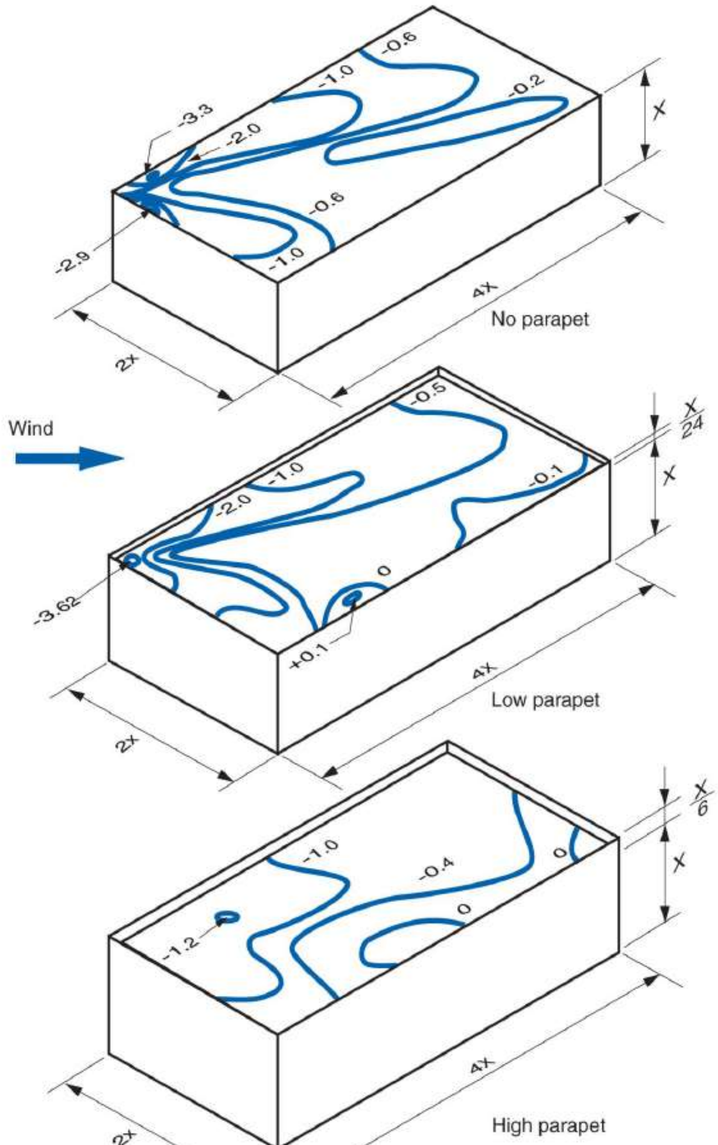

Wind across the corner of a roof produces a vortex spreading along edges from the windward corner



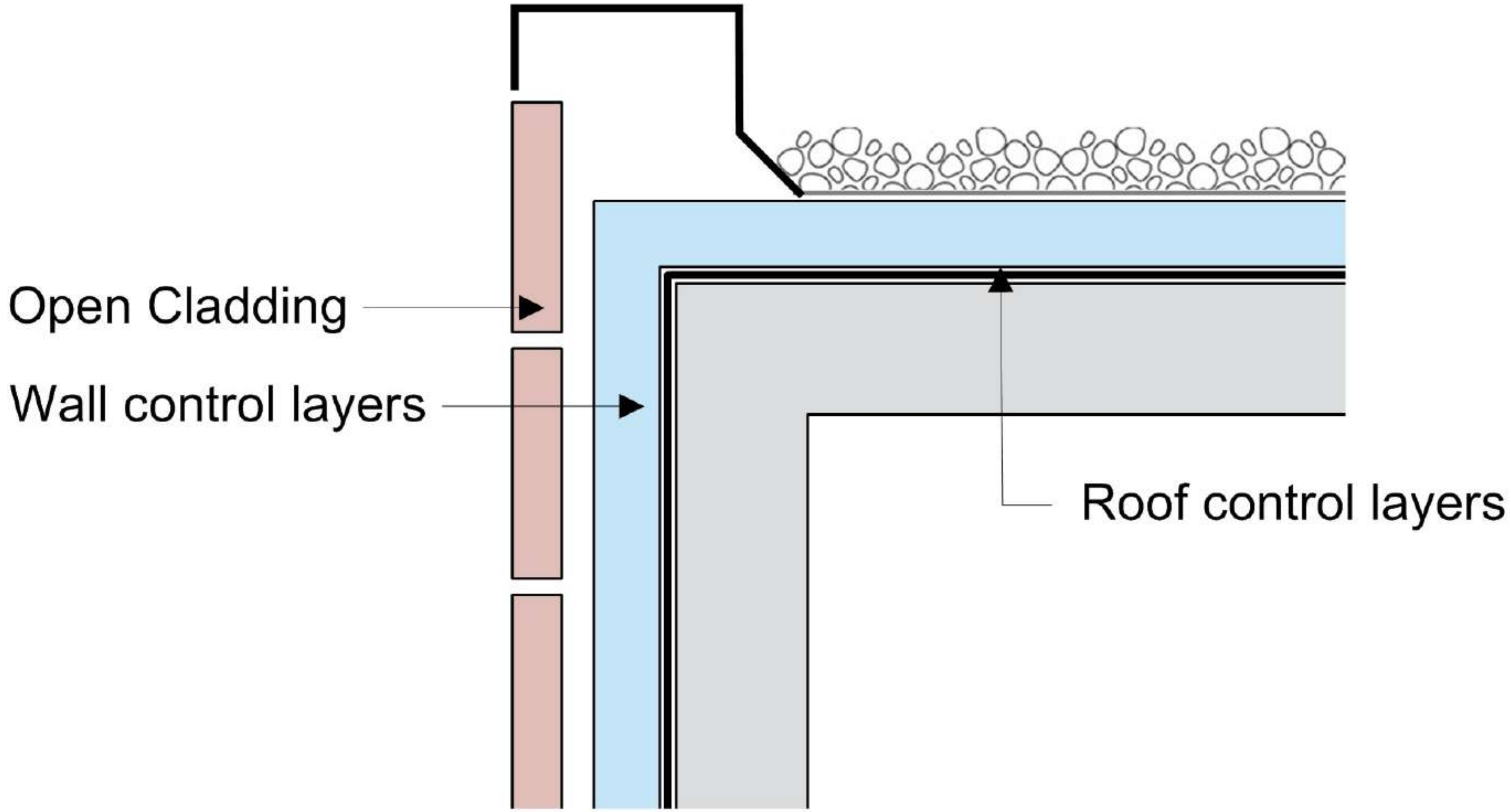
-0.3
-1.0 to -0.2
-0.2
X
-0.5
-0.2
-0.9
-0.8
-0.5
+1.0
-1.0
+0.5
0
4X
2X
Wind

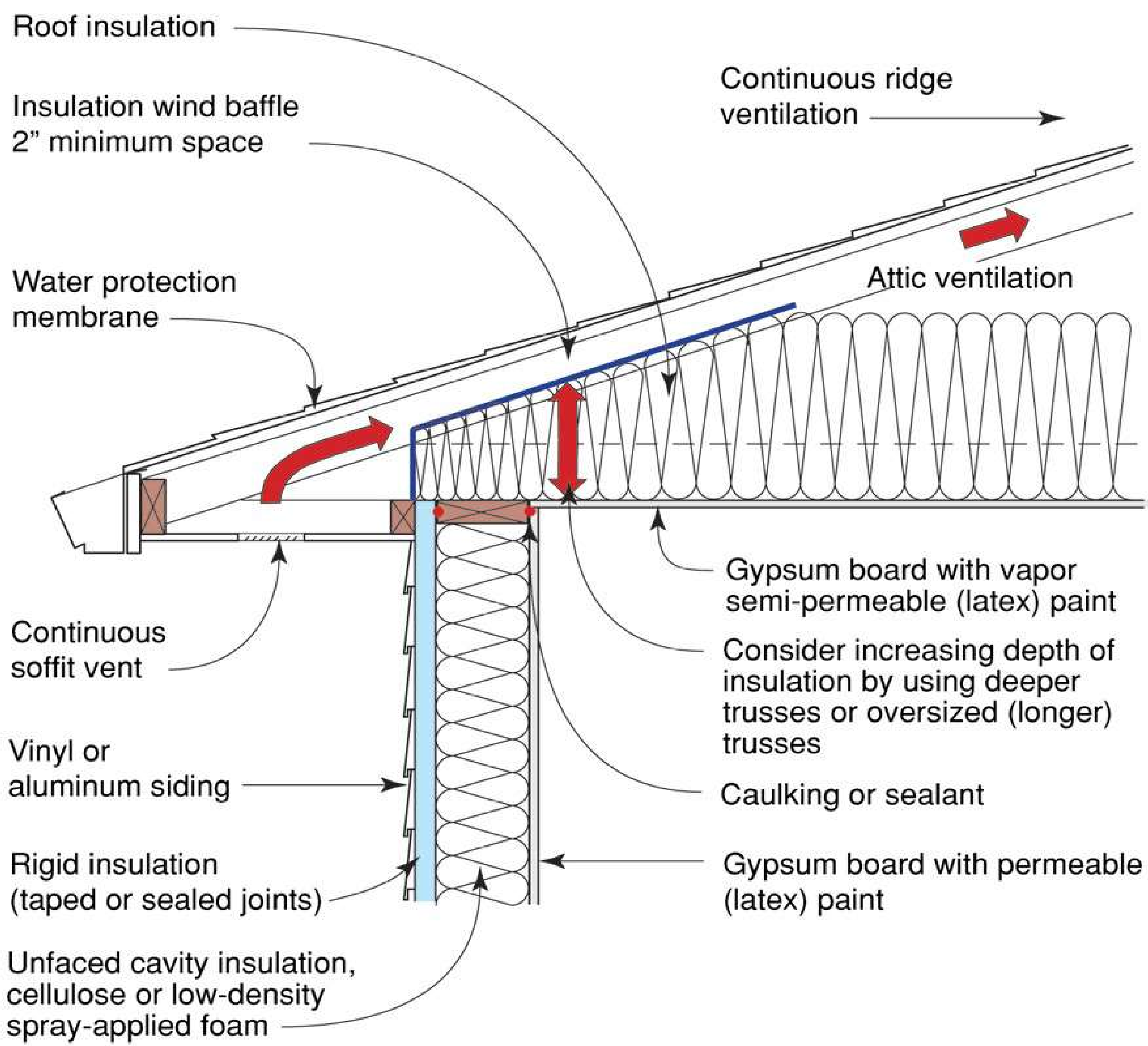
+0.8 to -0.9
-4
-0.8 to -0.5
-5
-0.5
Wind
-2
+0.8
-1
X
+0.5
-0.5
0
4X
2X
Adapted from Leutheusser, H.J.: 1964;
Courtesy University of Toronto

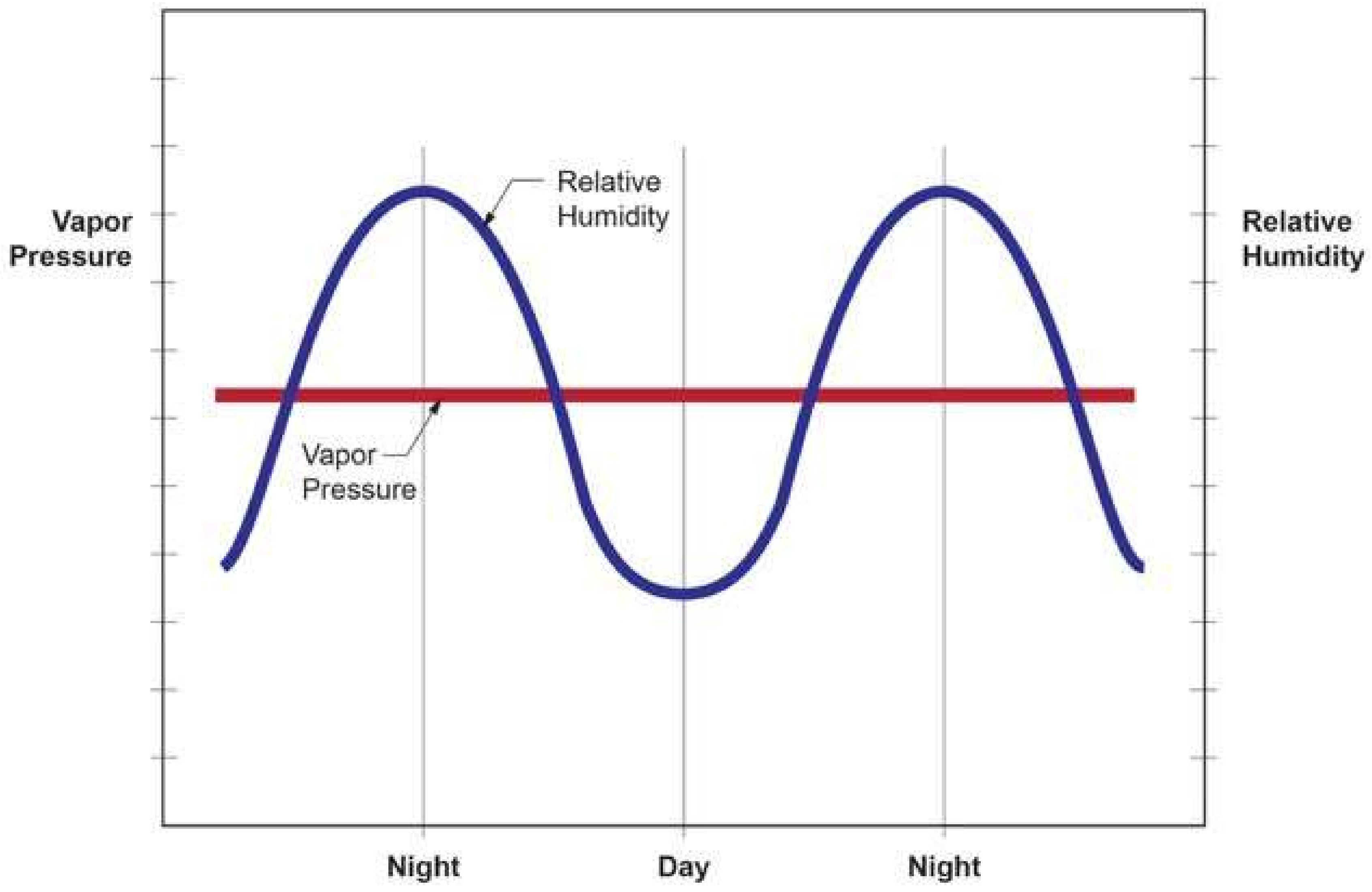


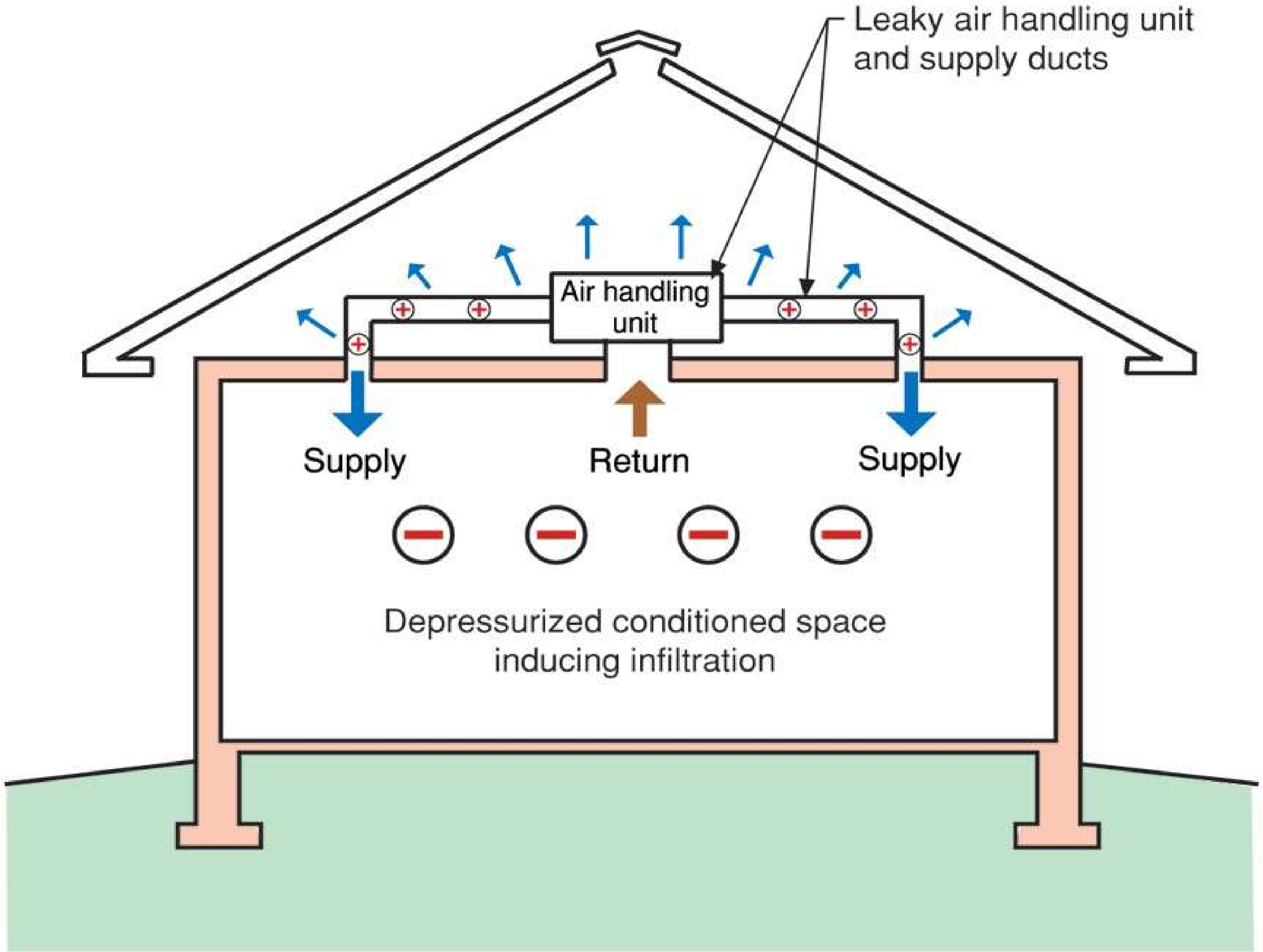

*Adapted from Leutheusser, H.J.; 1964; Courtesy University of Toronto*



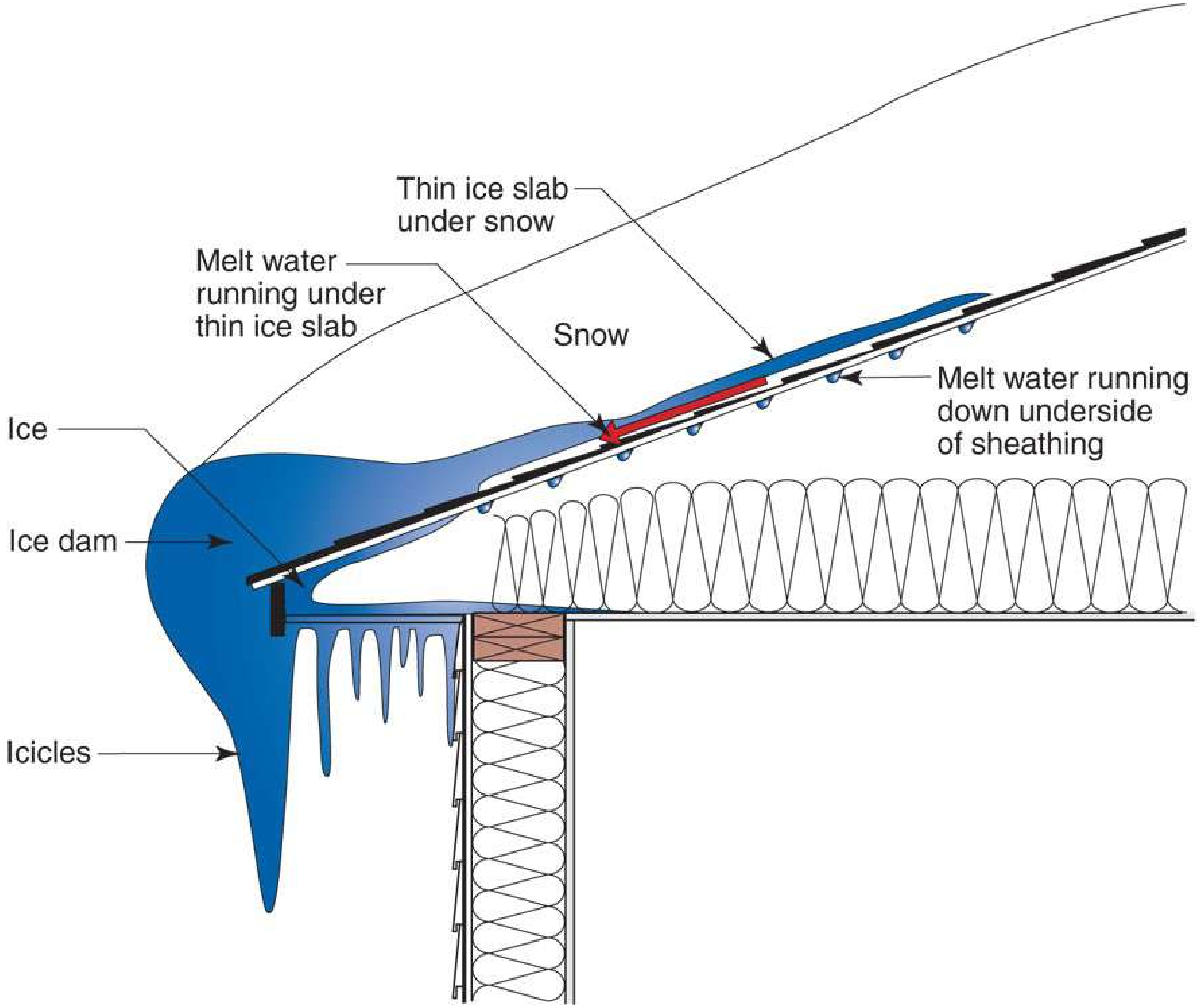
Open Cladding
Wall control layers
Roof control layers


Roof insulation
Insulation wind baffle
2" minimum space
Continuous ridge
ventilation
Water protection
membrane
Attic ventilation
Continuous
soffit vent
Gypsum board with vapor
semi-permeable (latex) paint
Consider increasing depth of
insulation by using deeper
trusses or oversized (longer)
trusses
Vinyl or
aluminum siding
Caulking or sealant
Rigid insulation
(taped or sealed joints)
Gypsum board with permeable
(latex) paint
Unfaced cavity insulation,
cellulose or low-density
spray-applied foam


Vapor
Pressure
Relative
Humidity
Relative
Humidity
Vapor
Pressure
Night
Day
Night




Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

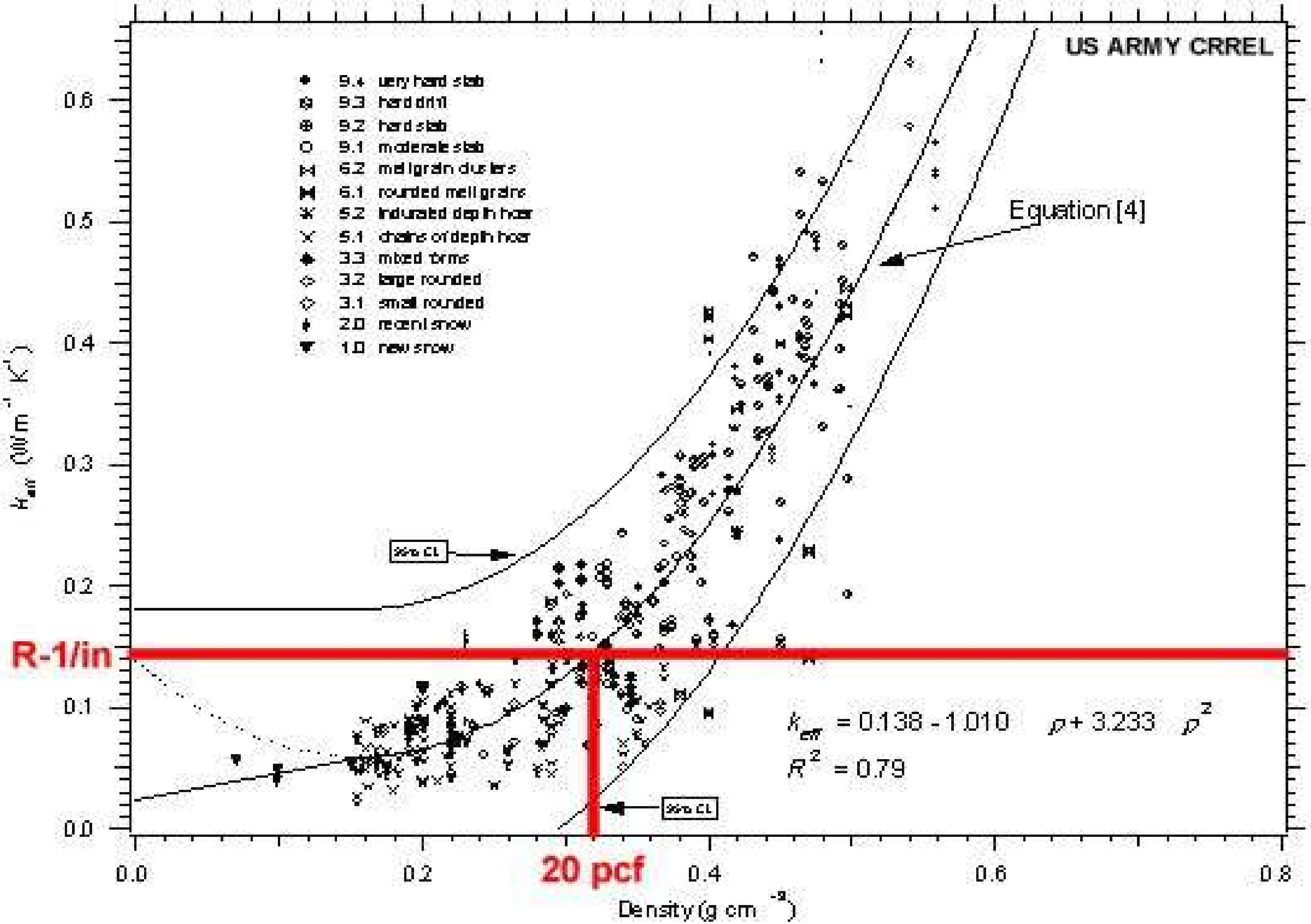

Thin ice slab
under snow
Melt water
running under
thin ice slab
Snow
Melt water running
down underside
of sheathing
Ice
Ice dam
Icicles

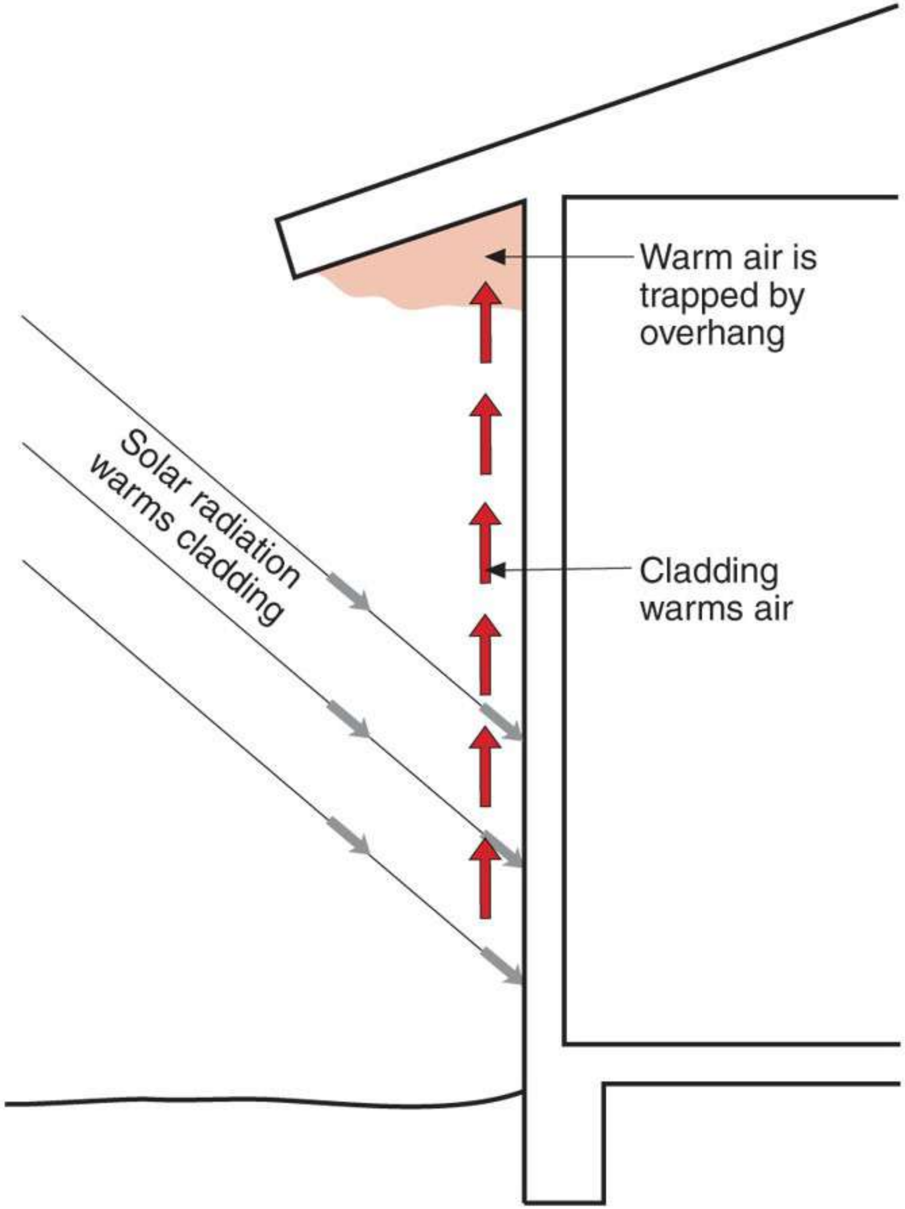
15


021


WESTFORD REAL ESTATE
Residential & Commercial

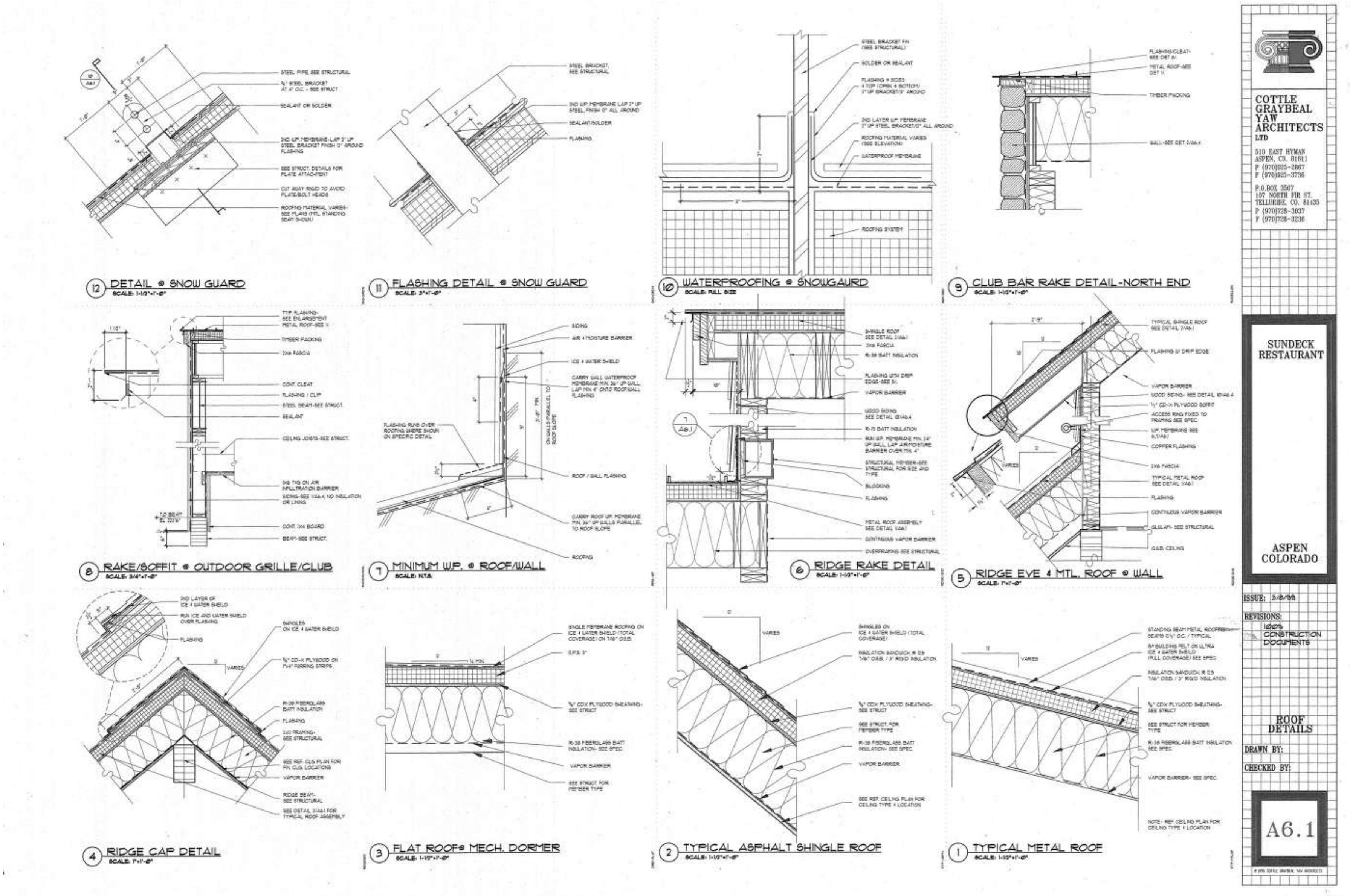

NO
PARKING
THIS BLOCK
THURSDAY

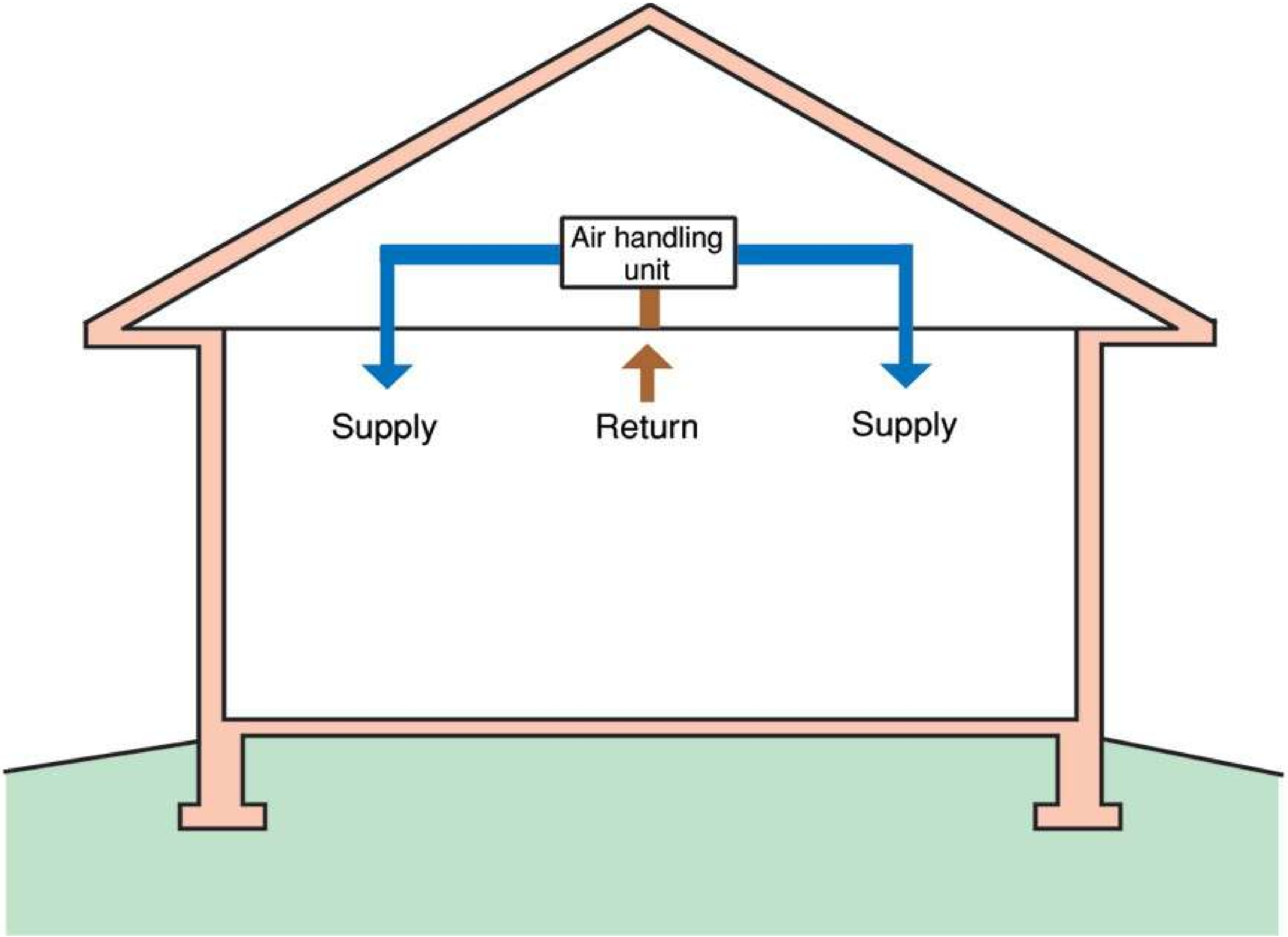

US ARMY CRREL
9.4 very hard slab
9.3 hard drift
9.2 hard slab
9.1 moderate slab
6.2 melt grain clusters
6.1 rounded melt grains
5.2 indurated depth hoar
5.1 chains of depth hoar
3.3 mixed forms
3.2 large rounded
3.1 small rounded
2.0 recent snow
1.0 new snow
Equation [4]
$k_{eff}$ = 0.138 - 1.010 ρ + 3.233 ρ²
R² = 0.79
R-1/in
20 pcf
$k_{eff}$ (W m⁻¹ K⁻¹)
Density (g cm⁻³)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.8


Warm air is trapped by overhang
Solar radiation warms cladding
Cladding warms air

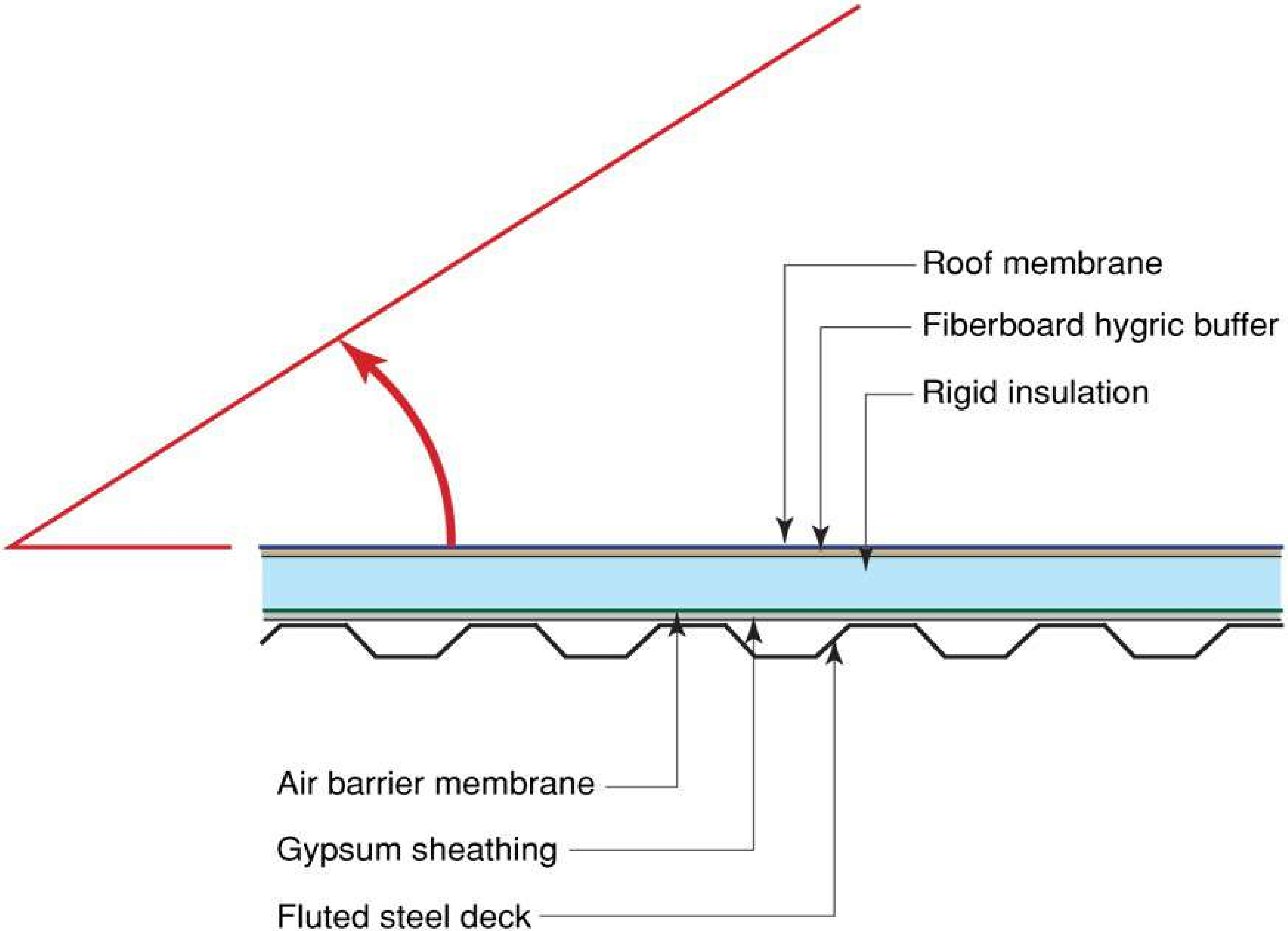

SNOW SLIDE AREA
KEEP OUT

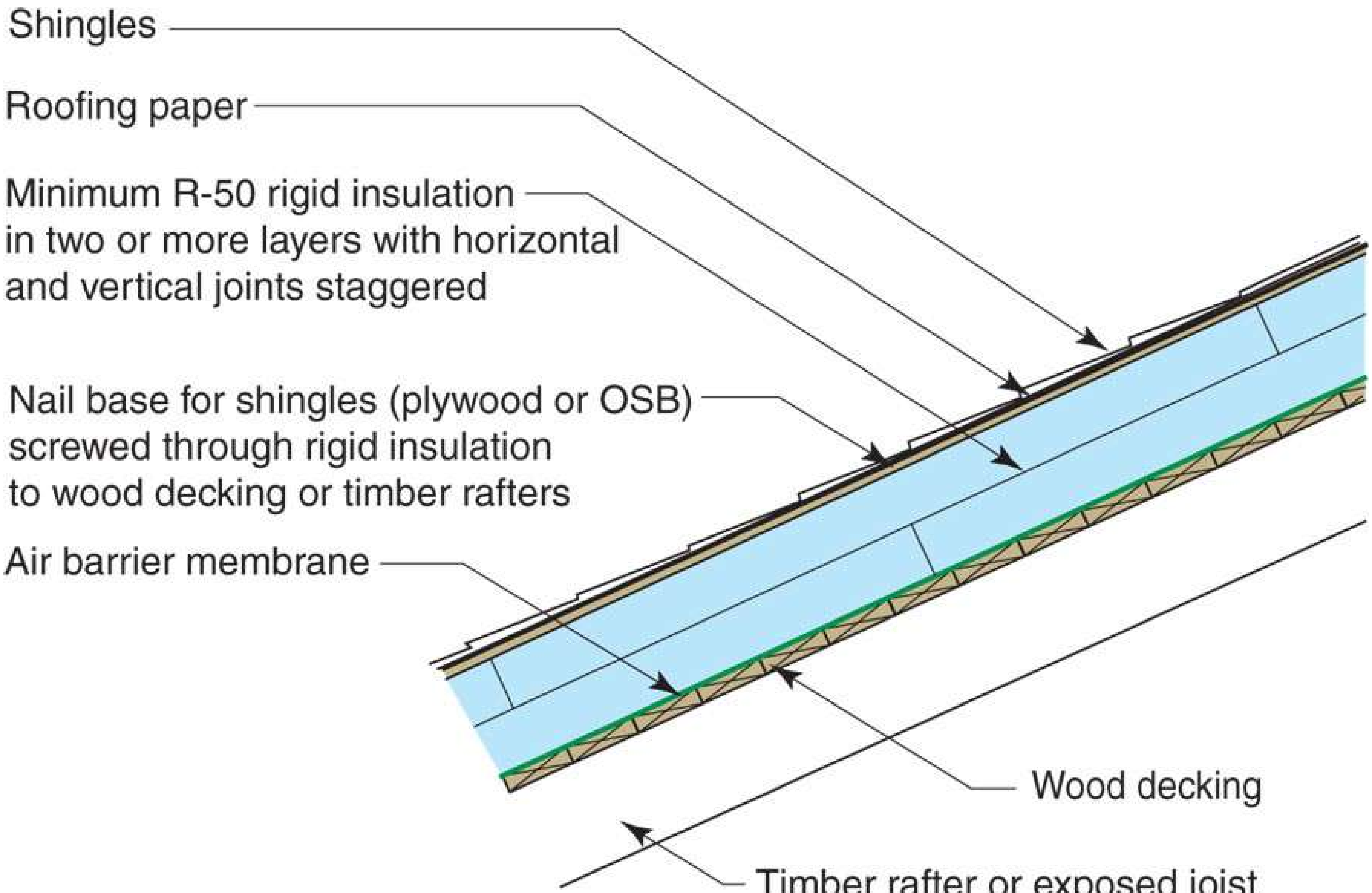

SNOWSLIDE
AREA
STAY OUT!

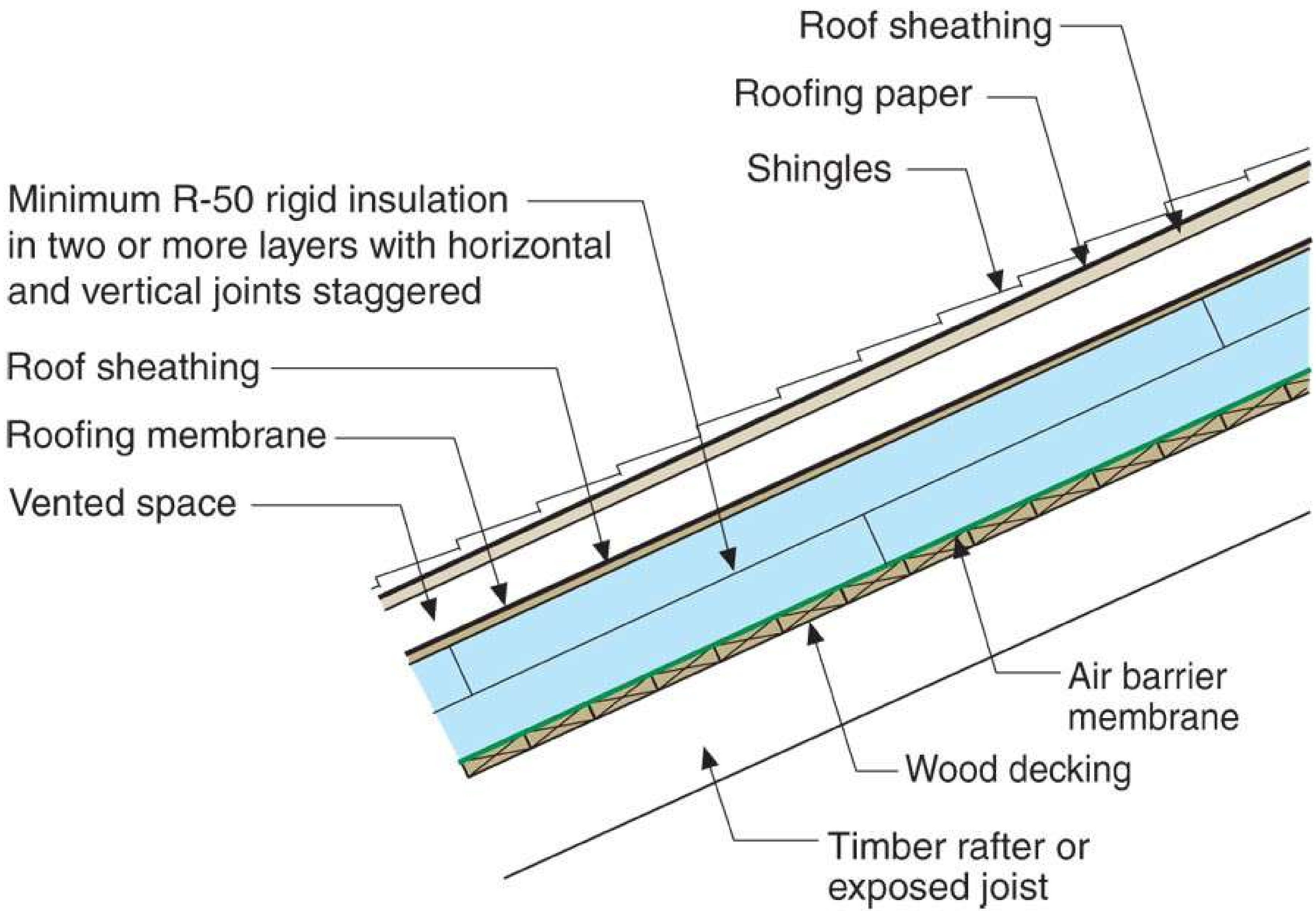

12 DETAIL @ SNOW GUARD
SCALE: 1-1/2"=1'-0"
11 FLASHING DETAIL @ SNOW GUARD
SCALE: 3"=1'-0"
10 WATERPROOFING @ SNOWGAURD
SCALE: FULL SIZE
9 CLUB BAR RAKE DETAIL-NORTH END
SCALE: 1-1/2"=1'-0"
8 RAKE/SOFFIT @ OUTDOOR GRILLE/CLUB
SCALE: 3/4"=1'-0"
7 MINIMUM W.P. @ ROOF/WALL
SCALE: N.T.S.
6 RIDGE RAKE DETAIL
SCALE: 1-1/2"=1'-0"
5 RIDGE EVE & MTL. ROOF @ WALL
SCALE: 1"=1'-0"
4 RIDGE CAP DETAIL
SCALE: 1"=1'-0"
3 FLAT ROOF@ MECH. DORMER
SCALE: 1-1/2"=1'-0"
2 TYPICAL ASPHALT SHINGLE ROOF
SCALE: 1-1/2"=1'-0"
1 TYPICAL METAL ROOF
SCALE: 1-1/2"=1'-0"
COTTLE
GRAYBEAL
YAW
ARCHITECTS
LTD
510 EAST HYMAN
ASPEN, CO. 81611
P (970)925-2867
F (970)925-3736
P.O.BOX 3507
107 NORTH FIR ST.
TELLURIDE, CO. 81435
P (970)728-3037
F (970)728-3236
SUNDECK
RESTAURANT
ASPEN
COLORADO
ISSUE: 3/6/98
REVISIONS:
100%
CONSTRUCTION
DOCUMENTS
ROOF
DETAILS
DRAWN BY:
CHECKED BY:
A6.1

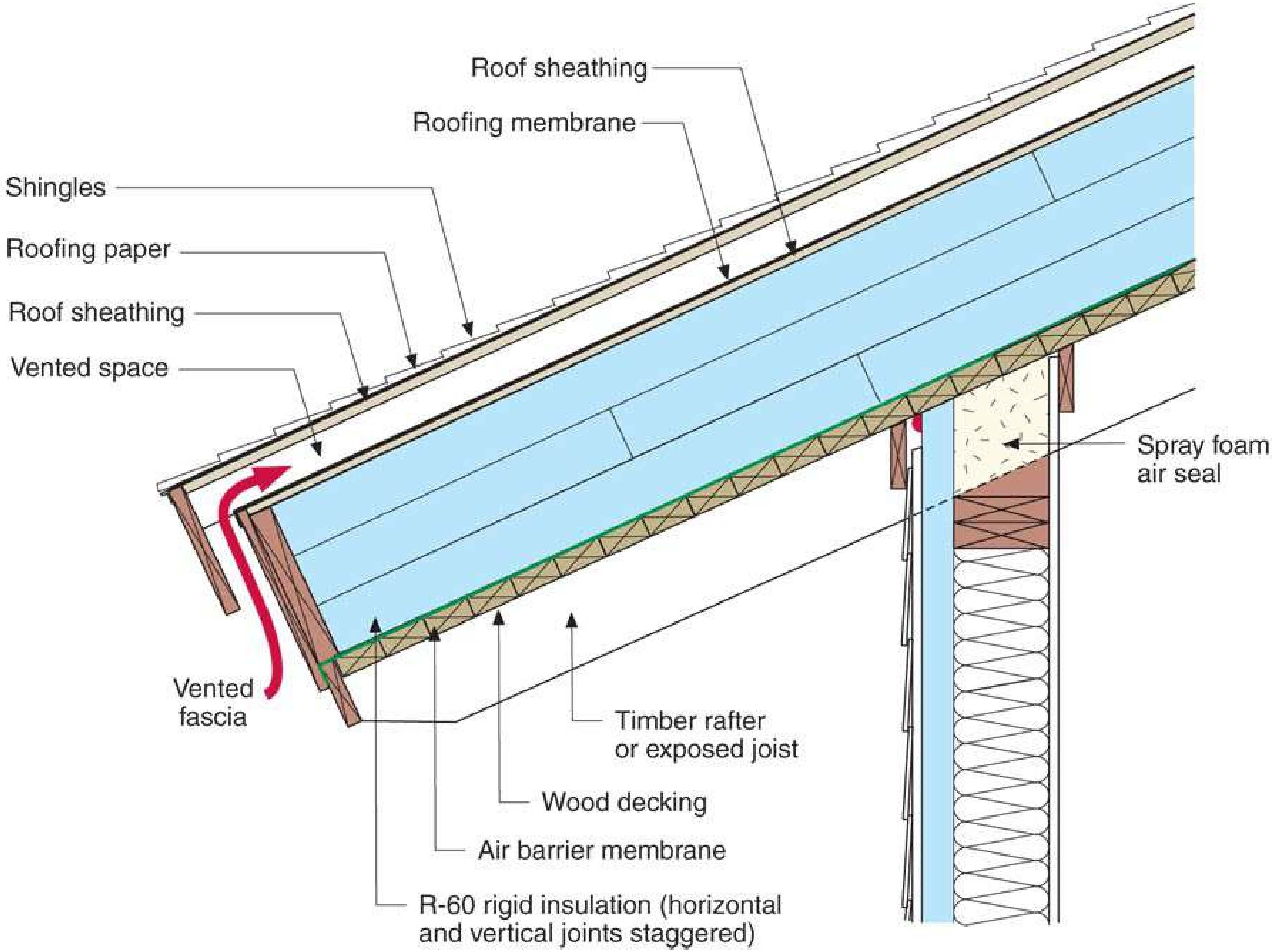



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

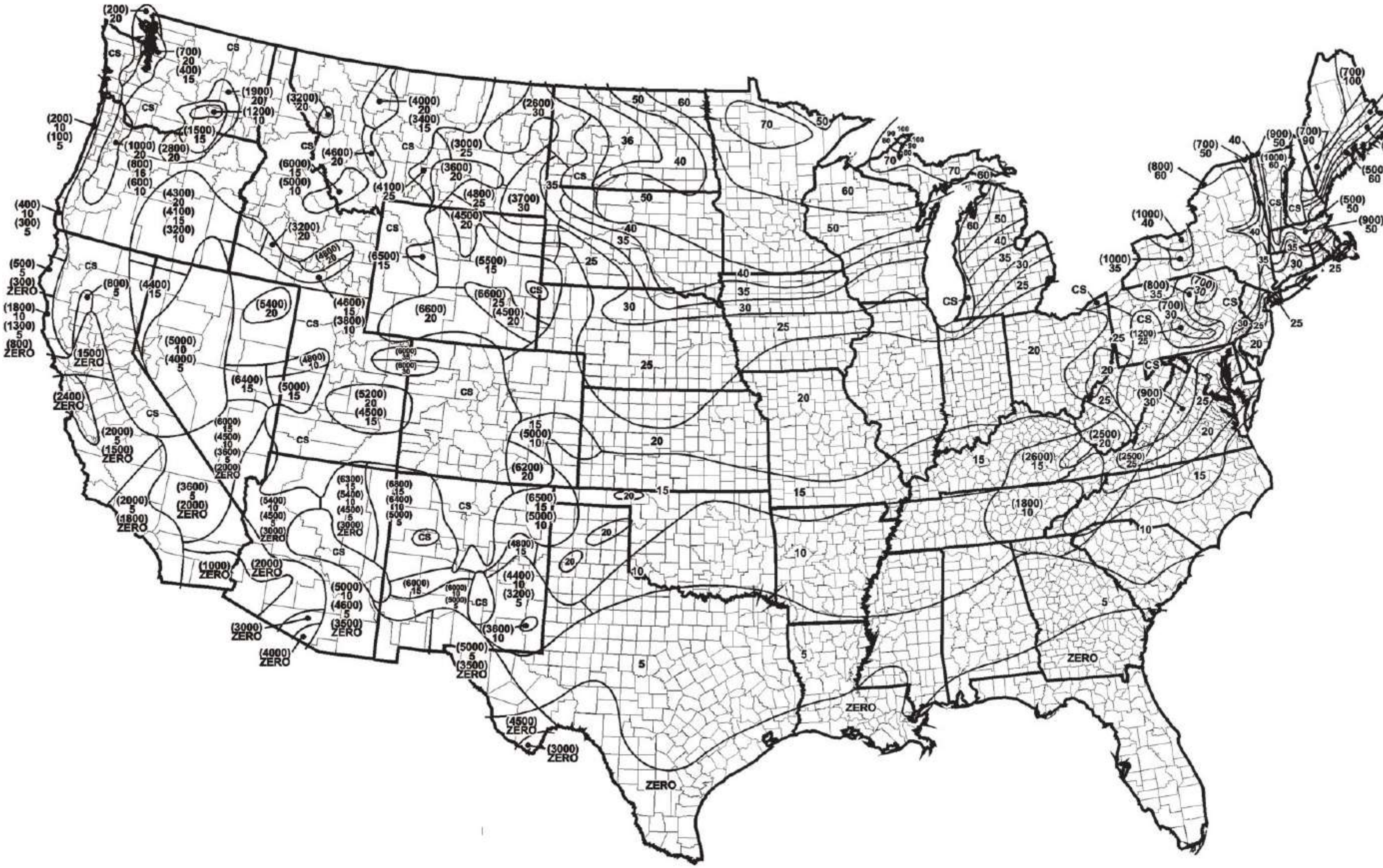

Roof membrane
Fiberboard hygric buffer
Rigid insulation
Air barrier membrane
Gypsum sheathing
Fluted steel deck

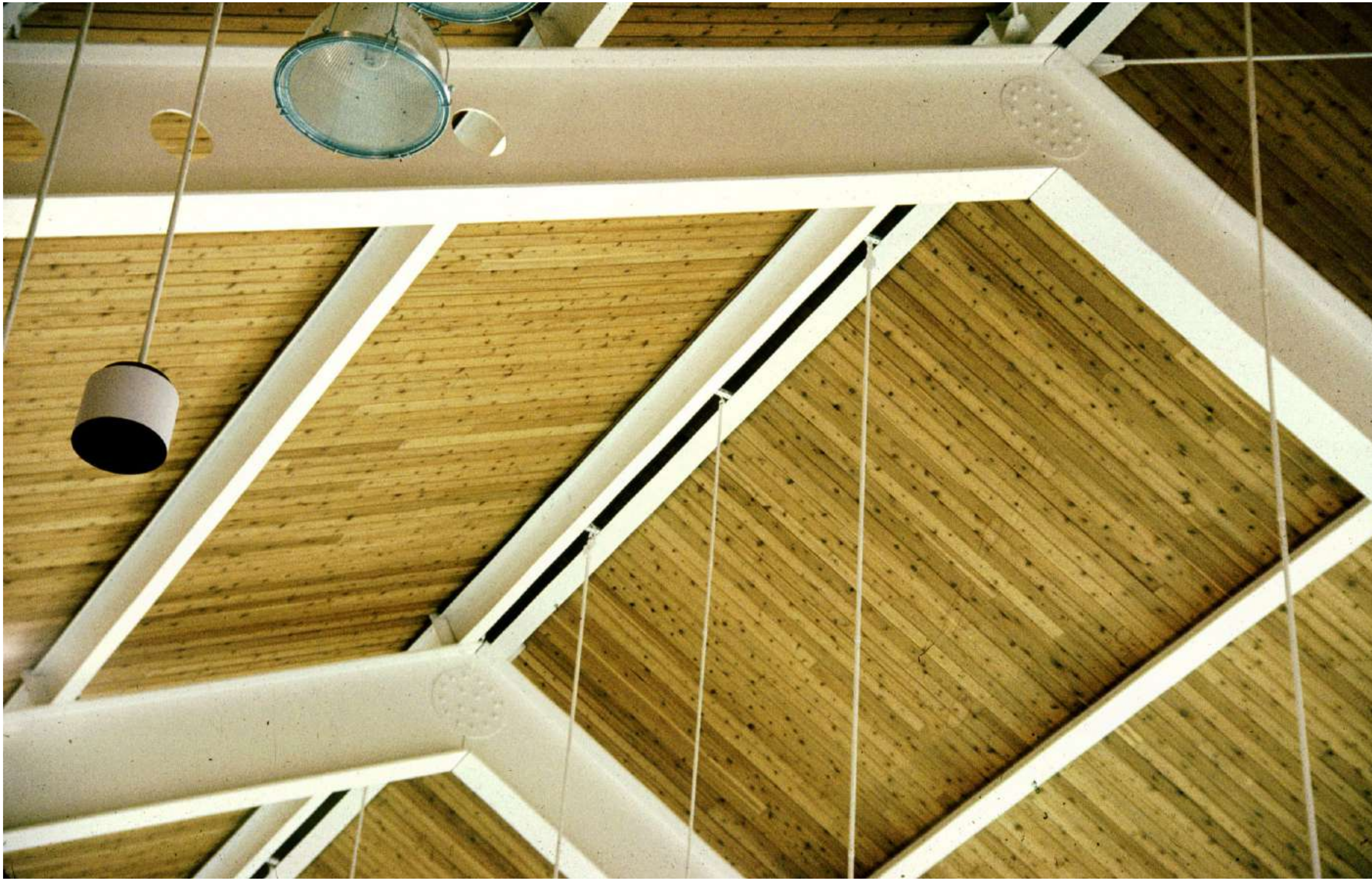

Shingles
Roofing paper
Minimum R-50 rigid insulation in two or more layers with horizontal and vertical joints staggered
Nail base for shingles (plywood or OSB) screwed through rigid insulation to wood decking or timber rafters
Air barrier membrane
Wood decking
Timber rafter or exposed joist


Roof sheathing
Roofing paper
Shingles
Minimum R-50 rigid insulation in two or more layers with horizontal and vertical joints staggered
Roof sheathing
Roofing membrane
Vented space
Air barrier membrane
Wood decking
Timber rafter or exposed joist

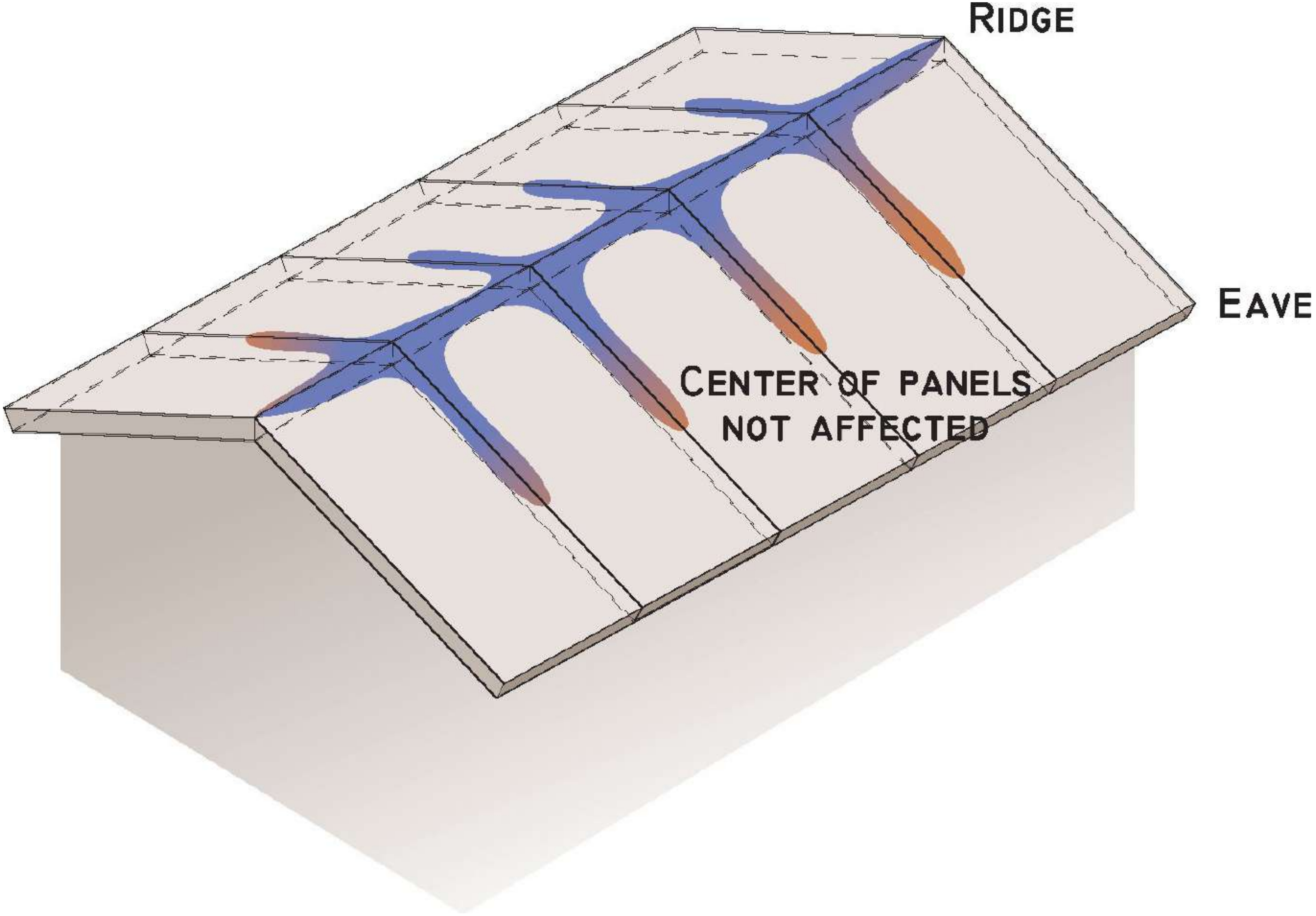


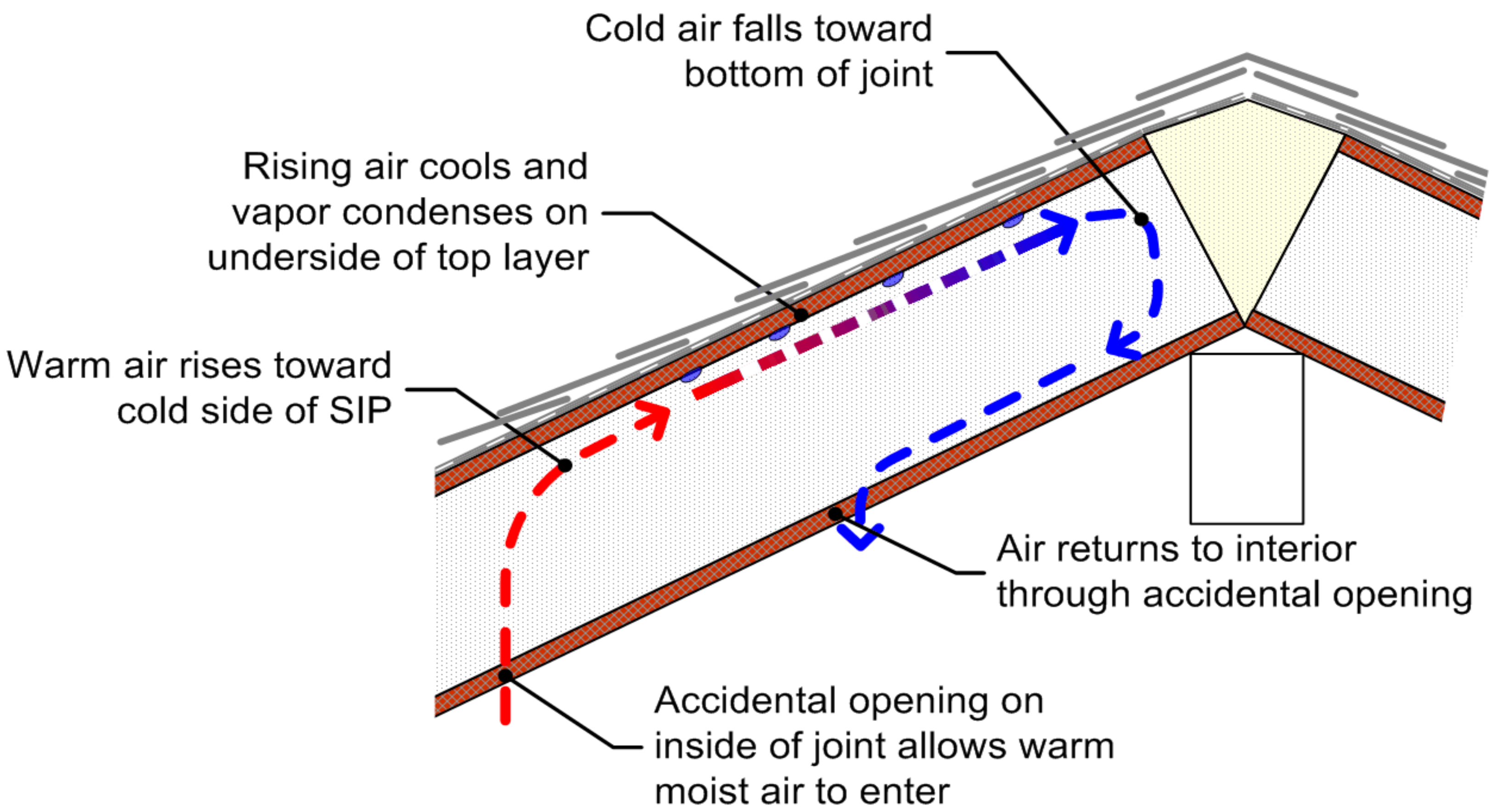
Roof sheathing
Roofing membrane
Shingles
Roofing paper
Roof sheathing
Vented space
Spray foam
air seal
Vented
fascia
Timber rafter
or exposed joist
Wood decking
Air barrier membrane
R-60 rigid insulation (horizontal
and vertical joints staggered)

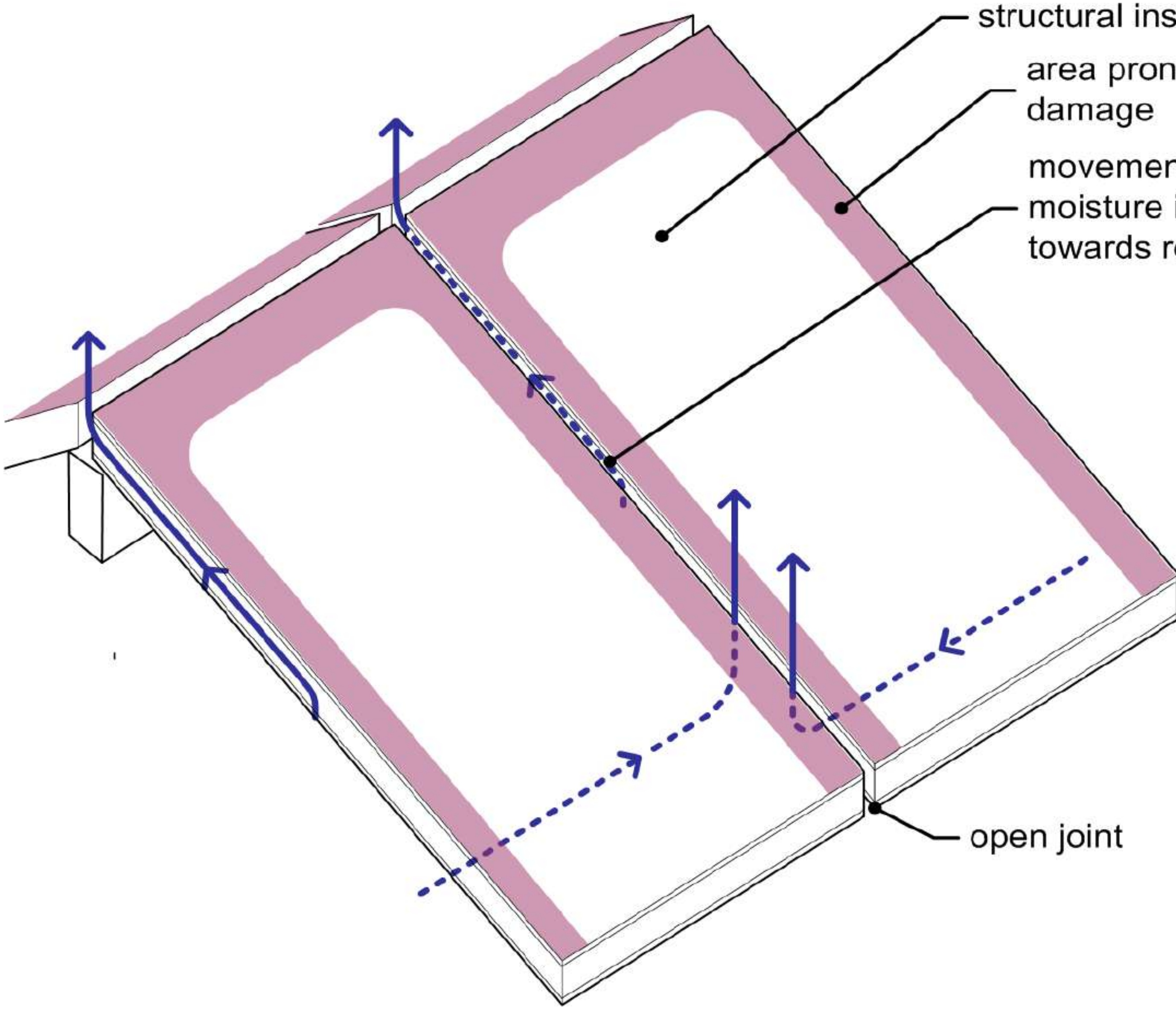


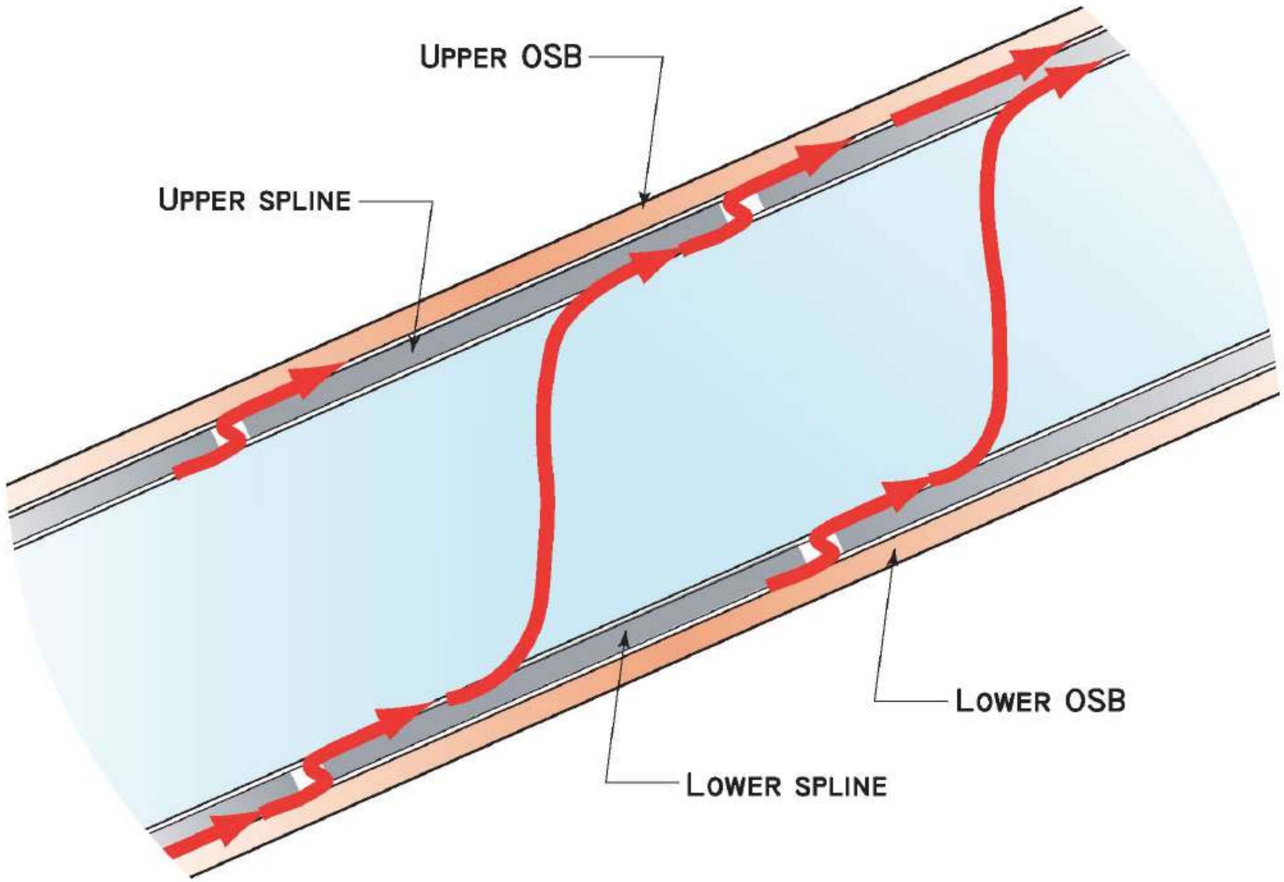



8/22/01 09:32


RIDGE
EAVE
CENTER OF PANELS
NOT AFFECTED


Cold air falls toward bottom of joint
Rising air cools and vapor condenses on underside of top layer
Warm air rises toward cold side of SIP
Air returns to interior through accidental opening
Accidental opening on inside of joint allows warm moist air to enter


structural insulated panel
area prone to moisture damage
movement of air and moisture in panel joint towards roof peak
open joint

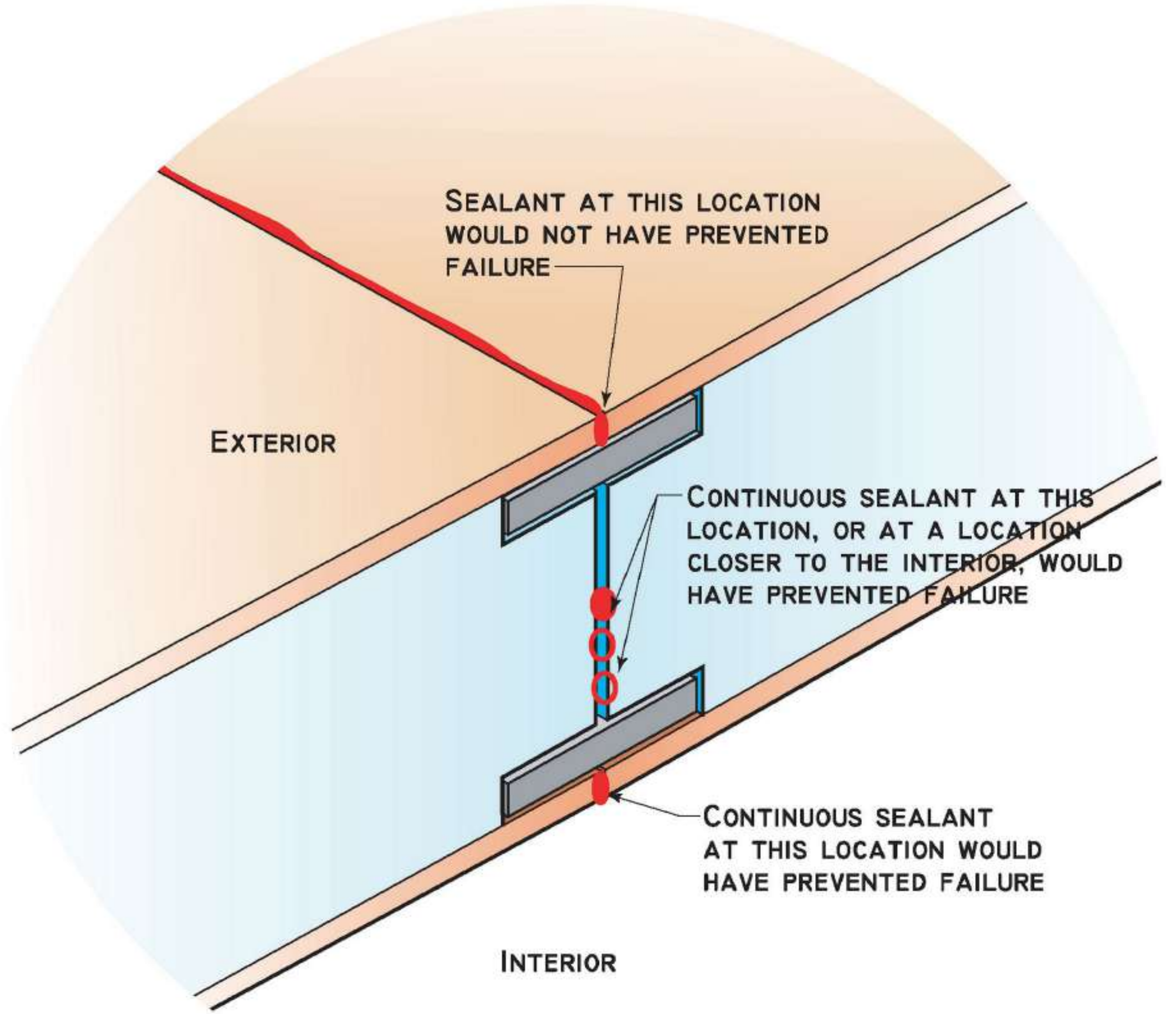

UPPER OSB
UPPER SPLINE
LOWER OSB
LOWER SPLINE


8/22/01 10:13


8/22/01 10:29


8/22/01 10:30


8/17/01 11:43


SEALANT AT THIS LOCATION
WOULD NOT HAVE PREVENTED
FAILURE
EXTERIOR
CONTINUOUS SEALANT AT THIS
LOCATION, OR AT A LOCATION
CLOSER TO THE INTERIOR, WOULD
HAVE PREVENTED FAILURE
CONTINUOUS SEALANT
AT THIS LOCATION WOULD
HAVE PREVENTED FAILURE
INTERIOR

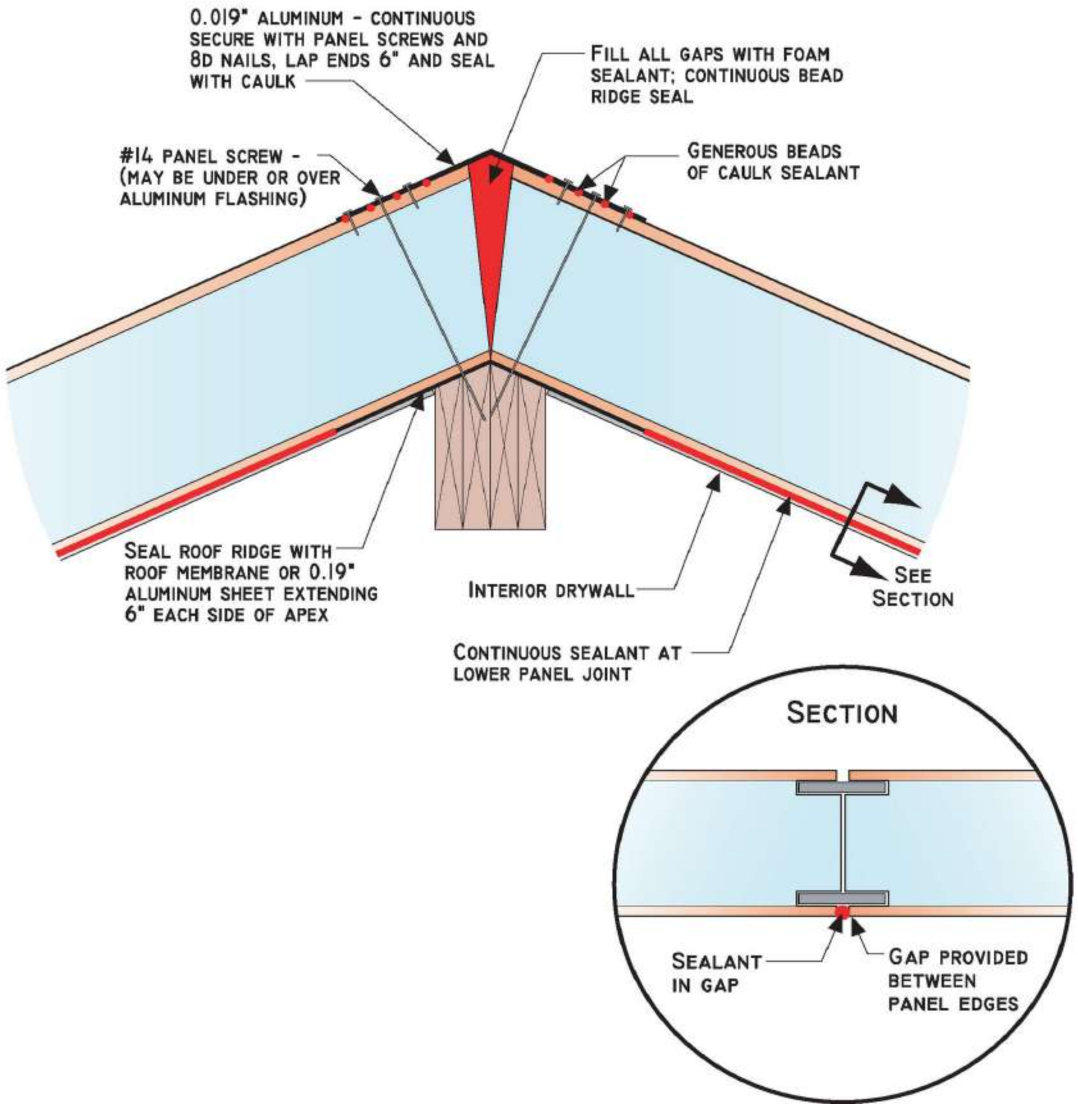

0.019" ALUMINUM - CONTINUOUS SECURE WITH PANEL SCREWS AND 8D NAILS, LAP ENDS 6" AND SEAL WITH CAULK
FILL ALL GAPS WITH FOAM SEALANT; CONTINUOUS BEAD RIDGE SEAL
#14 PANEL SCREW - (MAY BE UNDER OR OVER ALUMINUM FLASHING)
GENEROUS BEADS OF CAULK SEALANT
SEAL ROOF RIDGE WITH ROOF MEMBRANE OR 0.19" ALUMINUM SHEET EXTENDING 6" EACH SIDE OF APEX
INTERIOR DRYWALL
SEE SECTION
CONTINUOUS SEALANT AT LOWER PANEL JOINT
SECTION
SEALANT IN GAP
GAP PROVIDED BETWEEN PANEL EDGES

**Figure 1**

- Remove strip of OSB from each side of ridge

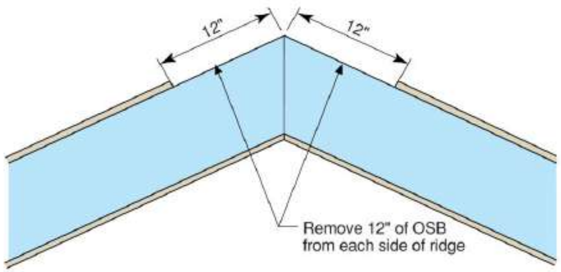



**Figure 2**

- Create air seal with strip of Tyvek® (tape seams of Tyvek®)
- Hold Tyvek® sheet in place with metal strapping

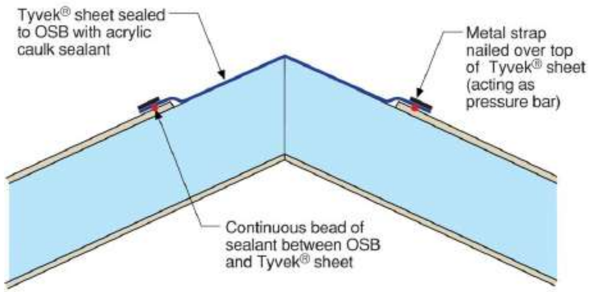
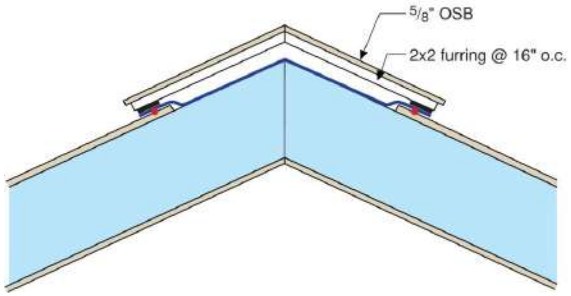
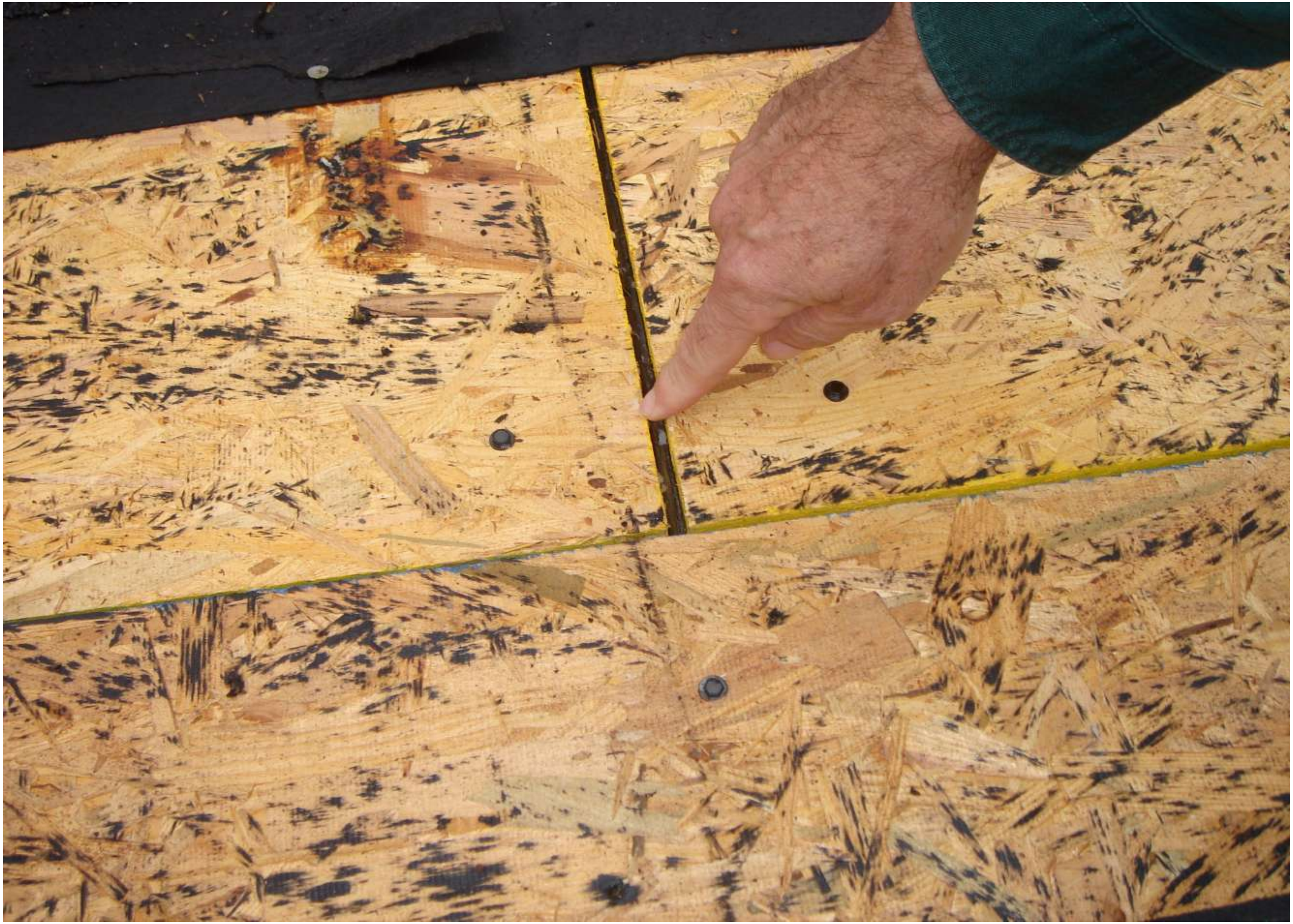


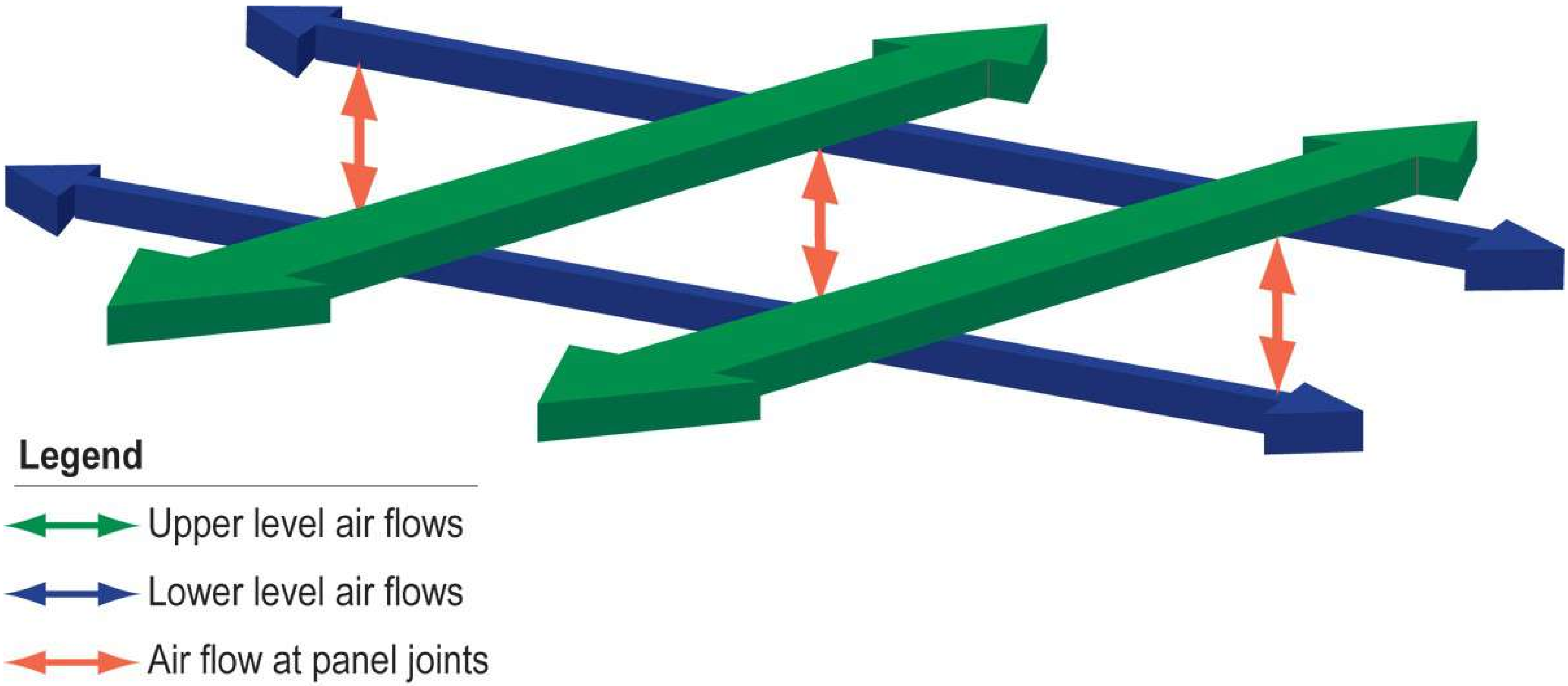

**Figure 3**

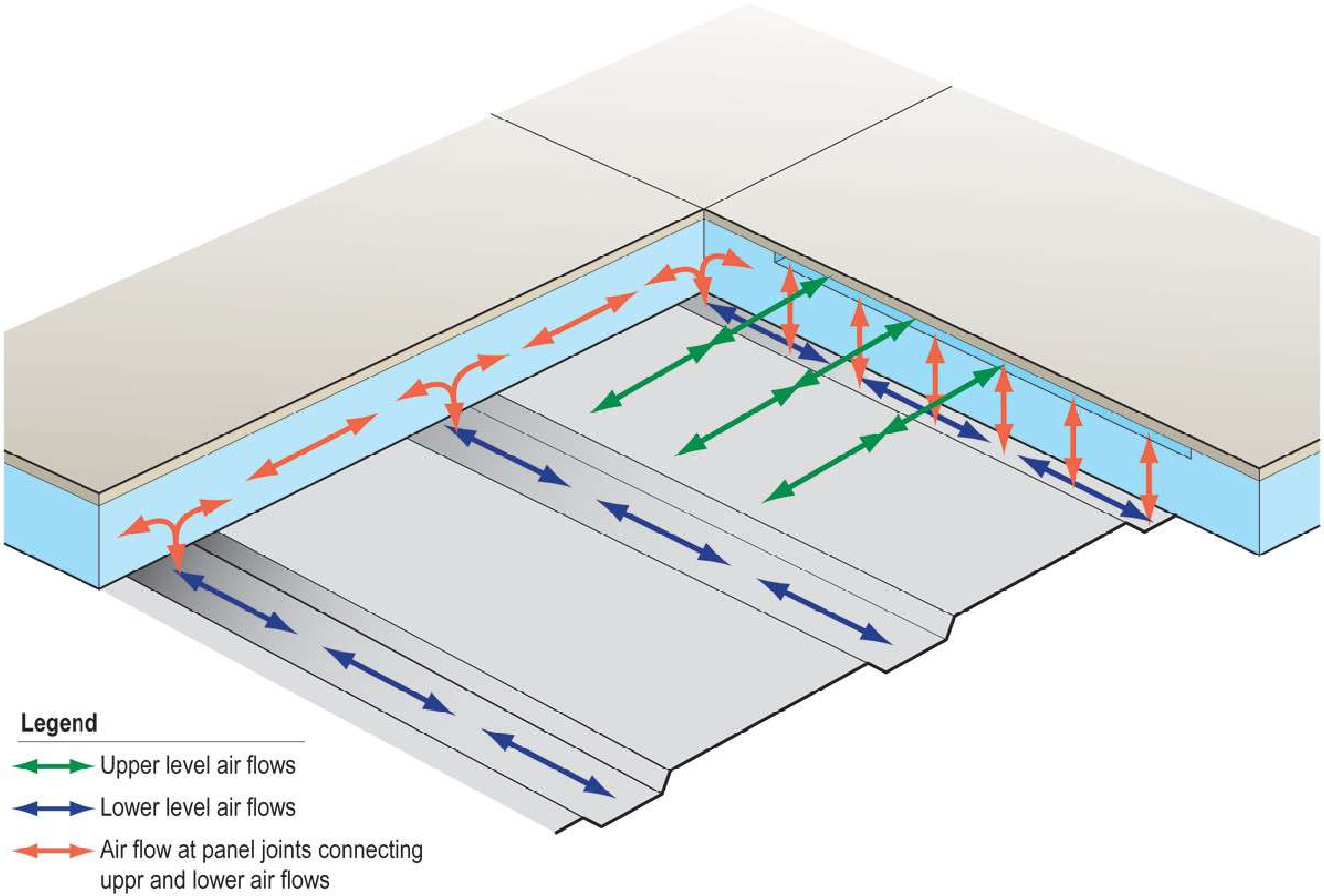
- Construct wood ridge vent with 2x2 furring
- Use Cobra® Ridge Vent roll mesh at edges of vent to control insect entry



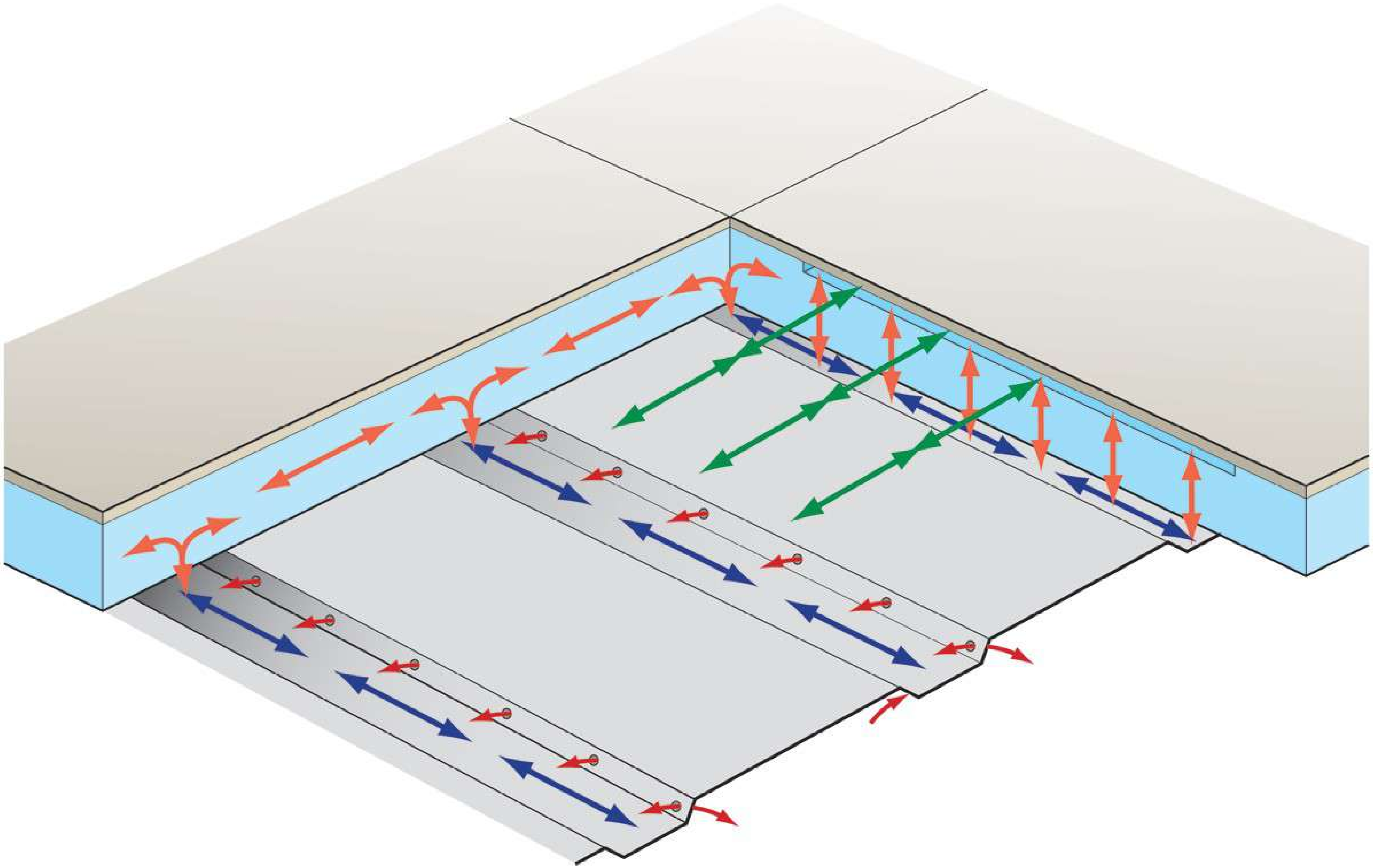
Frequency
Intensity
Time
Type
Exercises Promoting Physical Fitness
DIET

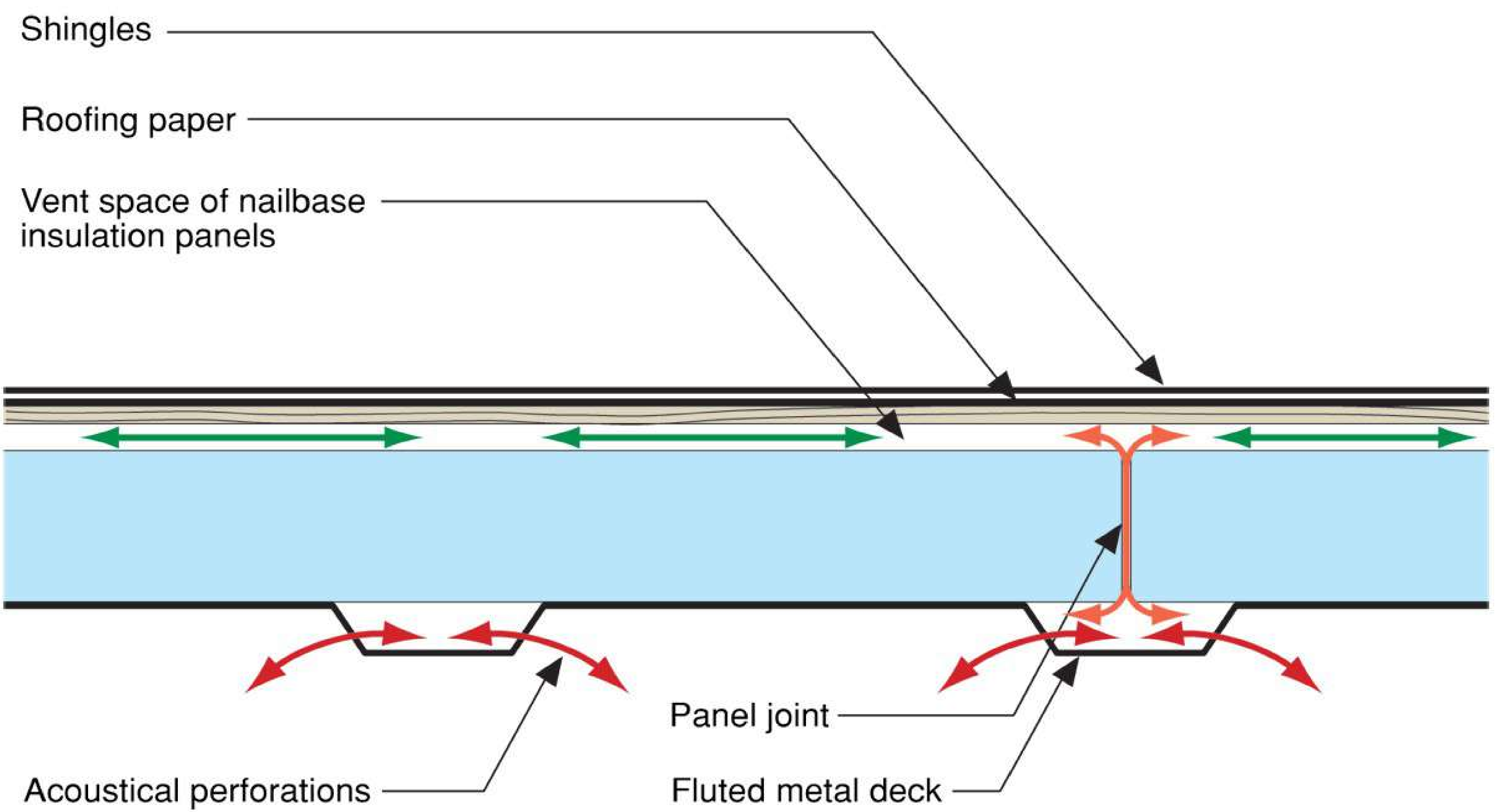


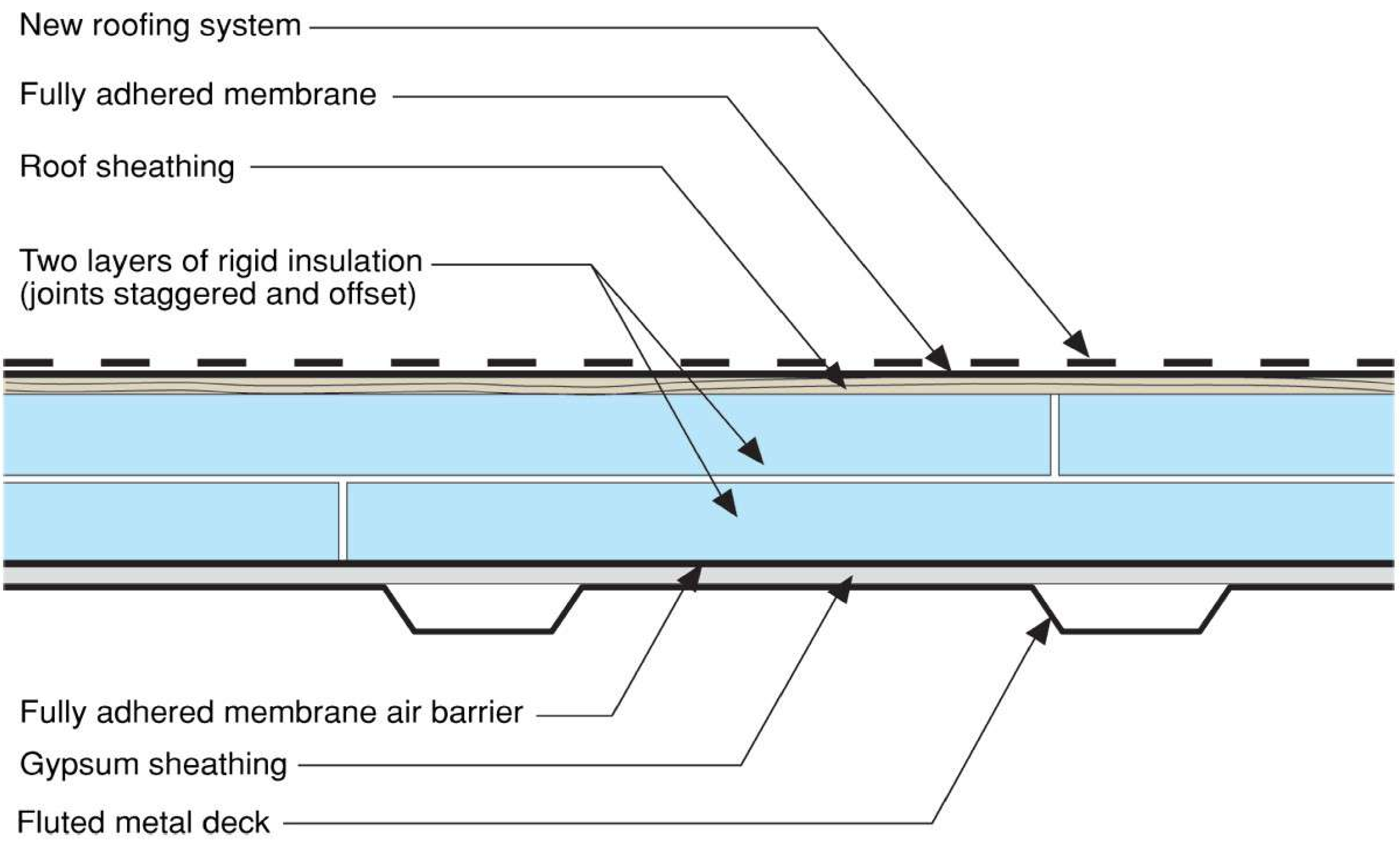

Legend
Upper level air flows
Lower level air flows
Air flow at panel joints

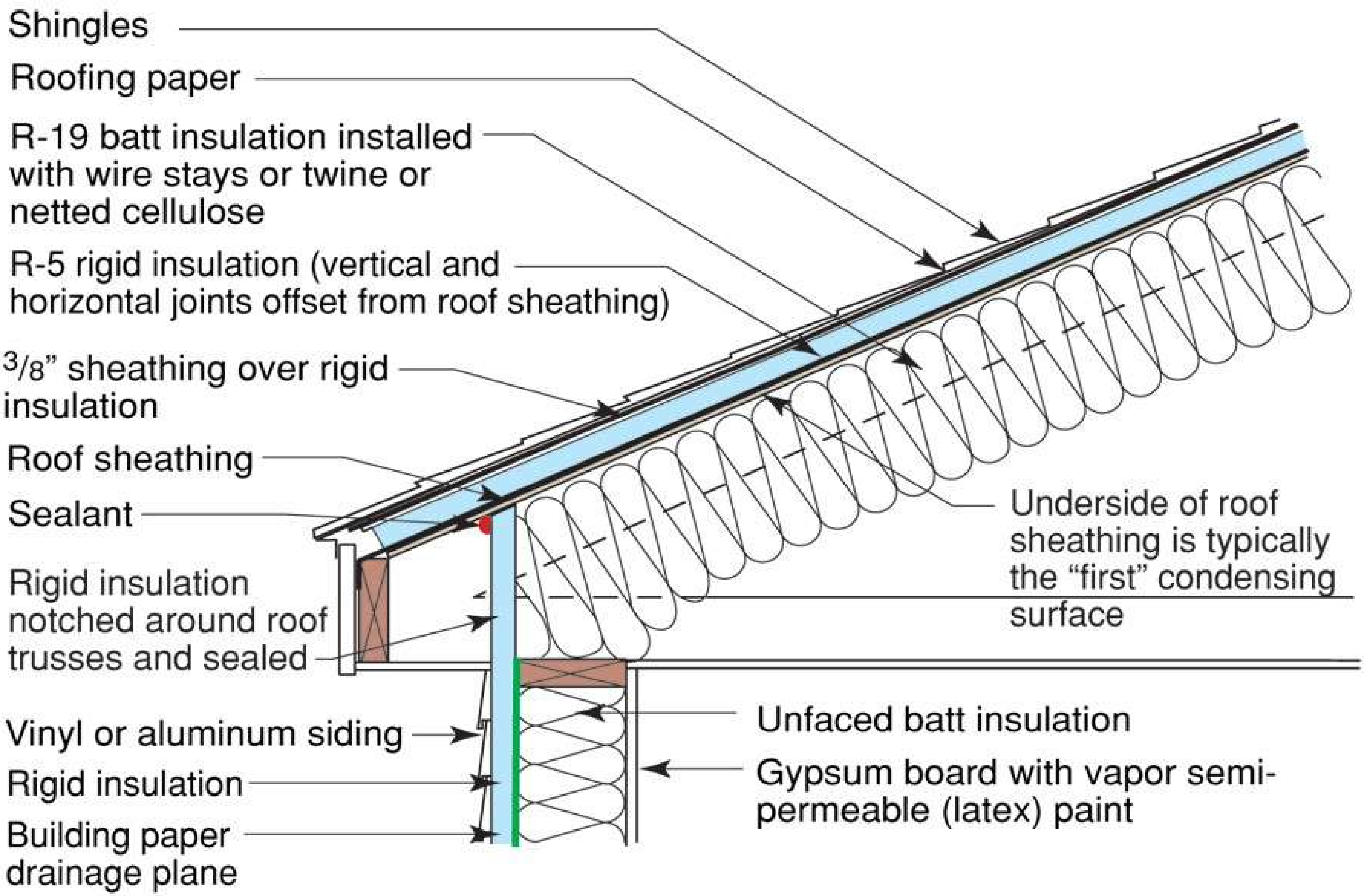


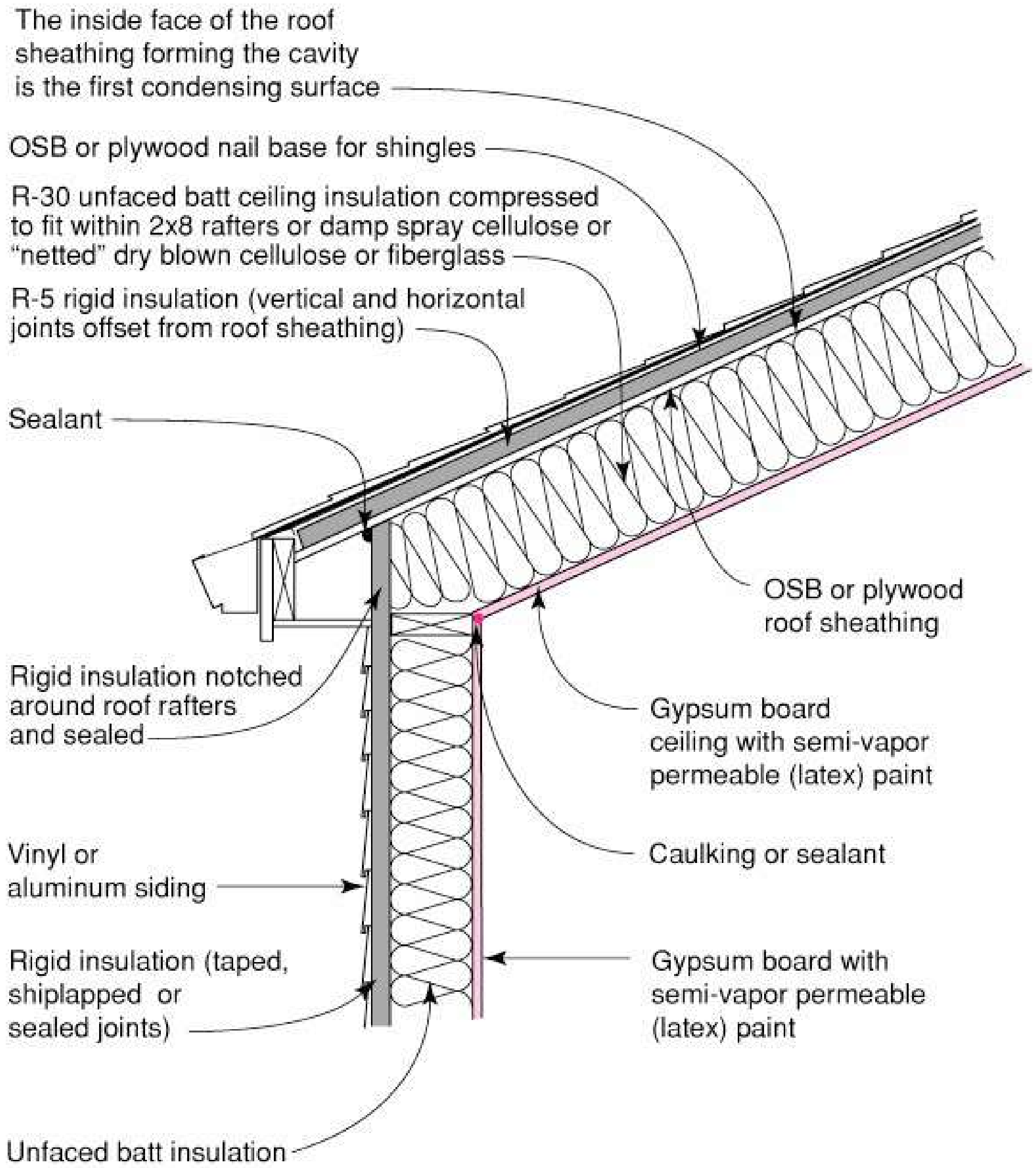
Legend
Upper level air flows
Lower level air flows
Air flow at panel joints connecting
uppr and lower air flows

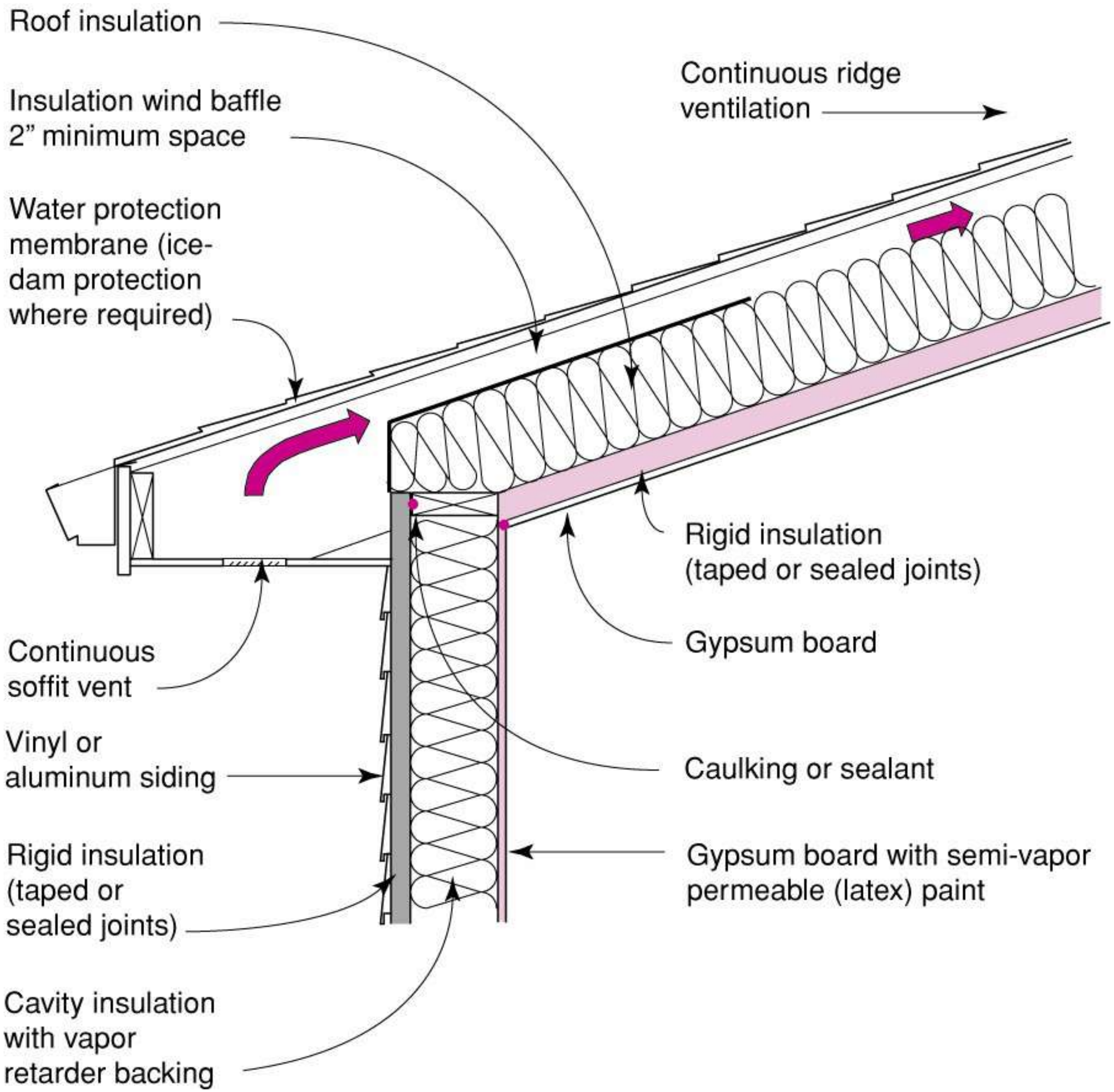


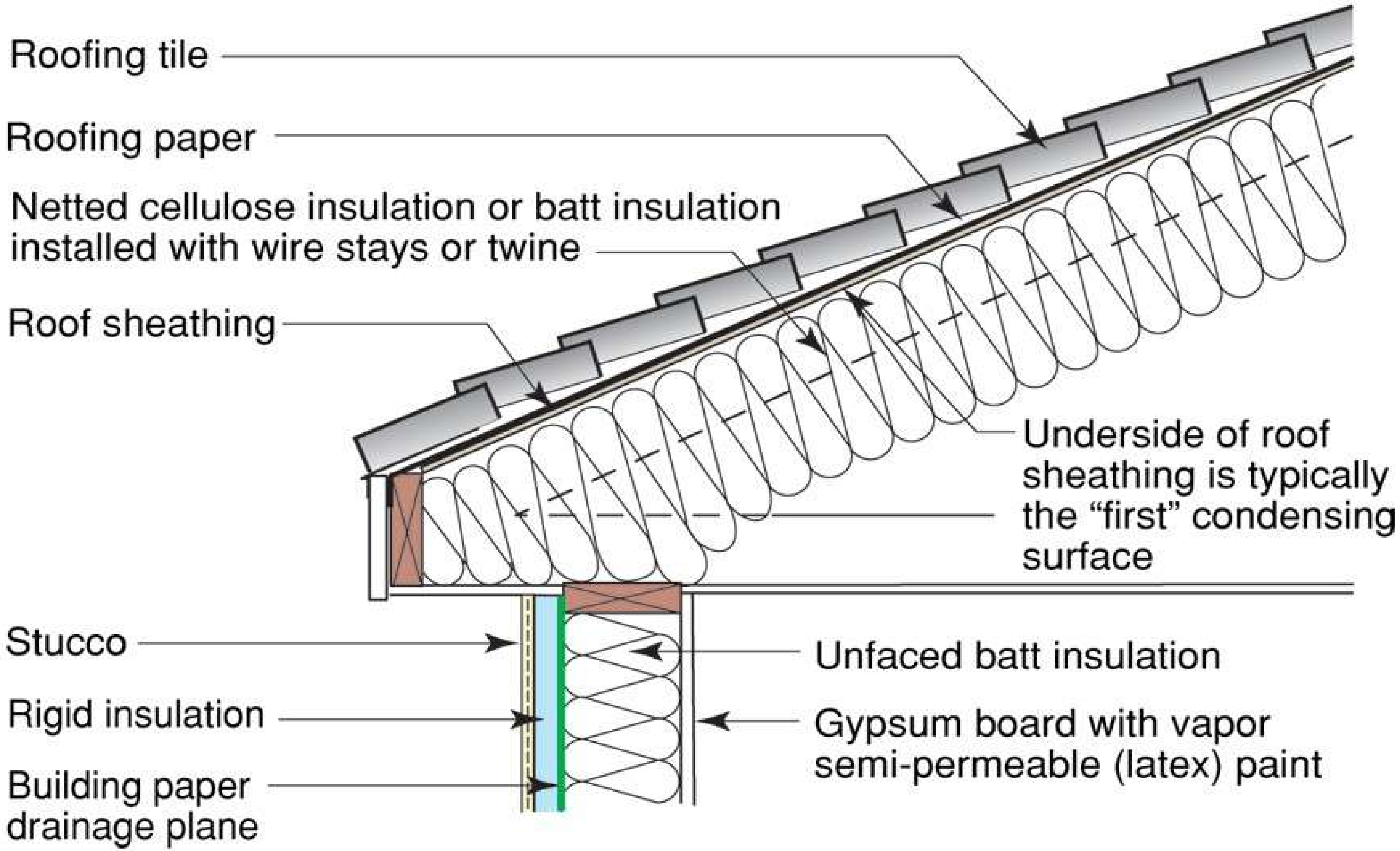

Shingles
Roofing paper
Vent space of nailbase insulation panels
Panel joint
Acoustical perforations
Fluted metal deck

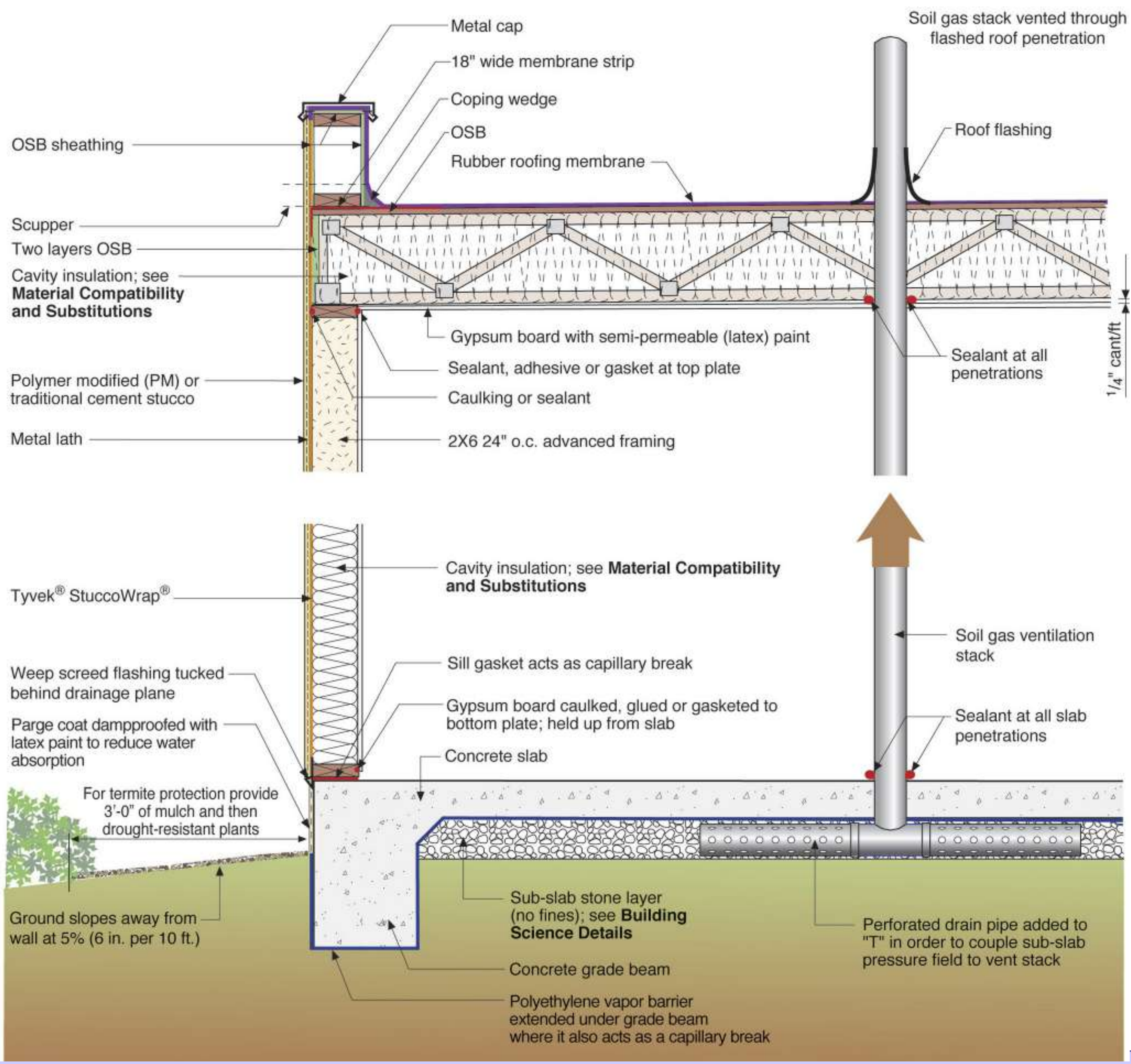

New roofing system
Fully adhered membrane
Roof sheathing
Two layers of rigid insulation
(joints staggered and offset)
Fully adhered membrane air barrier
Gypsum sheathing
Fluted metal deck

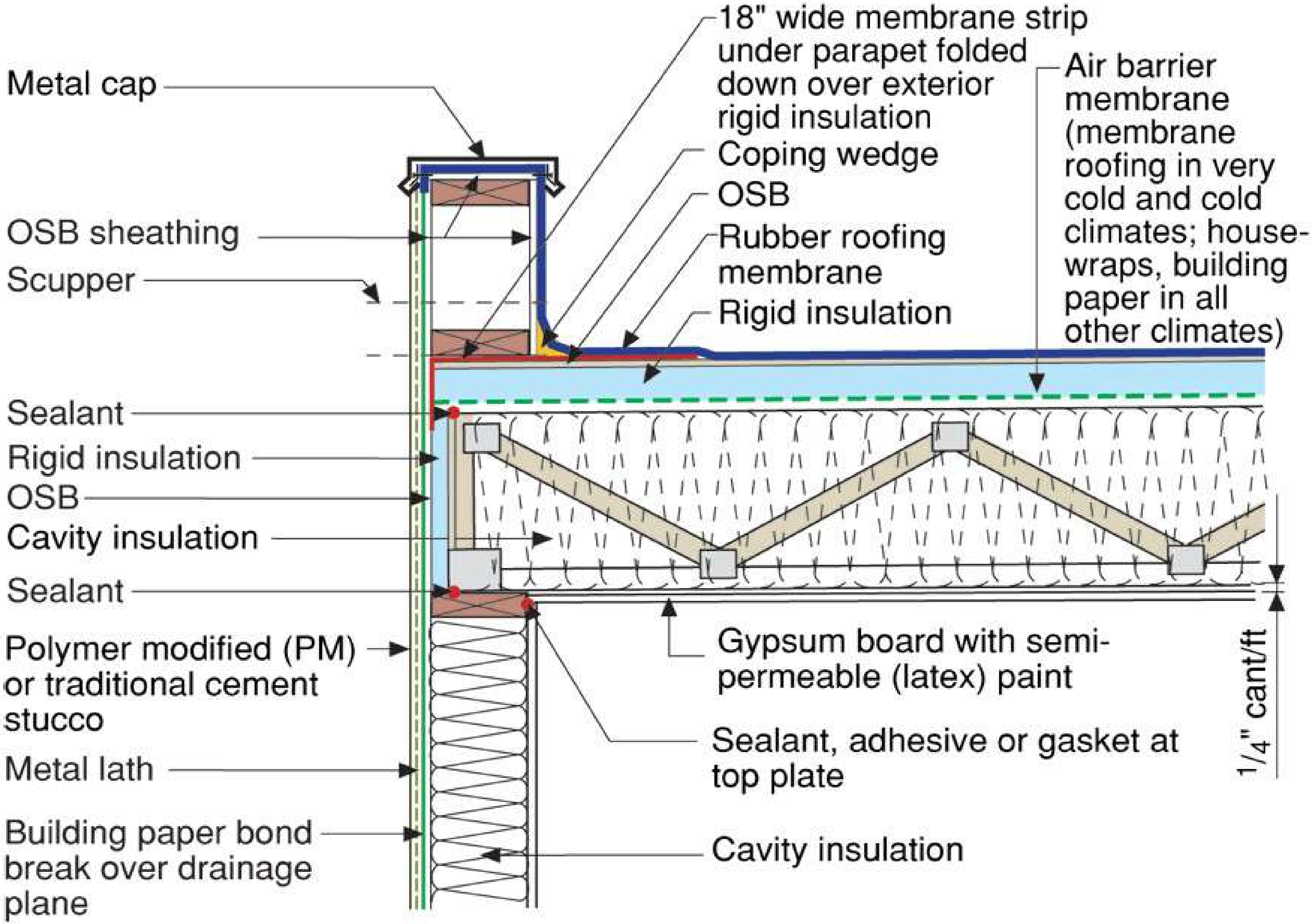

Shingles
Roofing paper
R-19 batt insulation installed with wire stays or twine or netted cellulose
R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)
3/8" sheathing over rigid insulation
Roof sheathing
Sealant
Rigid insulation notched around roof trusses and sealed
Vinyl or aluminum siding
Rigid insulation
Building paper drainage plane
Underside of roof sheathing is typically the "first" condensing surface
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint

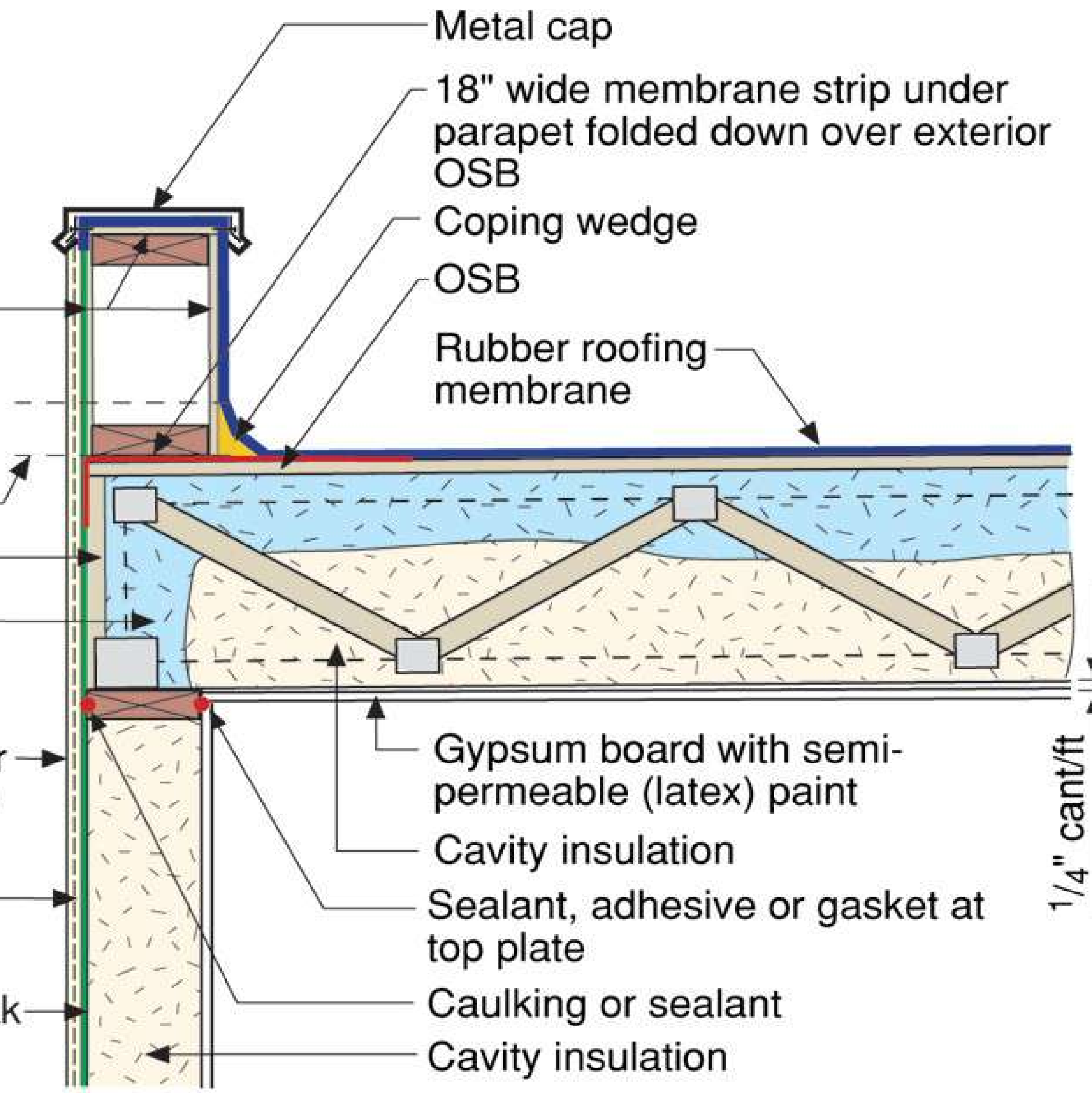

The inside face of the roof sheathing forming the cavity is the first condensing surface
OSB or plywood nail base for shingles
R-30 unfaced batt ceiling insulation compressed to fit within 2x8 rafters or damp spray cellulose or "netted" dry blown cellulose or fiberglass
R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)
Sealant
OSB or plywood roof sheathing
Rigid insulation notched around roof rafters and sealed
Gypsum board ceiling with semi-vapor permeable (latex) paint
Caulking or sealant
Vinyl or aluminum siding
Rigid insulation (taped, shiplapped or sealed joints)
Gypsum board with semi-vapor permeable (latex) paint
Unfaced batt insulation

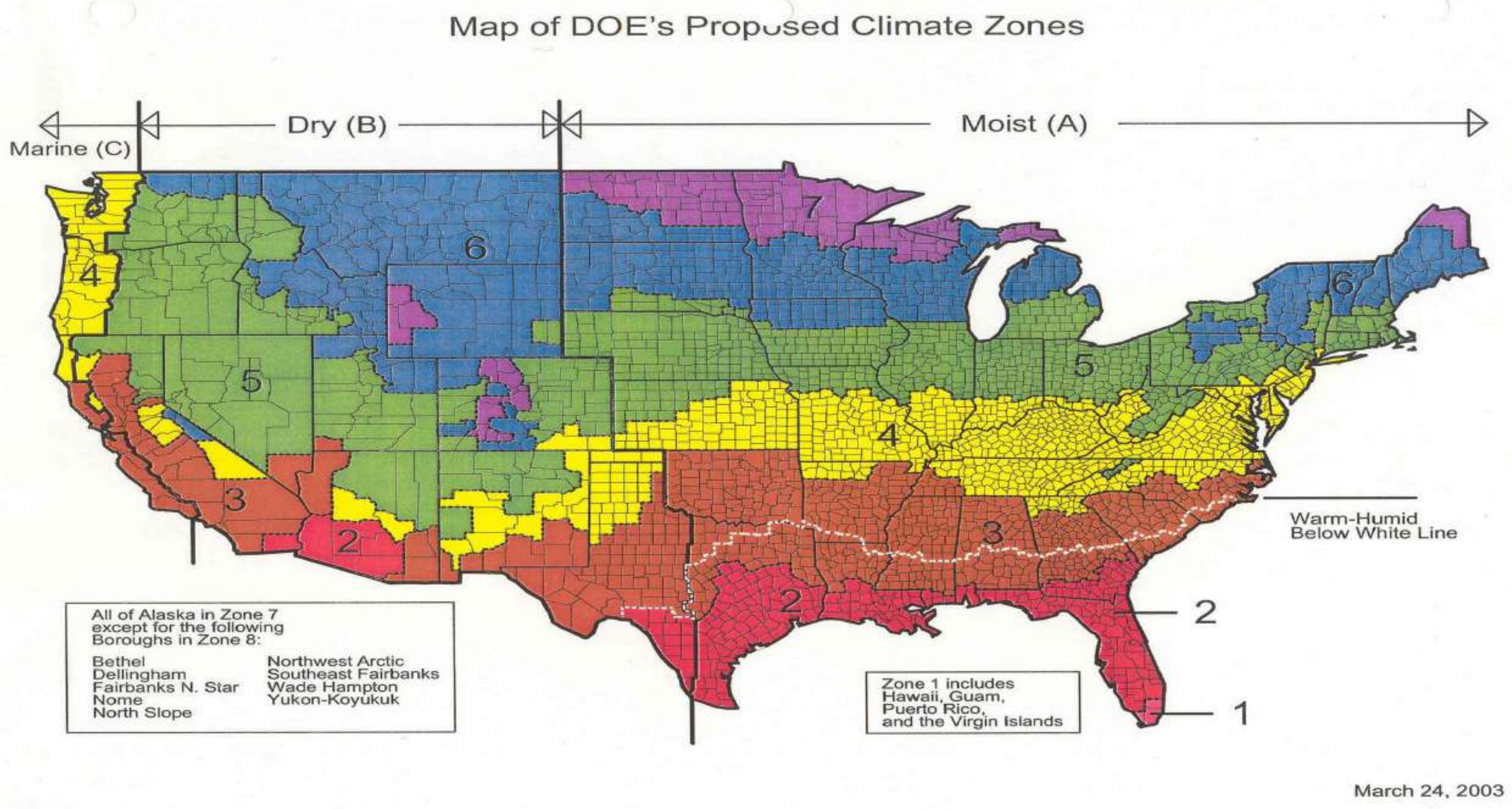

Roof insulation
Continuous ridge ventilation
Insulation wind baffle 2" minimum space
Water protection membrane (ice-dam protection where required)
Rigid insulation (taped or sealed joints)
Gypsum board
Continuous soffit vent
Vinyl or aluminum siding
Caulking or sealant
Rigid insulation (taped or sealed joints)
Gypsum board with semi-vapor permeable (latex) paint
Cavity insulation with vapor retarder backing

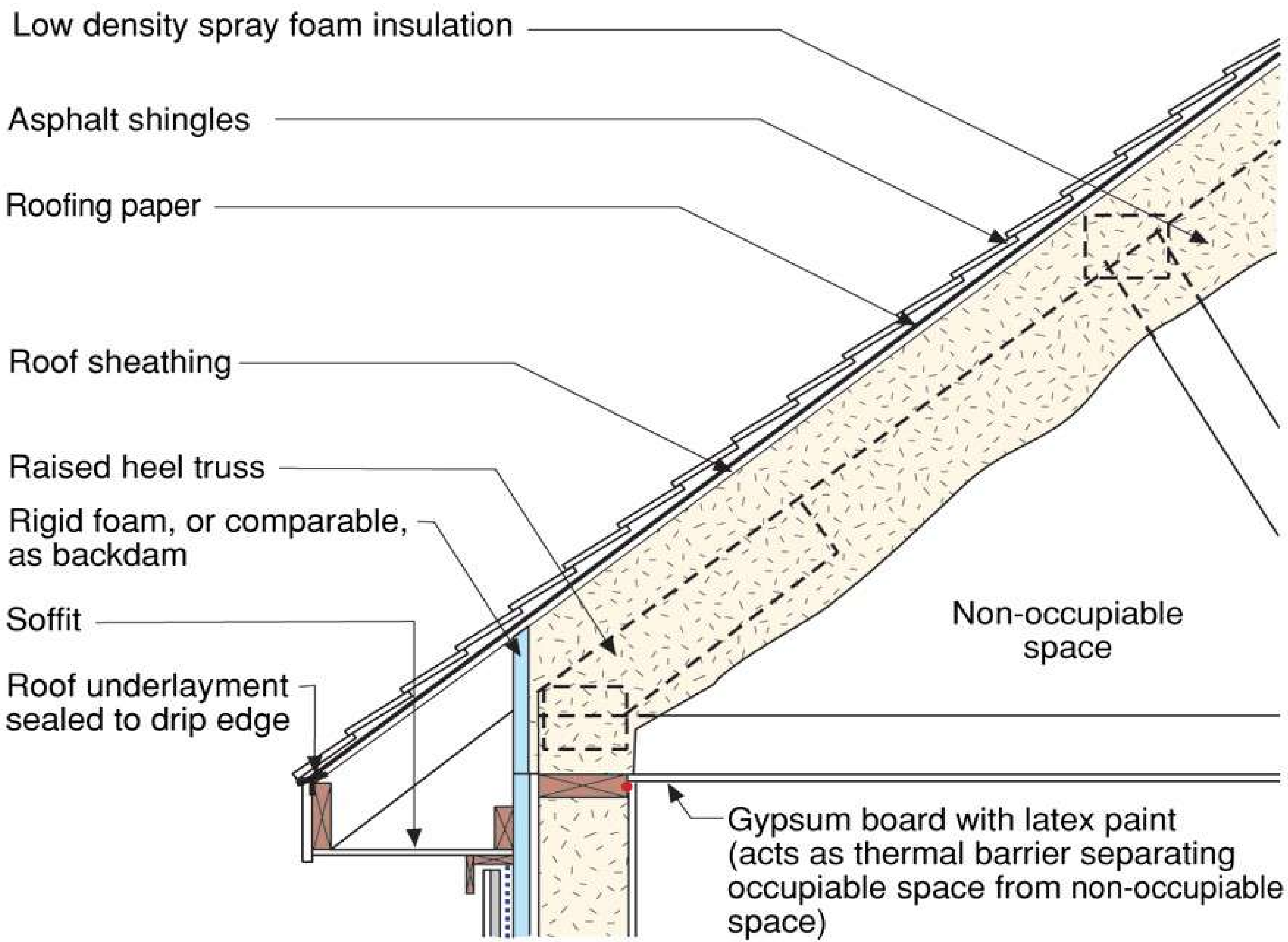

Roofing tile
Roofing paper
Netted cellulose insulation or batt insulation installed with wire stays or twine
Roof sheathing
Underside of roof sheathing is typically the "first" condensing surface
Stucco
Unfaced batt insulation
Rigid insulation
Gypsum board with vapor semi-permeable (latex) paint
Building paper drainage plane

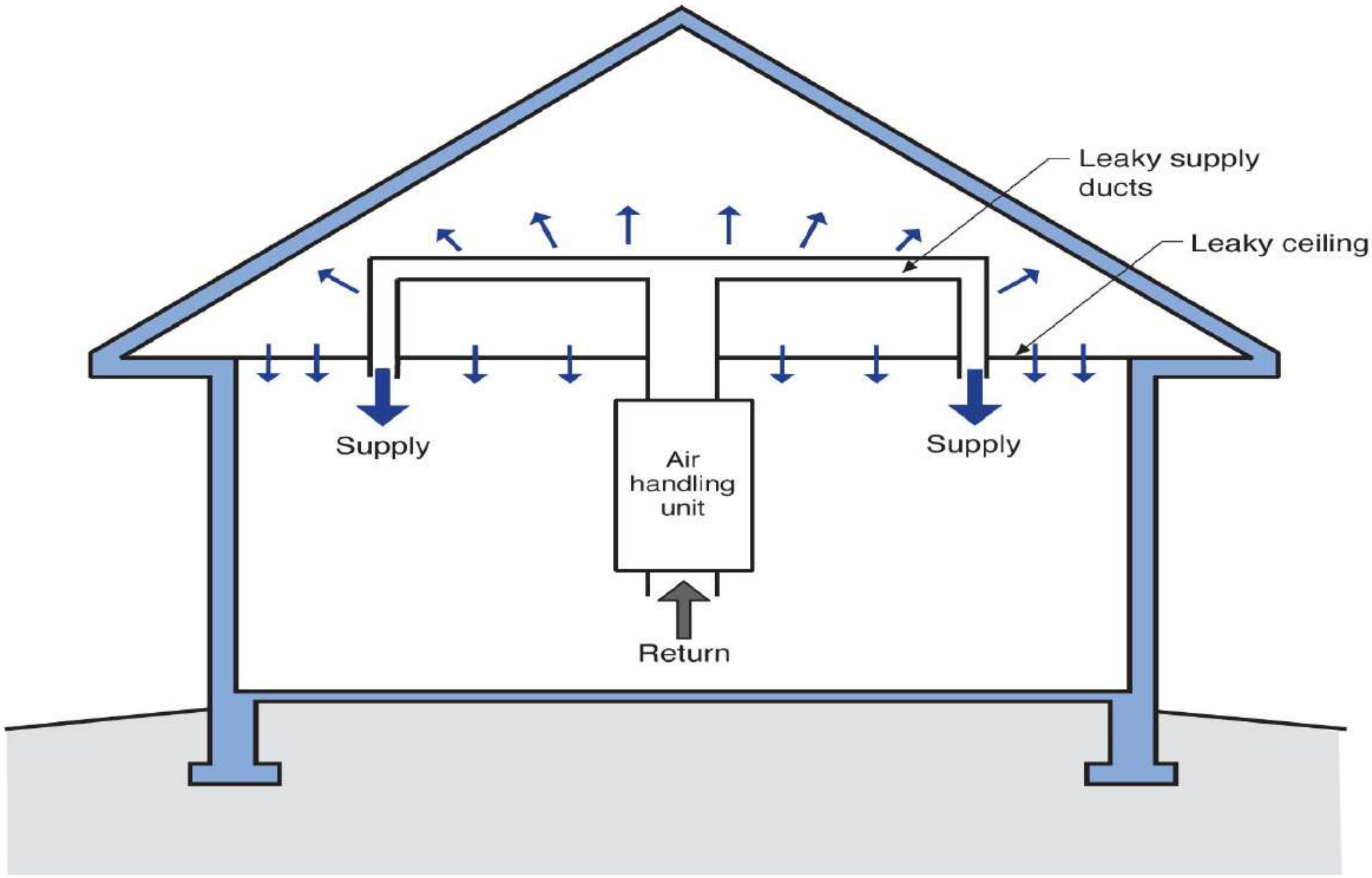

Metal cap
18" wide membrane strip
Coping wedge
OSB
Rubber roofing membrane
Soil gas stack vented through flashed roof penetration
Roof flashing
OSB sheathing
Scupper
Two layers OSB
Cavity insulation; see **Material Compatibility and Substitutions**
Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Caulking or sealant
Sealant at all penetrations
1/4" cant/ft
Polymer modified (PM) or traditional cement stucco
Metal lath
2X6 24" o.c. advanced framing
Tyvek® StuccoWrap®
Cavity insulation; see **Material Compatibility and Substitutions**
Soil gas ventilation stack
Weep screed flashing tucked behind drainage plane
Sill gasket acts as capillary break
Parge coat dampproofed with latex paint to reduce water absorption
Gypsum board caulked, glued or gasketed to bottom plate; held up from slab
Sealant at all slab penetrations
Concrete slab
For termite protection provide 3'-0" of mulch and then drought-resistant plants
Sub-slab stone layer (no fines); see **Building Science Details**
Perforated drain pipe added to "T" in order to couple sub-slab pressure field to vent stack
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Concrete grade beam
Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break


Metal cap
OSB sheathing
Scupper
Sealant
Rigid insulation
OSB
Cavity insulation
Sealant
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
18" wide membrane strip under parapet folded down over exterior rigid insulation
Coping wedge
OSB
Rubber roofing membrane
Rigid insulation
Air barrier membrane (membrane roofing in very cold and cold climates; housewraps, building paper in all other climates)
Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Cavity insulation
1/4" cant/ft


Metal cap
18" wide membrane strip under parapet folded down over exterior OSB
Coping wedge
OSB
Rubber roofing membrane
OSB sheathing
Scupper
Two layers OSB
High density spray foam insulation
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
Gypsum board with semi-permeable (latex) paint
Cavity insulation
Sealant, adhesive or gasket at top plate
Caulking or sealant
Cavity insulation
1/4" cant/ft


Map of DOE's Proposed Climate Zones
Marine (C)
Dry (B)
Moist (A)
7
6
6
5
5
4
4
4
3
3
2
2
2
1
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


Low density spray foam insulation
Asphalt shingles
Roofing paper
Roof sheathing
Raised heel truss
Rigid foam, or comparable, as backdam
Soffit
Roof underlayment sealed to drip edge
Non-occupiable space
Gypsum board with latex paint (acts as thermal barrier separating occupiable space from non-occupiable space)


Leaky supply
ducts
Leaky ceiling
Supply
Supply
Air
handling
unit
Return

Conditioned Attics Not Unvented Attics Need Supply Air

Conditioned Attics Not Unvented Attics

Need Supply Air

50 cfm/1000 ft2 of Attic

# Hygric Buoyancy

1 H — Atomic Number, Symbol

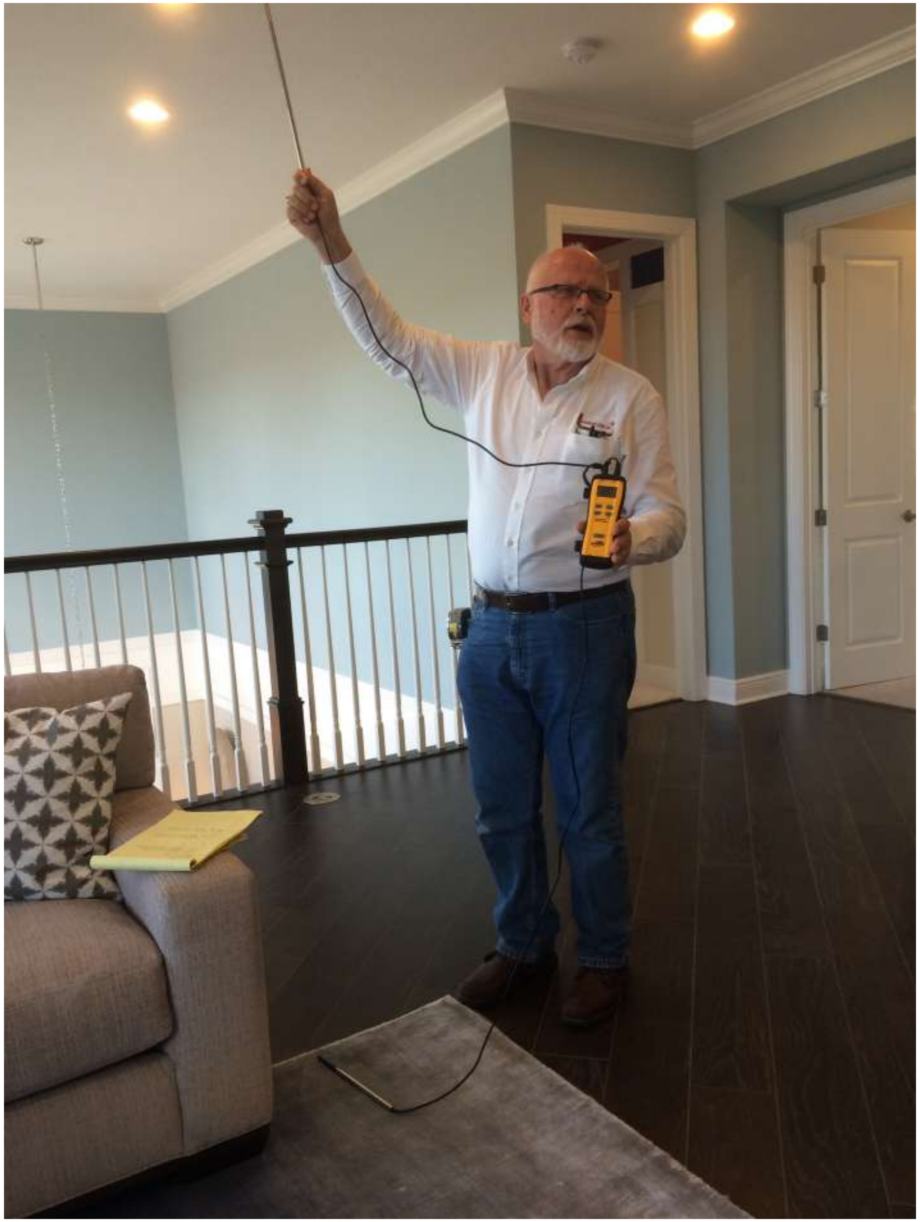
| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | * | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | ** | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Nh | 114 Fl | 115 Mc | 116 Lv | 117 Ts | 118 Og |
| | | * | 57 La | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu |
| | | ** | 89 Ac | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr |

Dry Air

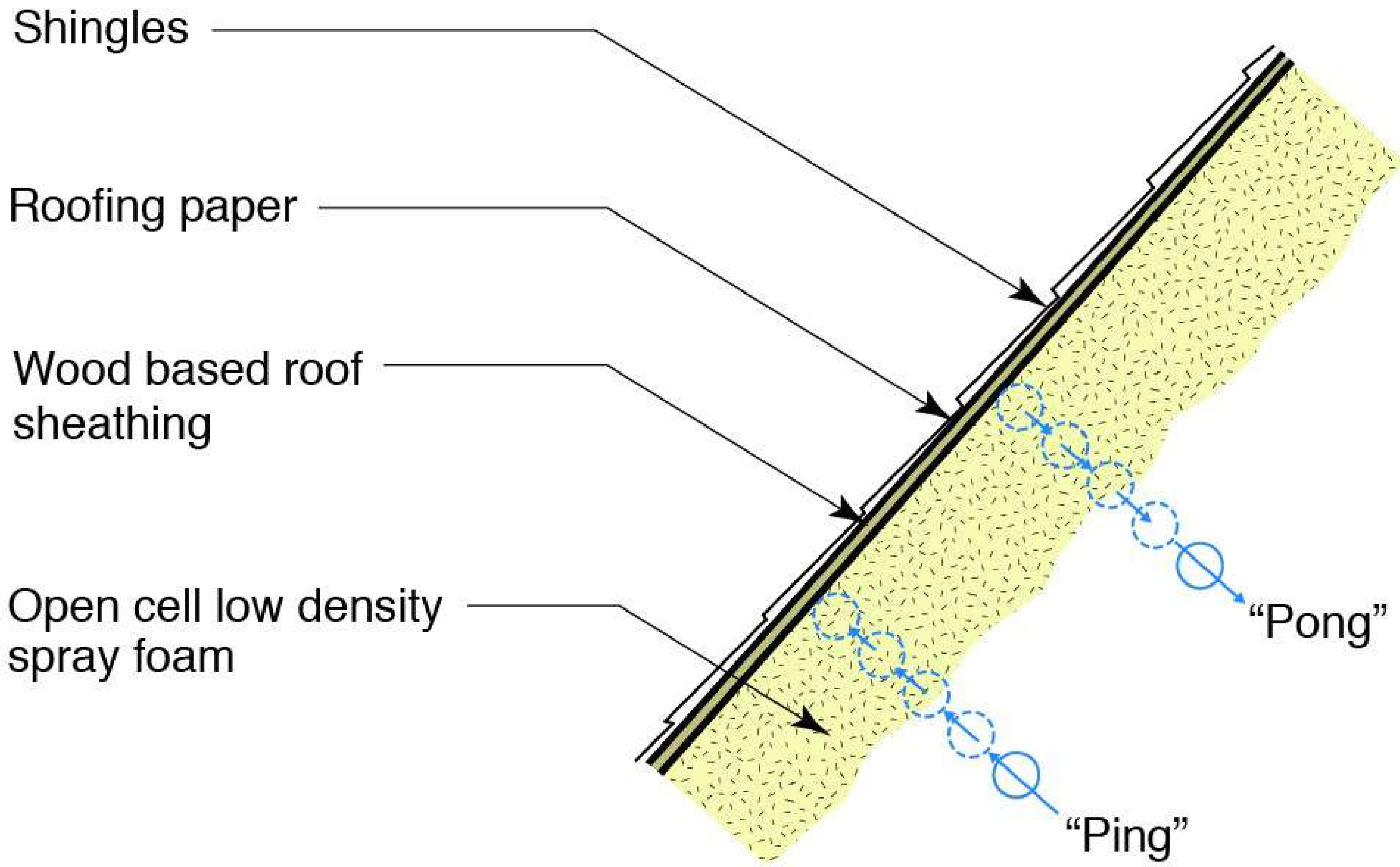
| | | | | |
|---|---|---|---|---|
| Oxygen | (21%) | 16 | $O_2$ | 32 |
| Nitrogen | (79%) | 14 | $N_2$ | 28 |
| | | | | 29 |

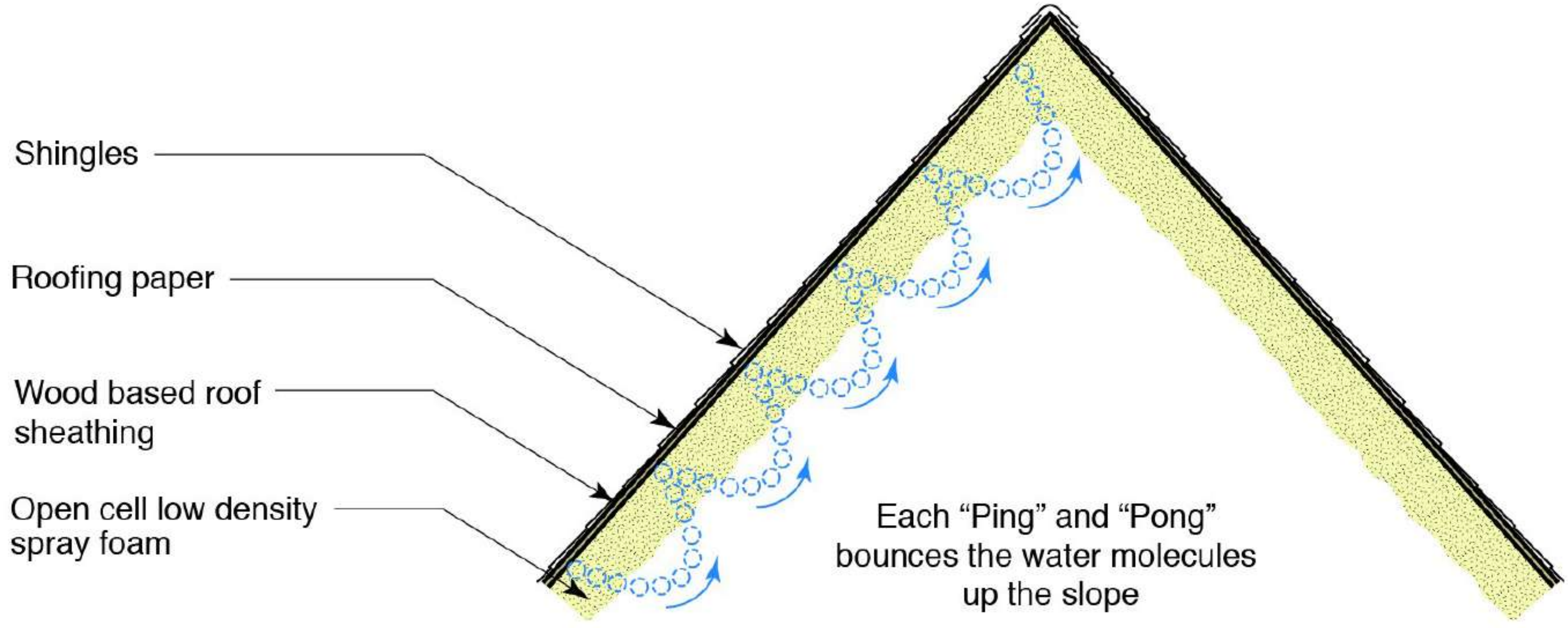
Moist Air

| | | | | |
|---|---|---|---|---|
| Oxygen | (21%) | 16 | $O_2$ | 32 |
| Nitrogen | (79%) | 14 | $N_2$ | 28 |
| Water | (tiny) | | $H_2O$ | 18 |
| | | less than | | 29 |



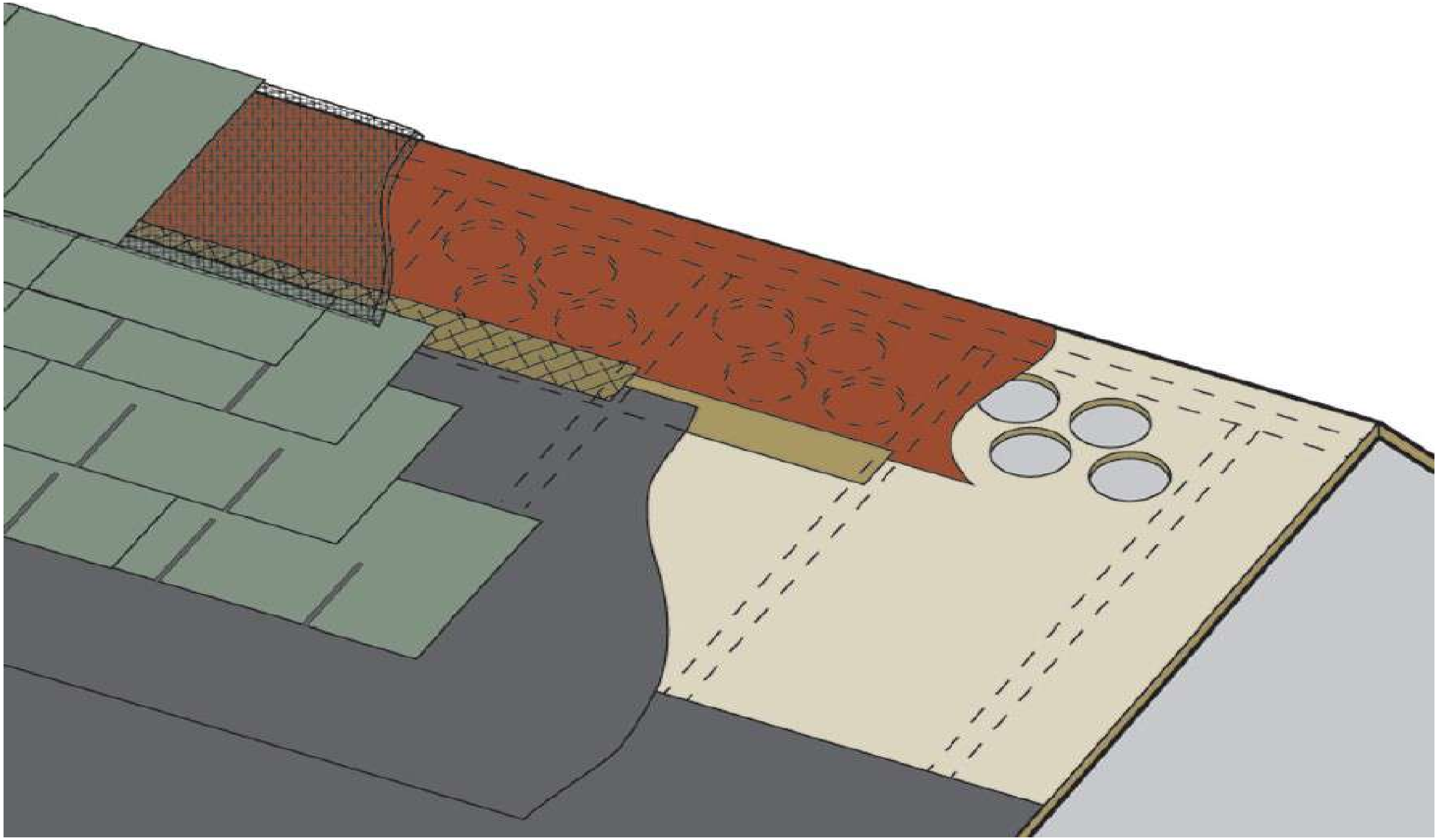

55.4
53.1
PARAM
SYNC
TEET/ΔT
Dual In-Duct Psychrometer
Fieldpiece
SDP2

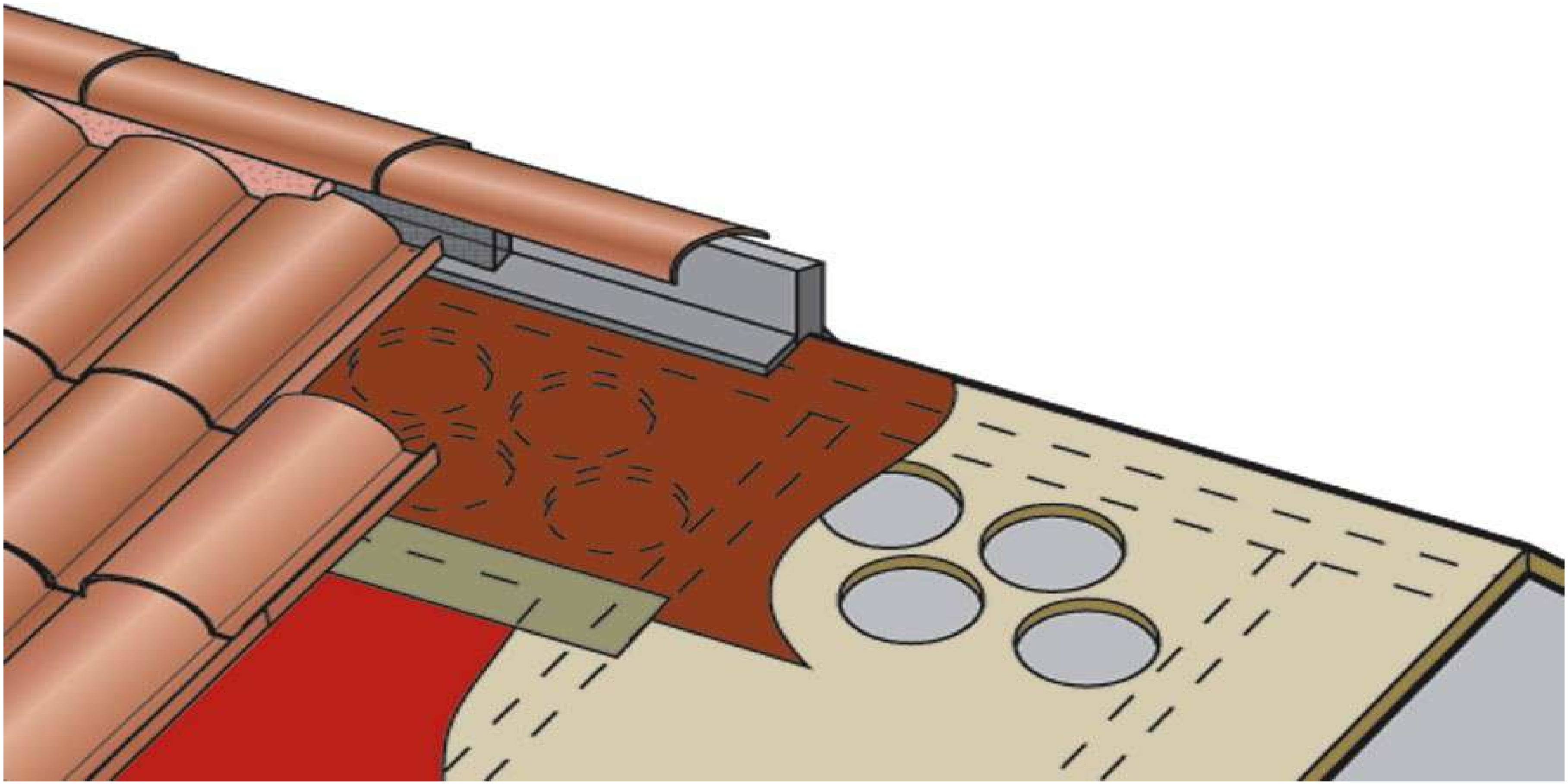

Shingles
Roofing paper
Wood based roof sheathing
Open cell low density spray foam
"Pong"
"Ping"

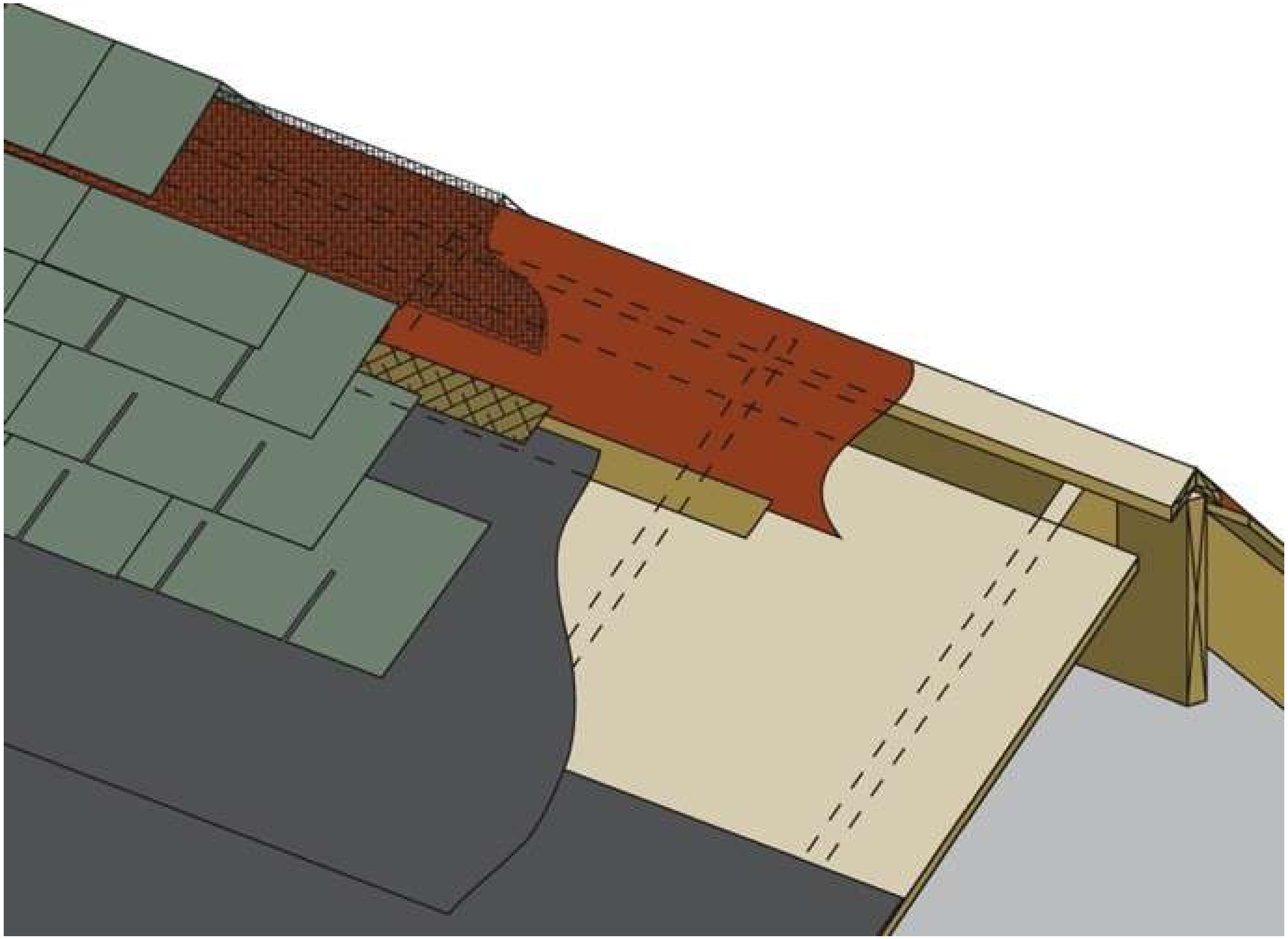

Shingles
Roofing paper
Wood based roof sheathing
Open cell low density spray foam
Each "Ping" and "Pong" bounces the water molecules up the slope

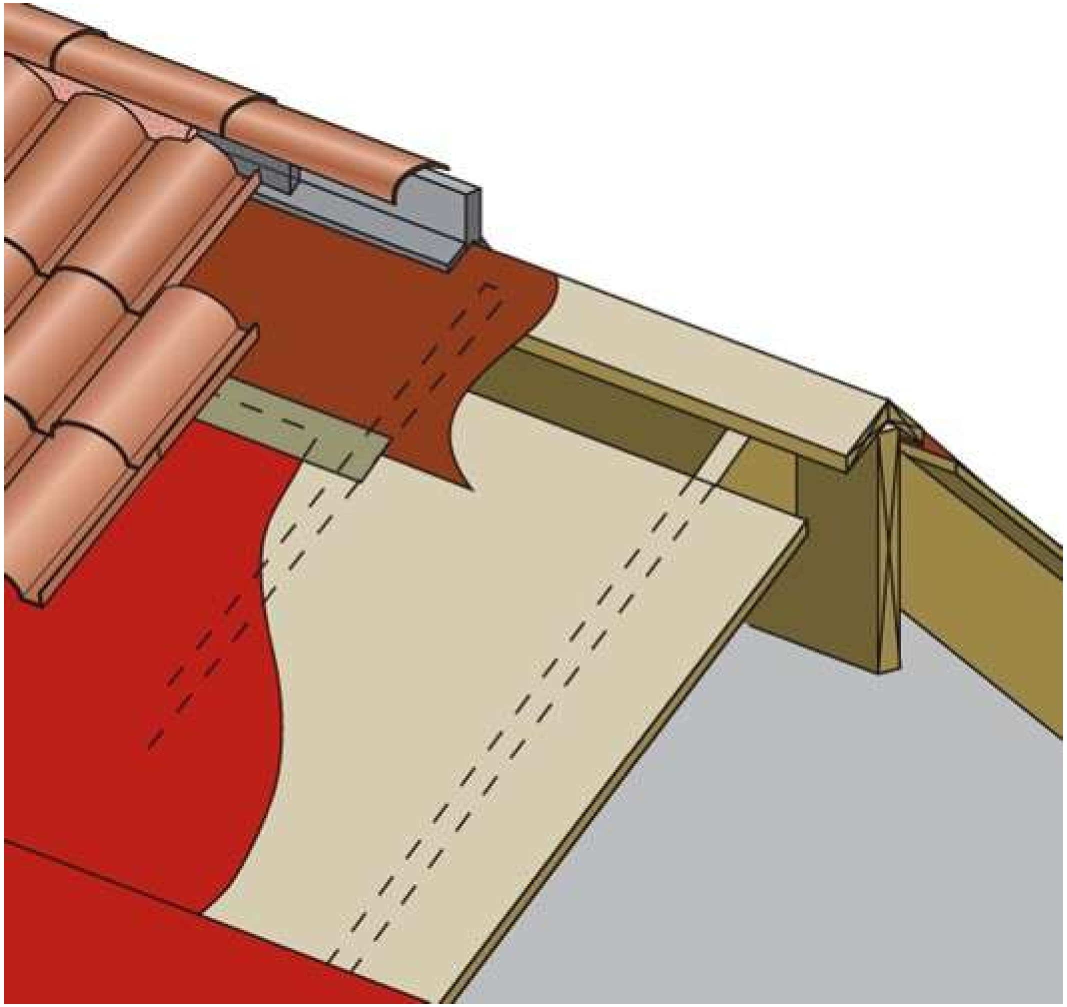

32/16


R-30
OWENS CORNING
PROPINK
High Performance
Attic System
R-30










R-30
PROPINK


2013


SWMJ


3M
All Weather
Flashing Tape 8067


DELTA DELTA DELTA DELTA

# Code Change

R806.5 Unvented attic and unvented attic enclosed rafter assemblies.

- vapor diffusion port
- port area 1:600 of the ceiling area
- vapor permeance greater than 20 perms
- roof slope greater than 3:12
- insulation under the roof deck or at the ceiling
- air supply 50 cfm/1000 ft2 ceiling area when insulation installed directly under the roof deck
- Climate Zones 1, 2 and 3

Vapor Diffusion Port: A passageway for conveying water vapor from an unvented attic to the atmosphere.

# Sweating Ducts

Sweating Ducts

Light Colored Roofs

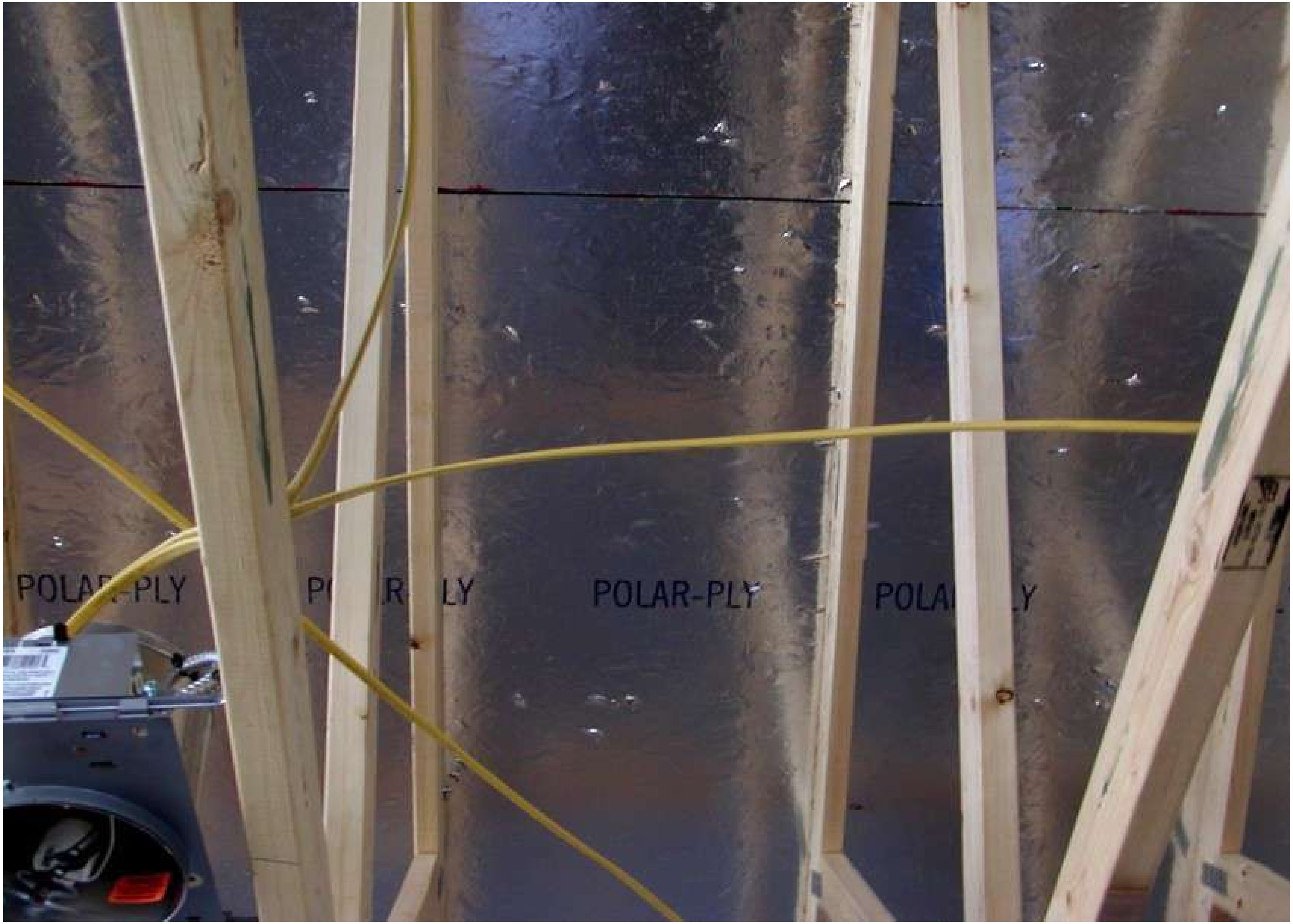
Cool Roofs

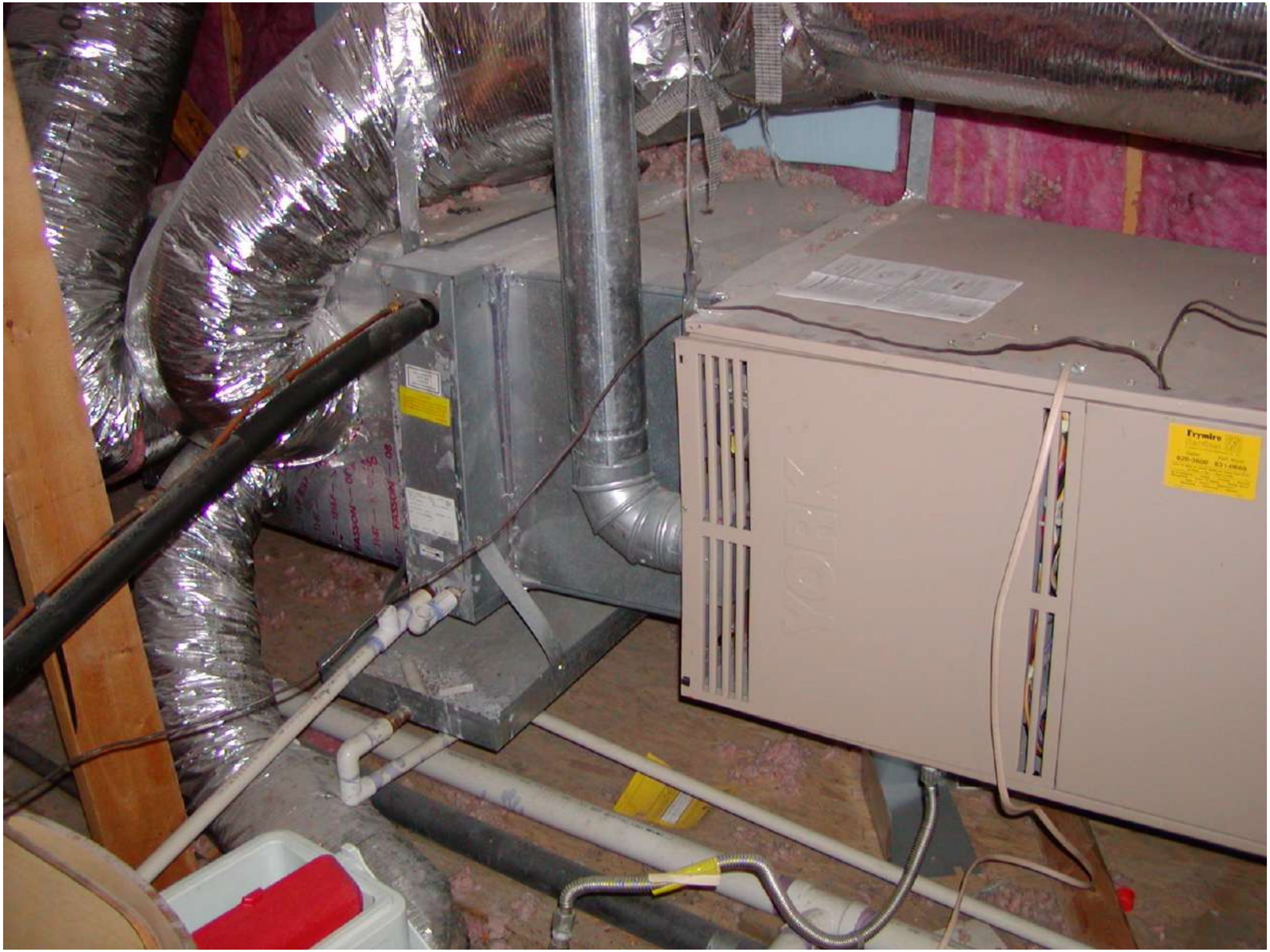
Radiant Barriers

ACCA Manual J, S and D

ASHRAE 62.2

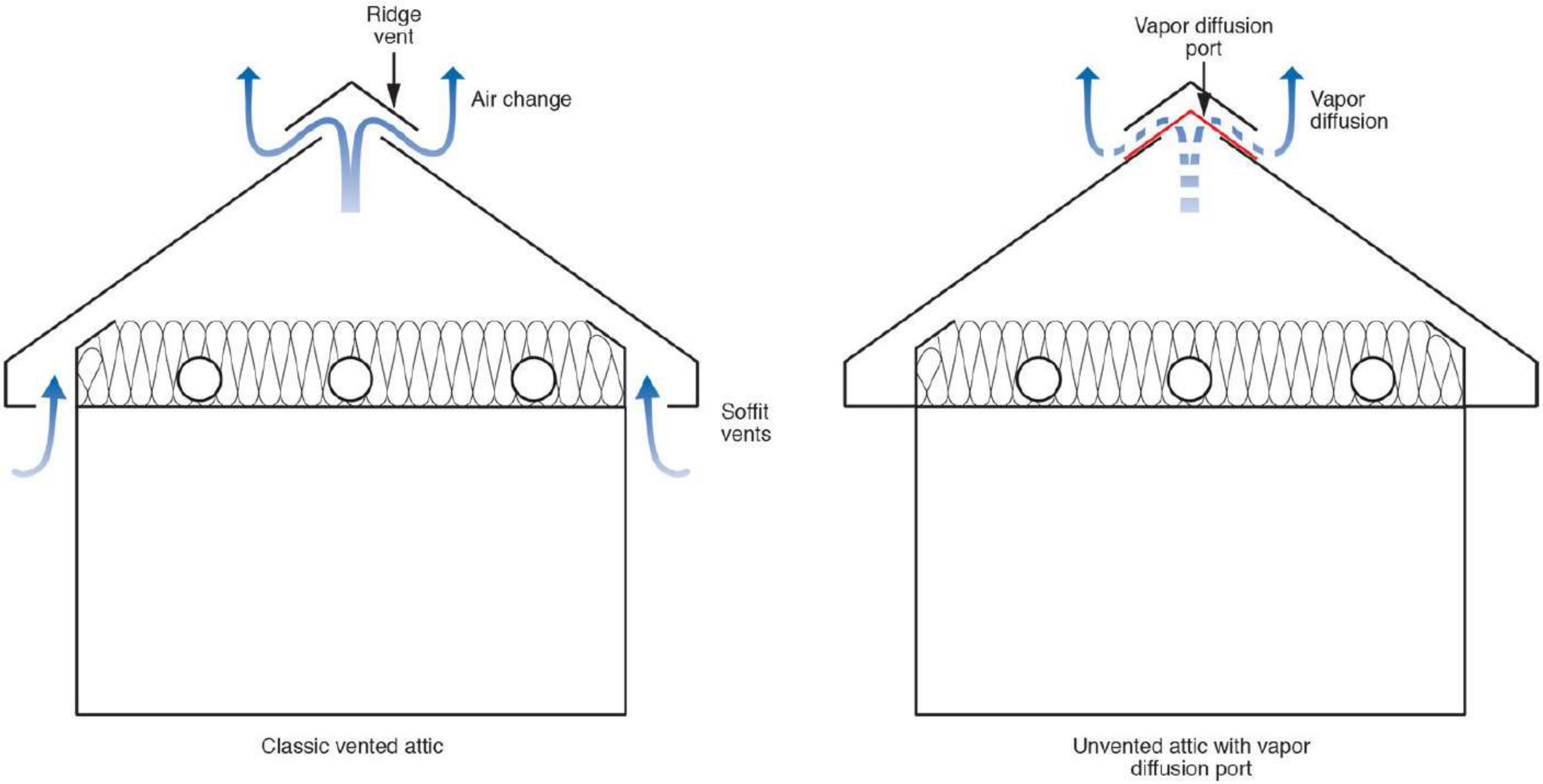
# Ductwork Attic Dehumidification System


POLAR-PLY


YORK

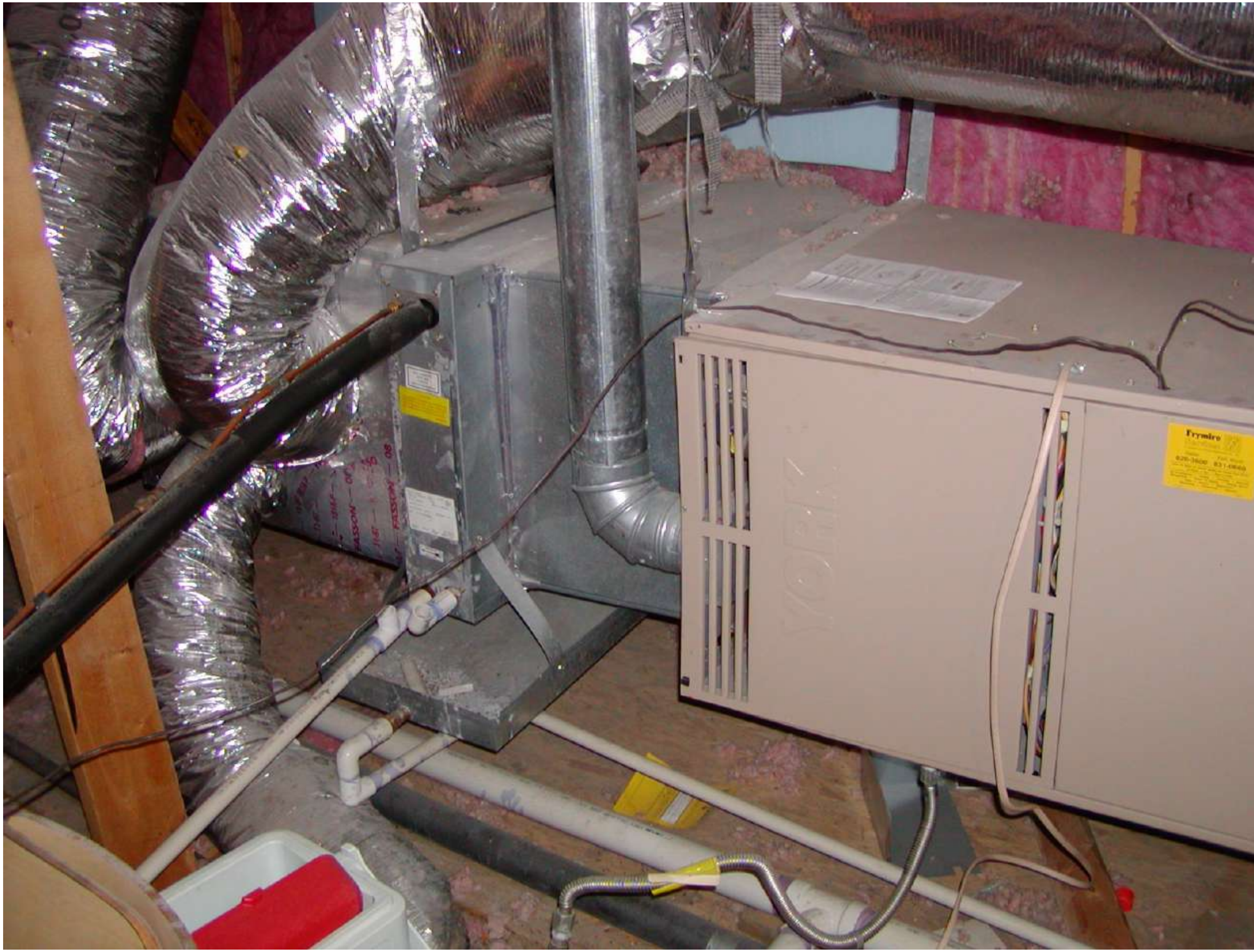

LP TECHSHIELD


11615



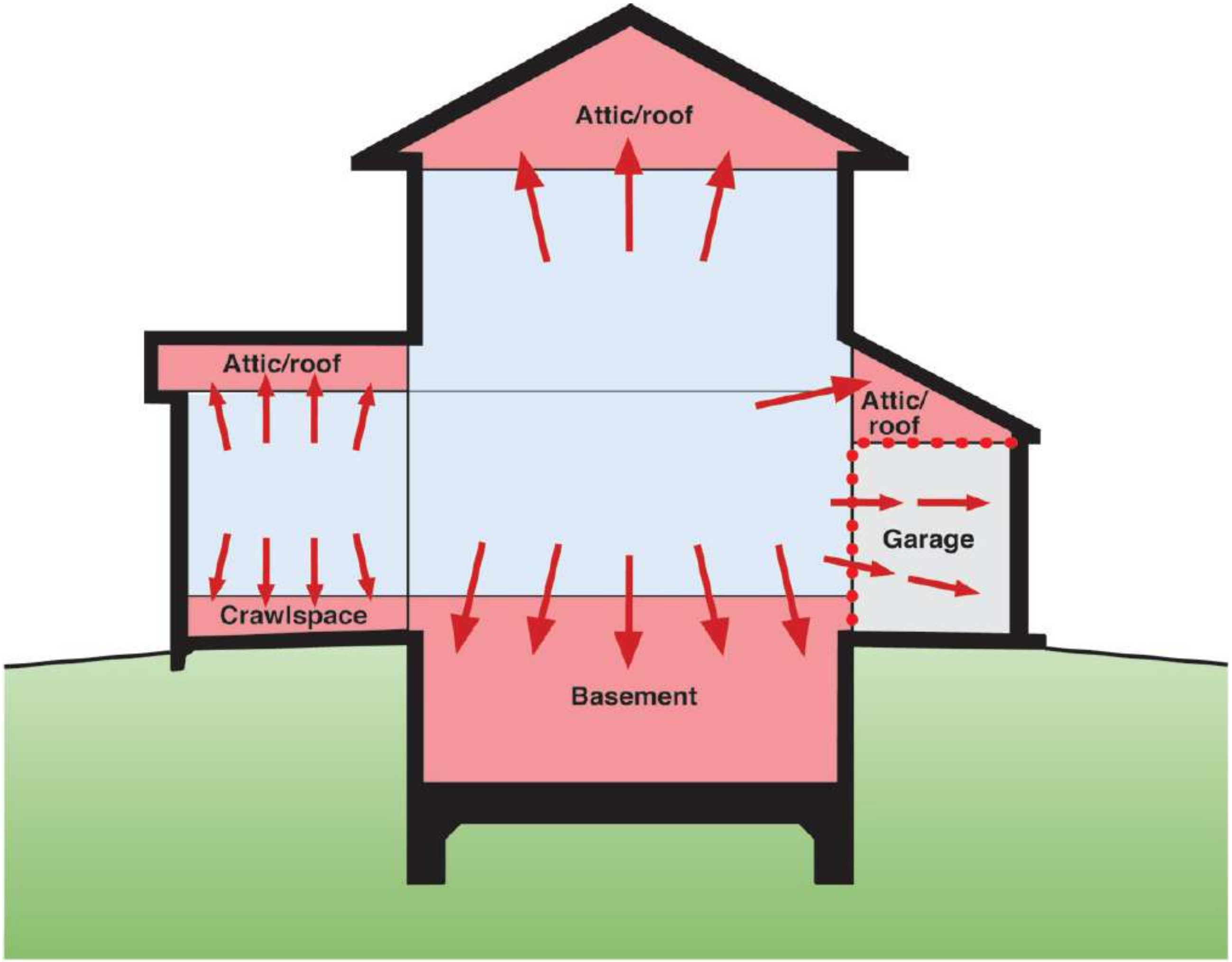
Ridge vent
Air change
Soffit vents
Classic vented attic
Vapor diffusion port
Vapor diffusion
Unvented attic with vapor diffusion port


AF 100
09/14


YORK


Lochinvar
XB80

# Basements

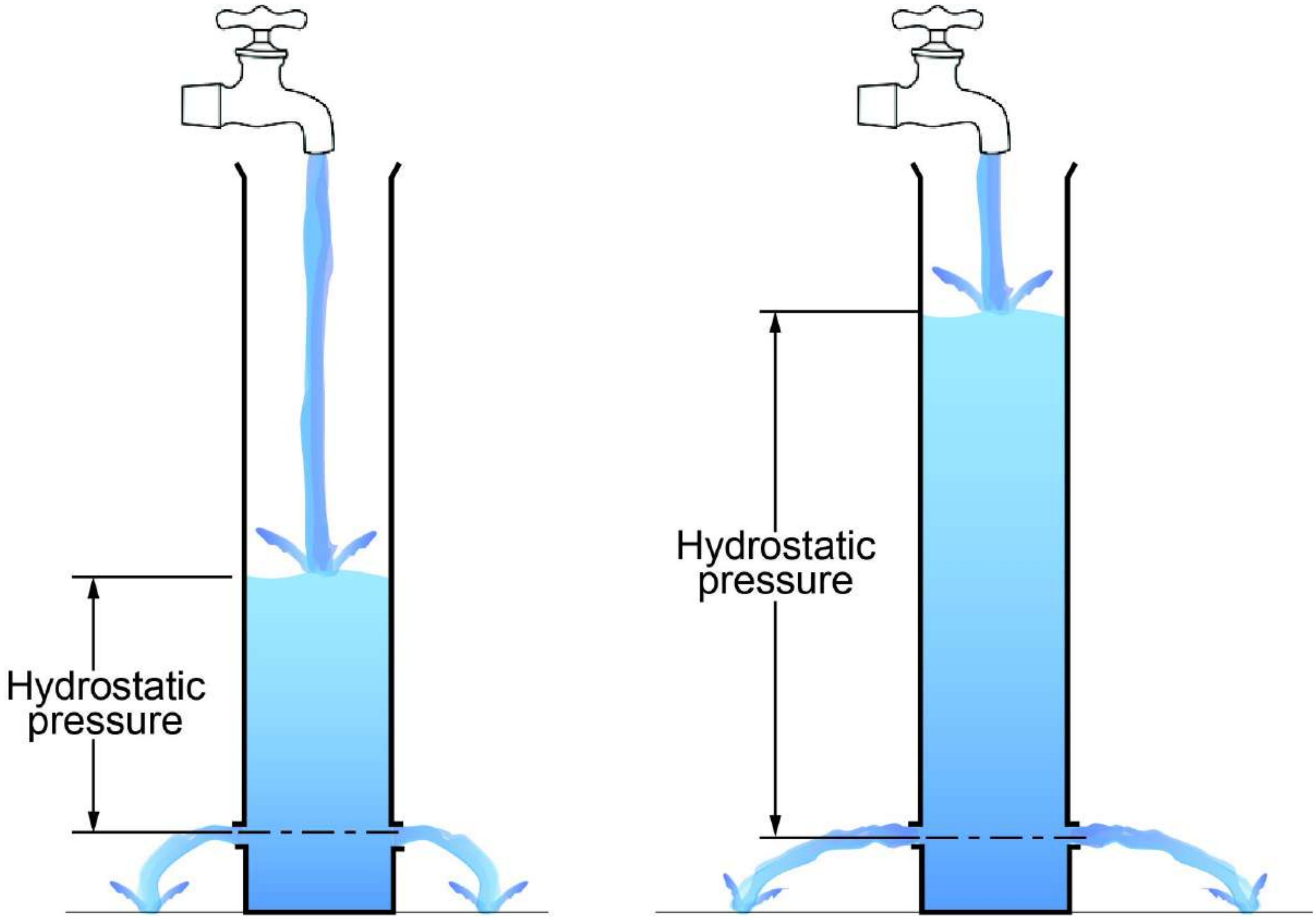


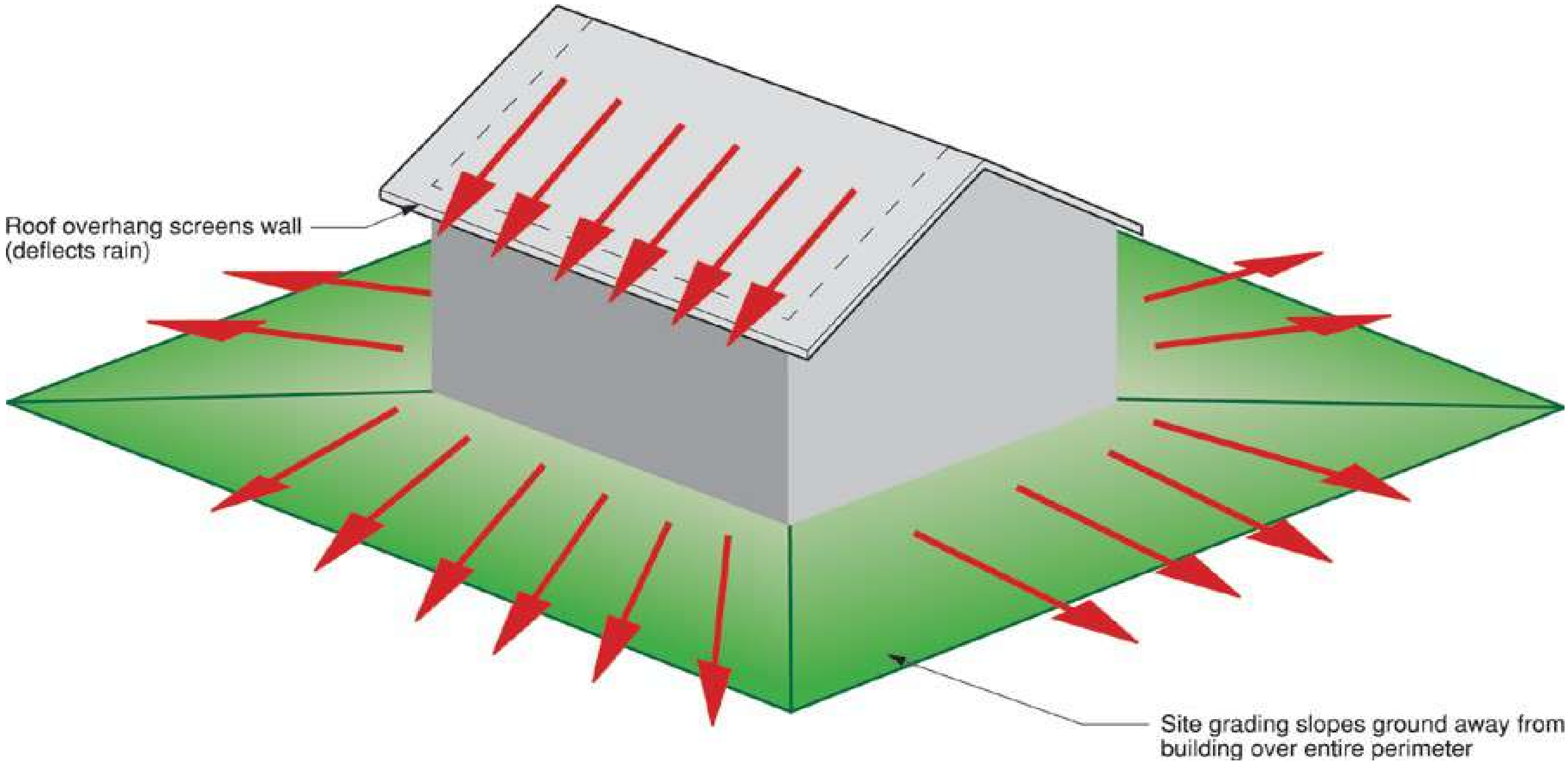

**Expansion of Conditioned Space**

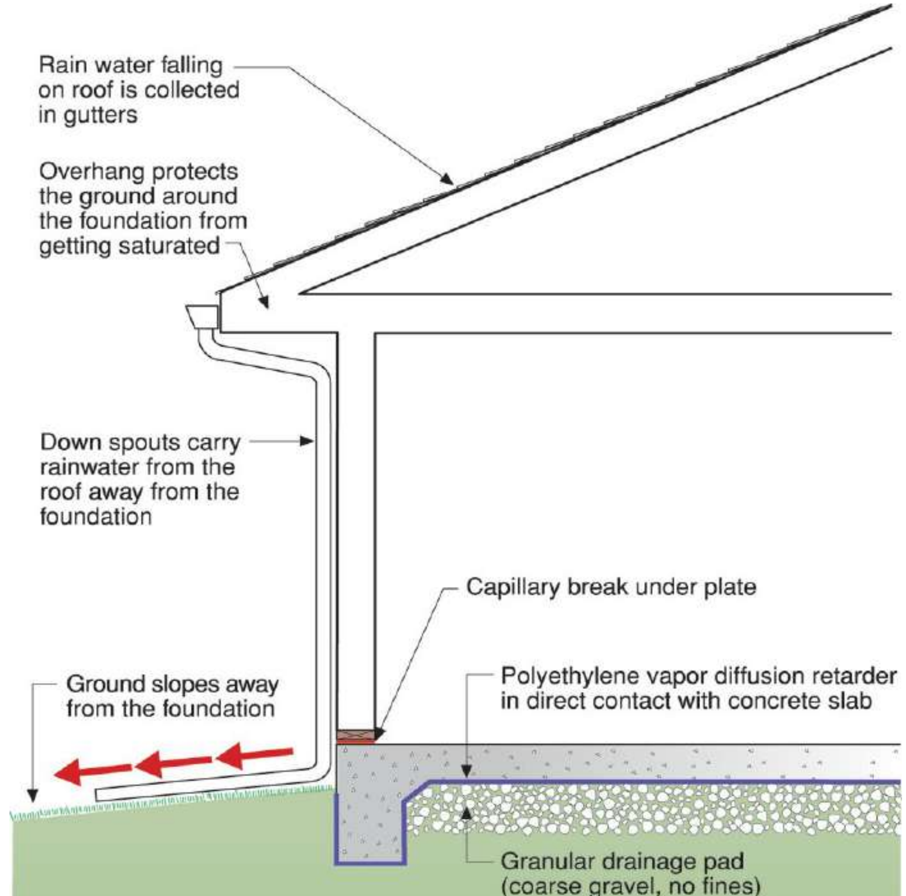
- Conditioned space boundaries moving towards exterior surfaces of building
- Garage isolated from house by air barrier/pressure boundary
- Garage ventilated and conditioned independently of rest of conditioned spaces

# Mechanisms of Flow

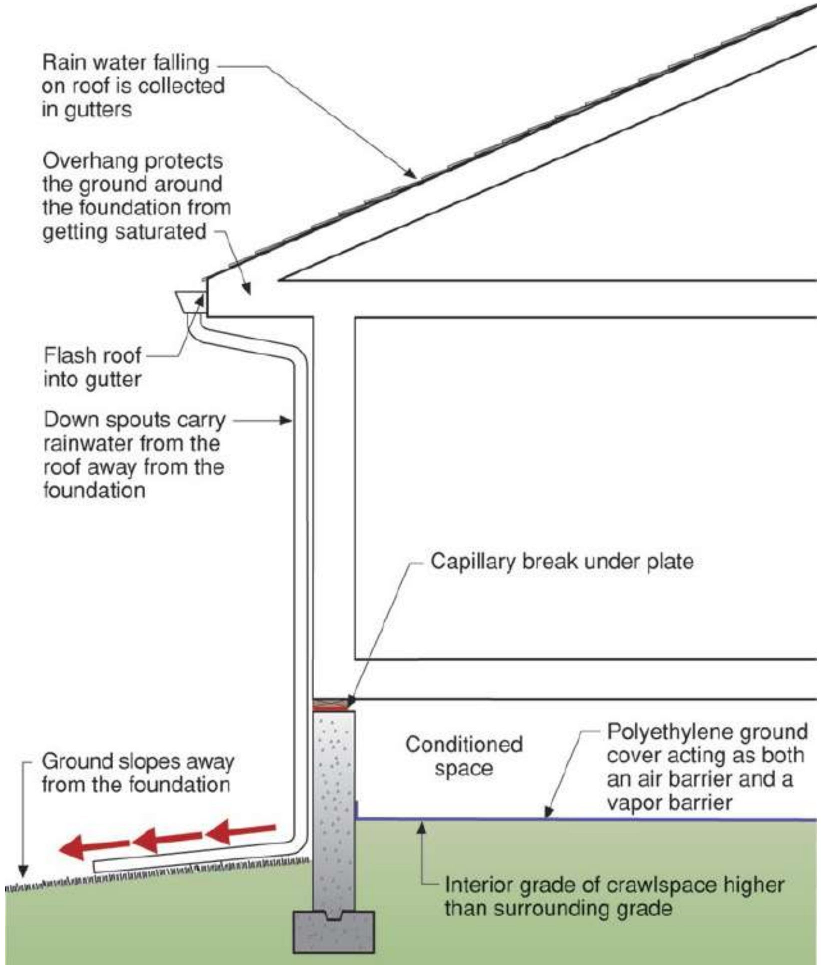
| | | | |
|---|---|---|---|
| • Liquid | Gravitational | Hydrostatic Pressure |
| | Capillary | Suction Pressure |
| | Osmosis | Solute Concentration |
| • Vapor | Diffusion | Vapor Pressure |
| | Convective | Air Pressure |


Hydrostatic
pressure
Hydrostatic
pressure

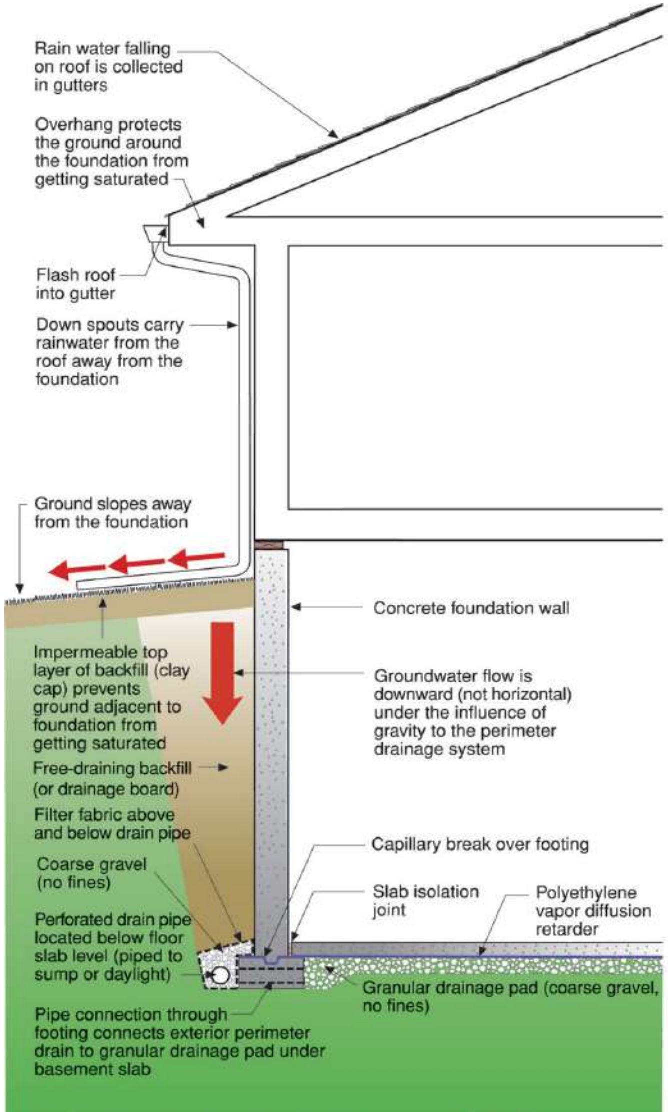

Roof overhang screens wall
(deflects rain)
Site grading slopes ground away from
building over entire perimeter




- 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 ($\cong$ 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

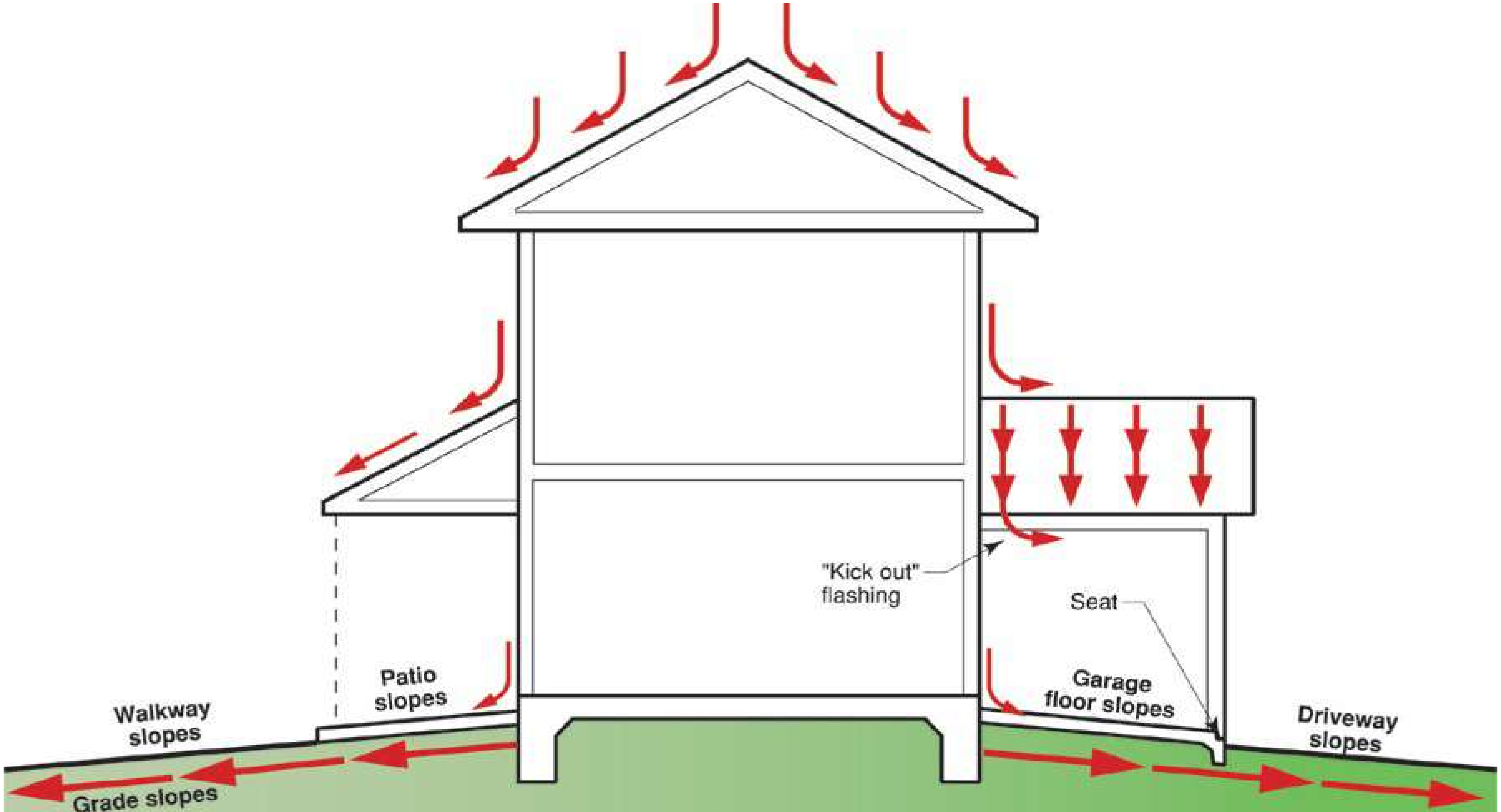



- Keep rain water away from the foundation perimeter
- If the interior crawlspace is lower than the exterior grade, a sub-grade perimeter footing drain is necessary as in a basement foundation
- The crawlspace is conditioned space; it is part of the "interior" of the building and should be heated, cooled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

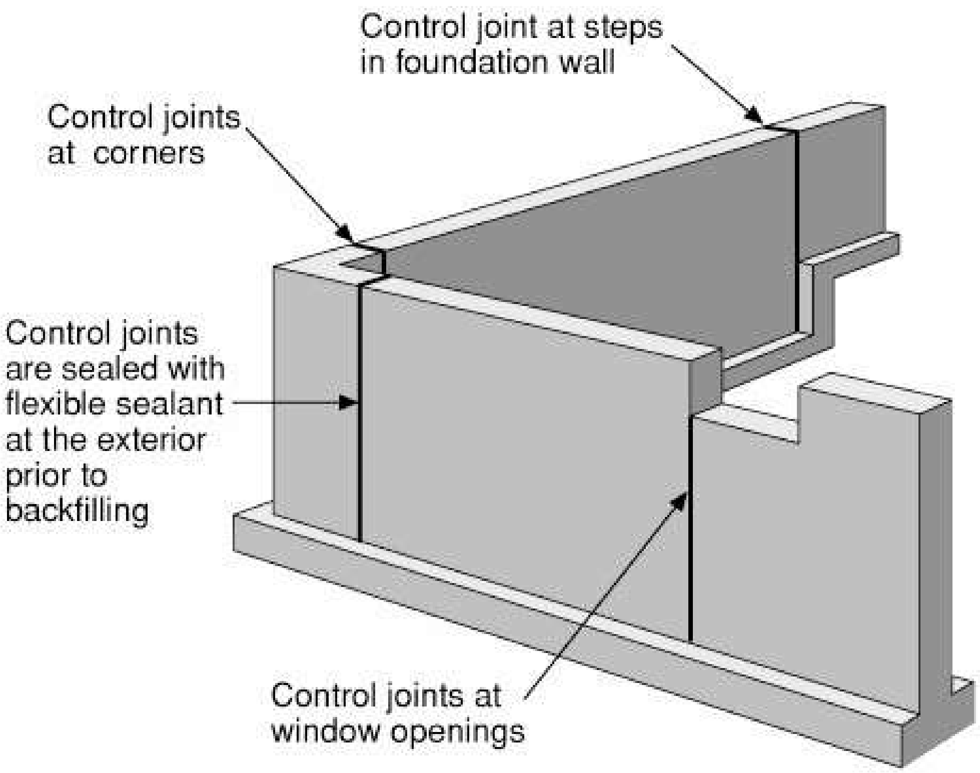


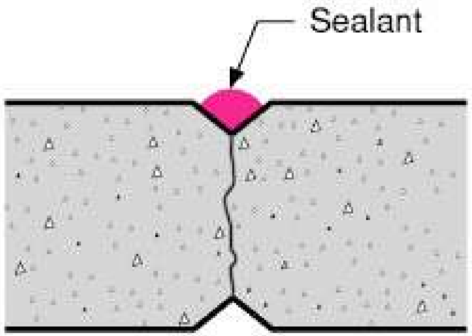

- Keep rain water away from the foundation perimeter
- Drain groundwater away in sub-grade perimeter footing drains before it gets to the foundation wall


DELTA-MS
DELTA-MS

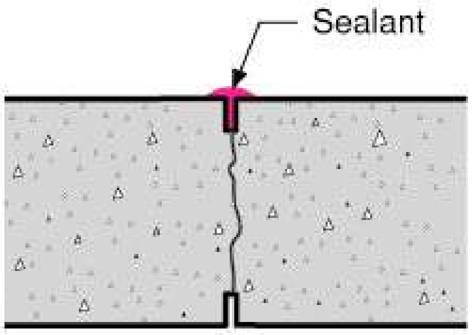



- Patios and decks lower than floors and slope away from building
- Garage floor lower than main floor and slope away from building
- Driveway lower than garage floor and slope away from building
- Grade lower than main floor and slope away from building
- Stoops and walkways lower than main floor and slope away from building
- Kick out flashings or diverters direct water away from walls at roof/wall intersections

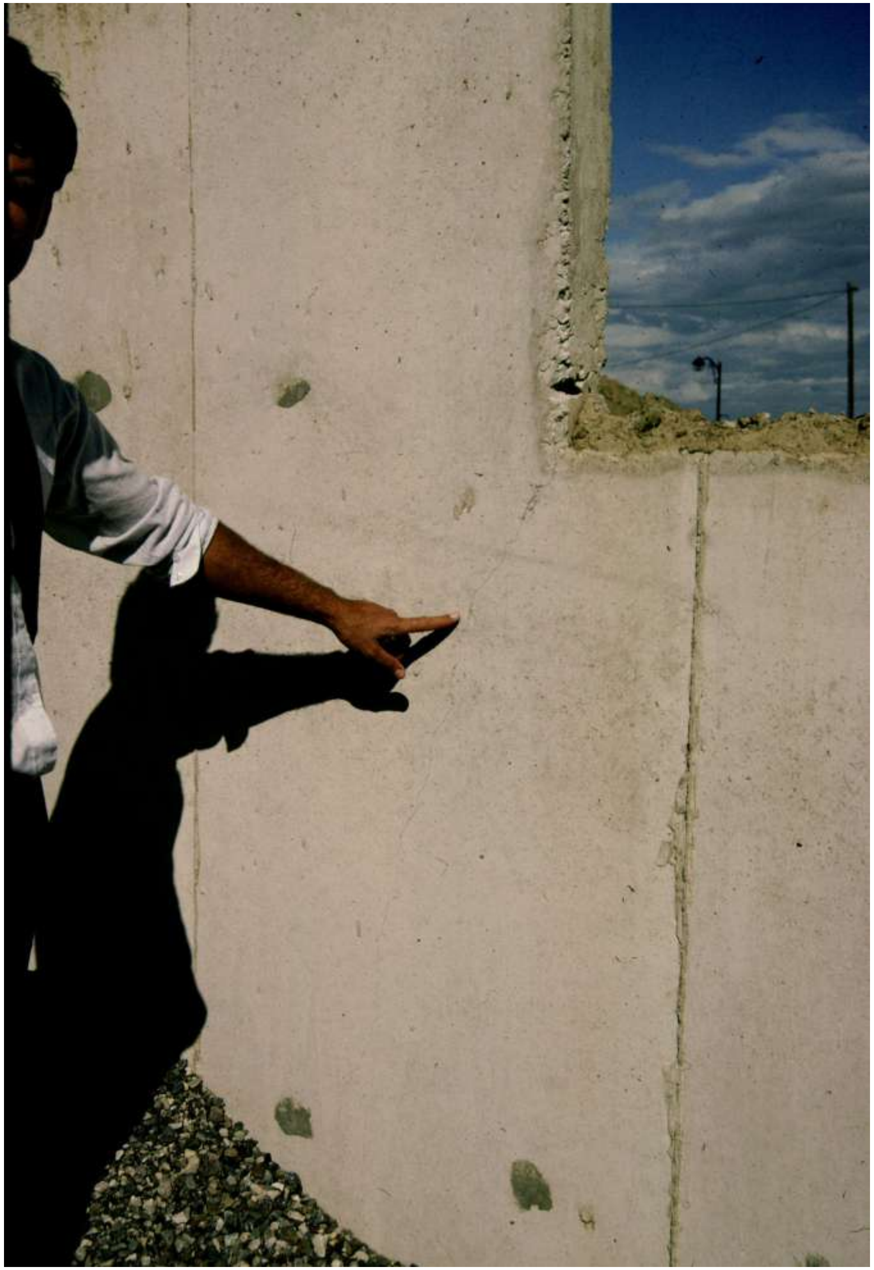


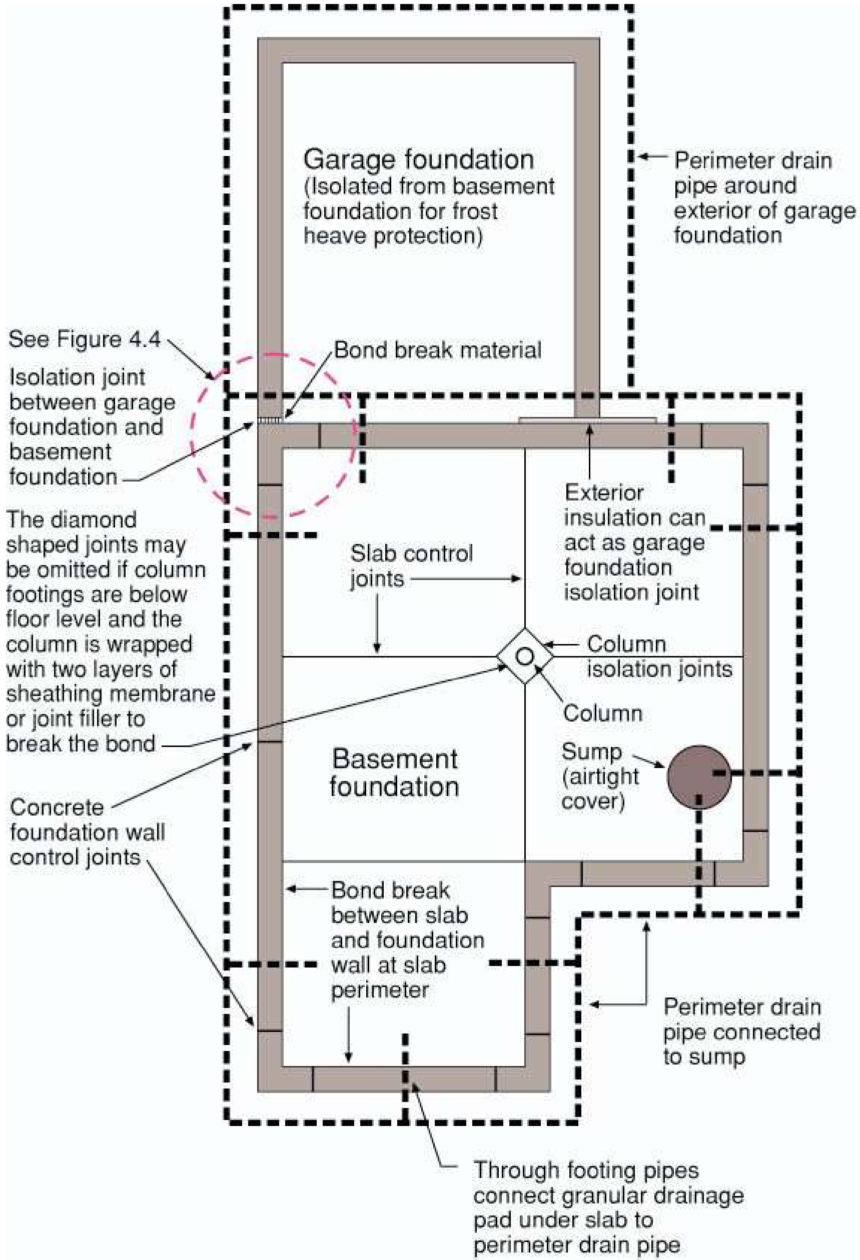



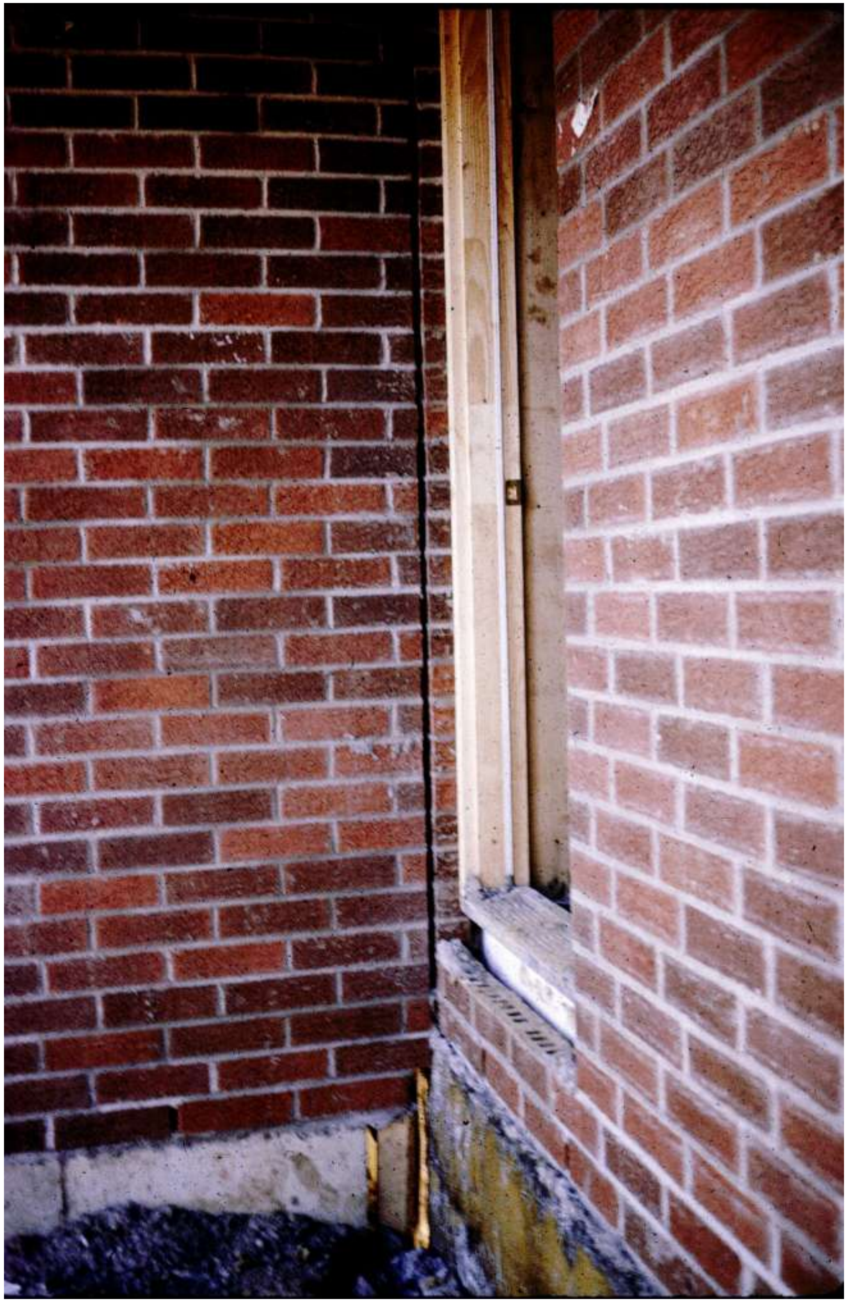

Diagonally cut 2 x 2's in forms
provide goose neck joint

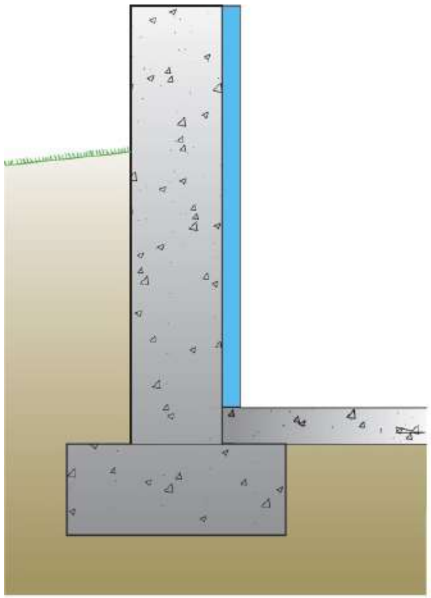



Saw cut joint

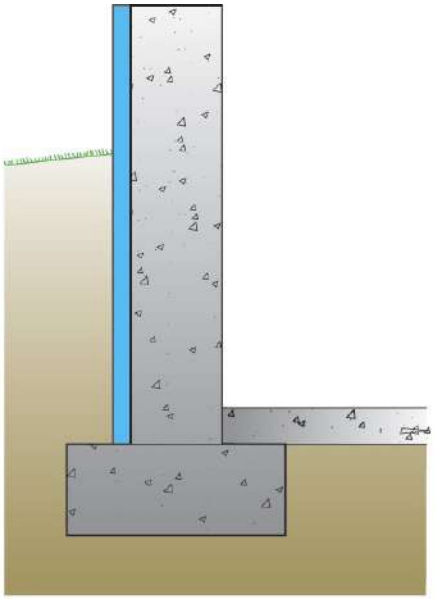



Garage foundation
(Isolated from basement foundation for frost heave protection)
Perimeter drain pipe around exterior of garage foundation
See Figure 4.4
Bond break material
Isolation joint between garage foundation and basement foundation
The diamond shaped joints may be omitted if column footings are below floor level and the column is wrapped with two layers of sheathing membrane or joint filler to break the bond
Slab control joints
Exterior insulation can act as garage foundation isolation joint
Column isolation joints
Column
Sump (airtight cover)
Basement foundation
Concrete foundation wall control joints
Bond break between slab and foundation wall at slab perimeter
Perimeter drain pipe connected to sump
Through footing pipes connect granular drainage pad under slab to perimeter drain pipe

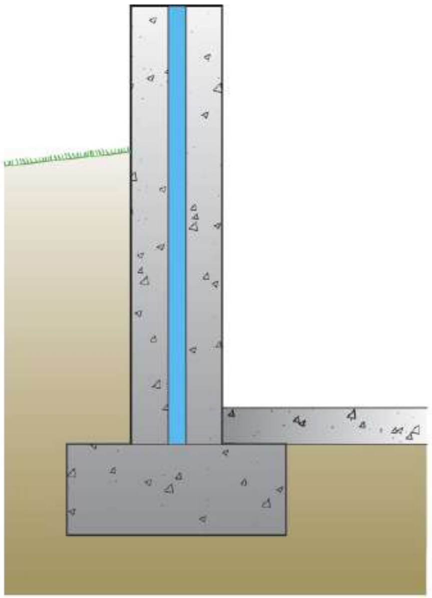




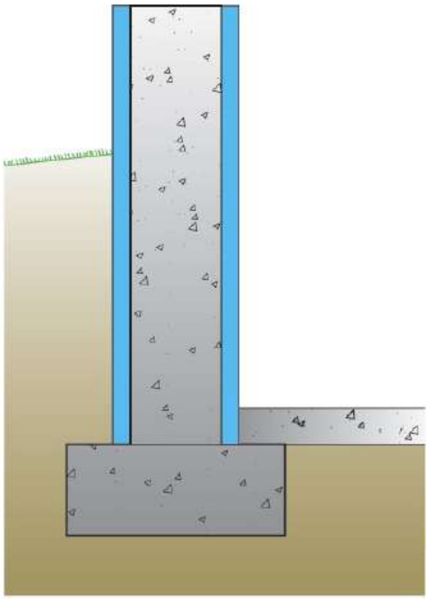
**Internally Insulated Basement**



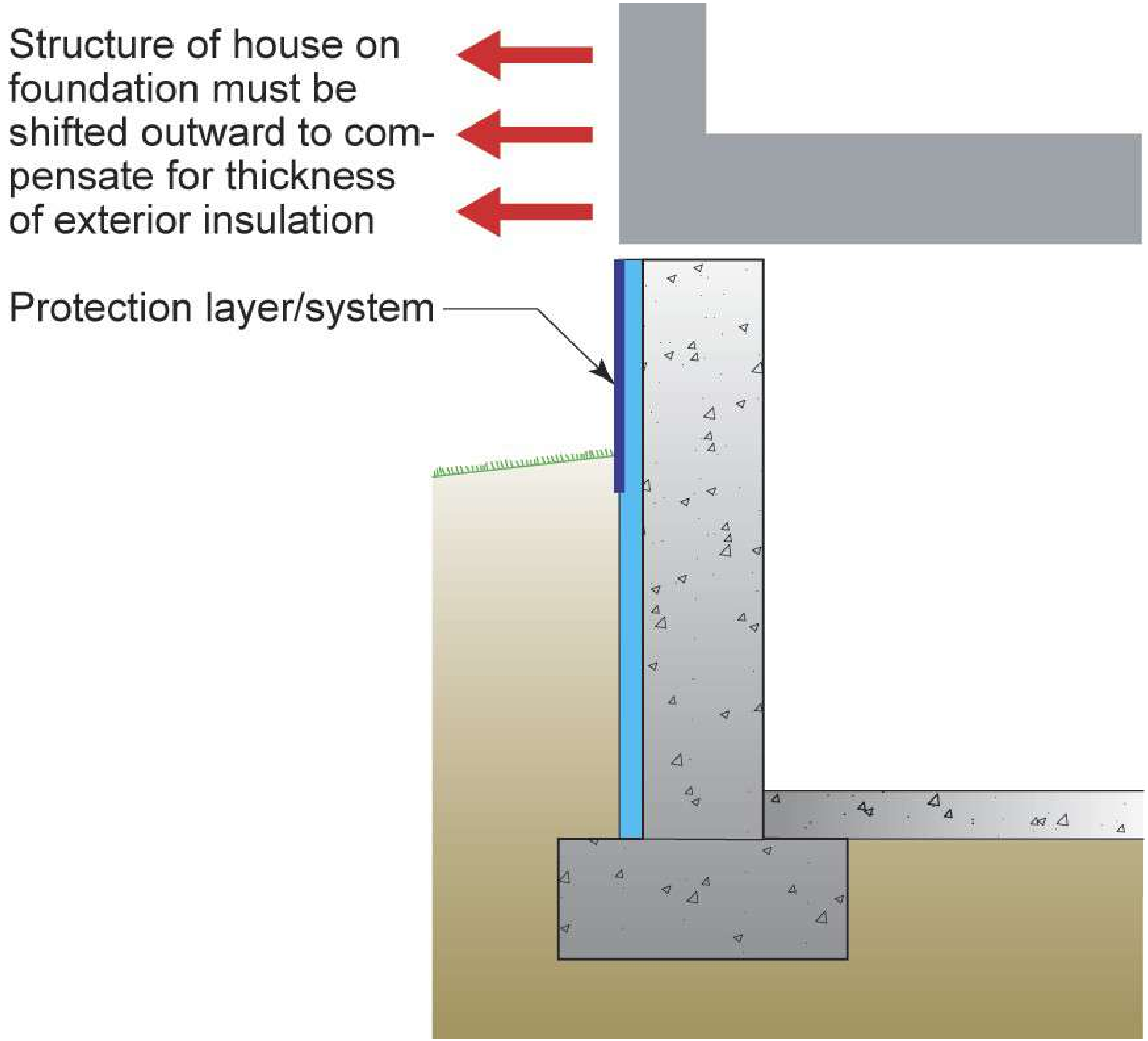
**Externally Insulated Basement**



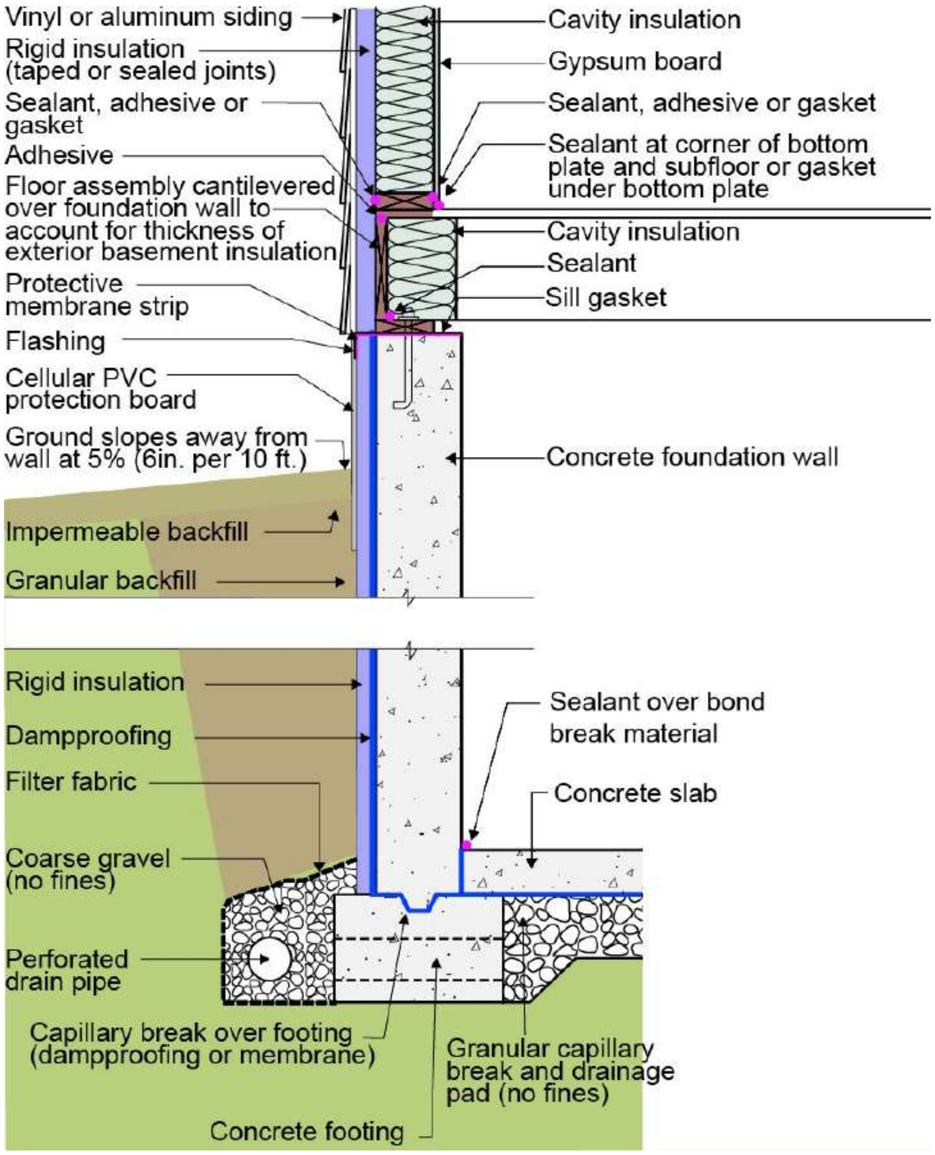
**Basement Insulated in the Middle**

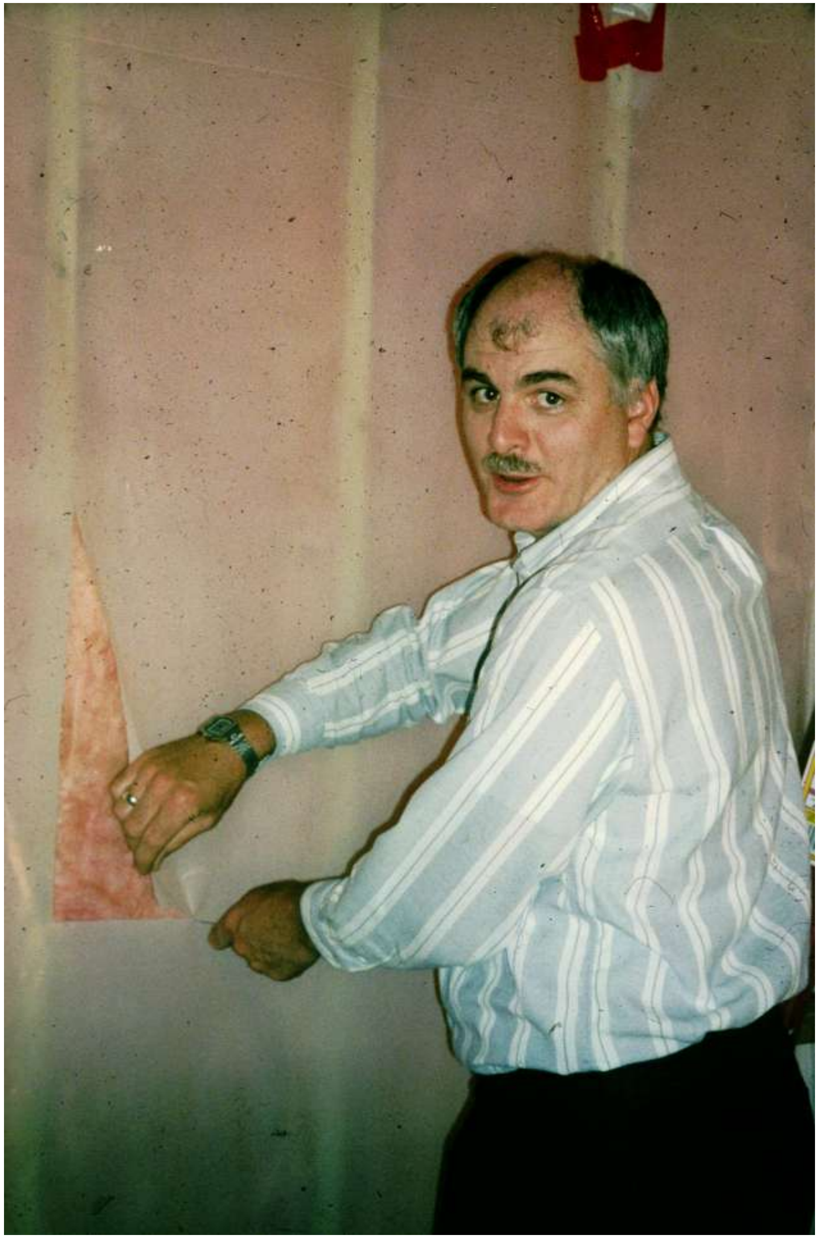


**Basement Insulated Both Externally and Internally**

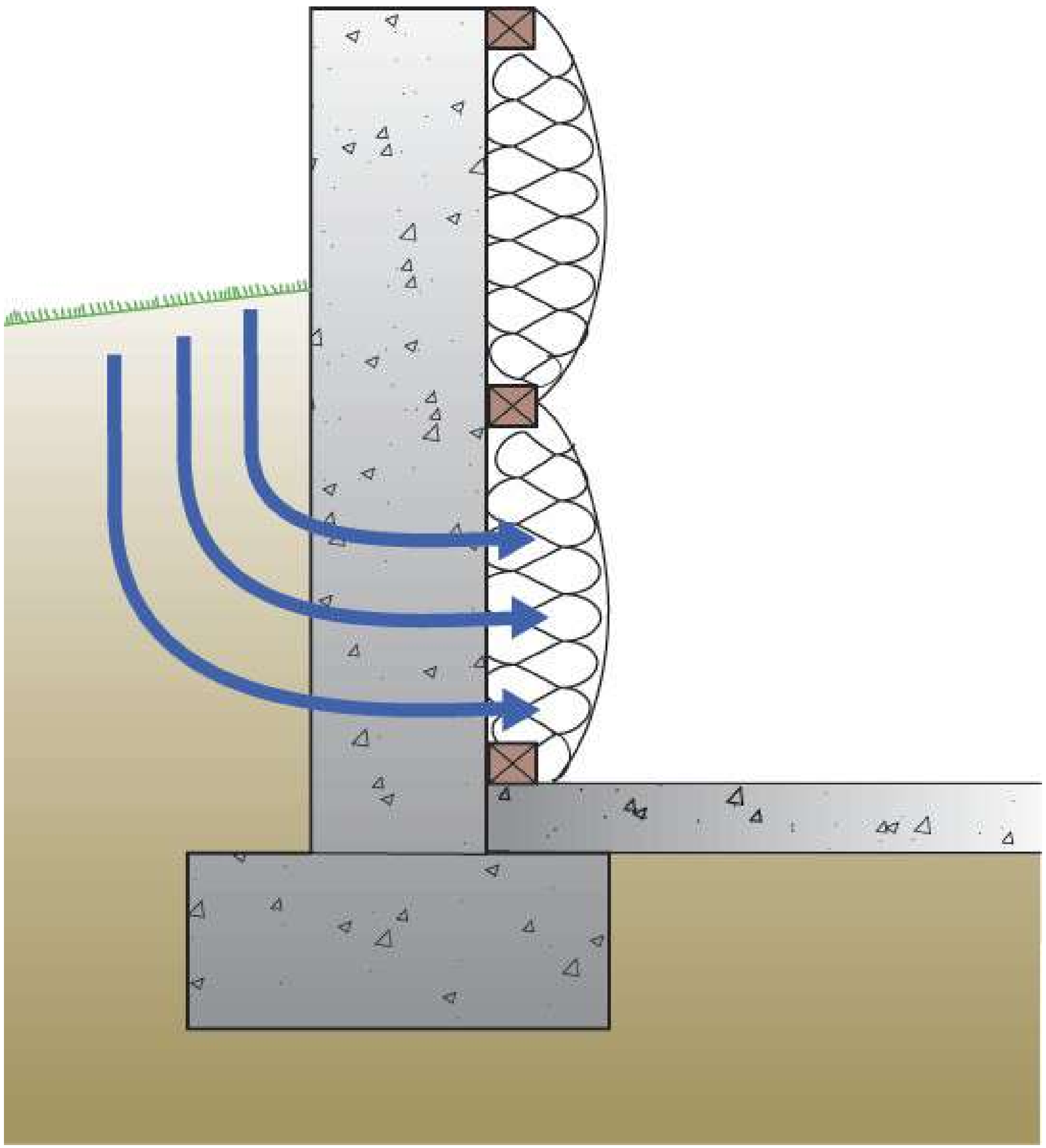

Structure of house on foundation must be shifted outward to com-pensate for thickness of exterior insulation
Protection layer/system

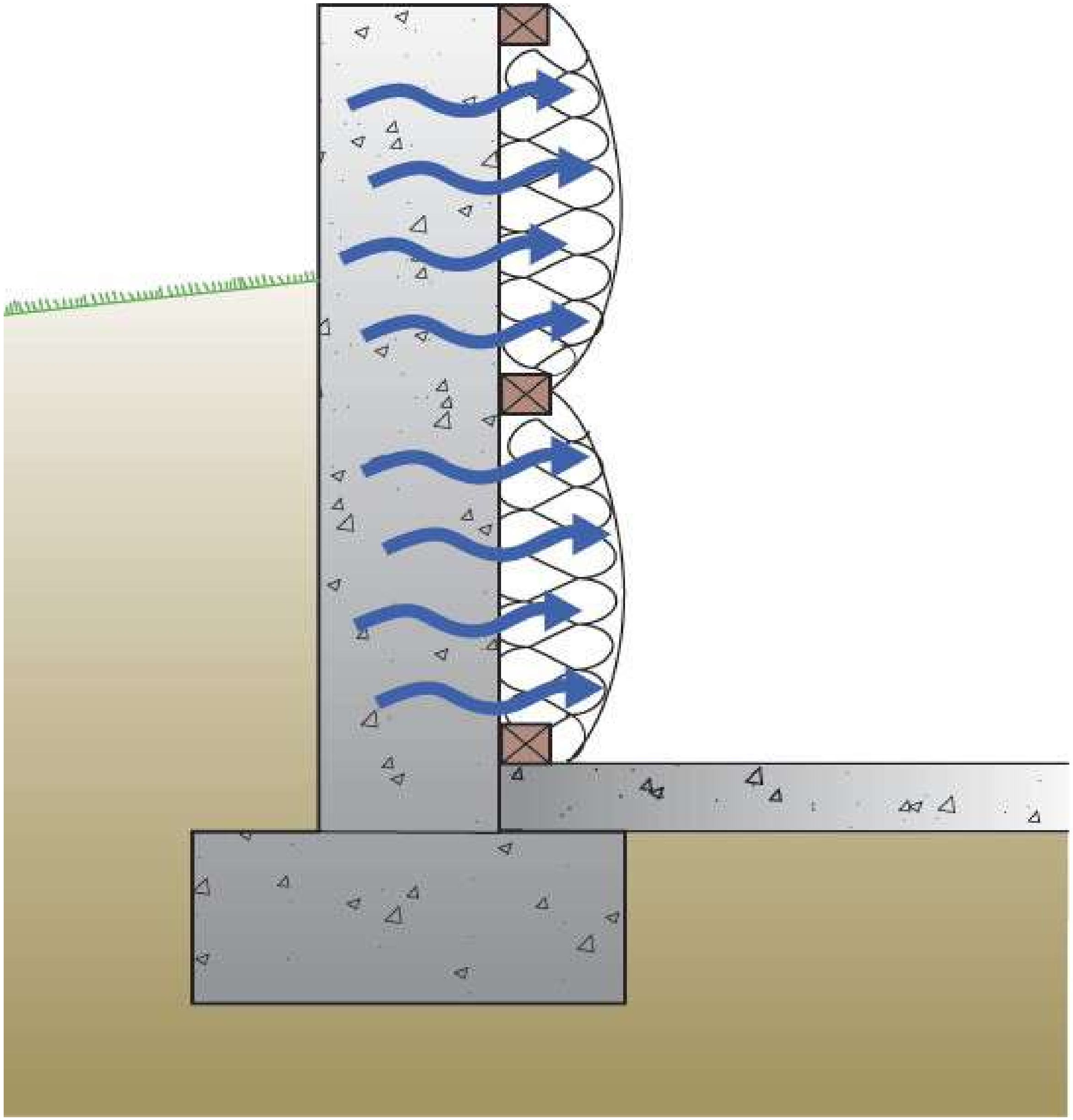

STYROFOAM
Foundation Coating Kit
27

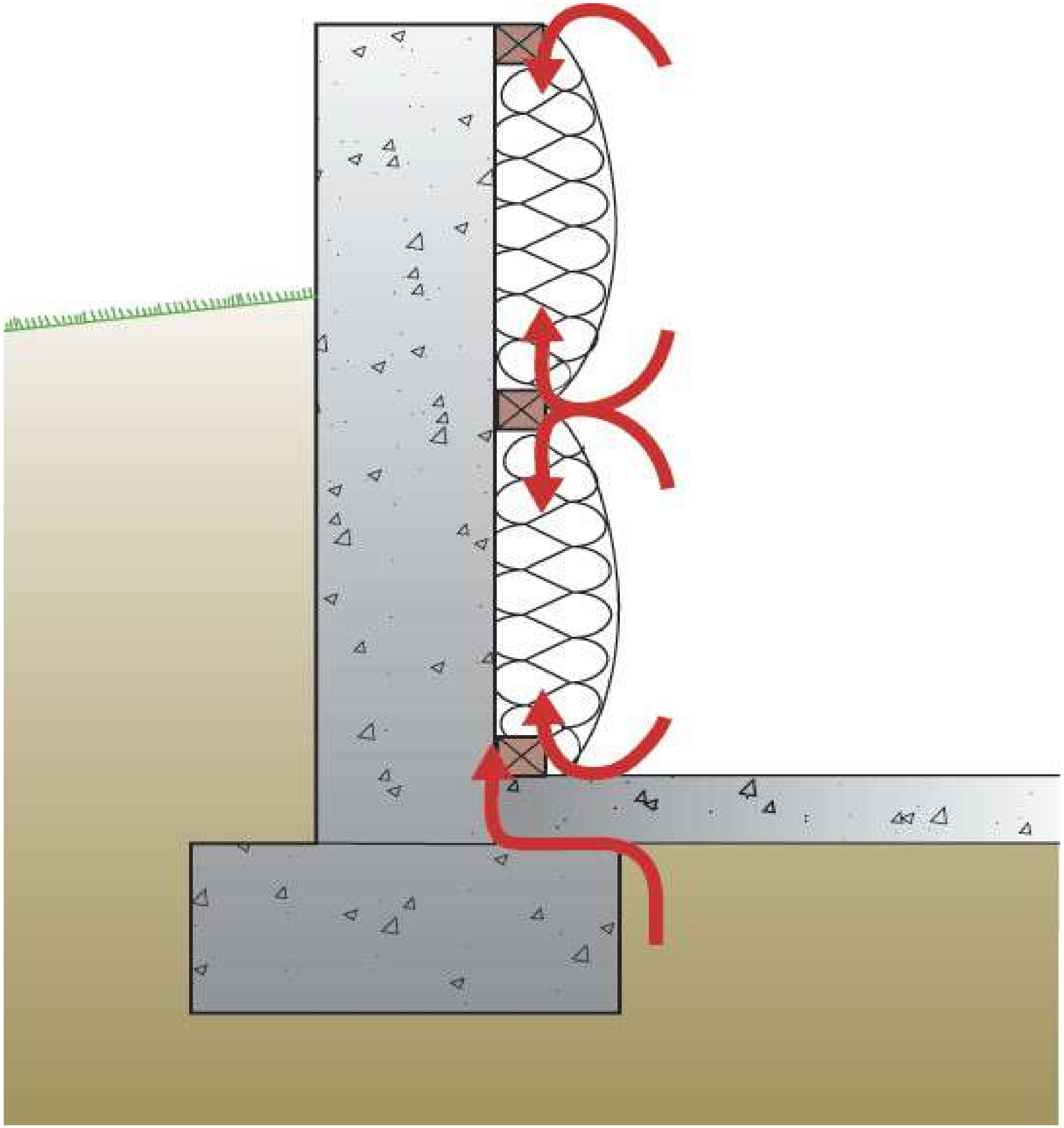

Vinyl or aluminum siding
Rigid insulation (taped or sealed joints)
Sealant, adhesive or gasket
Adhesive
Floor assembly cantilevered over foundation wall to account for thickness of exterior basement insulation
Protective membrane strip
Flashing
Cellular PVC protection board
Ground slopes away from wall at 5% (6in. per 10 ft.)
Impermeable backfill
Granular backfill
Cavity insulation
Gypsum board
Sealant, adhesive or gasket
Sealant at corner of bottom plate and subfloor or gasket under bottom plate
Cavity insulation
Sealant
Sill gasket
Concrete foundation wall
Rigid insulation
Dampproofing
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Capillary break over footing (dampproofing or membrane)
Concrete footing
Granular capillary break and drainage pad (no fines)
Sealant over bond break material
Concrete slab

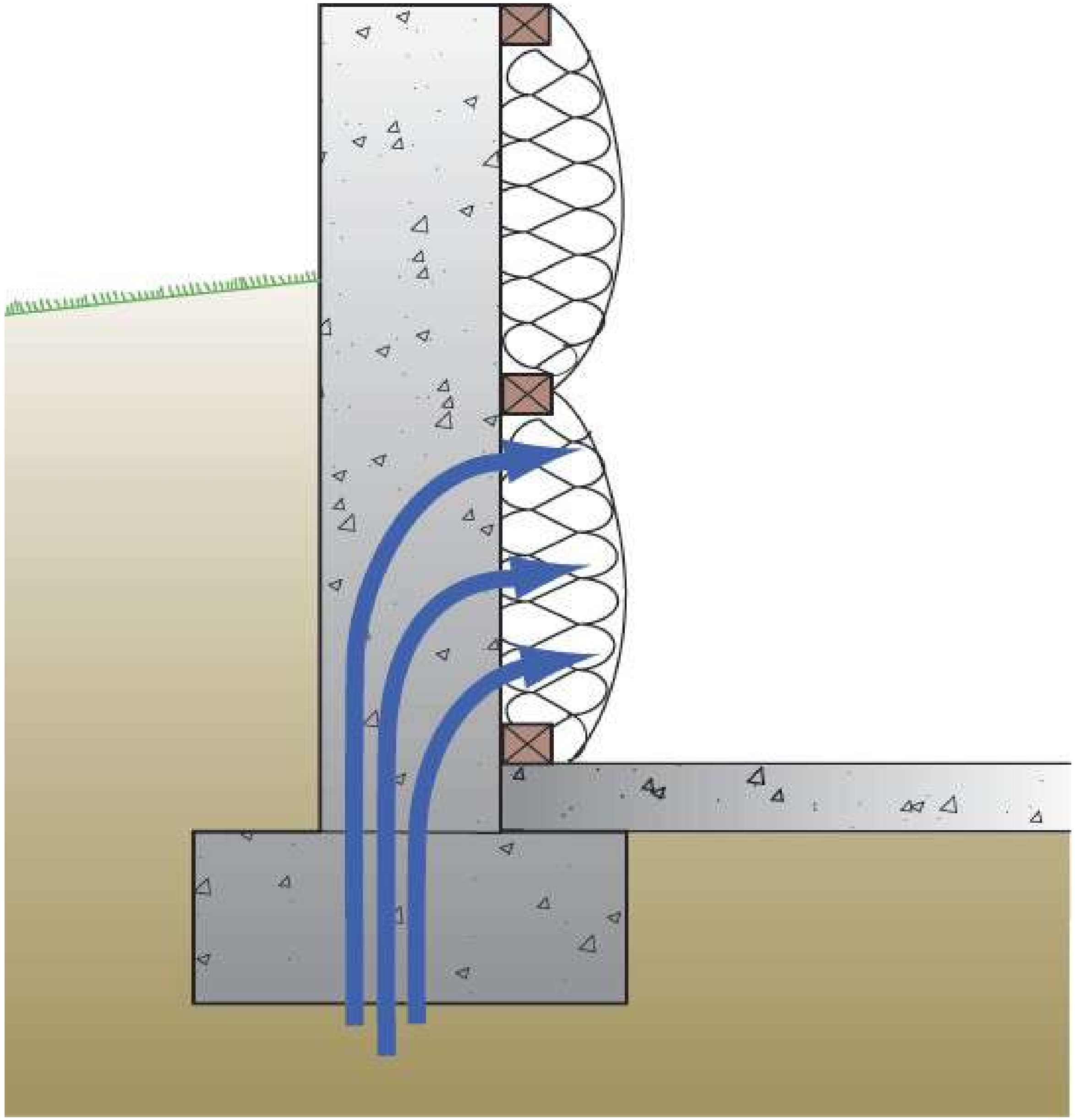


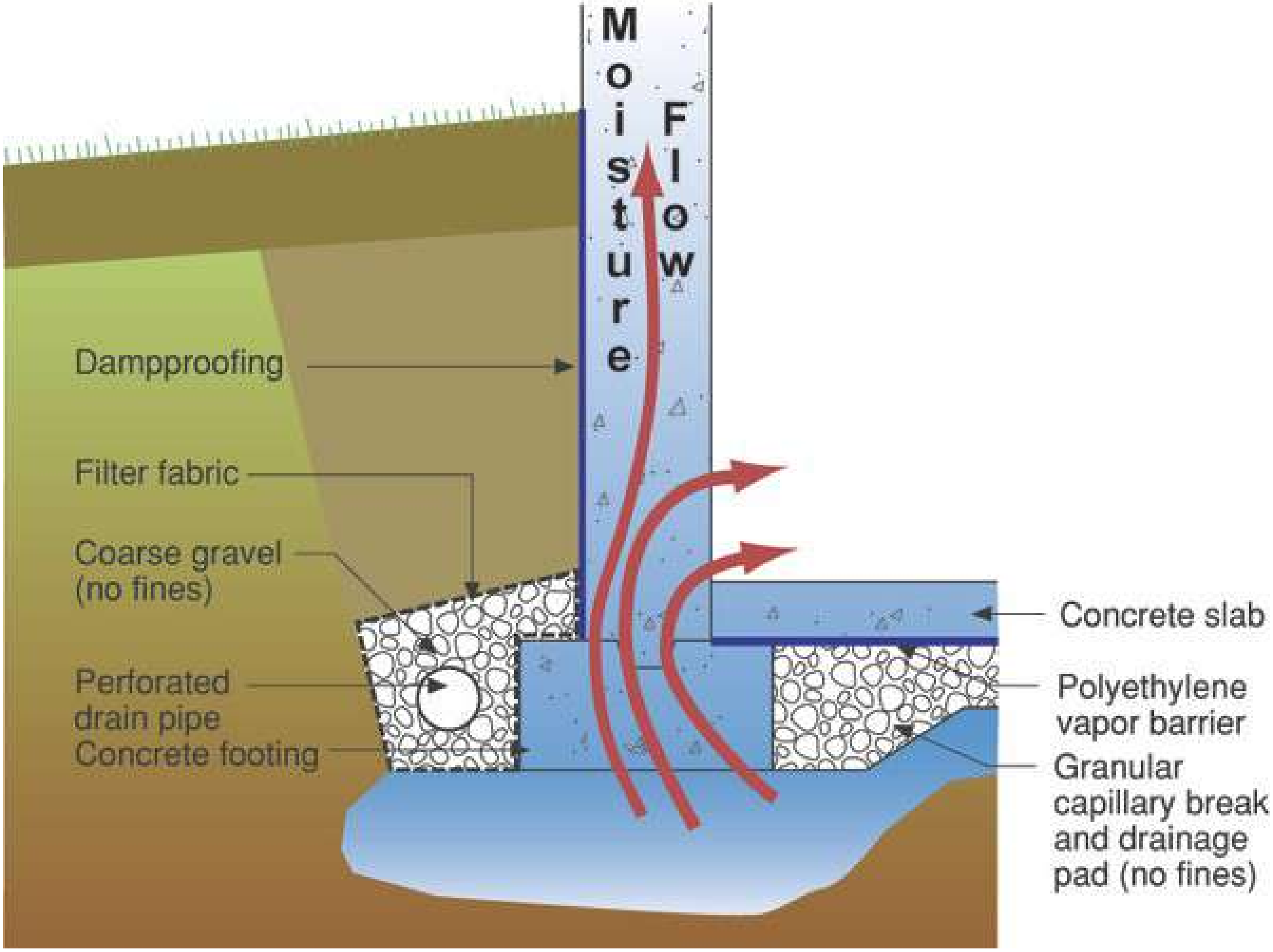

1 18 '00

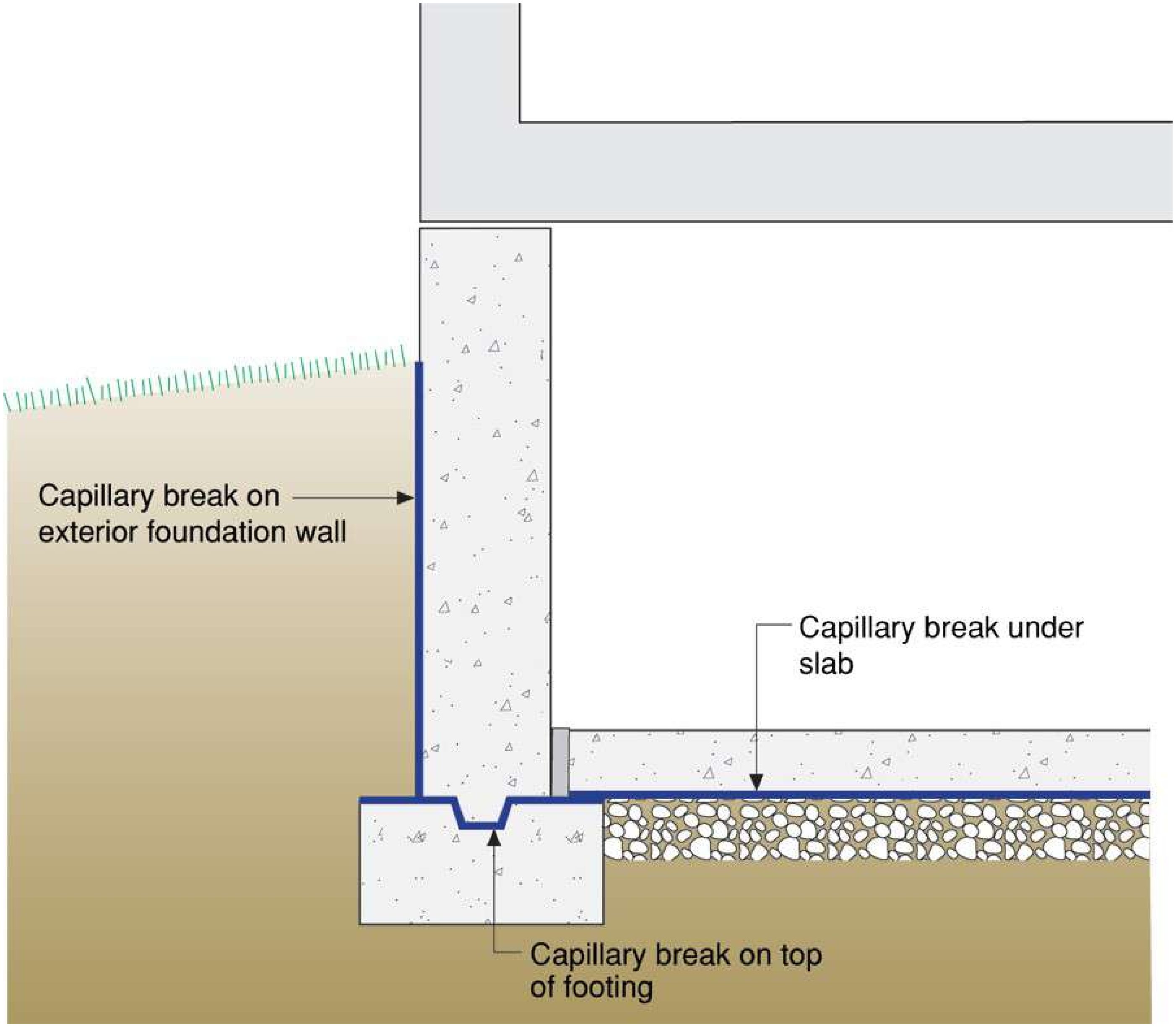


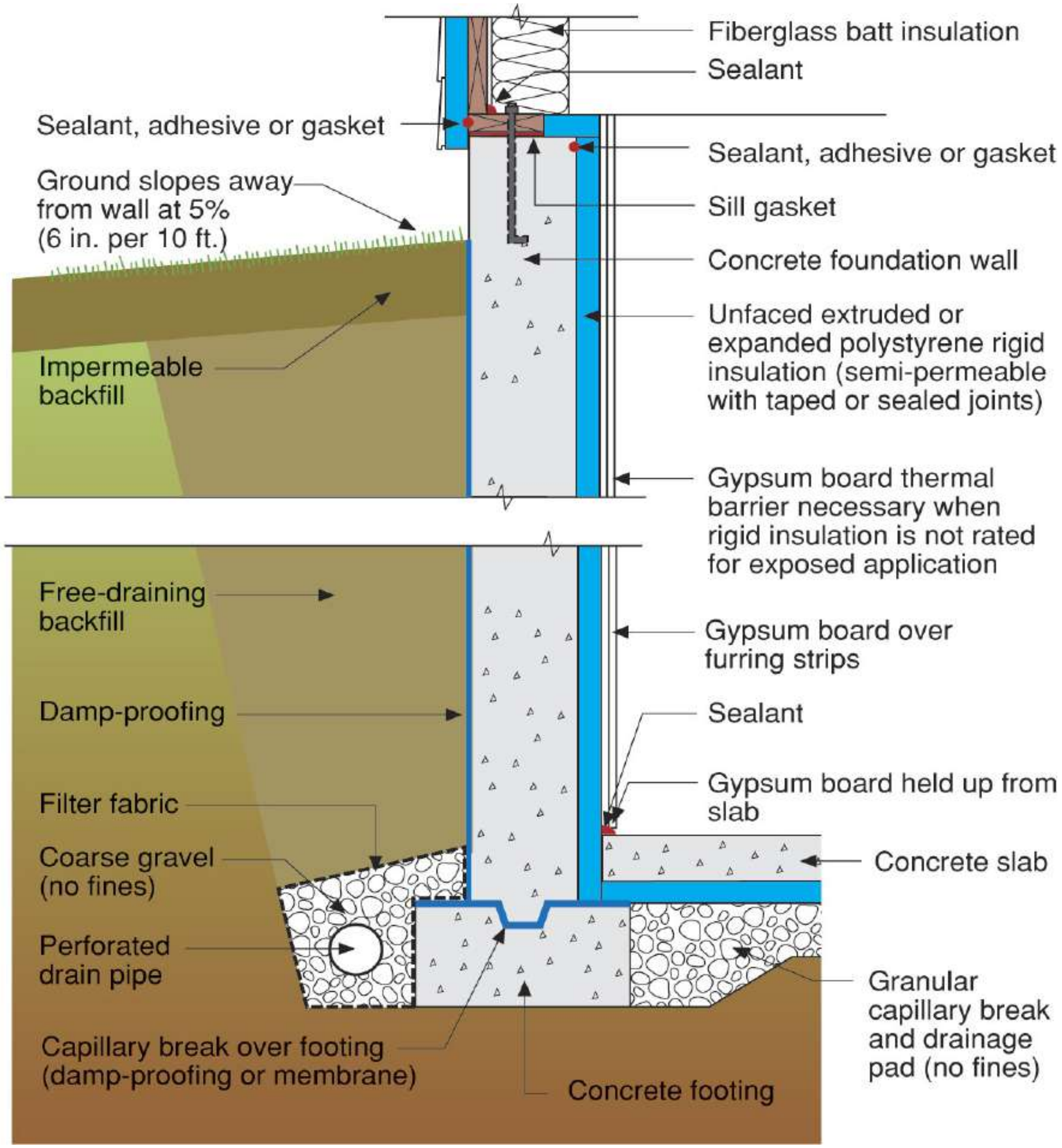


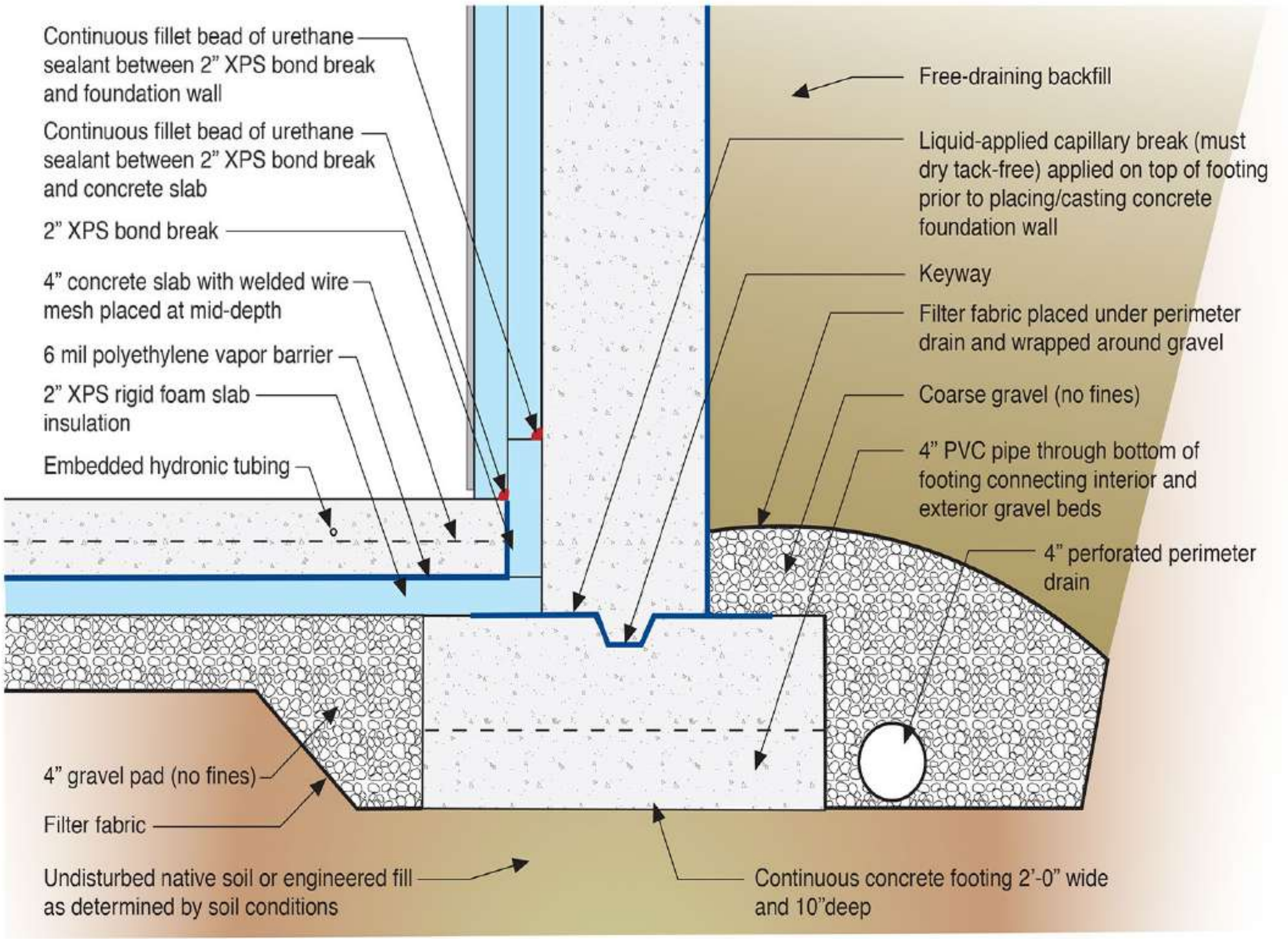




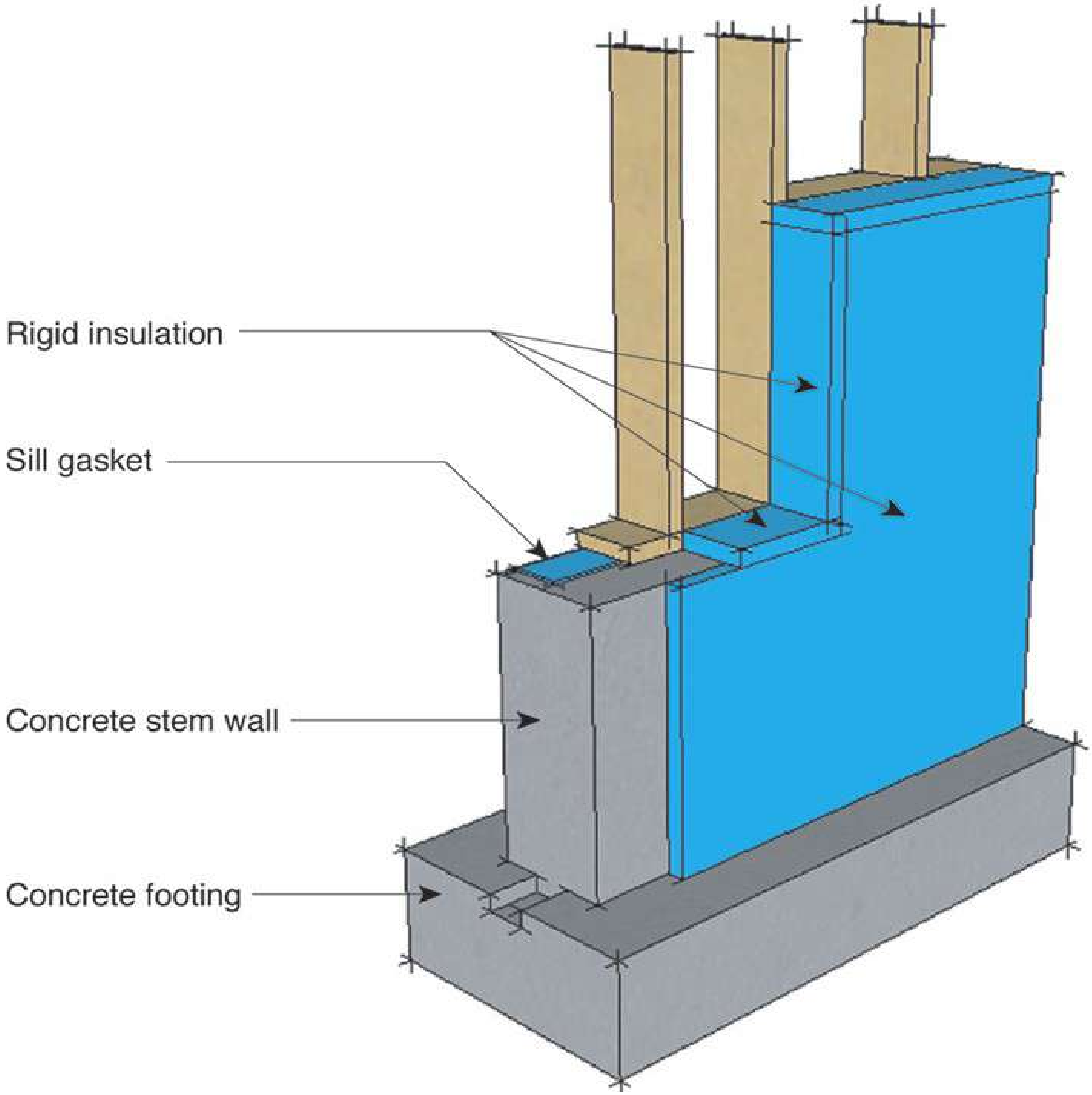

Moisture Flow
Dampproofing
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Concrete footing
Concrete slab
Polyethylene vapor barrier
Granular capillary break and drainage pad (no fines)

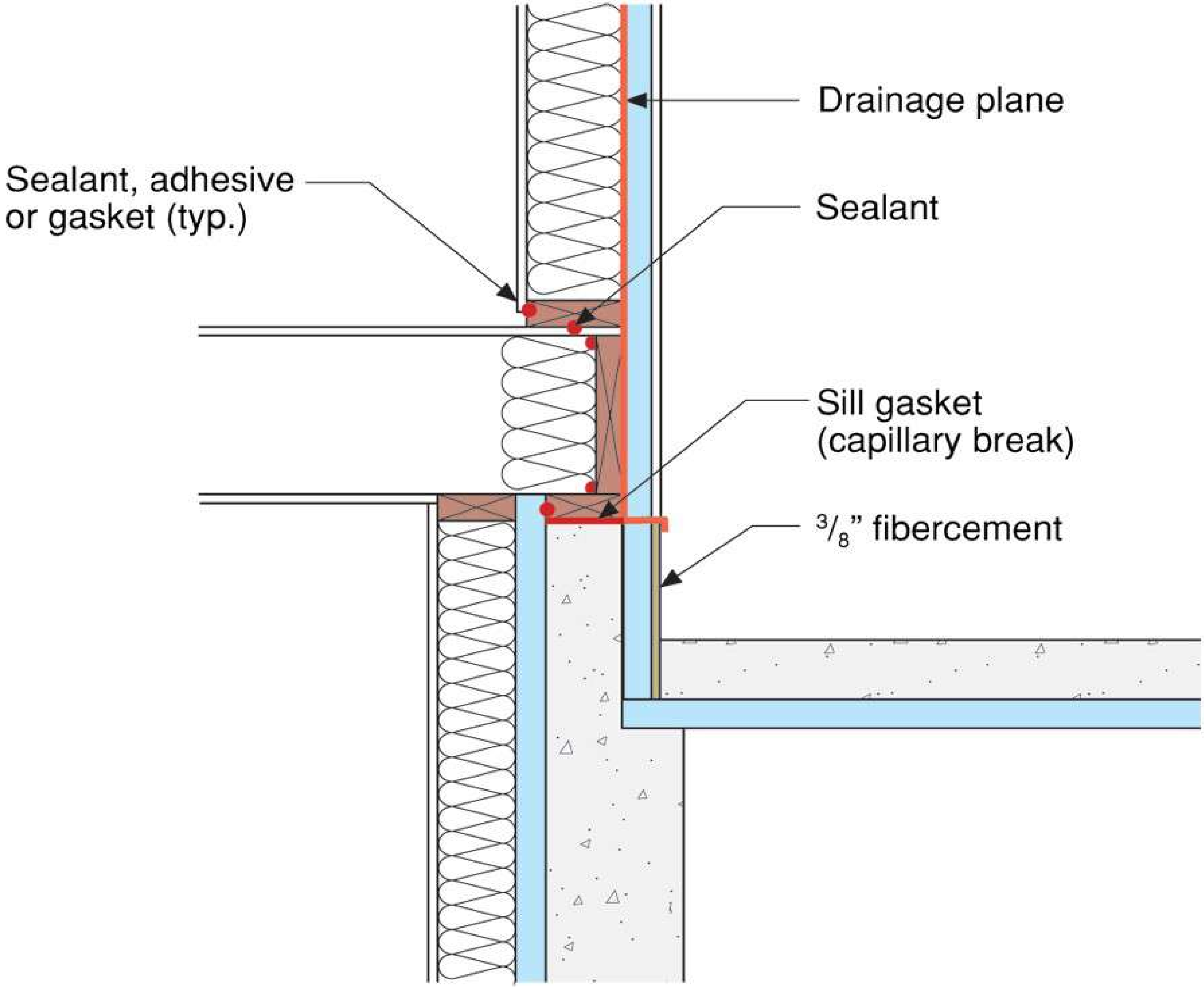

Capillary break on
exterior foundation wall
Capillary break under
slab
Capillary break on top
of footing

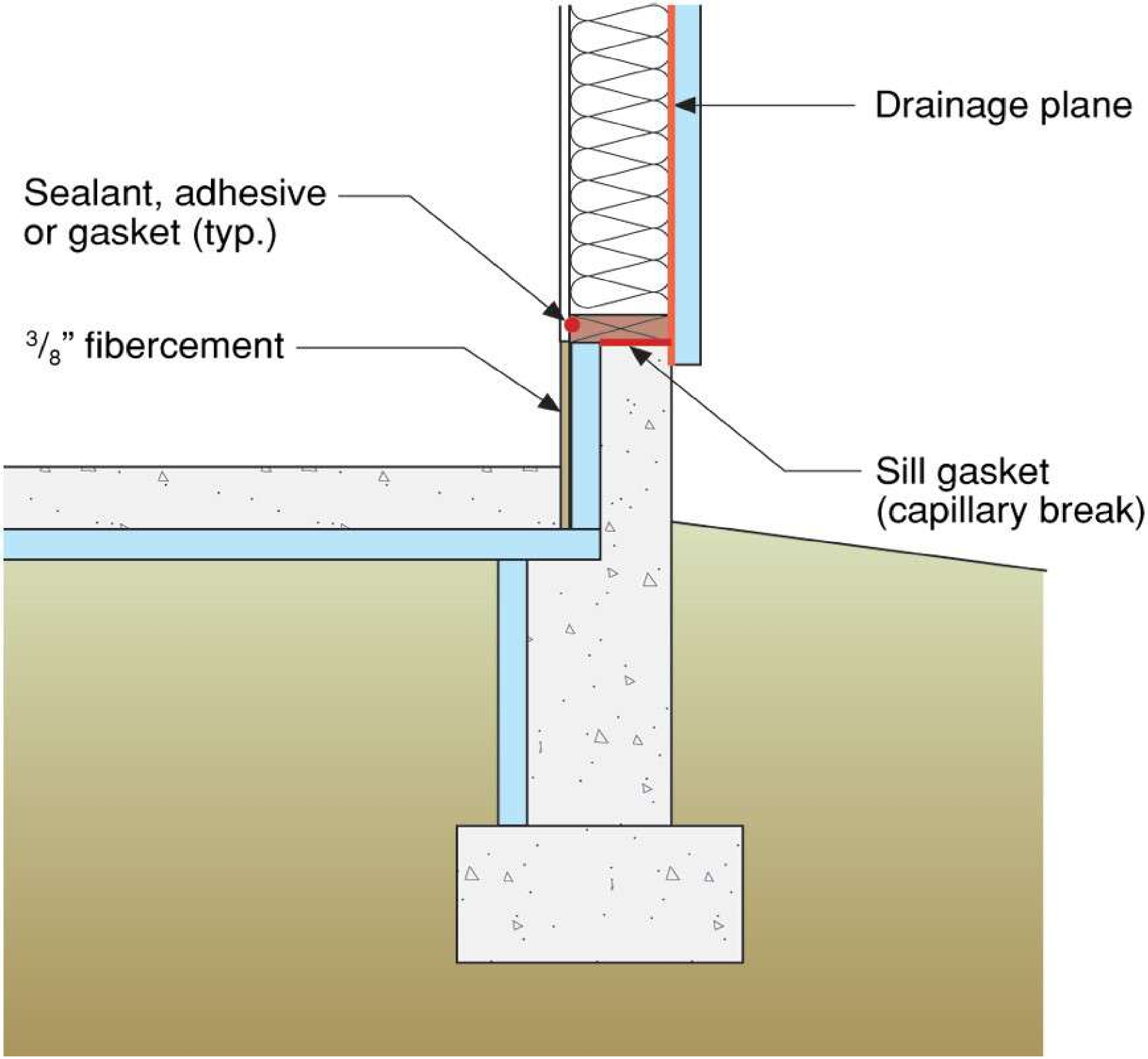

Fiberglass batt insulation
Sealant
Sealant, adhesive or gasket
Sealant, adhesive or gasket
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Sill gasket
Concrete foundation wall
Unfaced extruded or expanded polystyrene rigid insulation (semi-permeable with taped or sealed joints)
Impermeable backfill
Gypsum board thermal barrier necessary when rigid insulation is not rated for exposed application
Free-draining backfill
Gypsum board over furring strips
Damp-proofing
Sealant
Filter fabric
Gypsum board held up from slab
Coarse gravel (no fines)
Concrete slab
Perforated drain pipe
Granular capillary break and drainage pad (no fines)
Capillary break over footing (damp-proofing or membrane)
Concrete footing

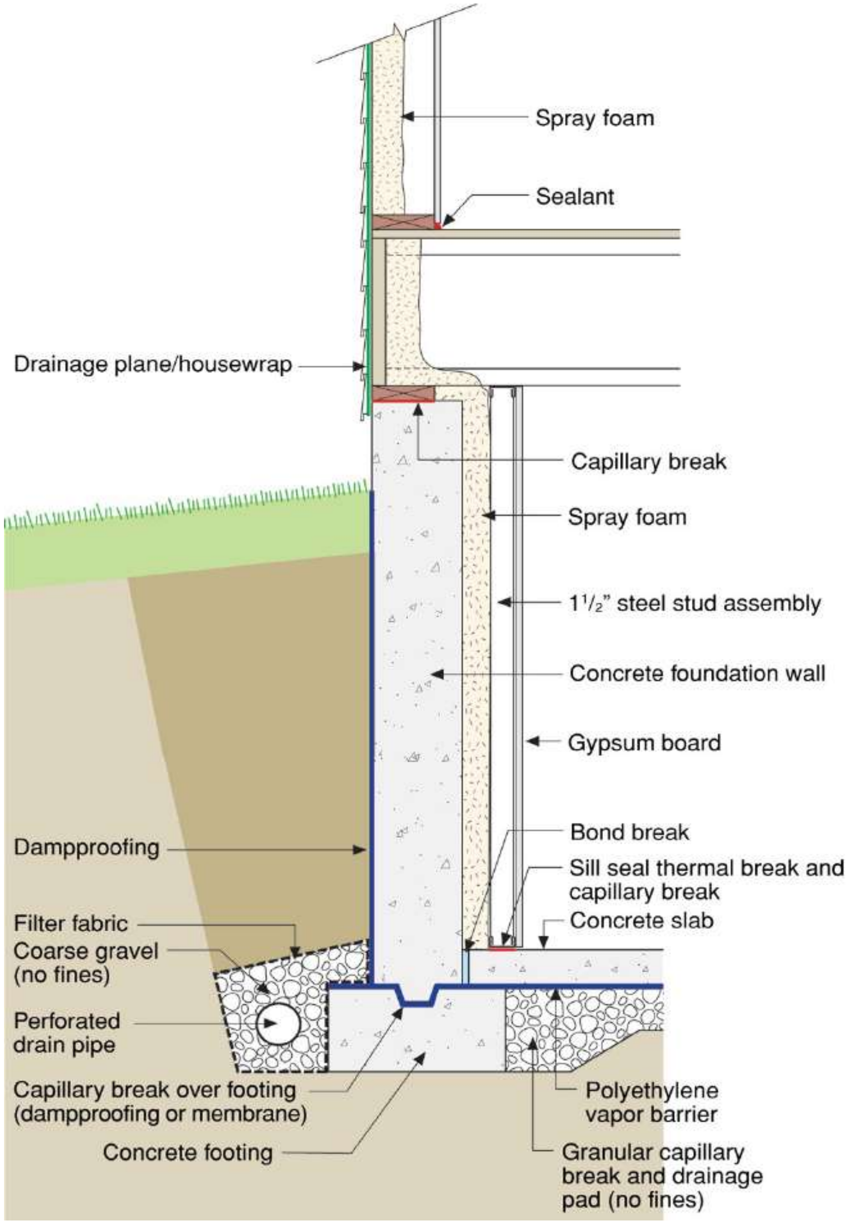


Continuous fillet bead of urethane sealant between 2" XPS bond break and foundation wall
Continuous fillet bead of urethane sealant between 2" XPS bond break and concrete slab
2" XPS bond break
4" concrete slab with welded wire mesh placed at mid-depth
6 mil polyethylene vapor barrier
2" XPS rigid foam slab insulation
Embedded hydronic tubing
Free-draining backfill
Liquid-applied capillary break (must dry tack-free) applied on top of footing prior to placing/casting concrete foundation wall
Keyway
Filter fabric placed under perimeter drain and wrapped around gravel
Coarse gravel (no fines)
4" PVC pipe through bottom of footing connecting interior and exterior gravel beds
4" perforated perimeter drain
4" gravel pad (no fines)
Filter fabric
Undisturbed native soil or engineered fill as determined by soil conditions
Continuous concrete footing 2'-0" wide and 10"deep

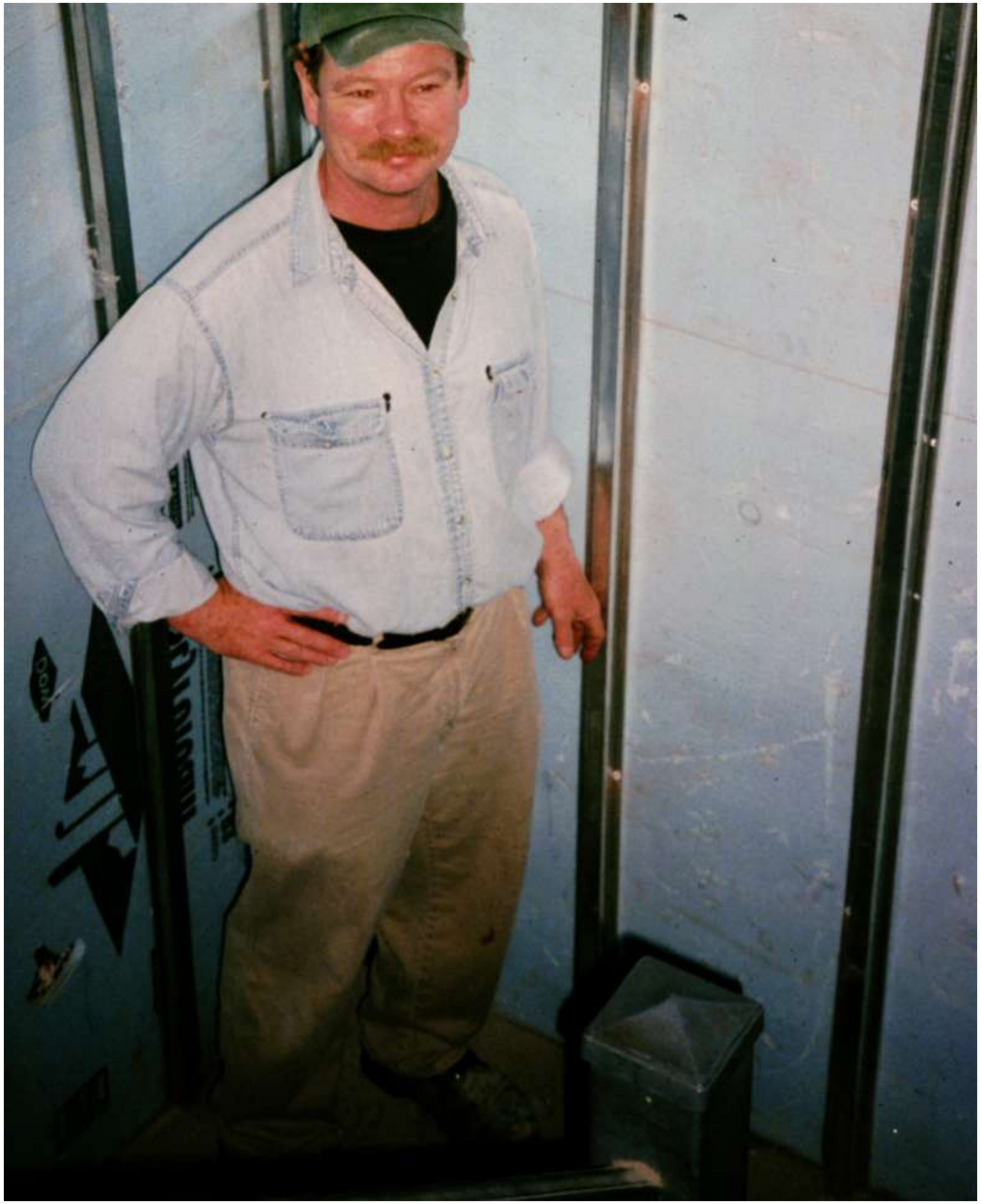

Rigid insulation
Sill gasket
Concrete stem wall
Concrete footing


Drainage plane
Sealant, adhesive or gasket (typ.)
Sealant
Sill gasket (capillary break)
3/8" fibercement


Drainage plane
Sealant, adhesive or gasket (typ.)
3/8" fibercement
Sill gasket (capillary break)



Spray foam
Sealant
Drainage plane/housewrap
Capillary break
Spray foam
1 1/2" steel stud assembly
Concrete foundation wall
Gypsum board
Bond break
Sill seal thermal break and capillary break
Concrete slab
Dampproofing
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)



# Crawl Spaces

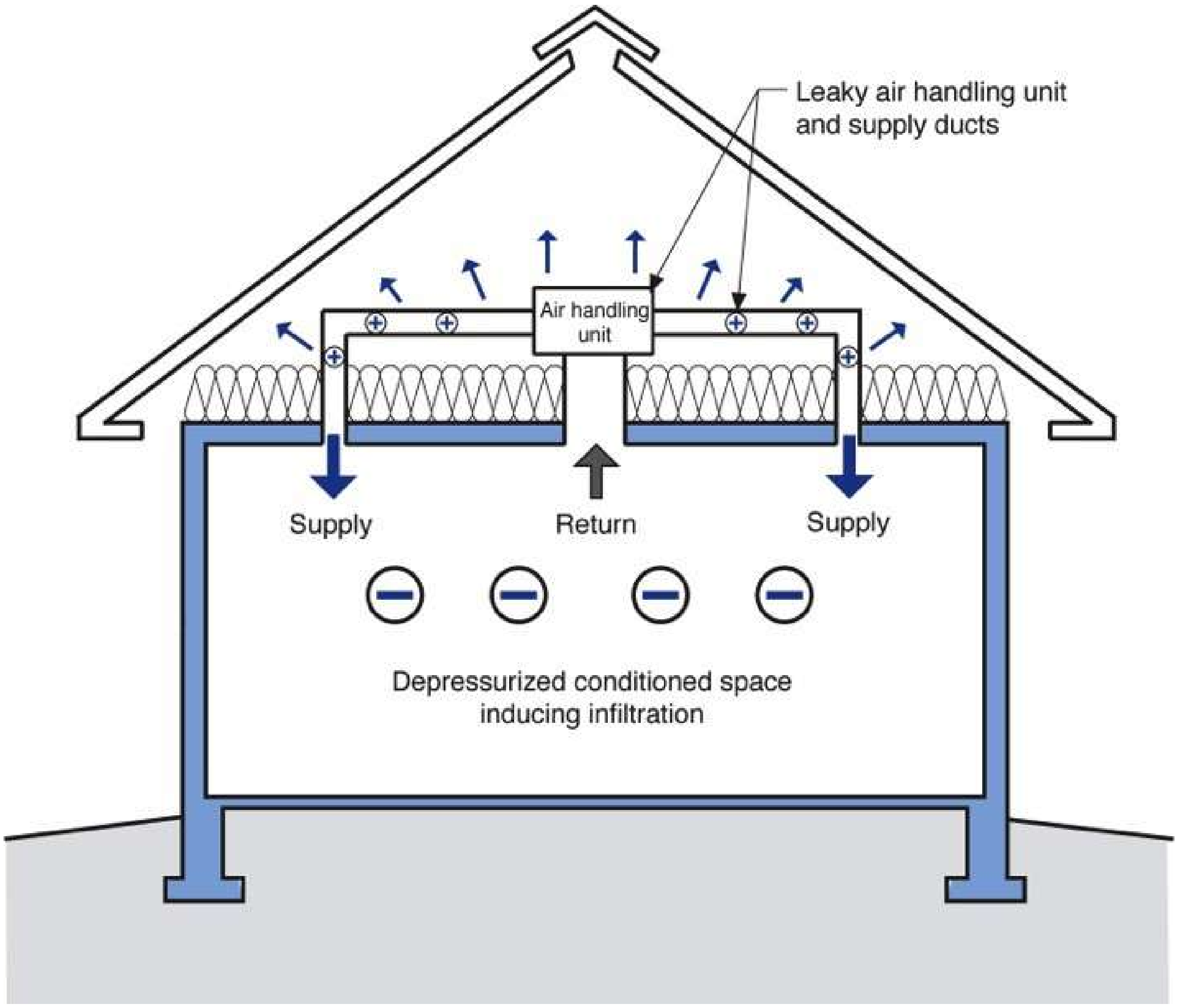
Crawl spaces must be completely connected to either the outside or the inside

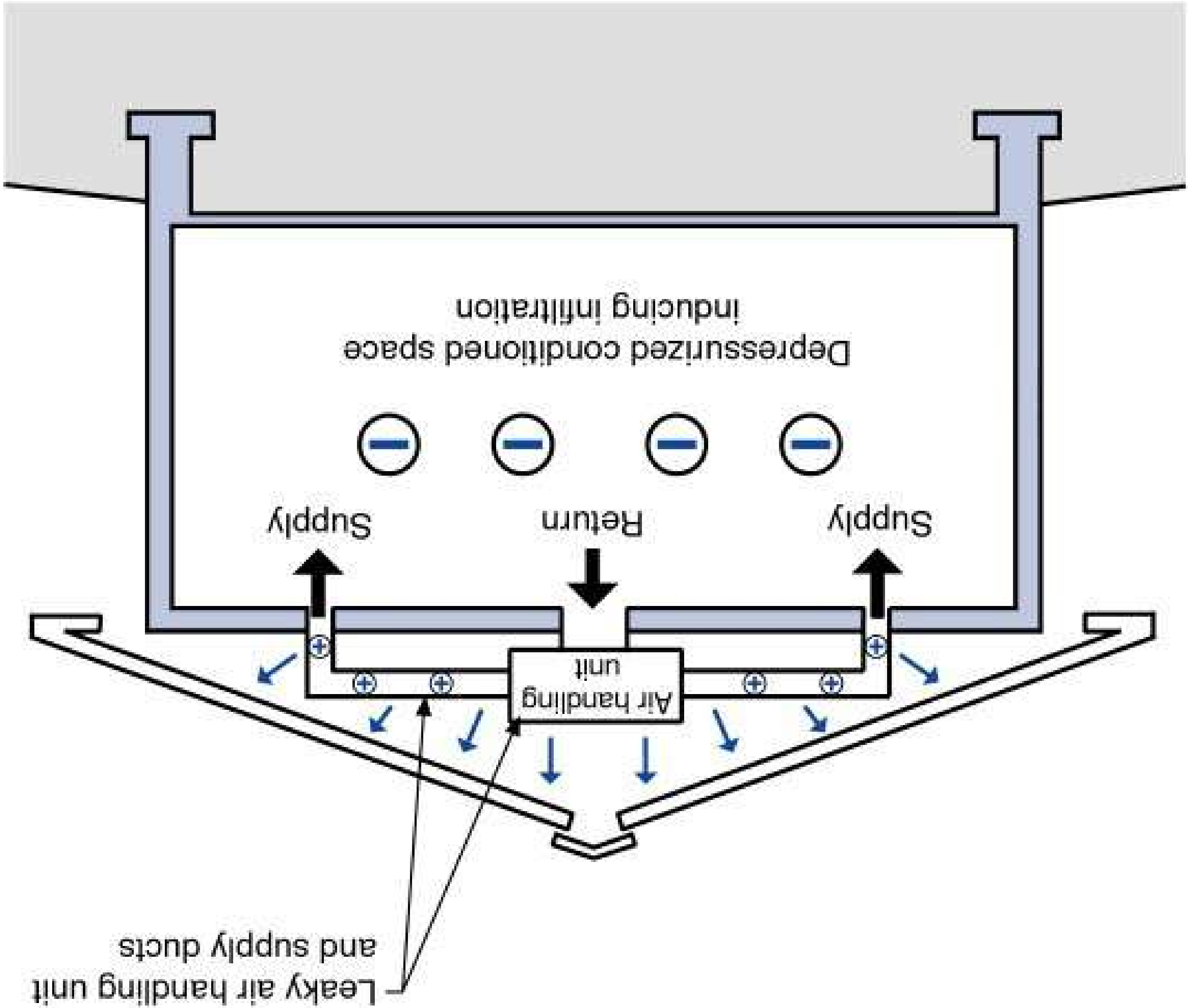
Crawl spaces must be completely connected to either the outside or the inside

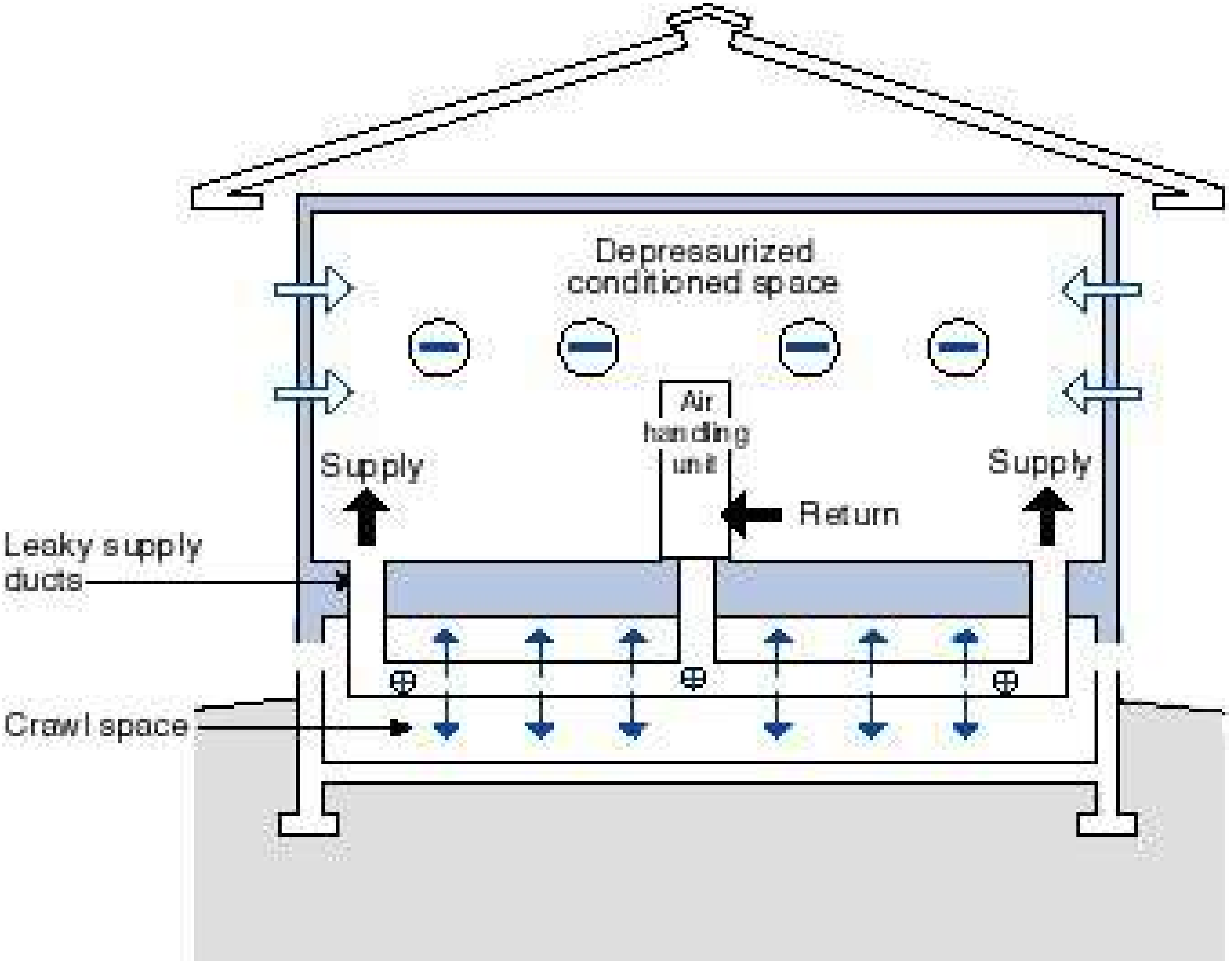
Vented crawl spaces work

Unvented conditioned crawl spaces work

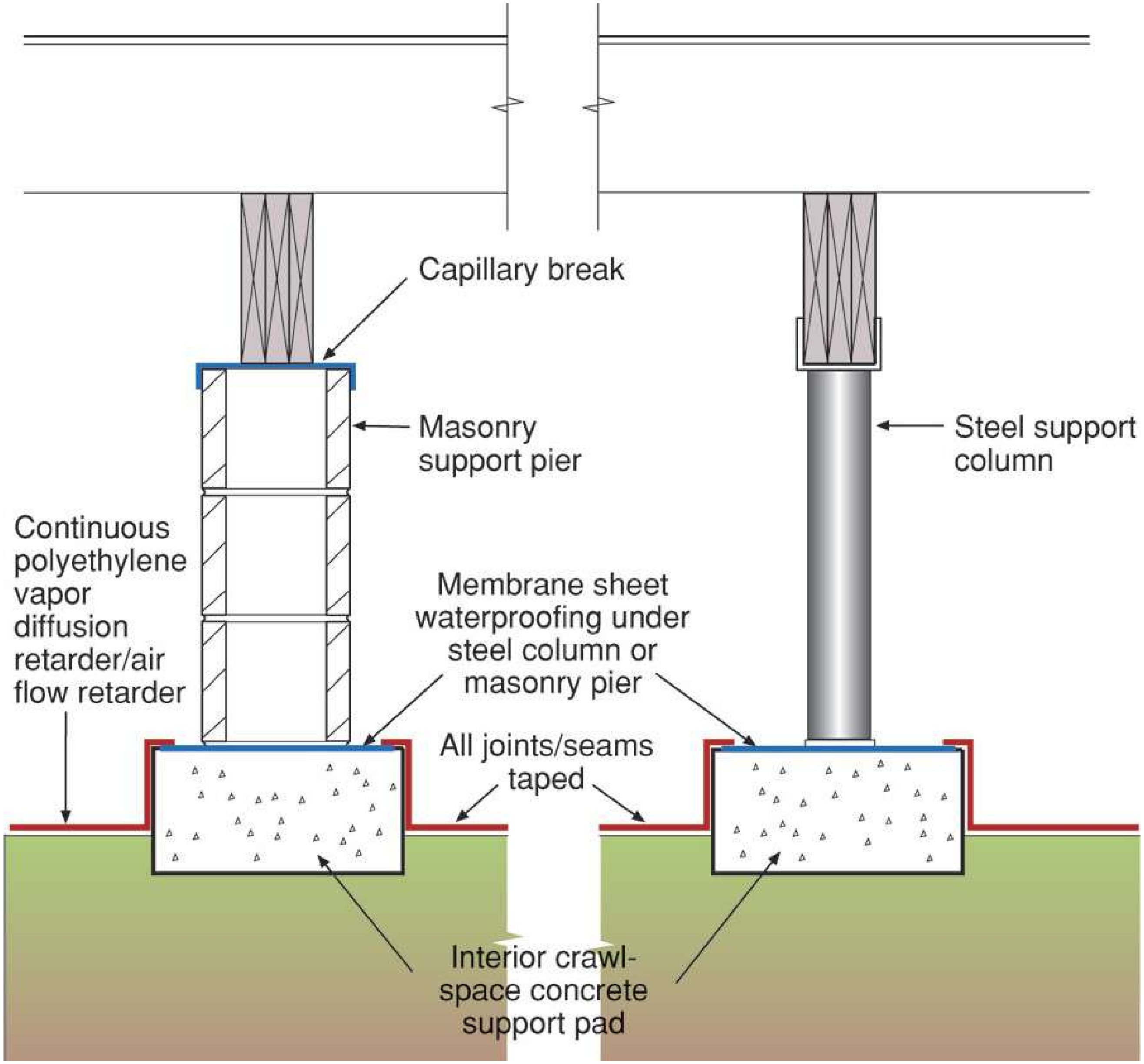
# Don’t Do Stupid Things


Leaky air handling unit
and supply ducts
Air handling
unit
Supply
Return
Supply
Depressurized conditioned space
inducing infiltration


Depressurized conditioned space
inducing infiltration
Supply
Return
Supply
Air handling
unit
Leaky air handling unit
and supply ducts


Depressurized
conditioned space
Air
handling
unit
Supply
Supply
Return
Leaky supply
ducts
Crawl space

# Smart Thing


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

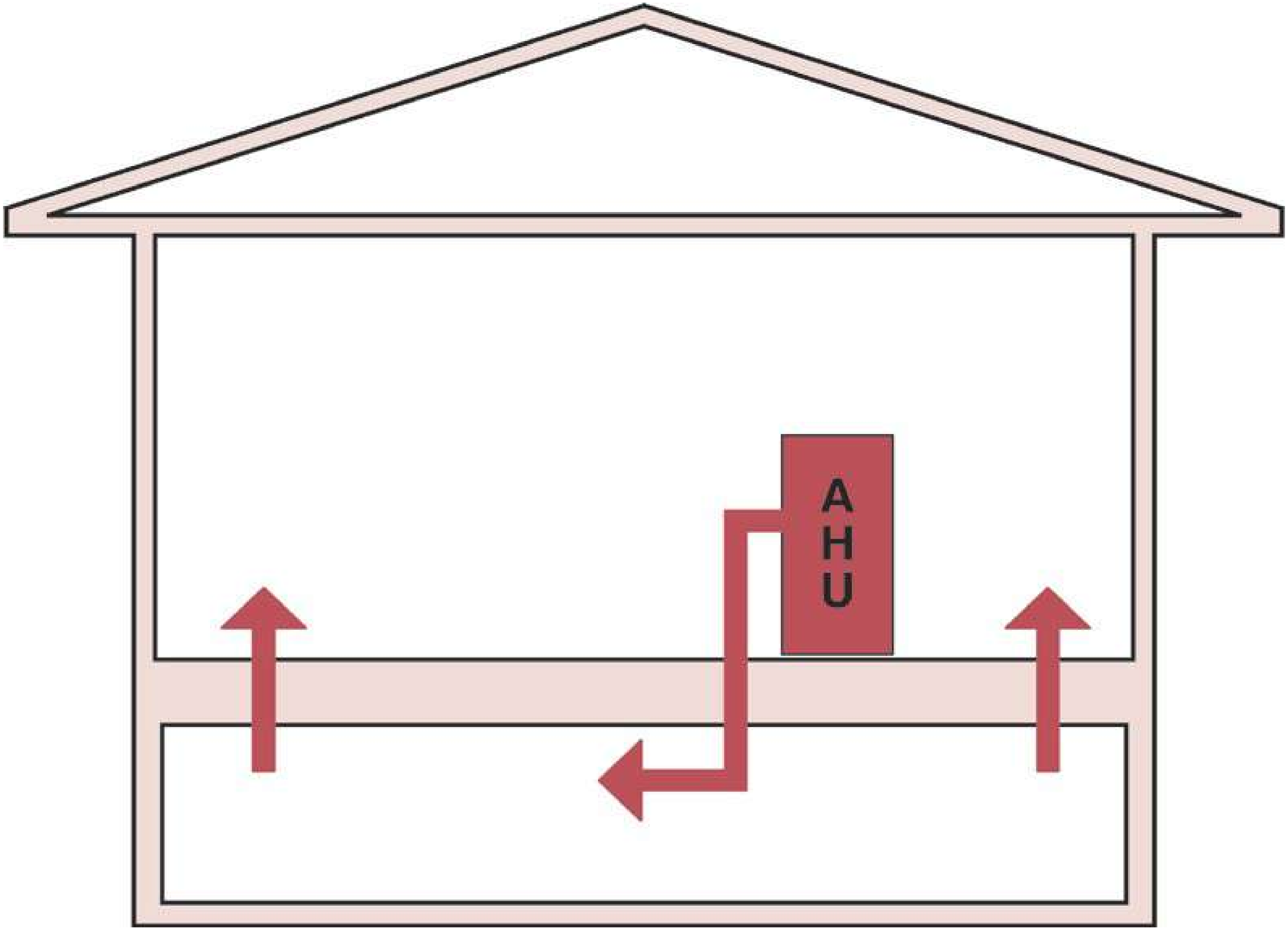
Conditioned Crawlspaces Not Unvented Crawlspaces

Need Supply Air

50 cfm/1000 ft2 of Crawlspace Area

Or

Dehumidification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H
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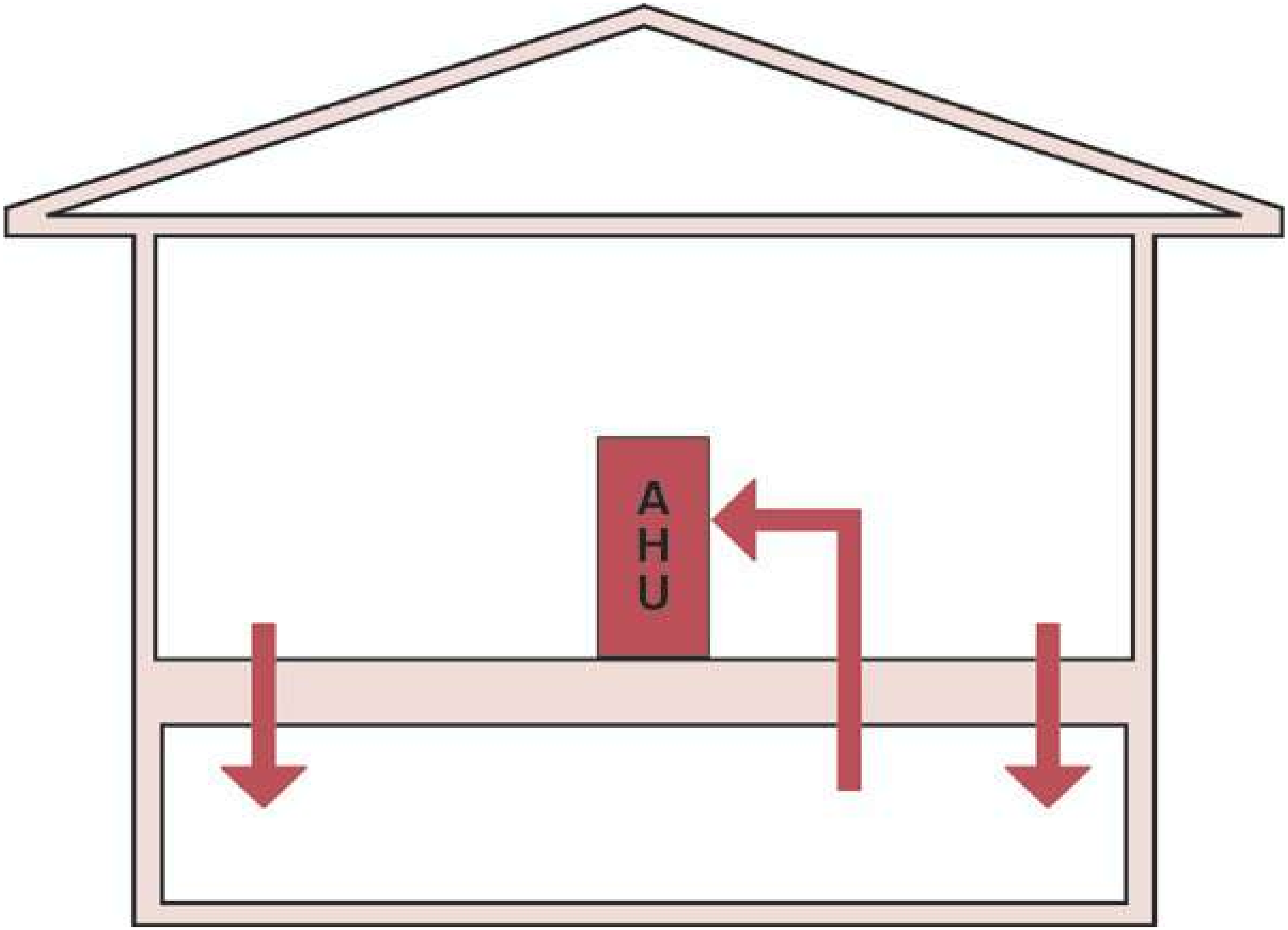
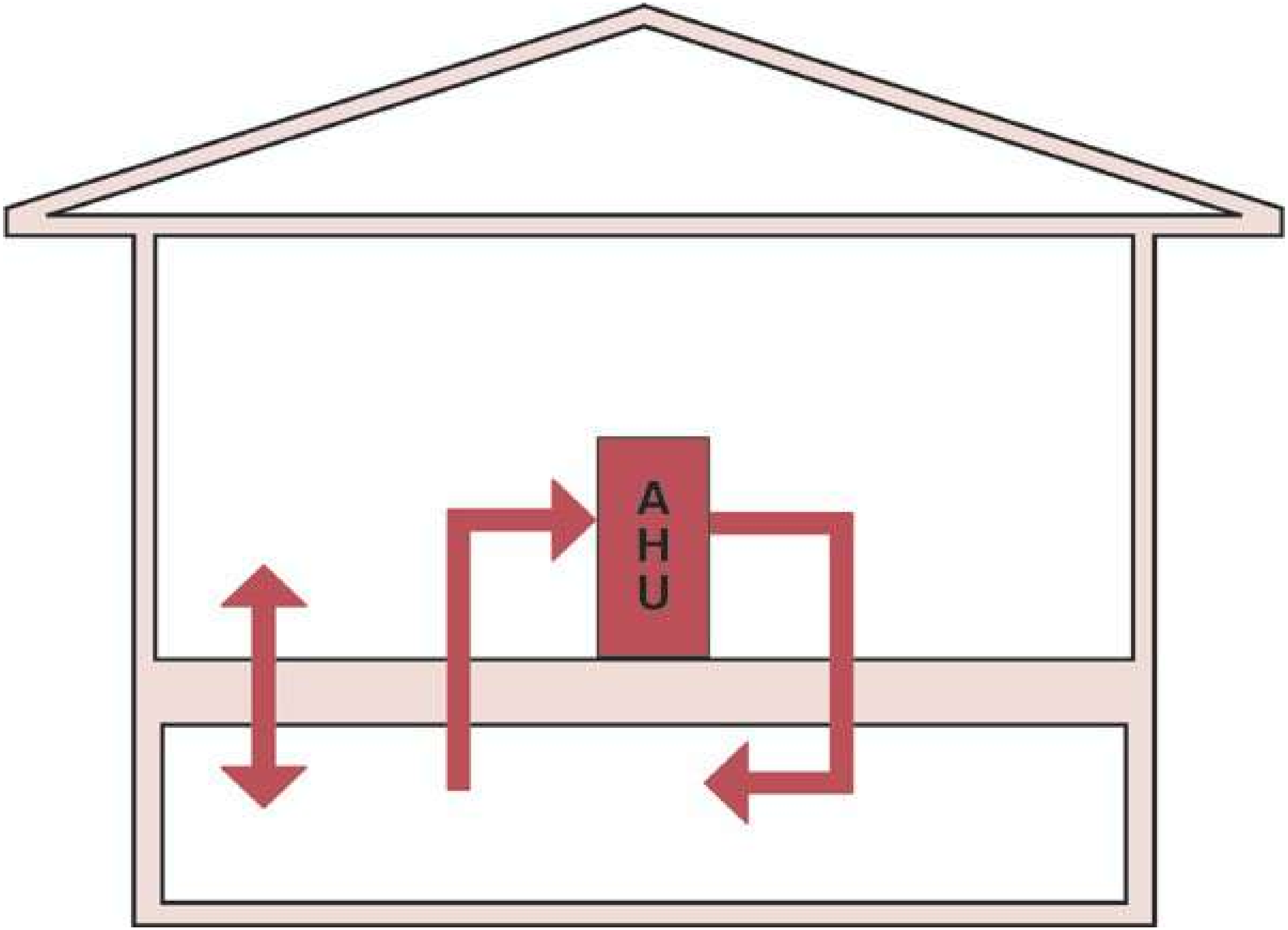
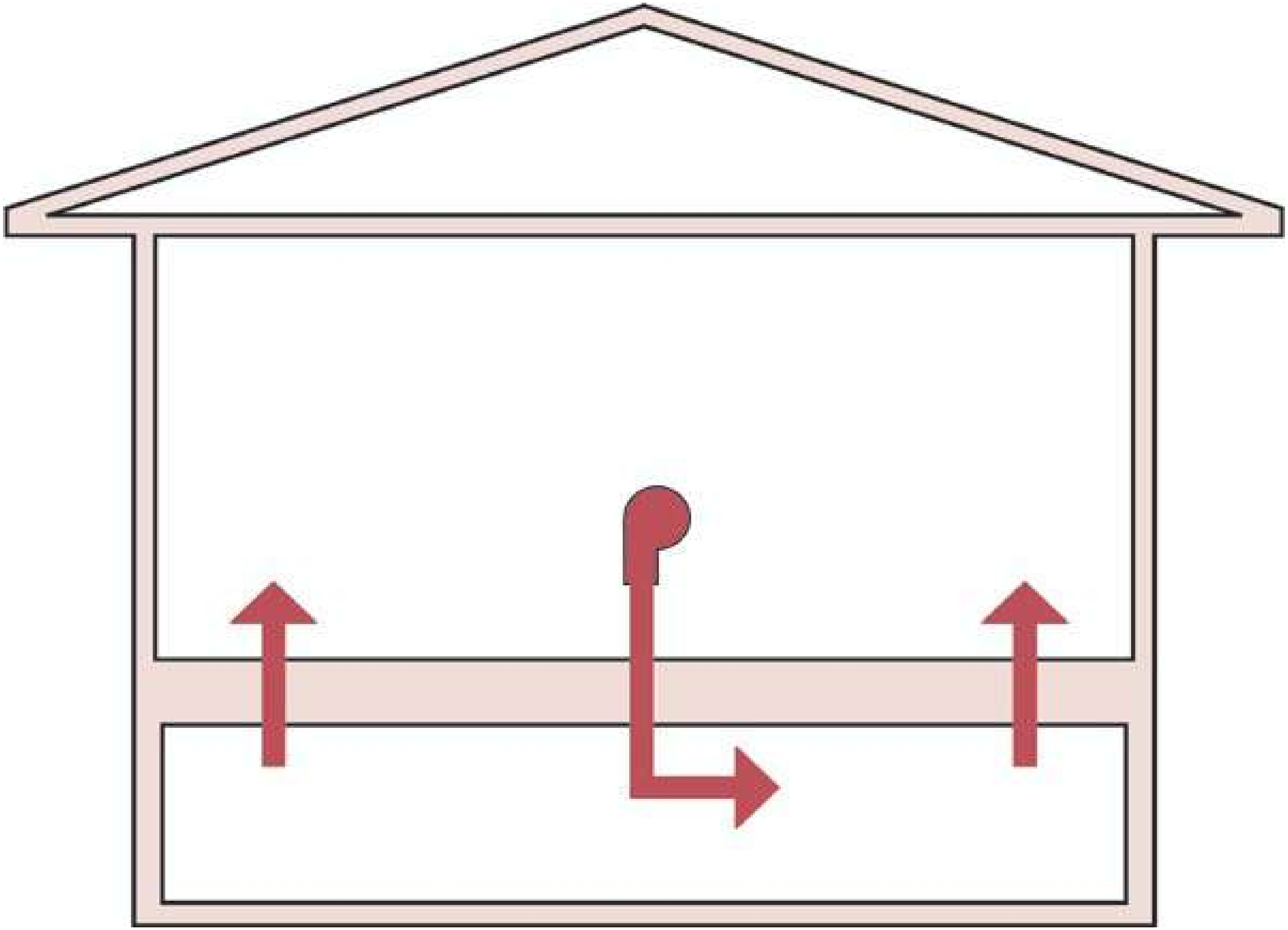
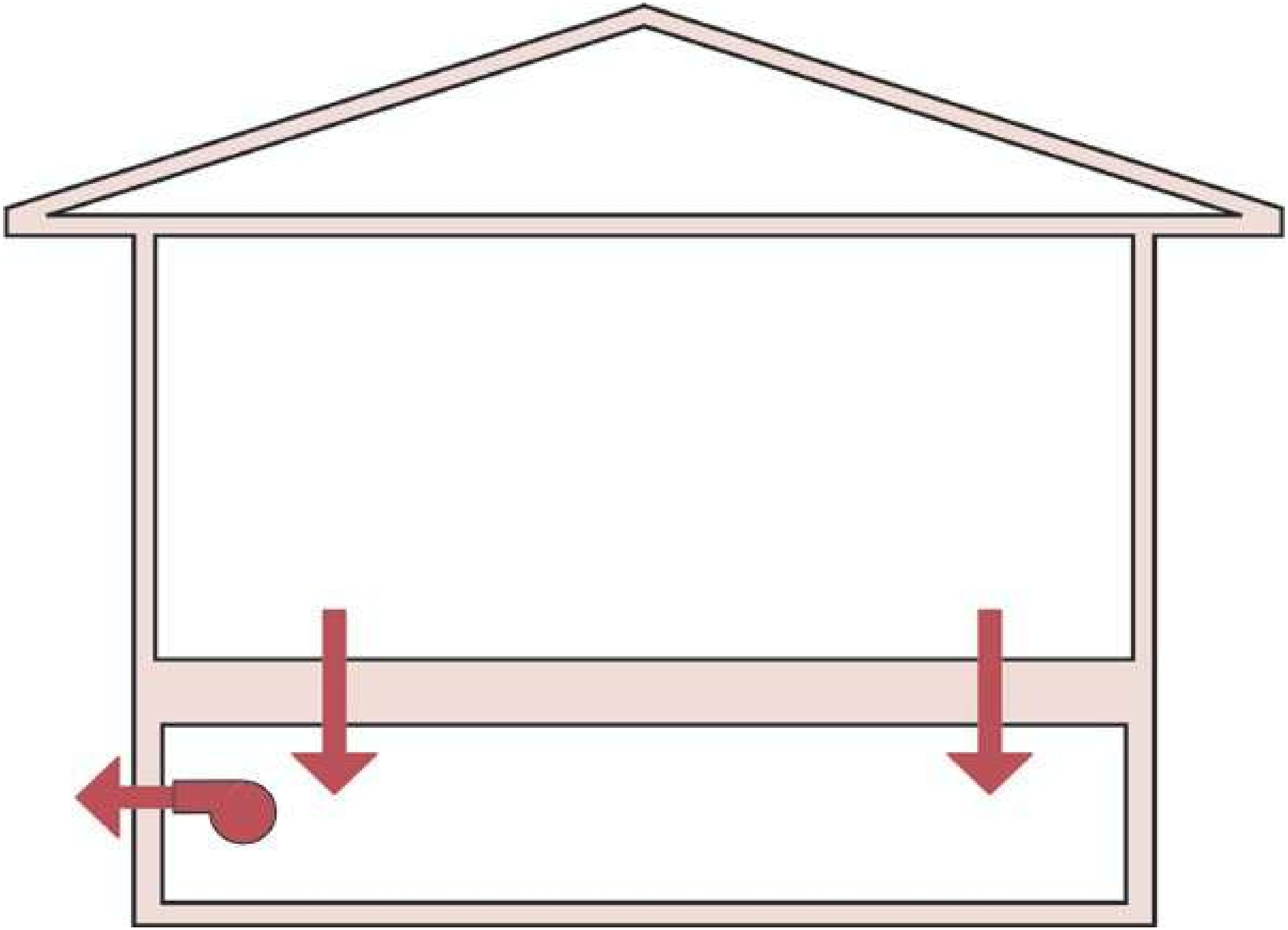
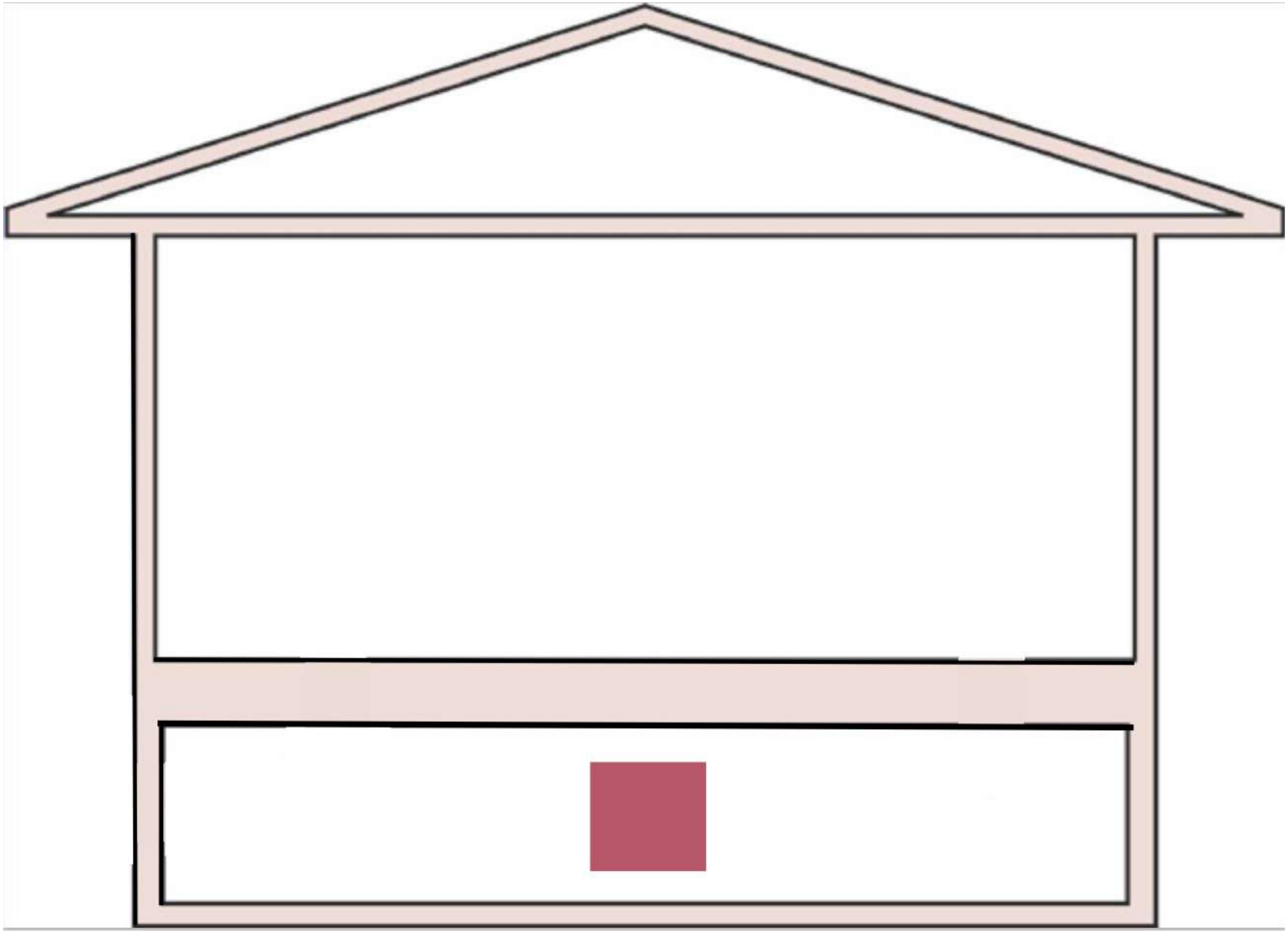
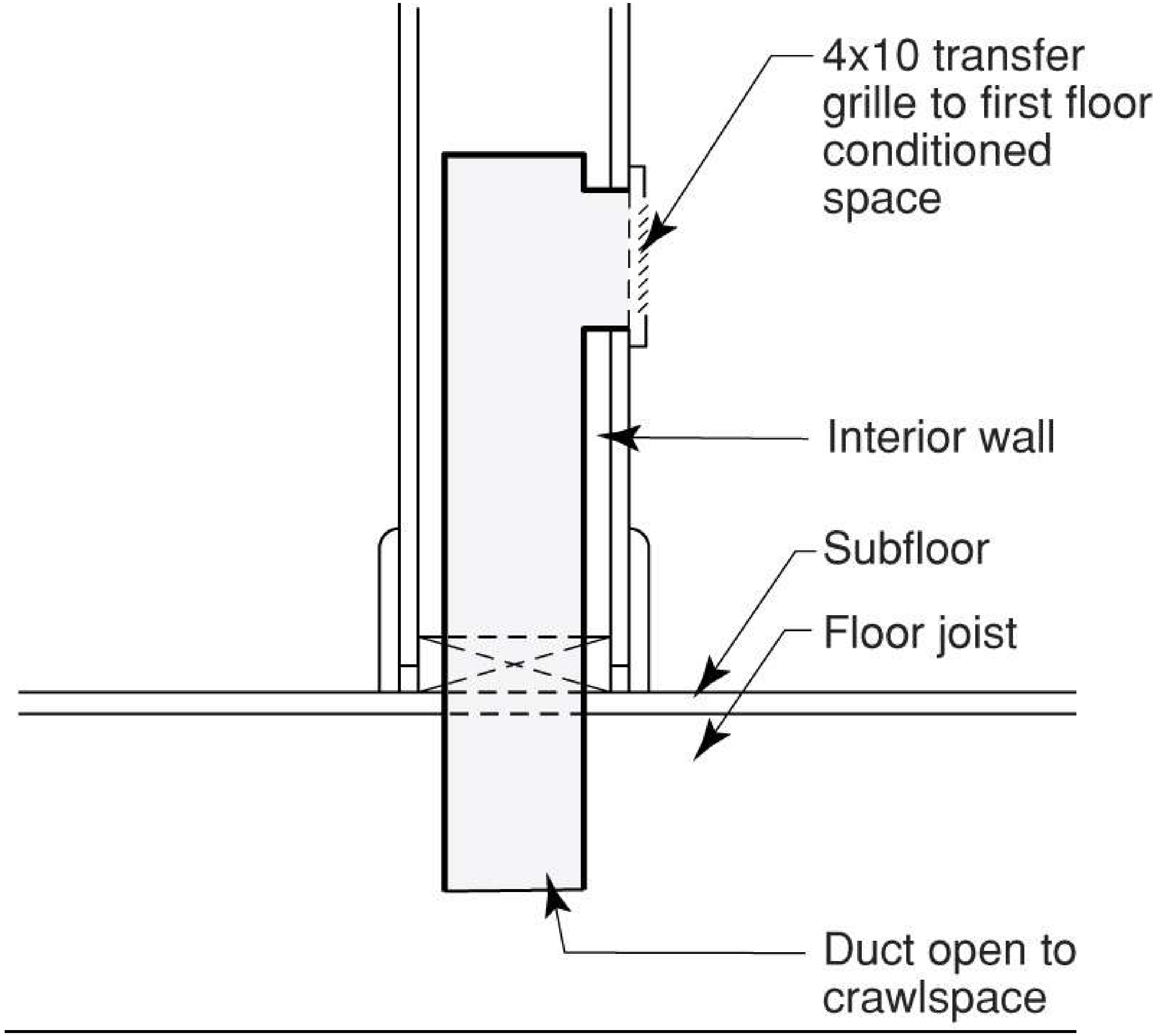

AHU

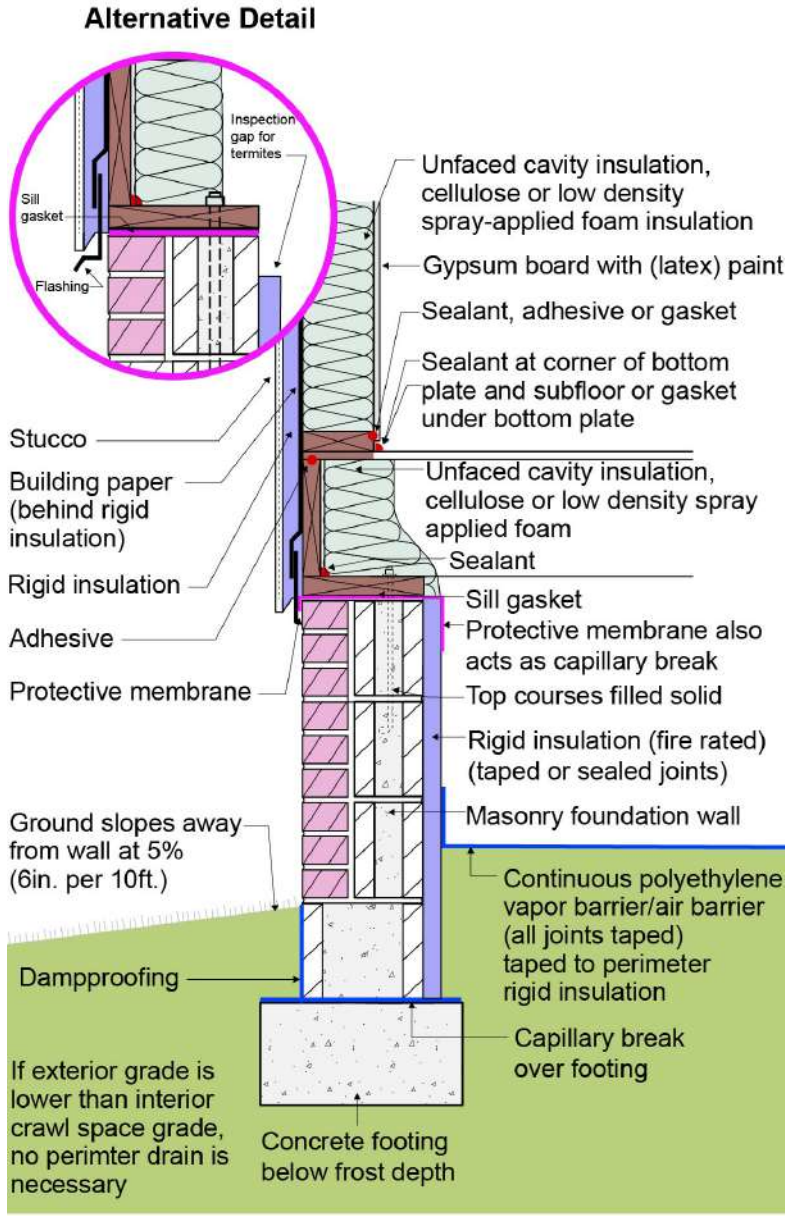

AHU



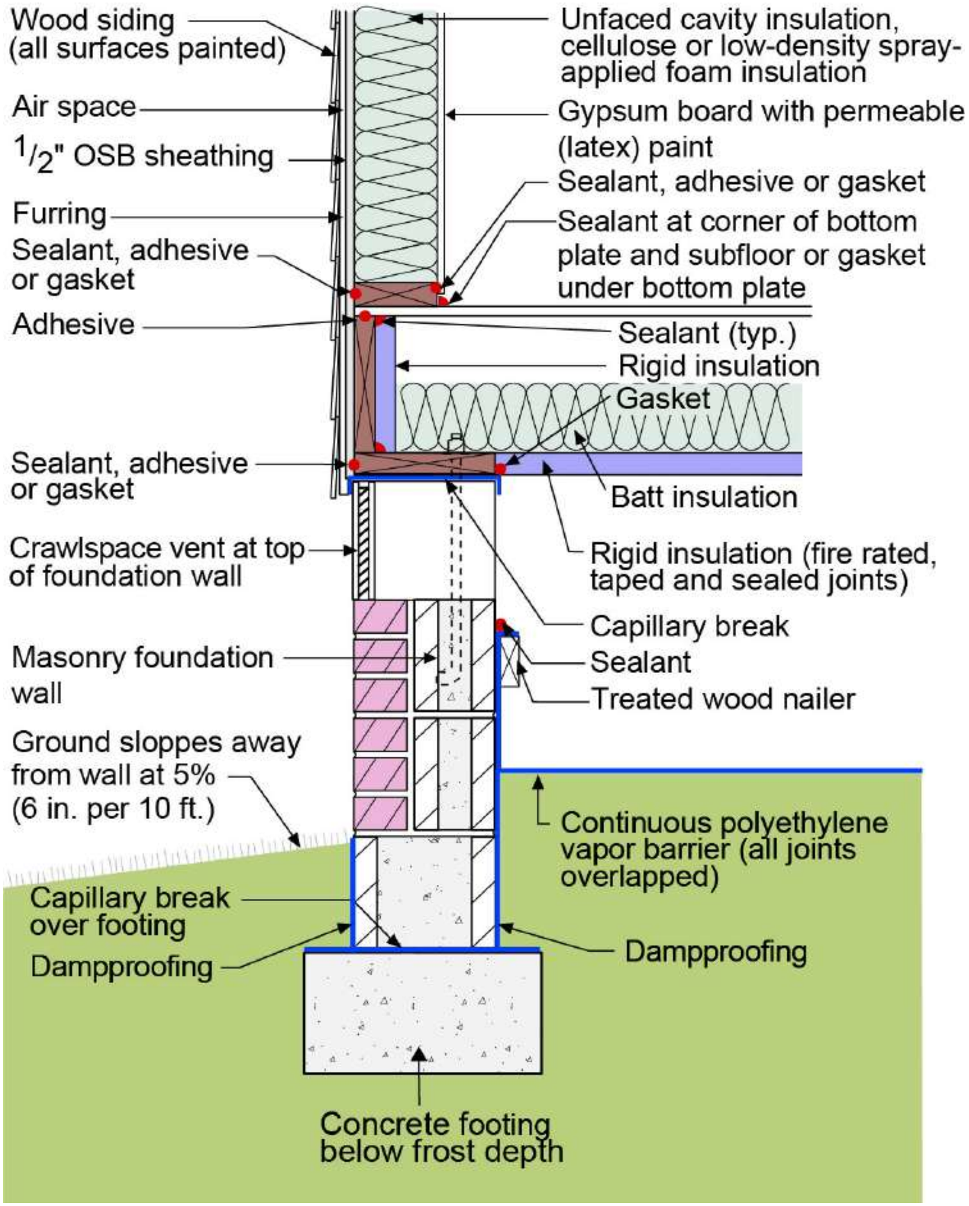


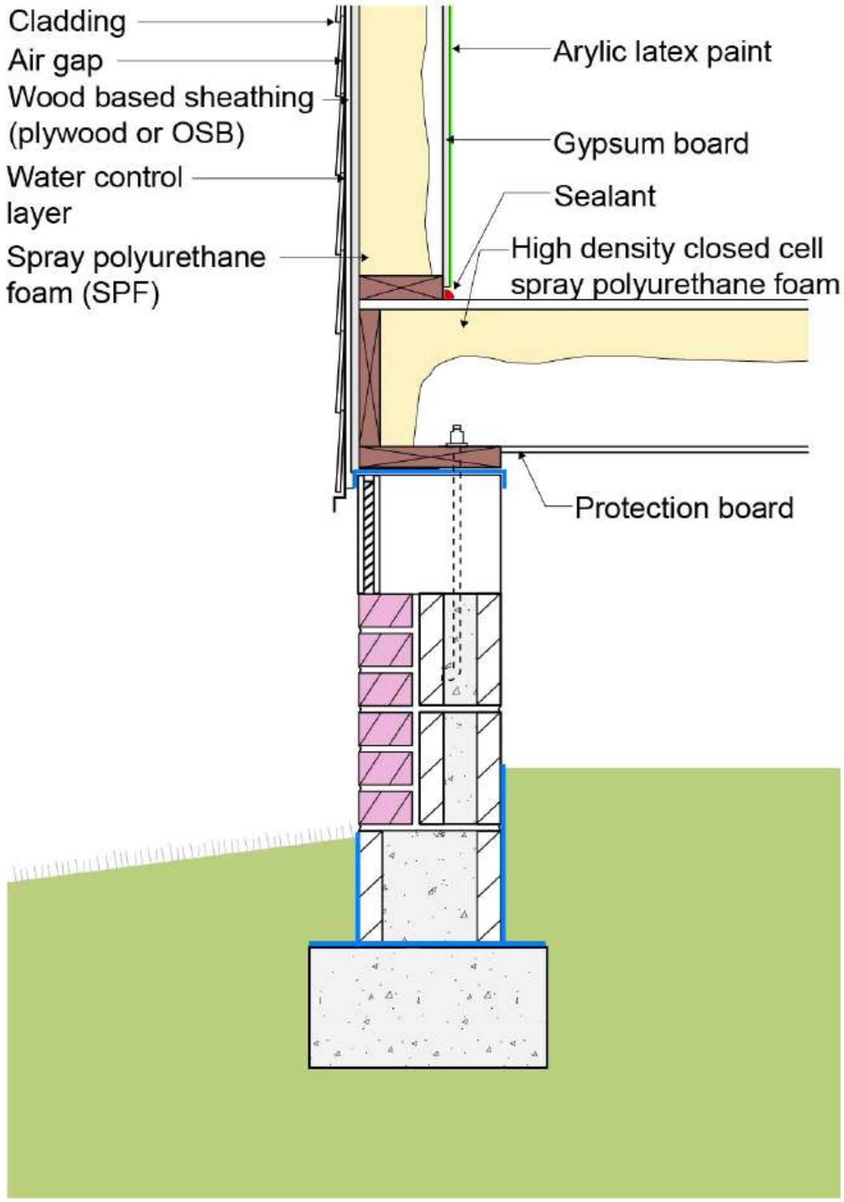


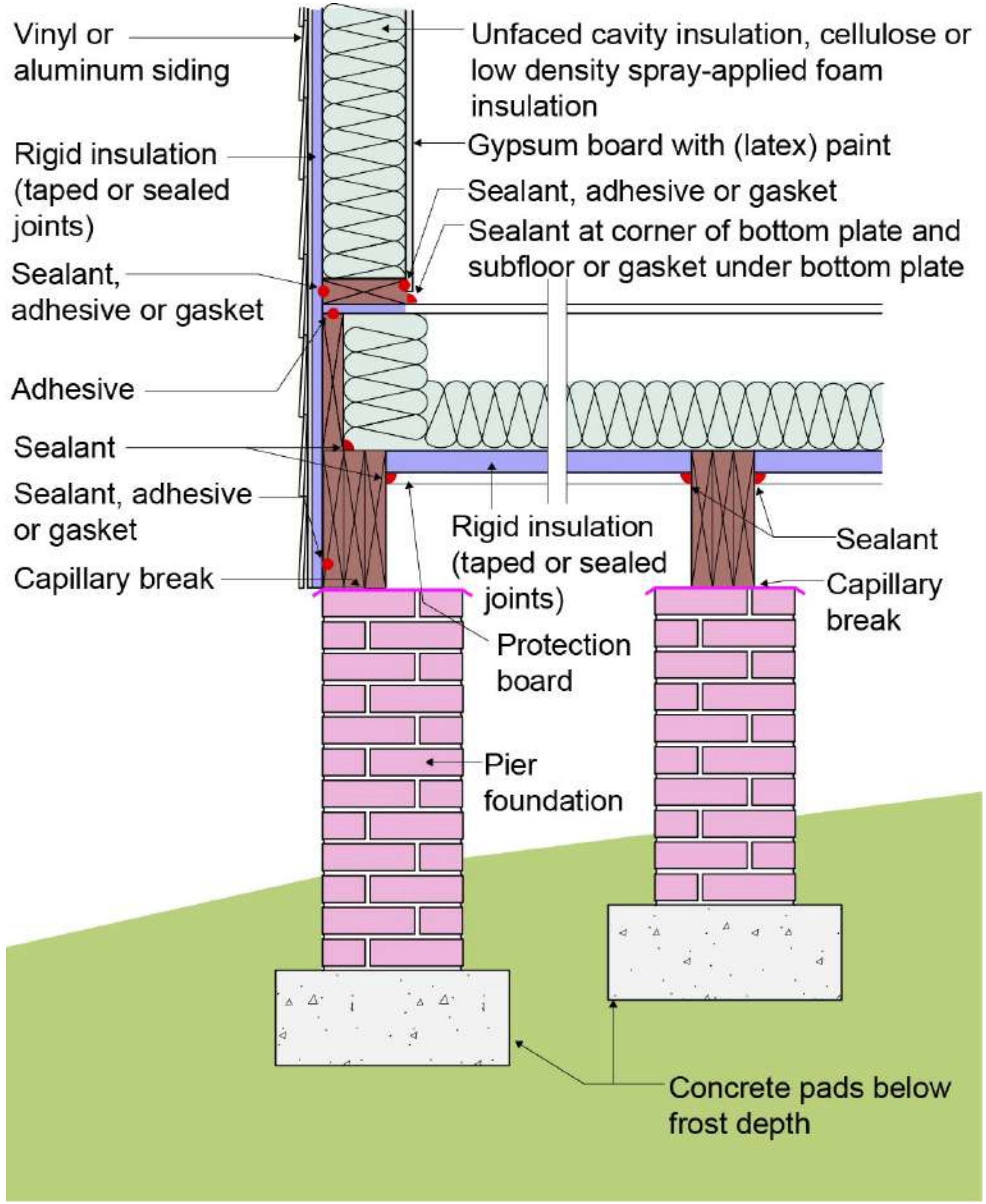

4x10 transfer grille to first floor conditioned space
Interior wall
Subfloor
Floor joist
Duct open to crawlspace

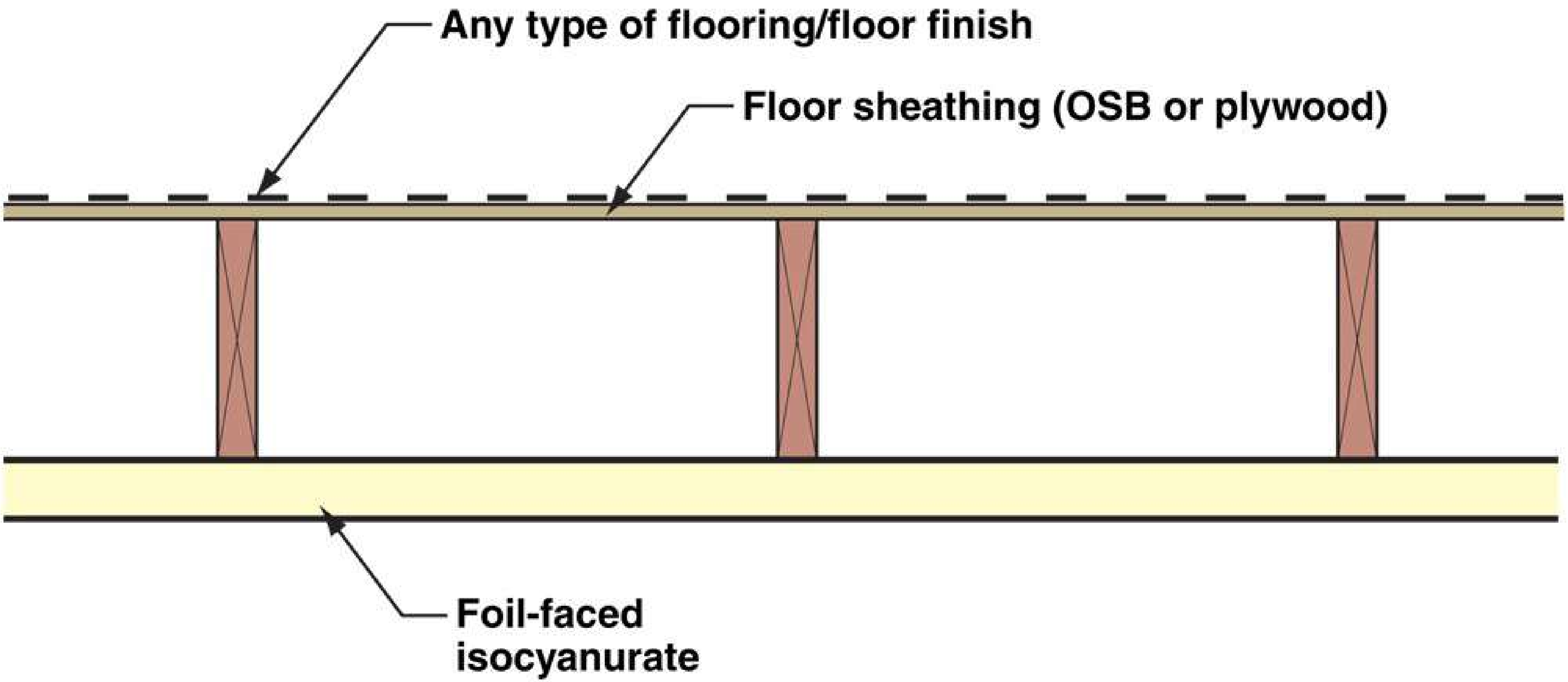

Alternative Detail
Inspection gap for termites
Sill gasket
Flashing
Unfaced cavity insulation, cellulose or low density spray-applied foam insulation
Gypsum board with (latex) paint
Sealant, adhesive or gasket
Sealant at corner of bottom plate and subfloor or gasket under bottom plate
Stucco
Building paper (behind rigid insulation)
Rigid insulation
Adhesive
Protective membrane
Unfaced cavity insulation, cellulose or low density spray applied foam
Sealant
Sill gasket
Protective membrane also acts as capillary break
Top courses filled solid
Rigid insulation (fire rated) (taped or sealed joints)
Masonry foundation wall
Ground slopes away from wall at 5% (6in. per 10ft.)
Continuous polyethylene vapor barrier/air barrier (all joints taped) taped to perimeter rigid insulation
Dampproofing
Capillary break over footing
If exterior grade is lower than interior crawl space grade, no perimter drain is necessary
Concrete footing below frost depth

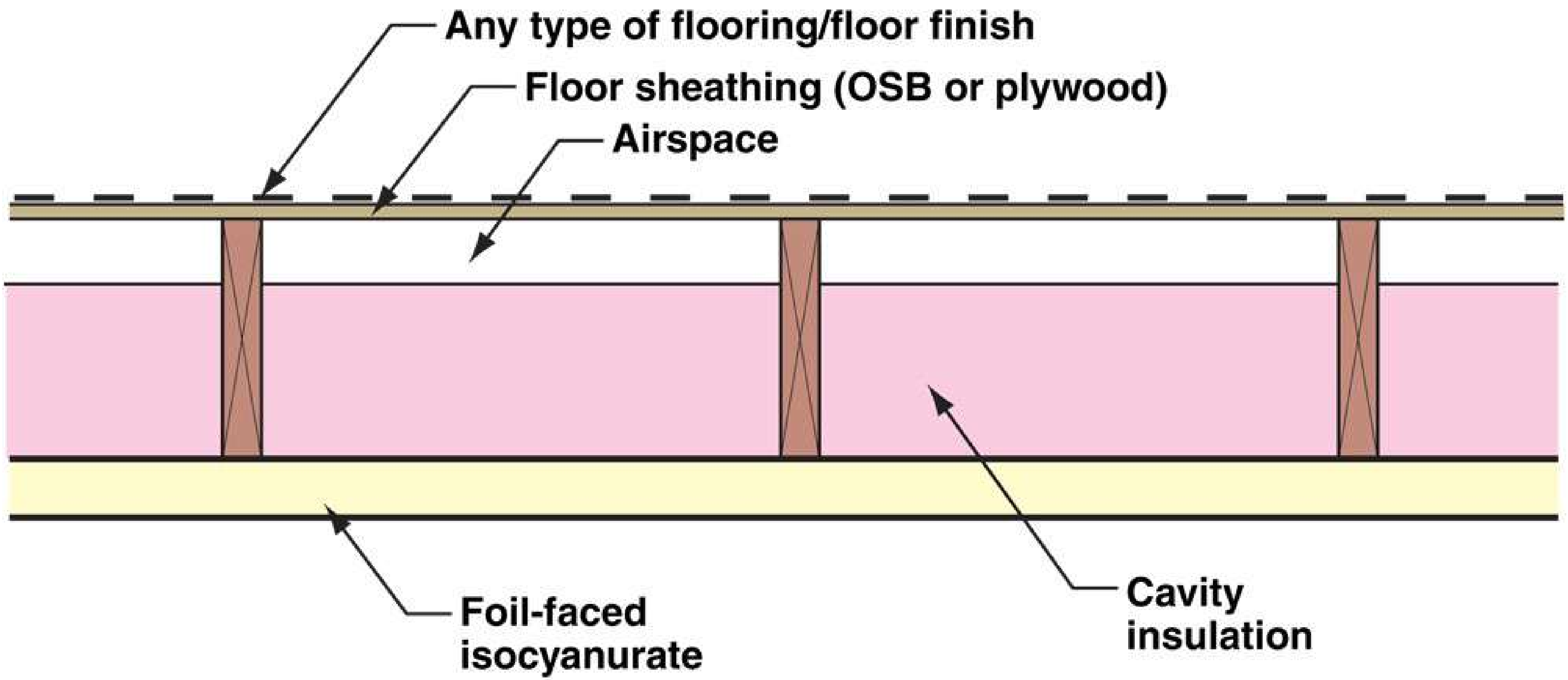
# Smart Thing

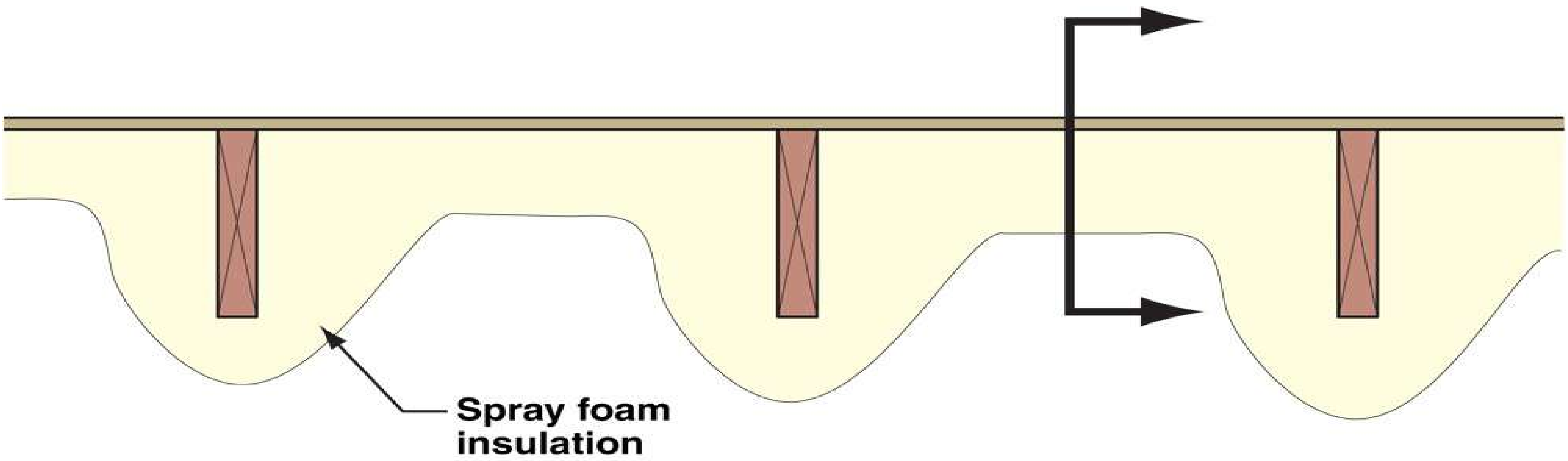

Wood siding
(all surfaces painted)
Air space
1/2" OSB sheathing
Furring
Sealant, adhesive
or gasket
Adhesive
Sealant, adhesive
or gasket
Crawlspace vent at top
of foundation wall
Masonry foundation
wall
Ground sloppes away
from wall at 5%
(6 in. per 10 ft.)
Capillary break
over footing
Dampproofing
Unfaced 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
Concrete footing
below frost depth

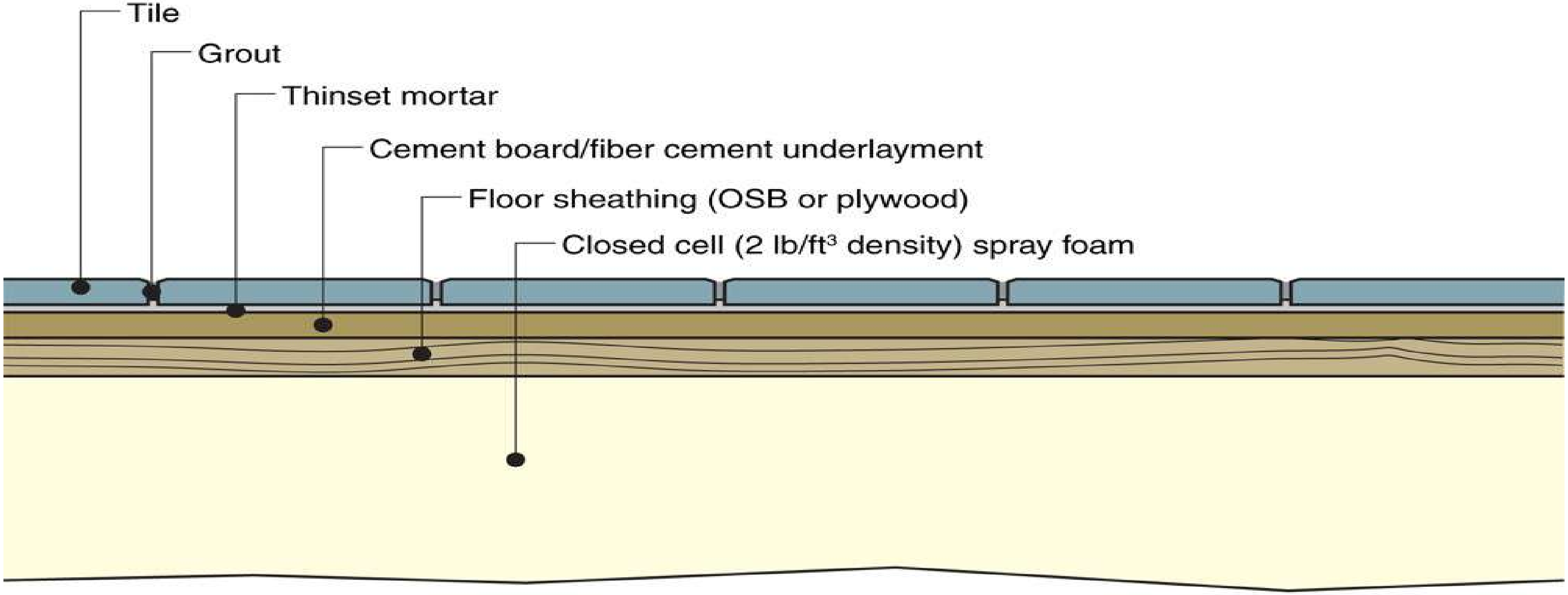

Cladding
Air gap
Wood based sheathing
(plywood or OSB)
Water control
layer
Spray polyurethane
foam (SPF)
Arylic latex paint
Gypsum board
Sealant
High density closed cell
spray polyurethane foam
Protection board

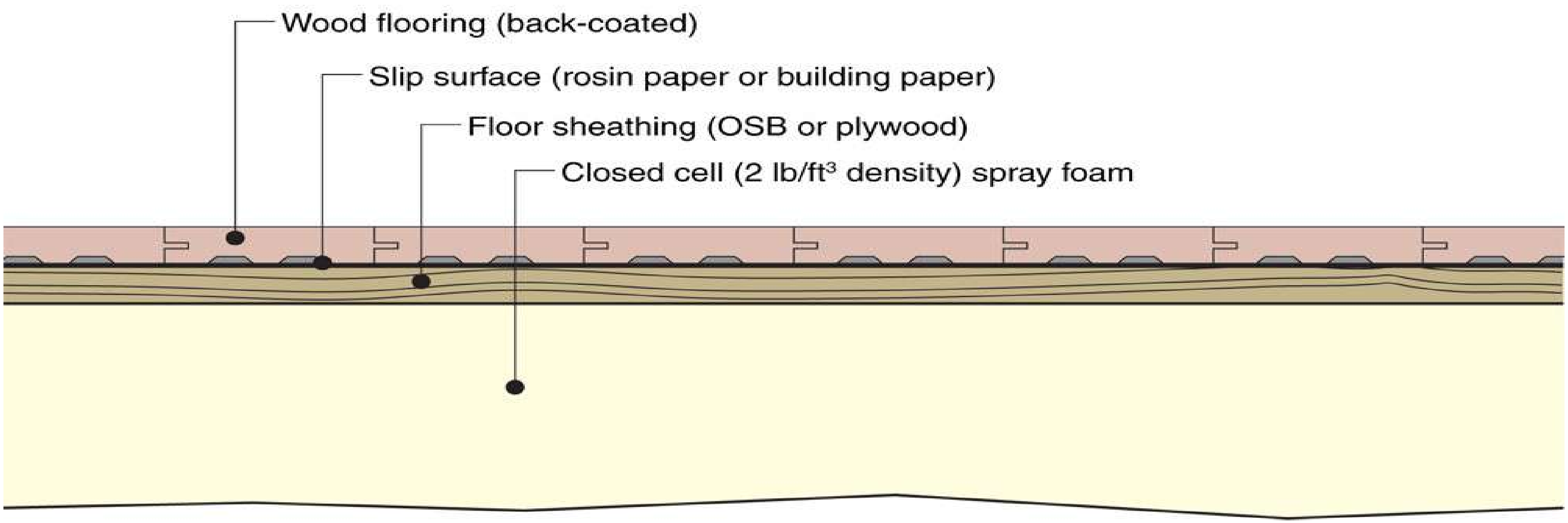

Vinyl or aluminum siding
Unfaced cavity insulation, cellulose or low density spray-applied foam insulation
Gypsum board with (latex) paint
Rigid insulation (taped or sealed joints)
Sealant, adhesive or gasket
Sealant at corner of bottom plate and subfloor or gasket under bottom plate
Sealant, adhesive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

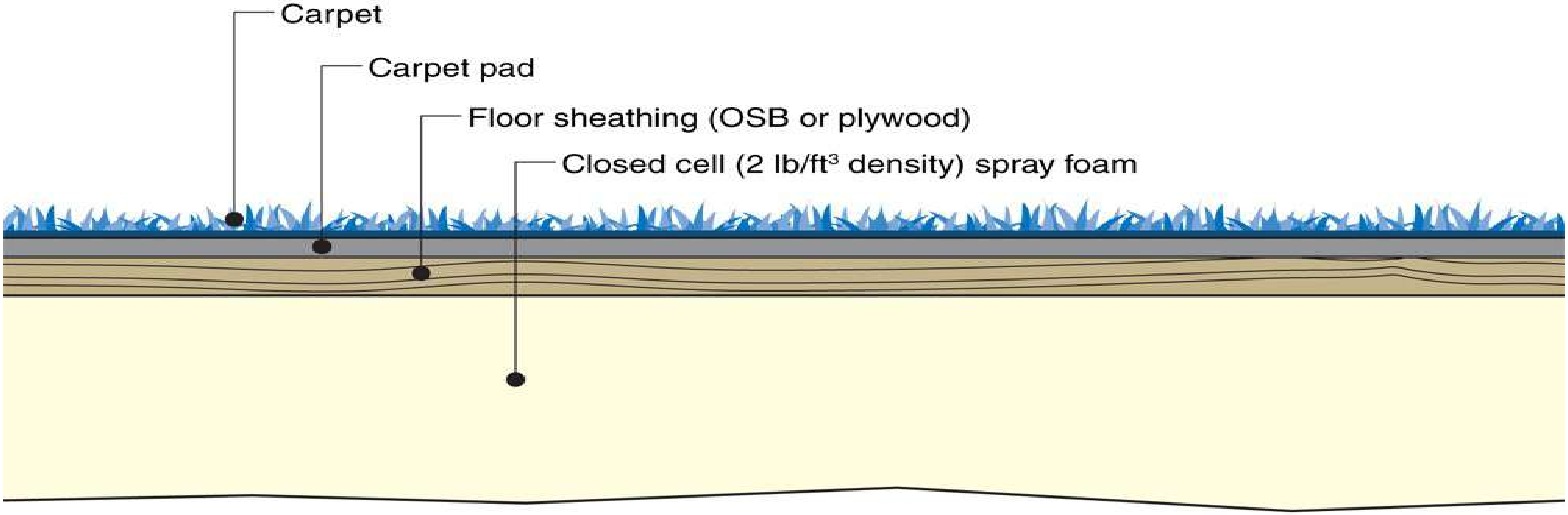

Any type of flooring/floor finish
Floor sheathing (OSB or plywood)
Foil-faced
isocyanurate

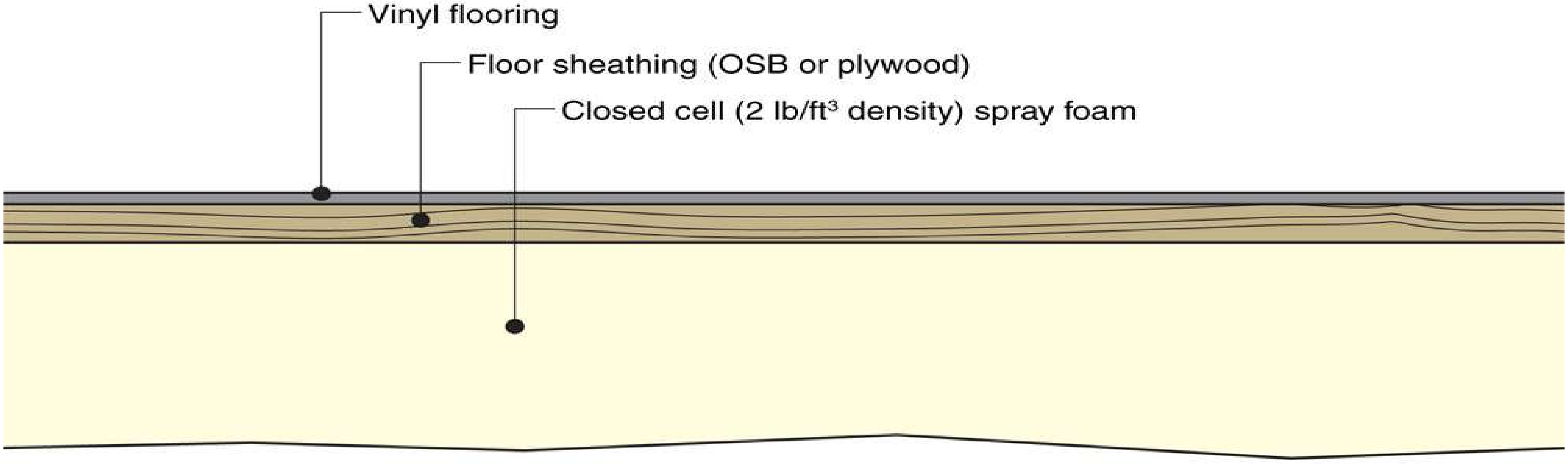

Any type of flooring/floor finish
Floor sheathing (OSB or plywood)
Airspace
Foil-faced isocyanurate
Cavity insulation

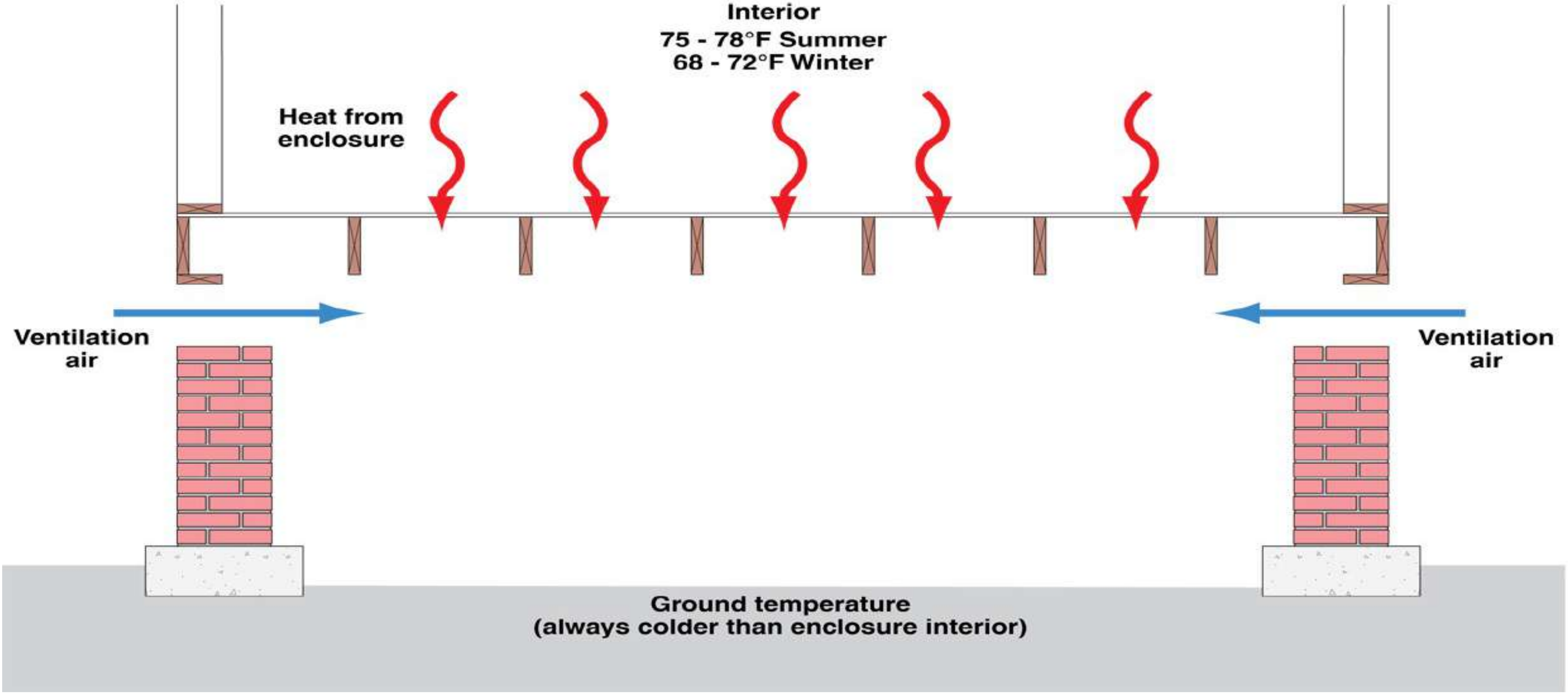

Spray foam
insulation

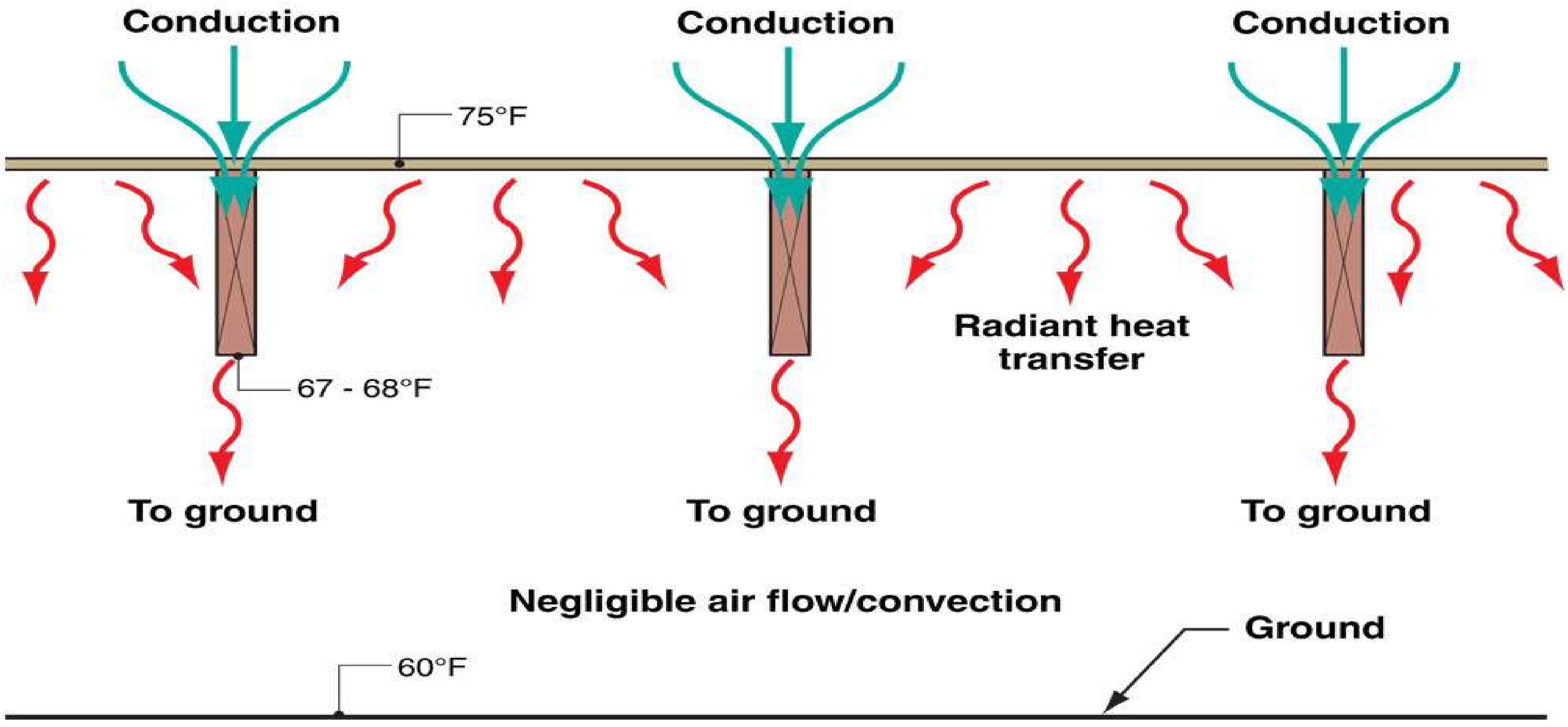

Tile
Grout
Thinset mortar
Cement board/fiber cement underlayment
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft³ density) spray foam

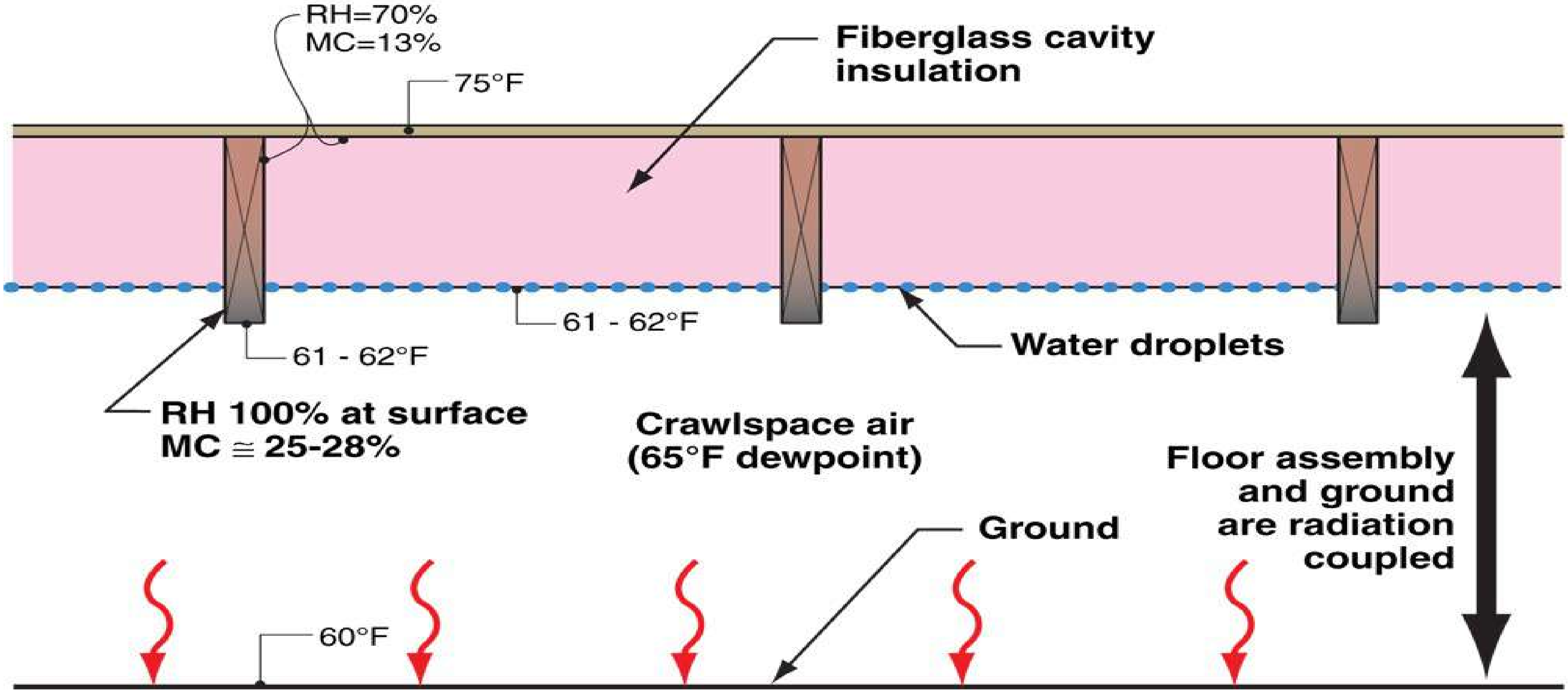

Wood flooring (back-coated)
Slip surface (rosin paper or building paper)
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft³ density) spray foam

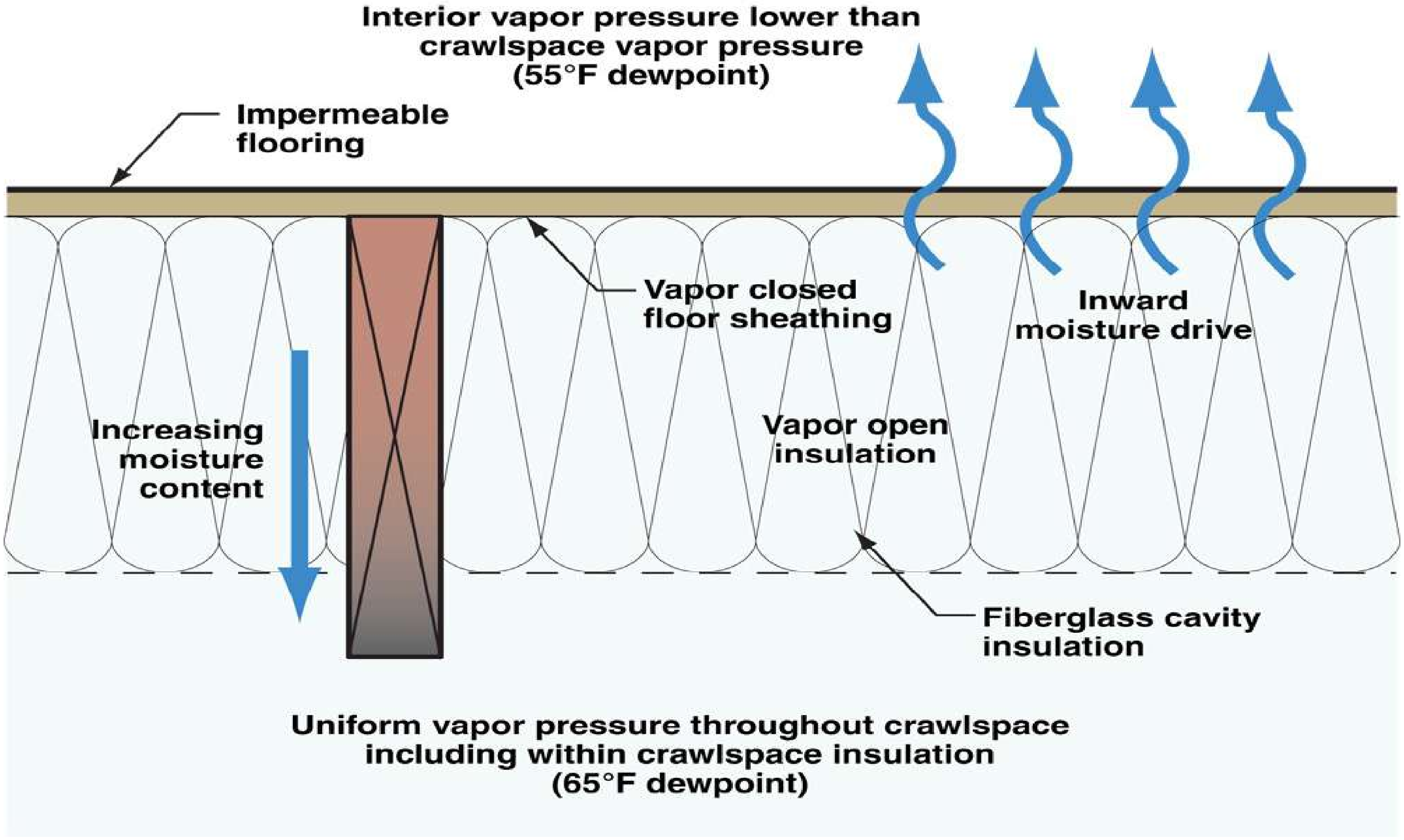

Carpet
Carpet pad
Floor sheathing (OSB or plywood)
Closed cell (2 lb/ft³ density) spray foam


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

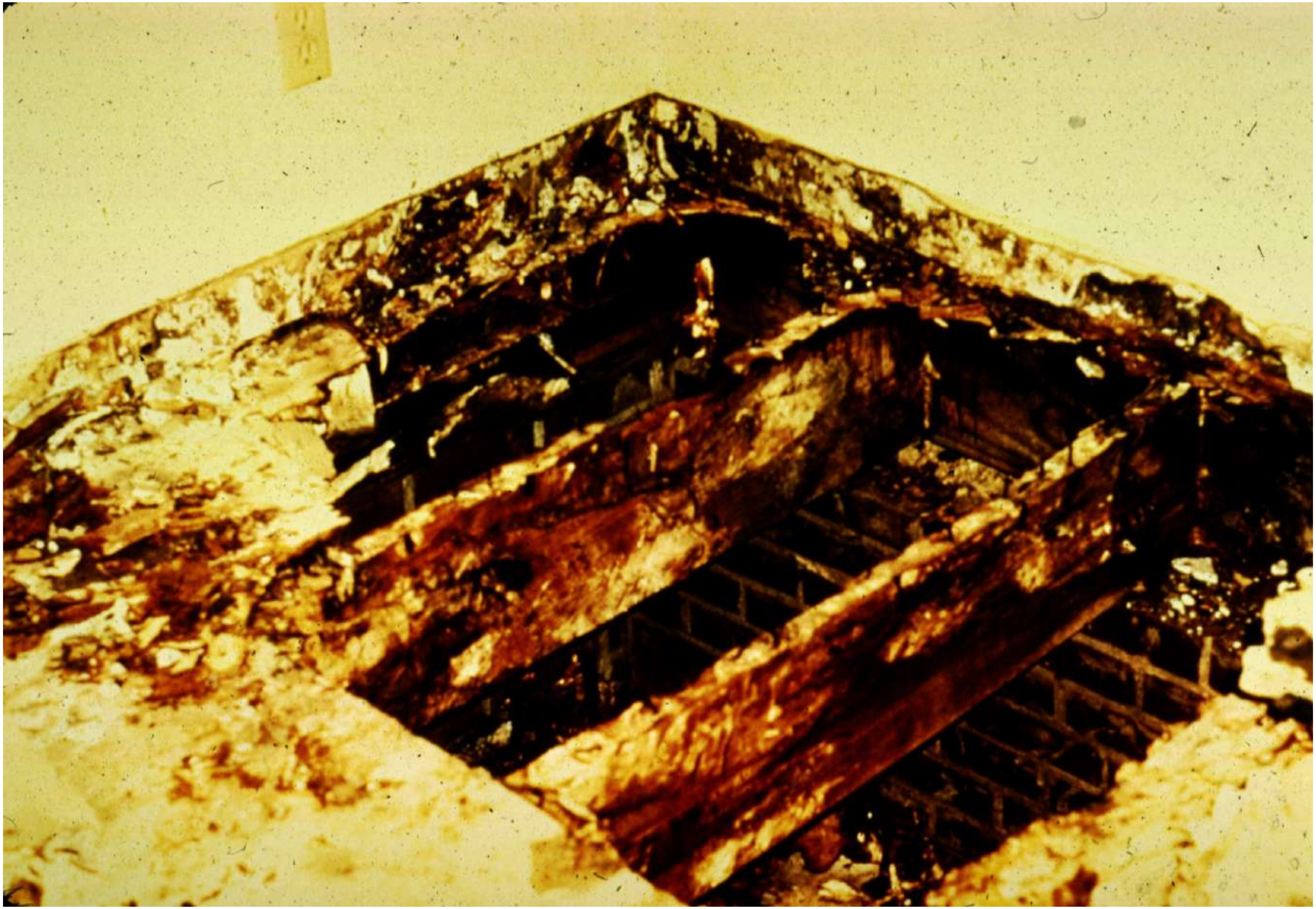

Interior
75 - 78°F Summer
68 - 72°F Winter
Heat from enclosure
Ventilation air
Ventilation air
Ground temperature
(always colder than enclosure interior)

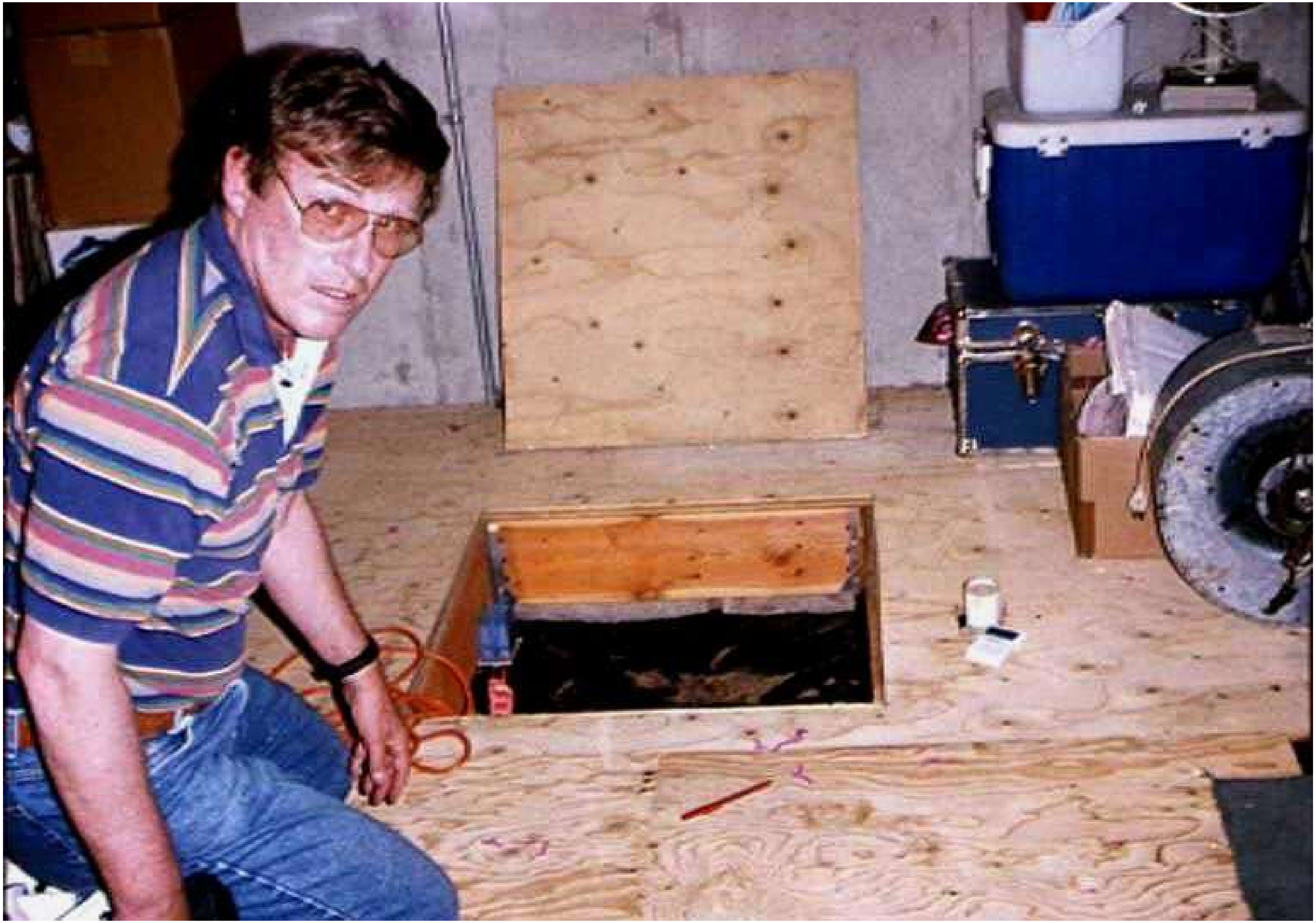

Conduction
Conduction
Conduction
75°F
Radiant heat transfer
67 - 68°F
To ground
To ground
To ground
Negligible air flow/convection
Ground
60°F


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

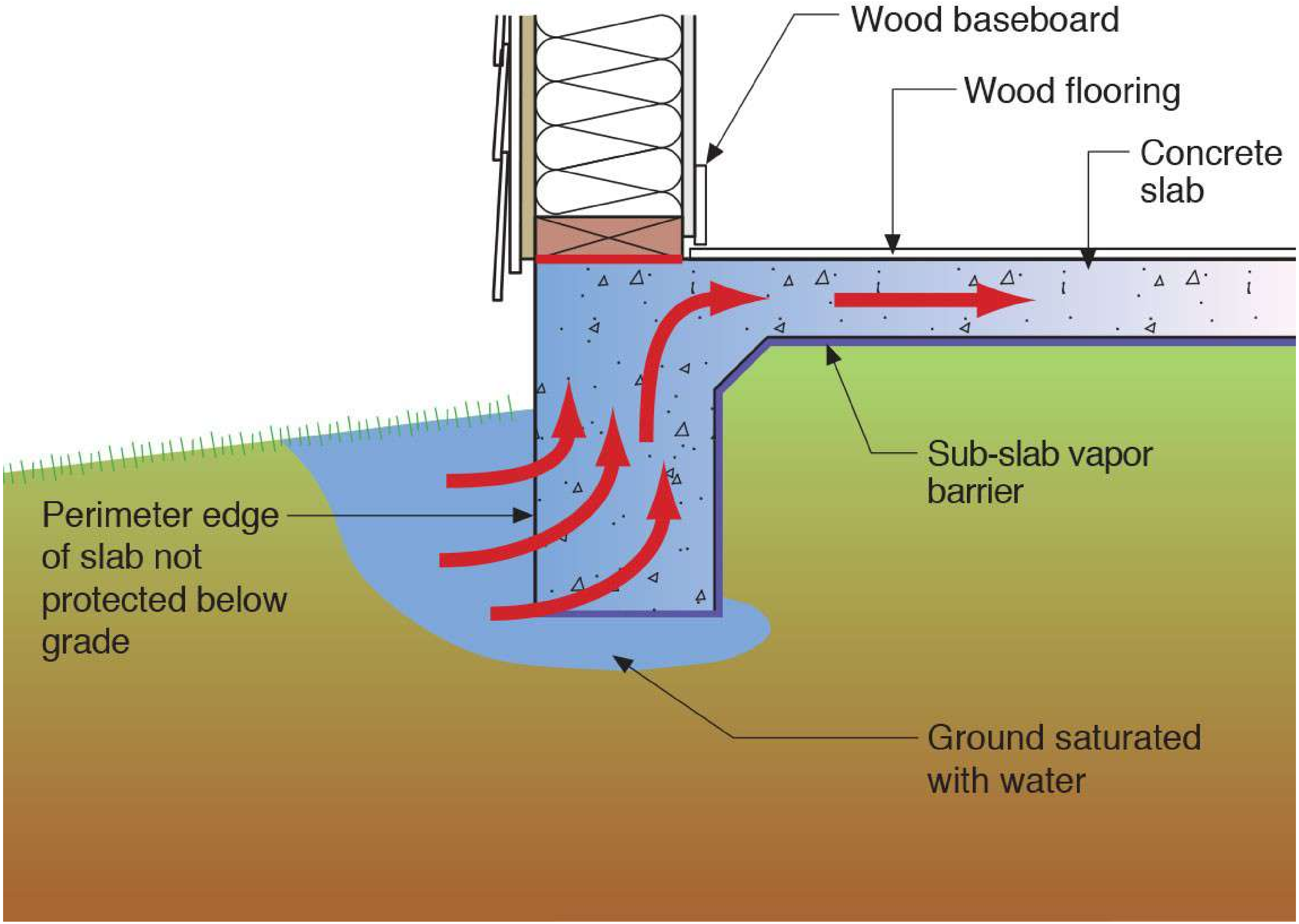


Interior vapor pressure lower than crawlspace vapor pressure (55°F dewpoint)
Impermeable flooring
Vapor closed floor sheathing
Inward moisture drive
Increasing moisture content
Vapor open insulation
Fiberglass cavity insulation
Uniform vapor pressure throughout crawlspace including within crawlspace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

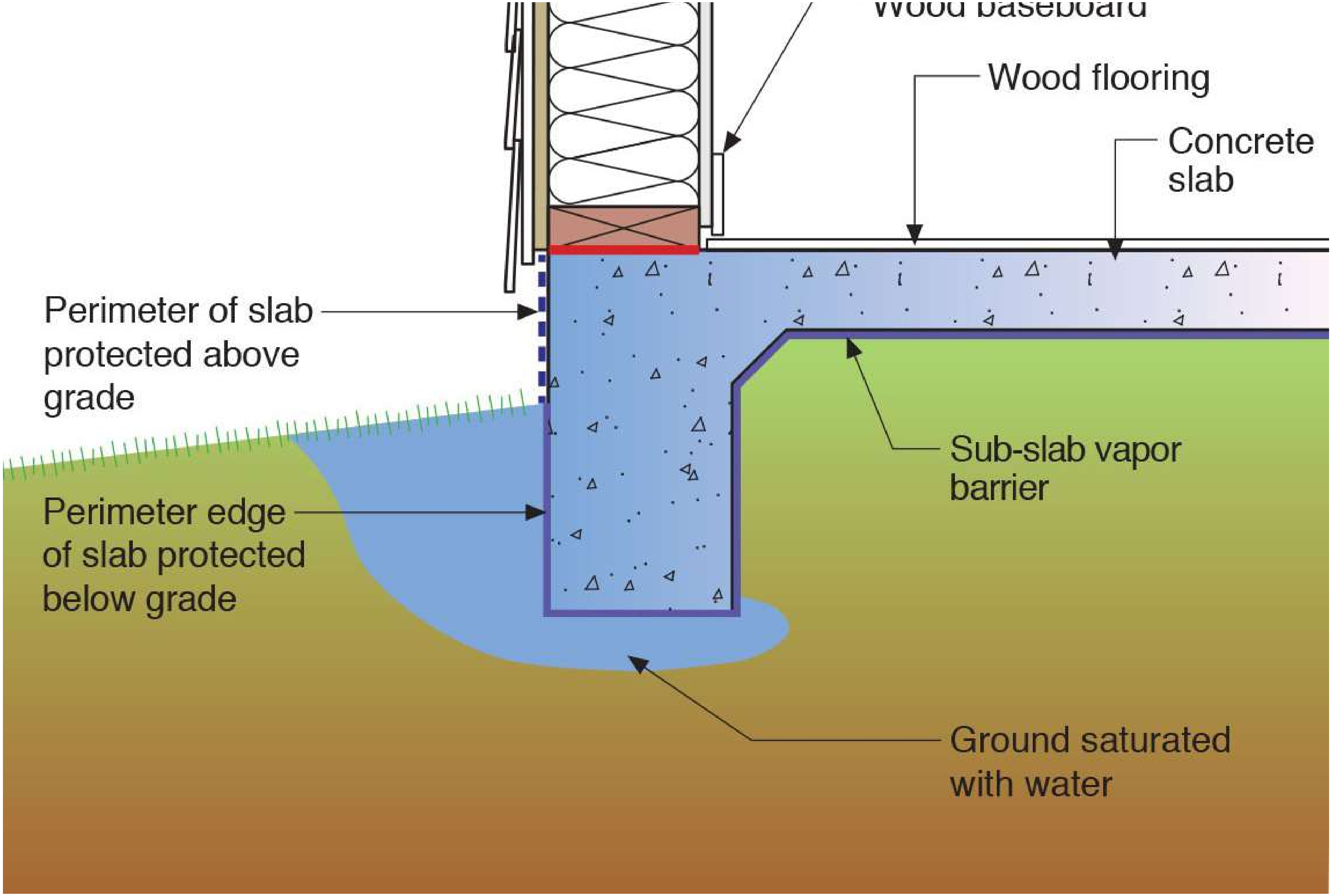


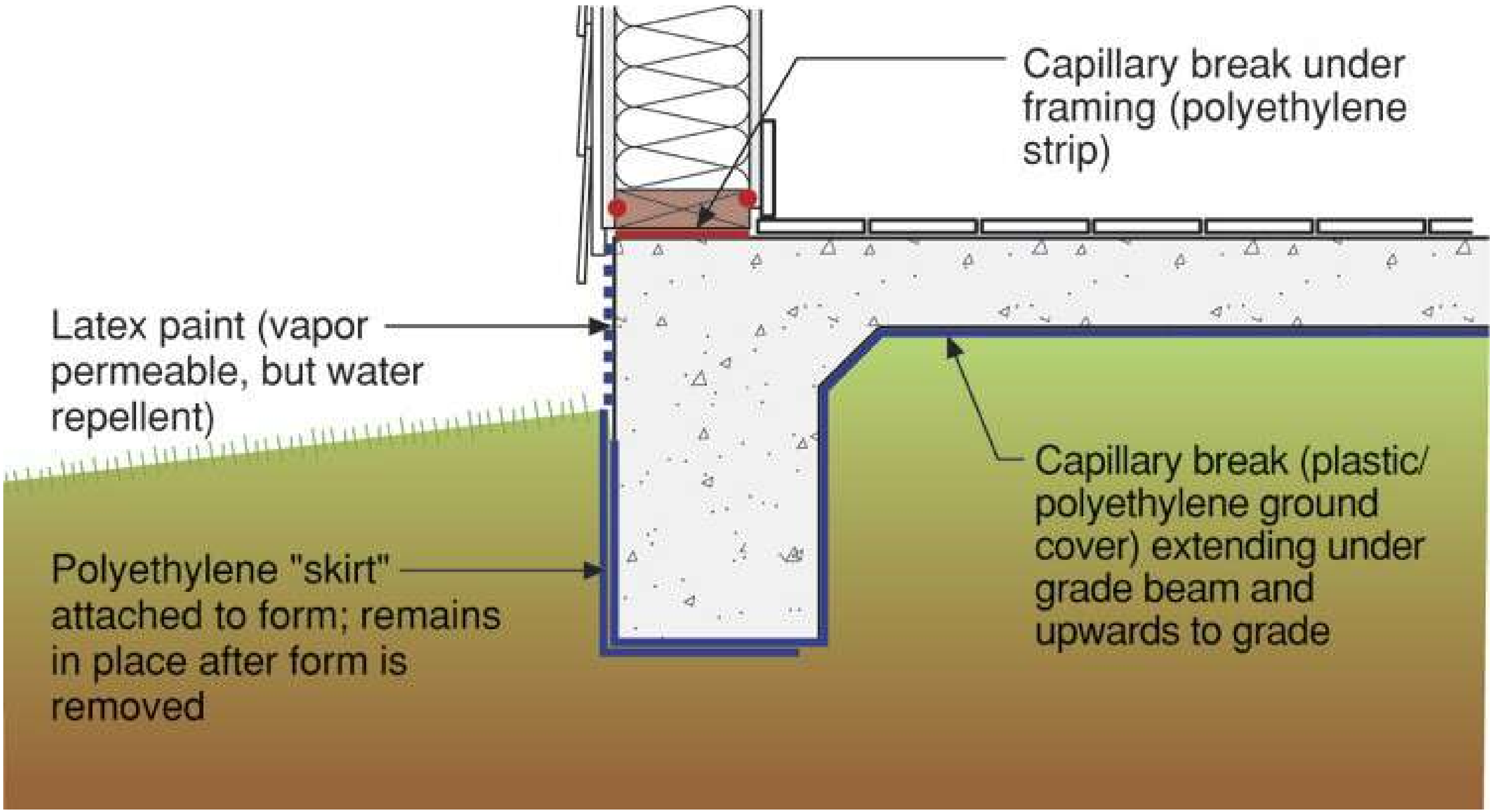


# Slabs

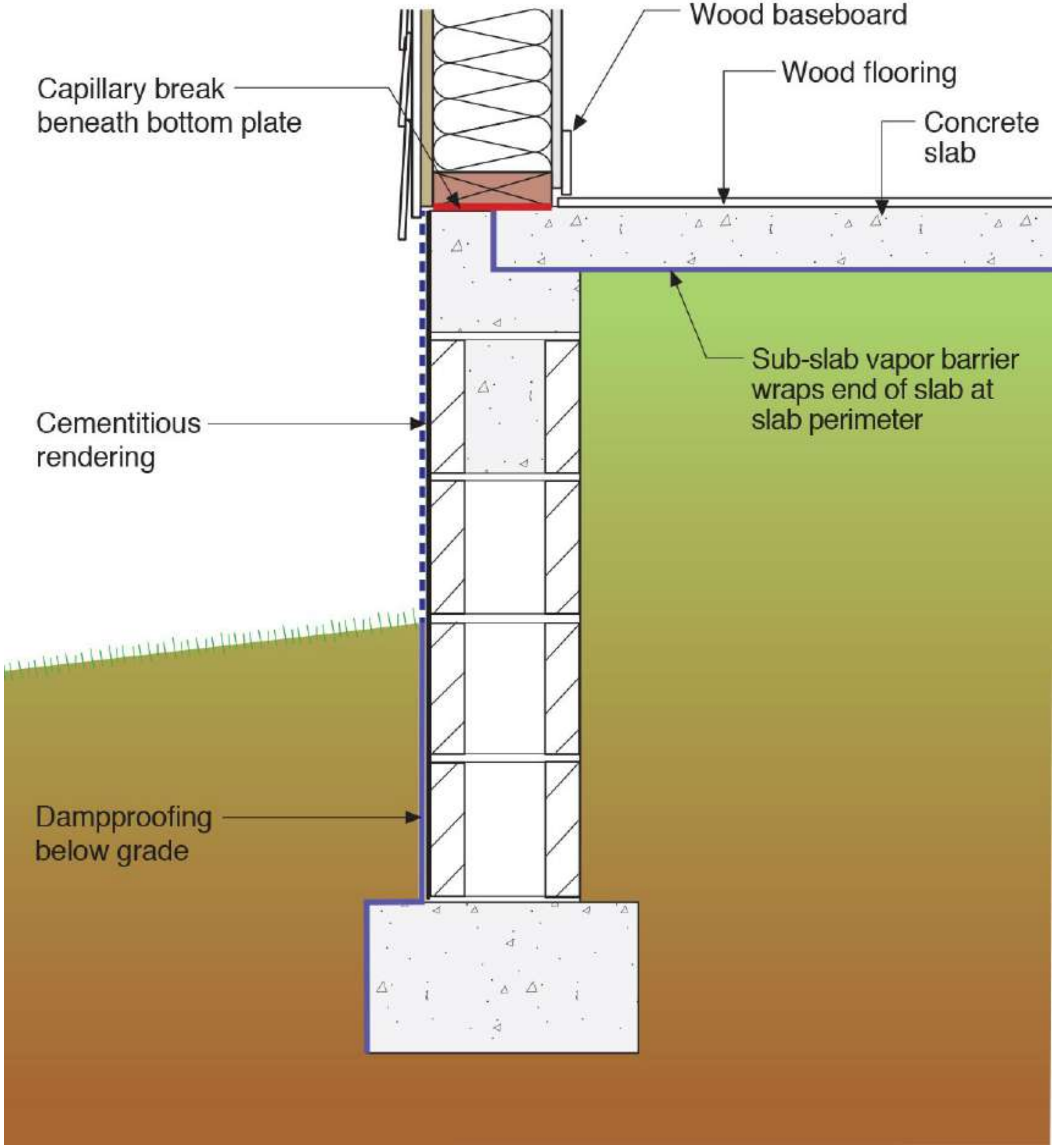

Wood baseboard
Wood flooring
Concrete slab
Sub-slab vapor barrier
Perimeter edge of slab not protected below grade
Ground saturated with water


25
U-HAUL
MOVE YOURSELF AND SA

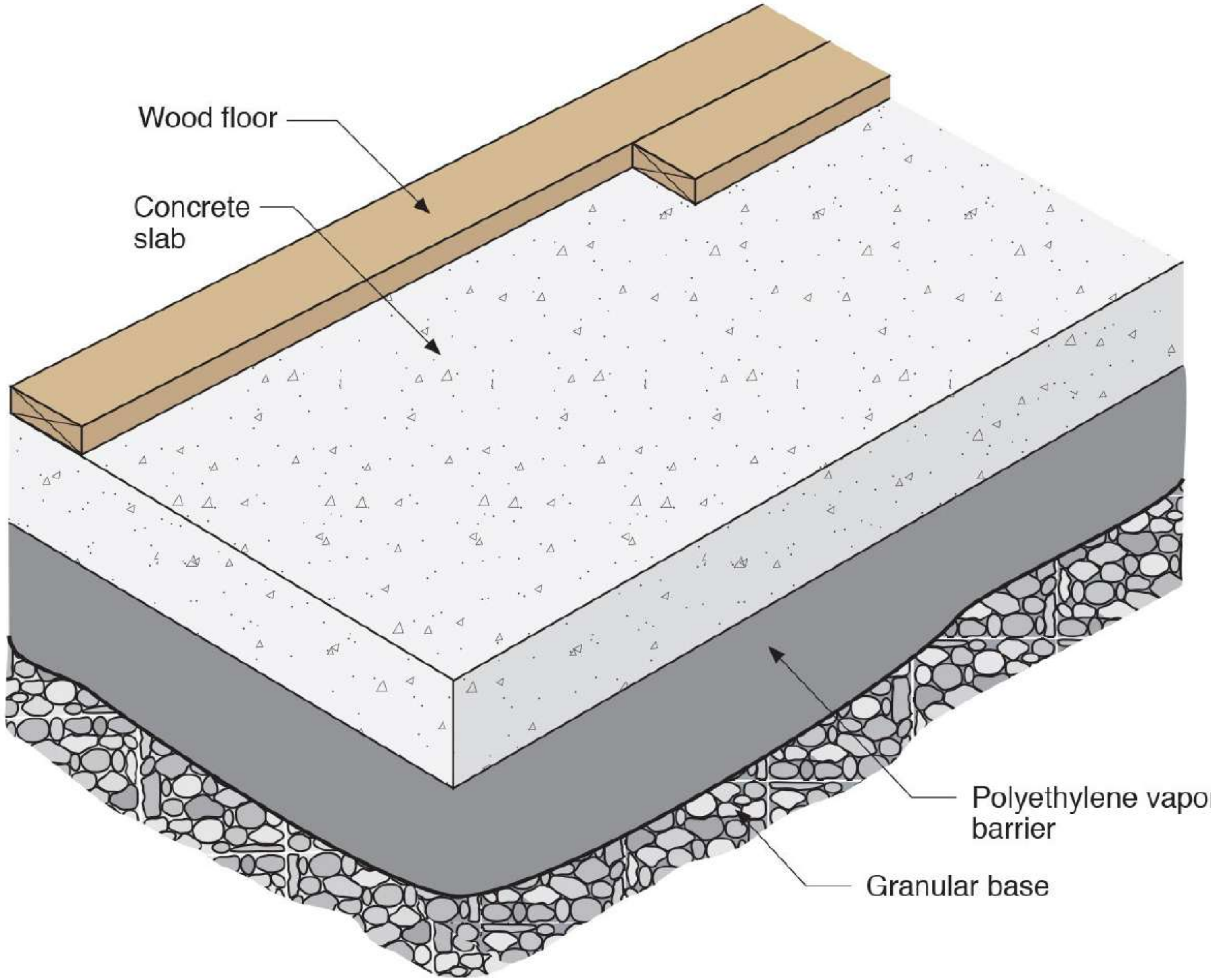

Wood flooring
Concrete slab
Perimeter of slab protected above grade
Perimeter edge of slab protected below grade
Sub-slab vapor barrier
Ground saturated with water

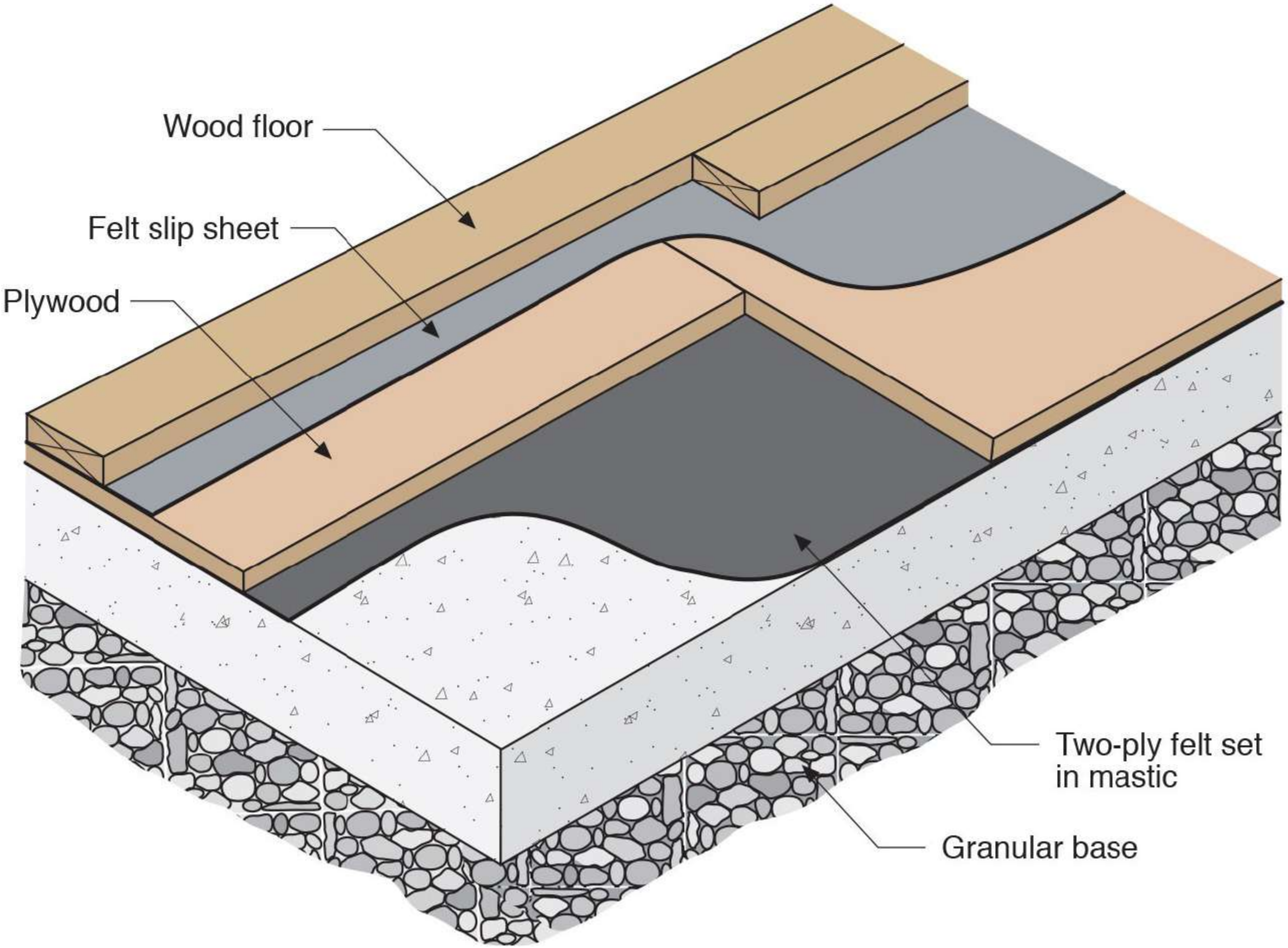

Capillary break under framing (polyethylene strip)
Latex paint (vapor permeable, but water repellent)
Polyethylene "skirt" attached to form; remains in place after form is removed
Capillary break (plastic/ polyethylene ground cover) extending under grade beam and upwards to grade

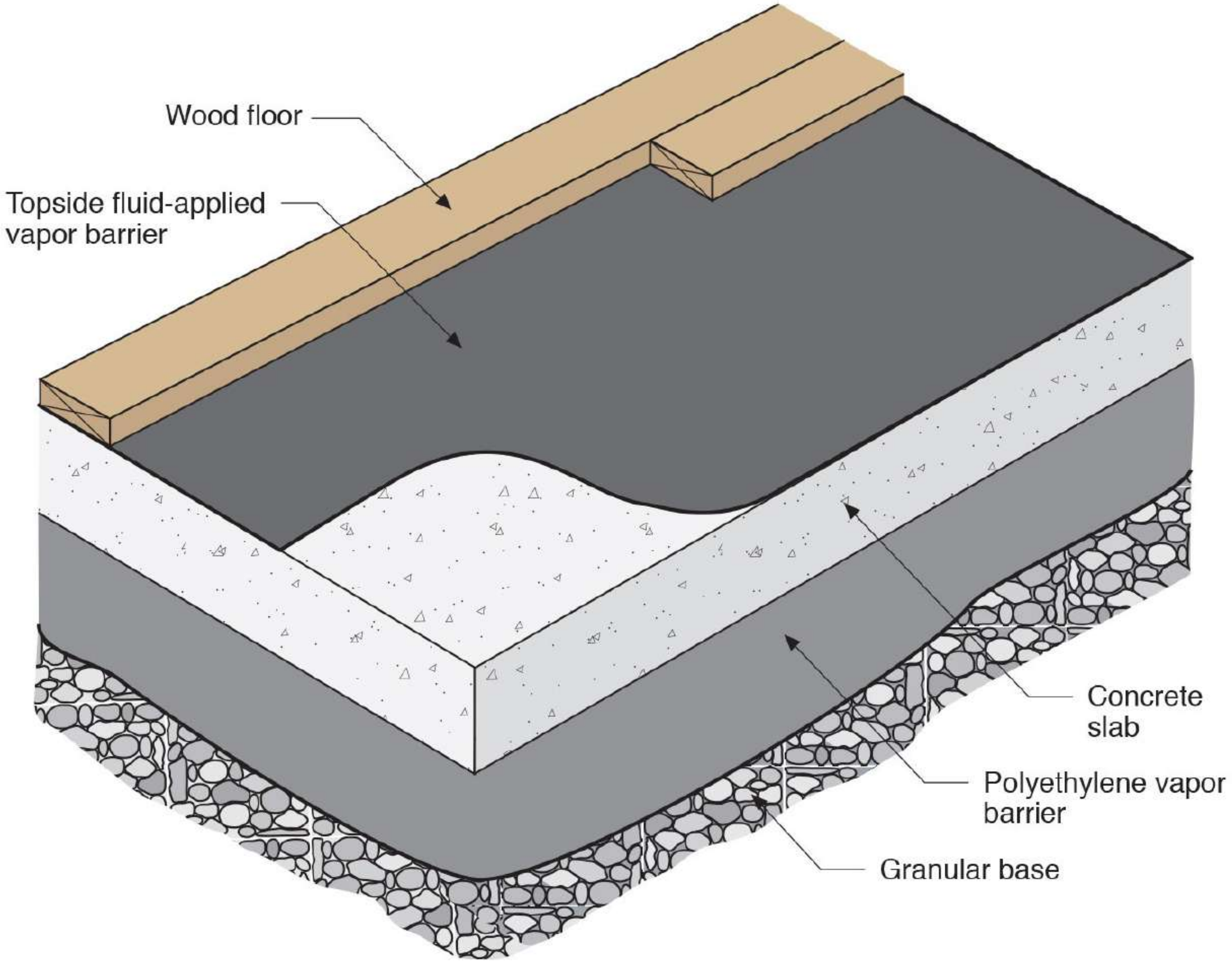

Cheetos



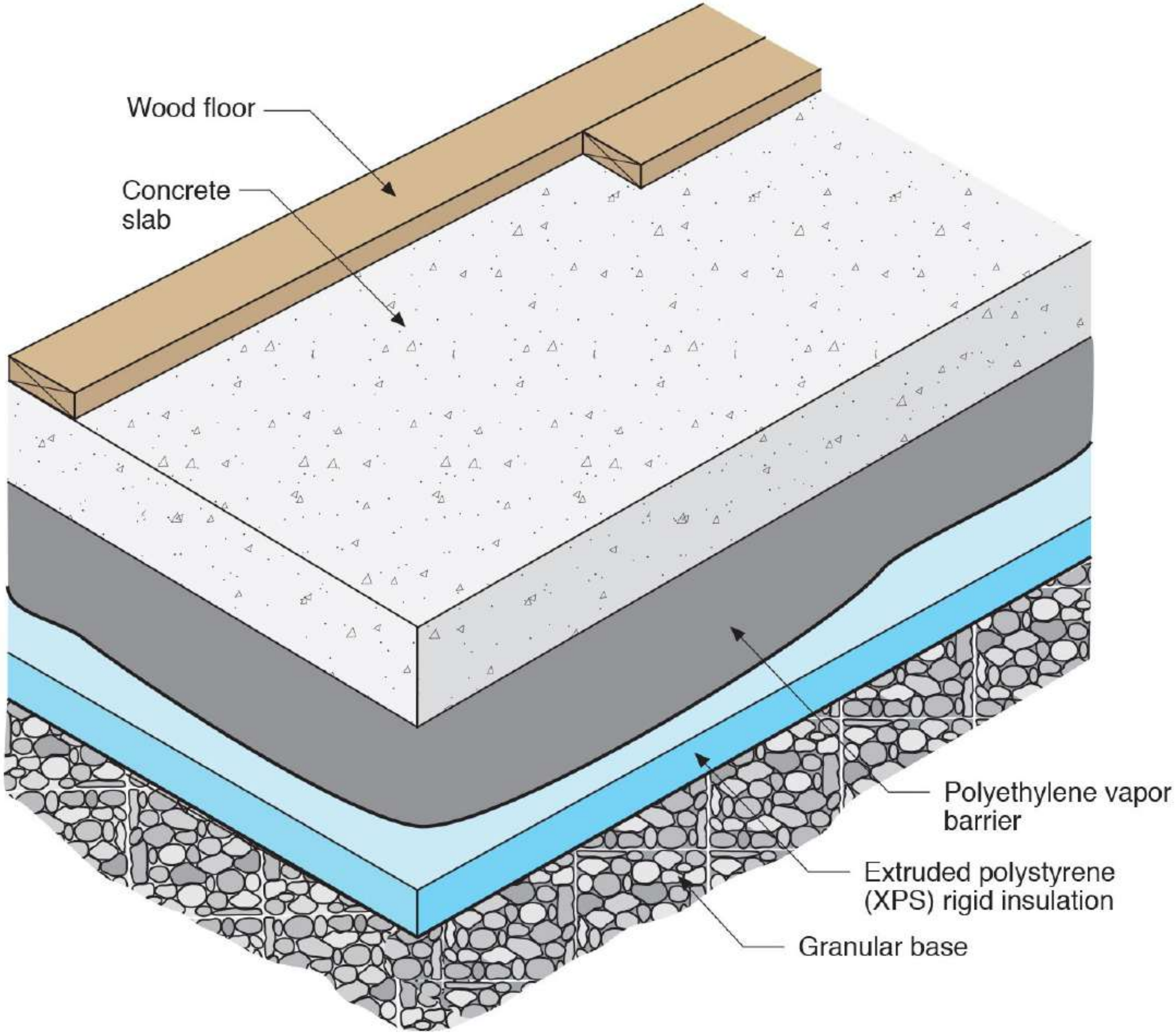
Wood baseboard
Wood flooring
Capillary break beneath bottom plate
Concrete slab
Sub-slab vapor barrier wraps end of slab at slab perimeter
Cementitious rendering
Dampproofing below grade


Wood floor
Concrete slab
Polyethylene vapor barrier
Granular base

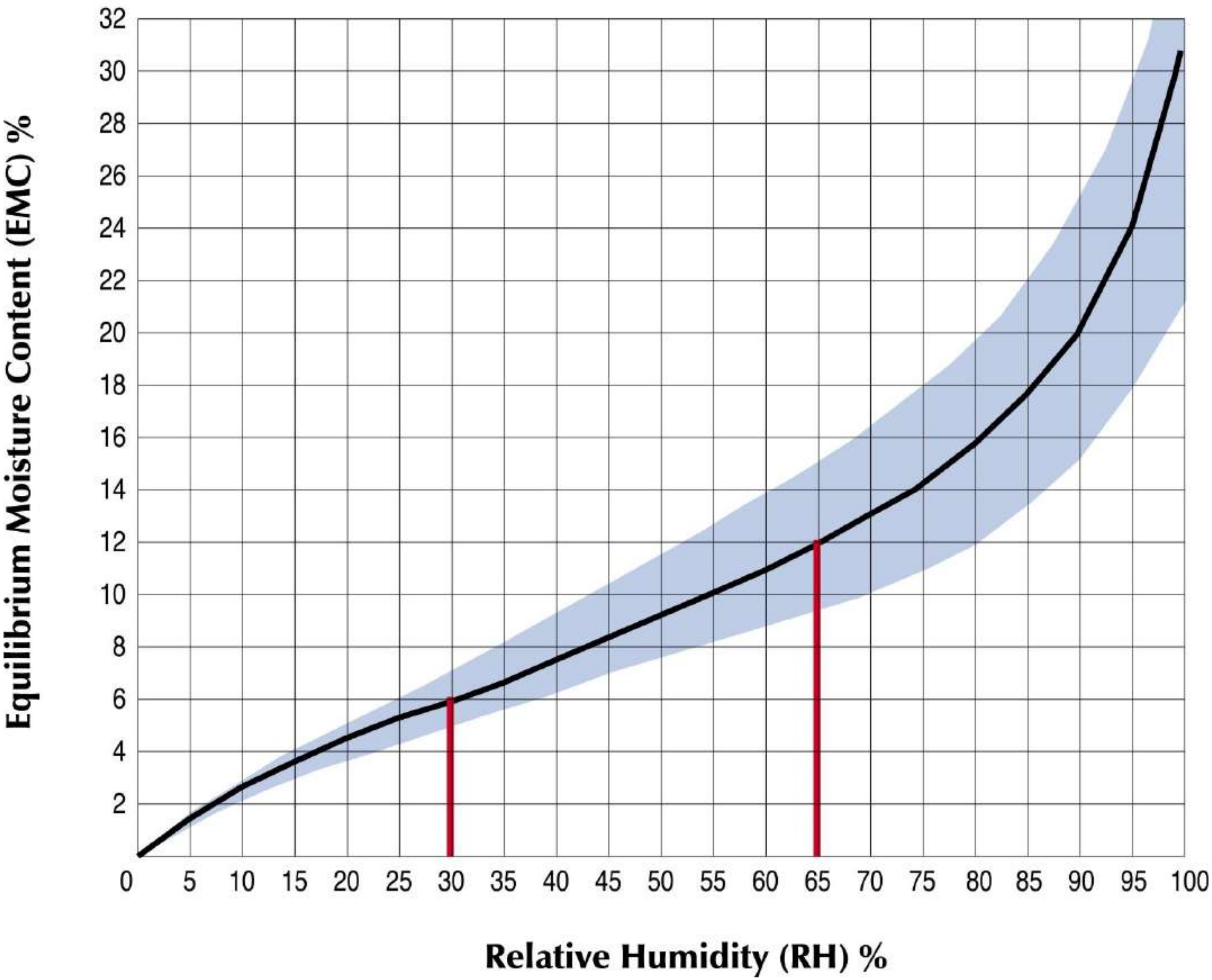

Wood floor
Felt slip sheet
Plywood
Two-ply felt set in mastic
Granular base

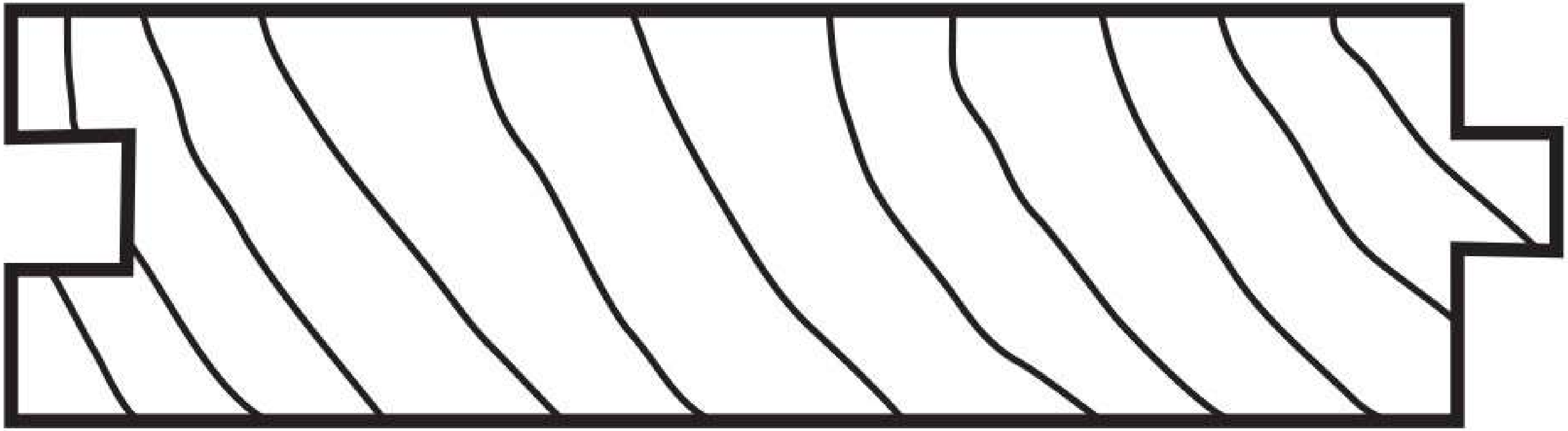

Wood floor
Topside fluid-applied vapor barrier
Concrete slab
Polyethylene vapor barrier
Granular base


COLA

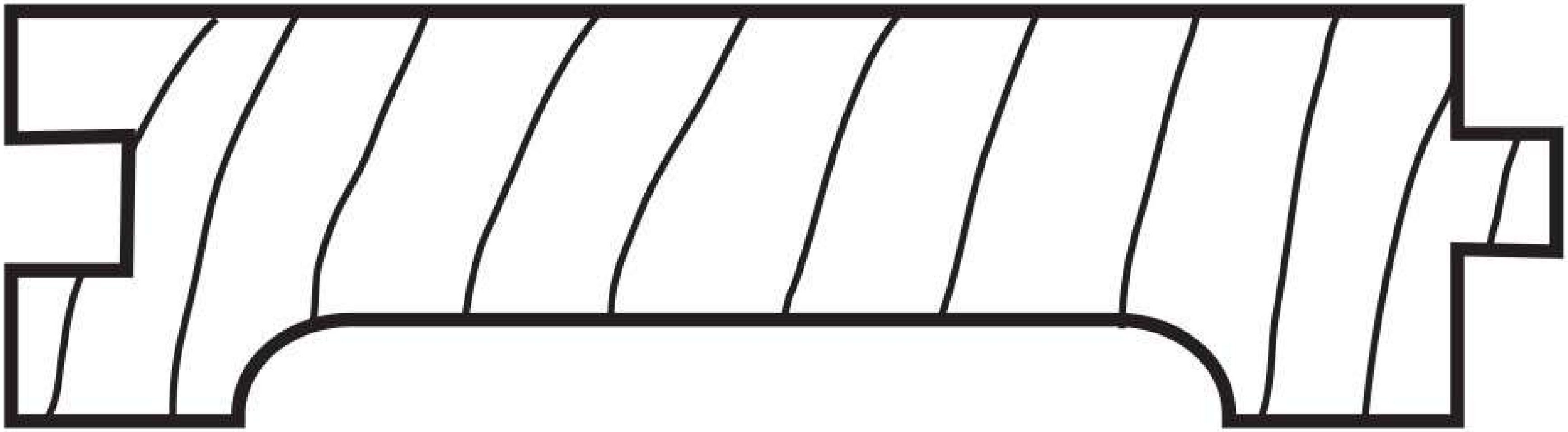

Wood floor
Concrete slab
Polyethylene vapor barrier
Extruded polystyrene (XPS) rigid insulation
Granular base

# Moisture Content vs. Relative Humidity

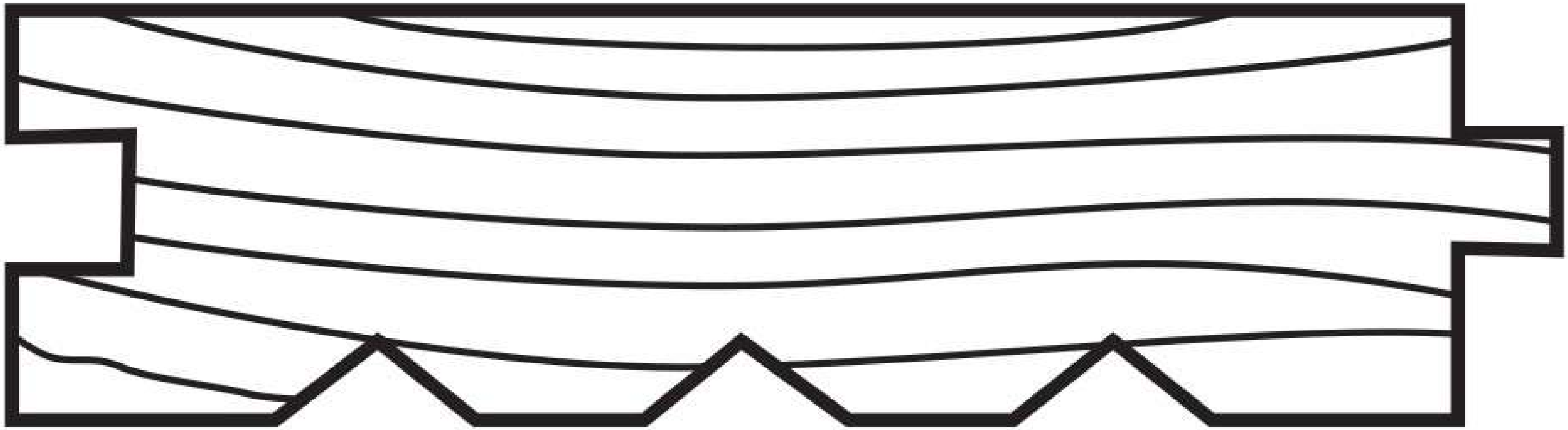




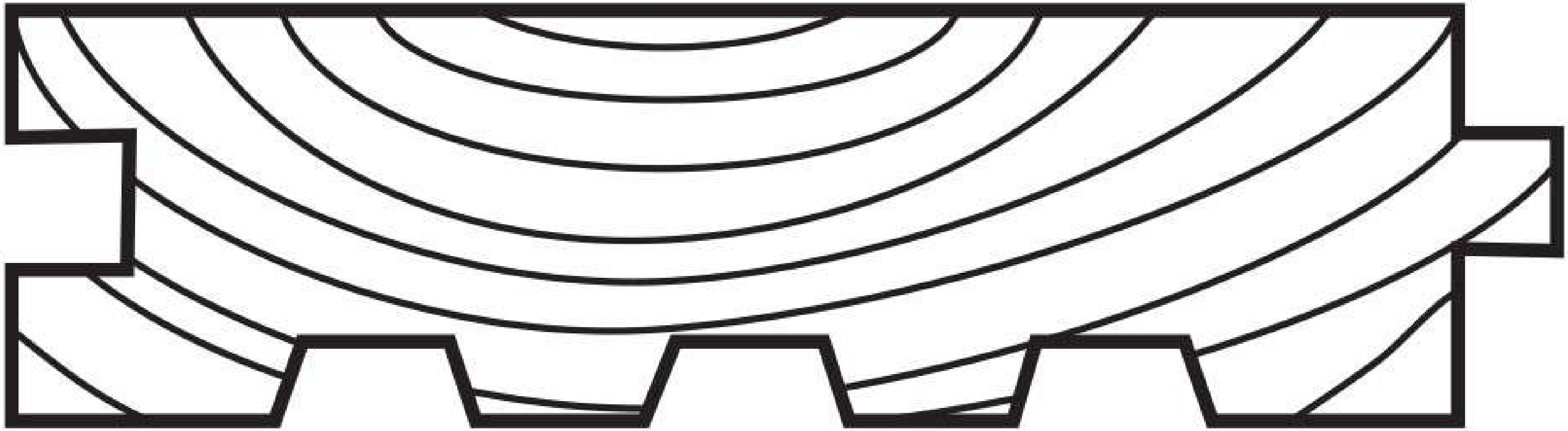
Plain



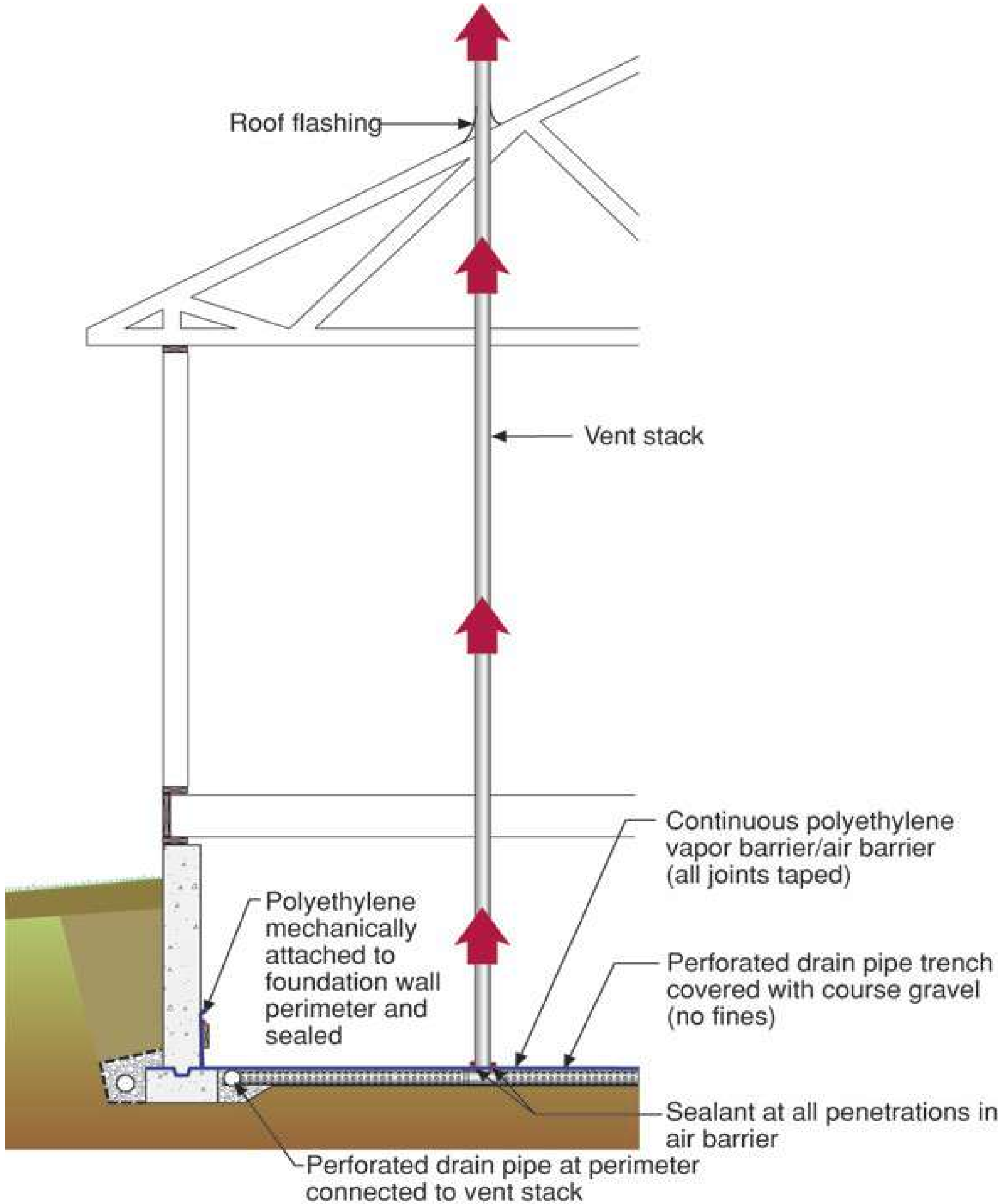
Hollow Back

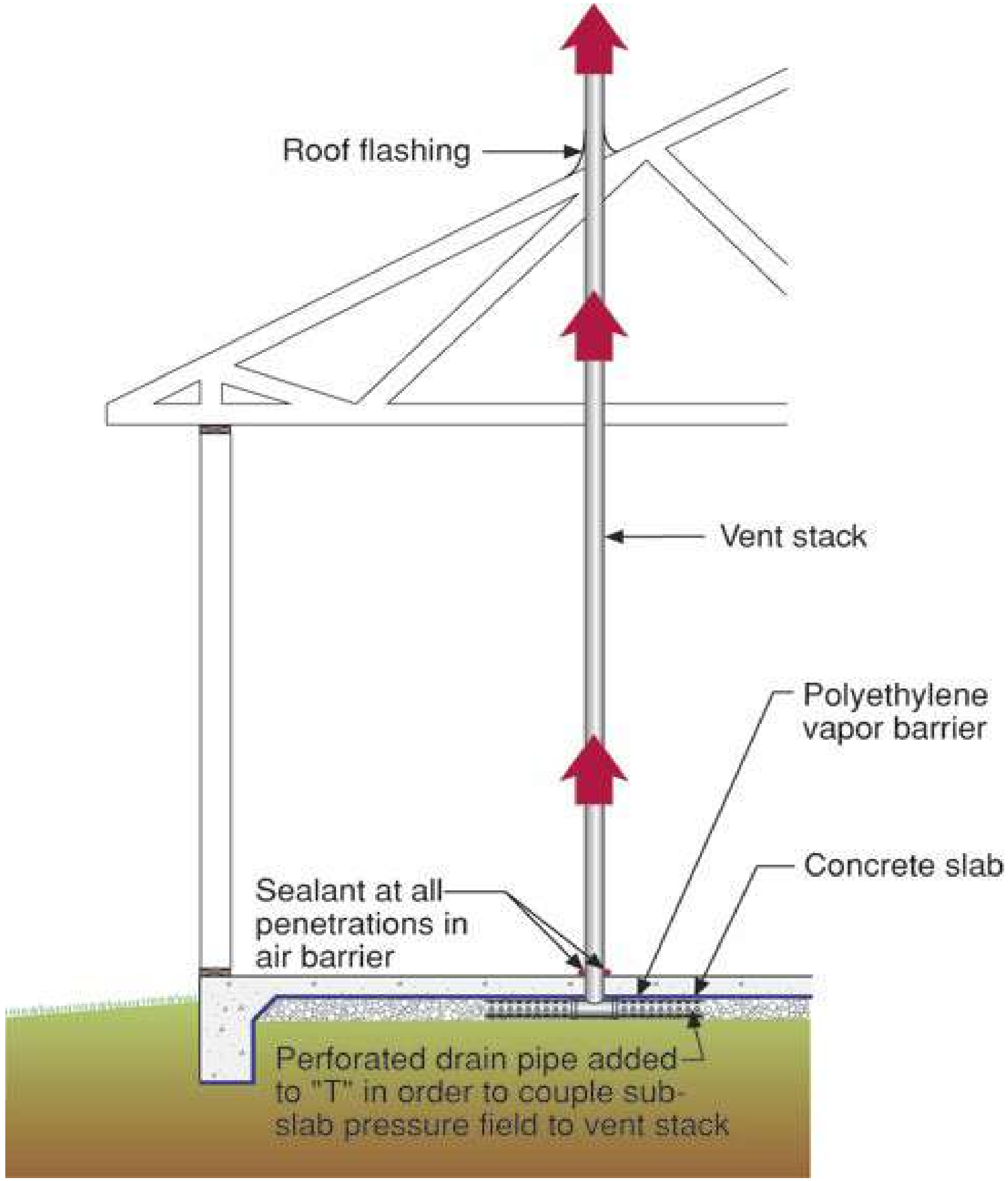


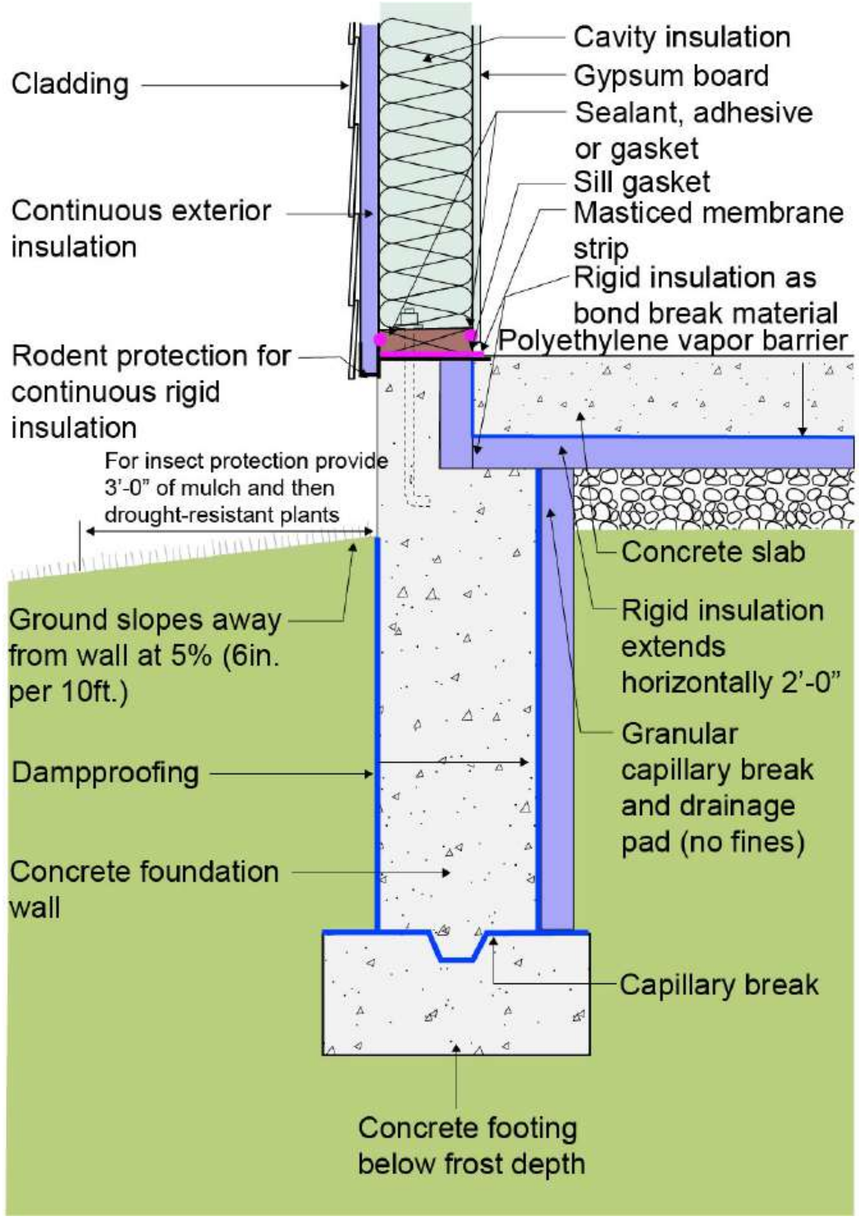
# Scratch Back

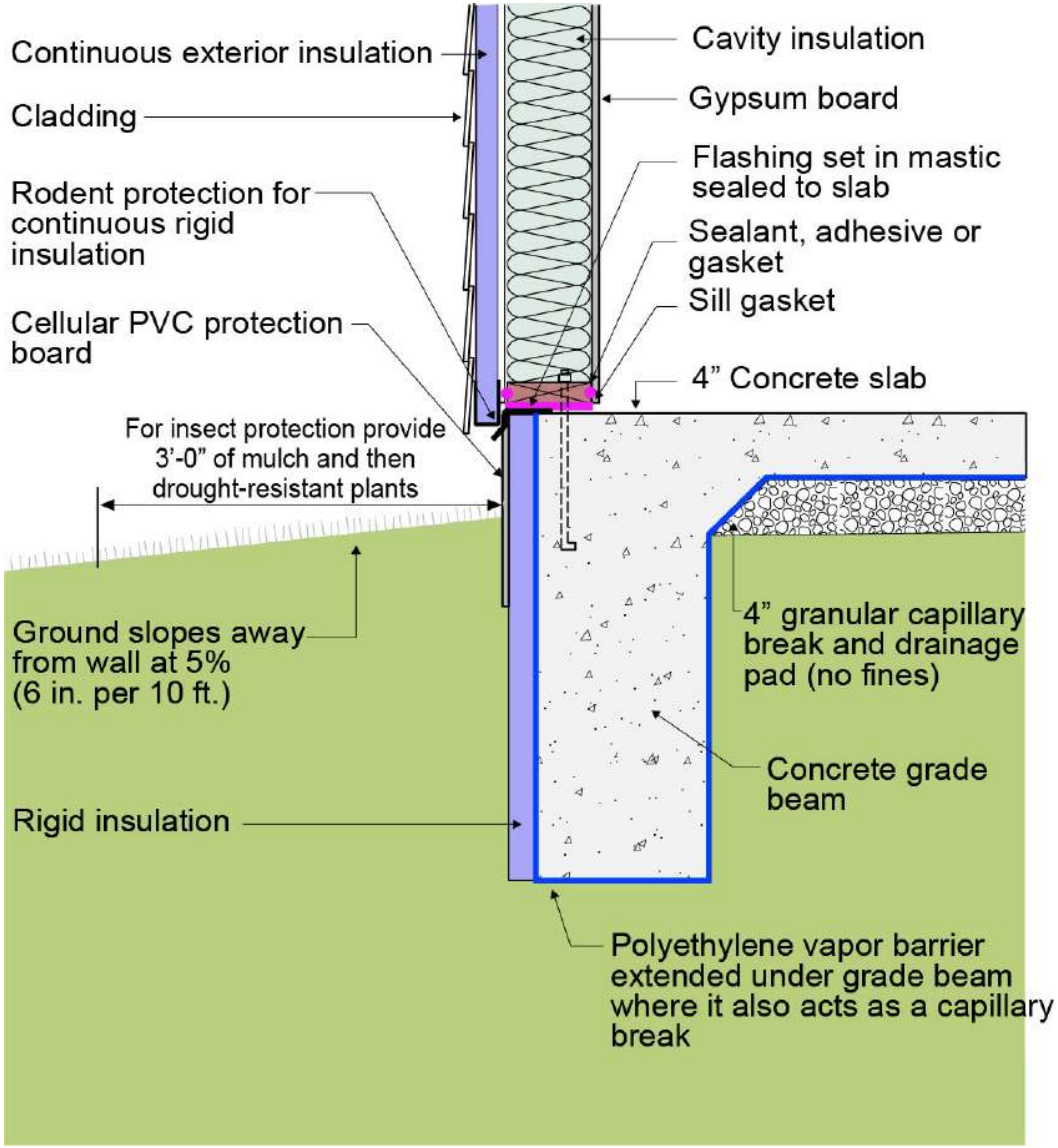


# Hollow or Scratch Back

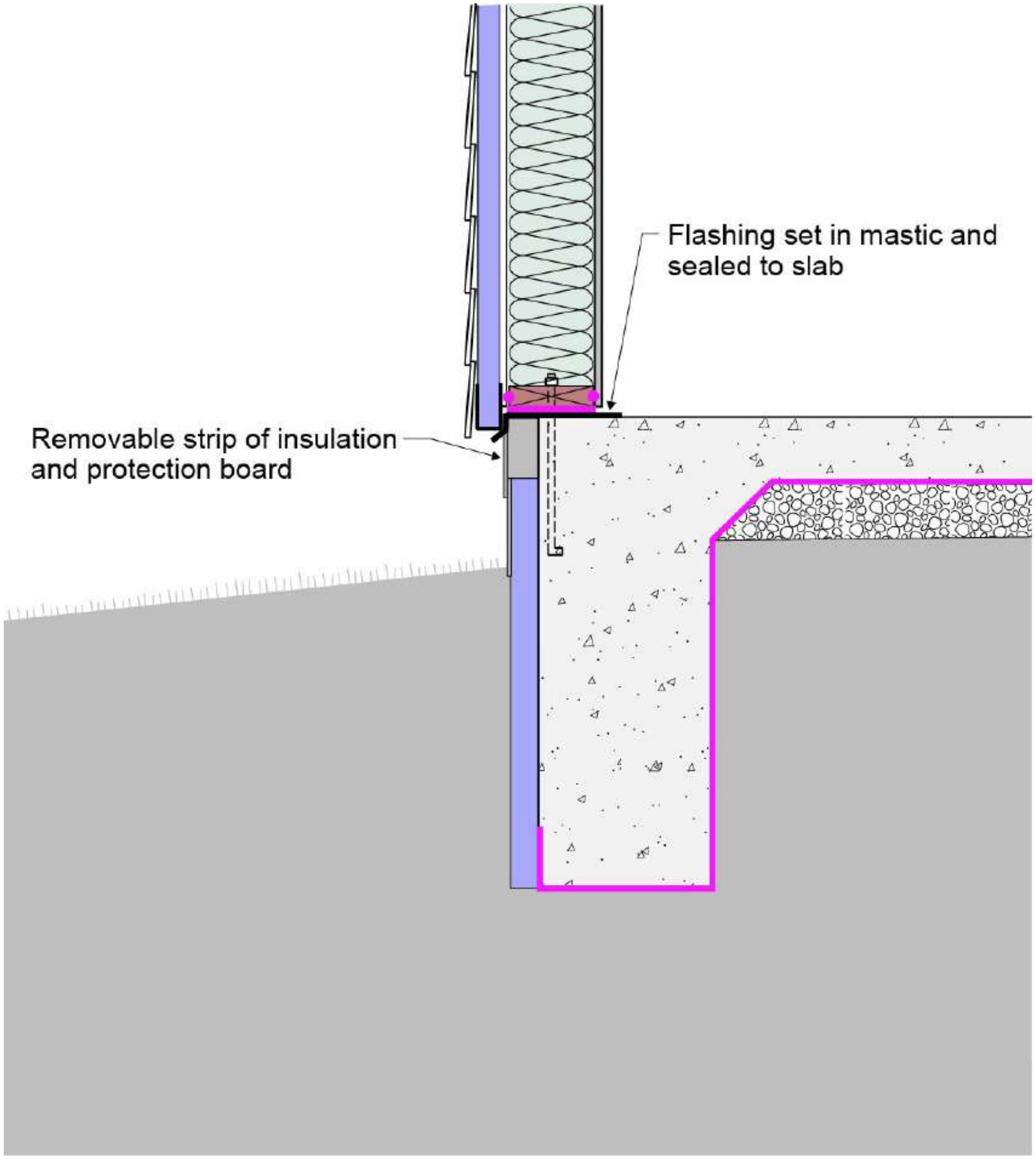

Roof flashing
Vent stack
Continuous polyethylene
vapor barrier/air barrier
(all joints taped)
Polyethylene
mechanically
attached to
foundation wall
perimeter and
sealed
Perforated drain pipe trench
covered with course gravel
(no fines)
Sealant at all penetrations in
air barrier
Perforated drain pipe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

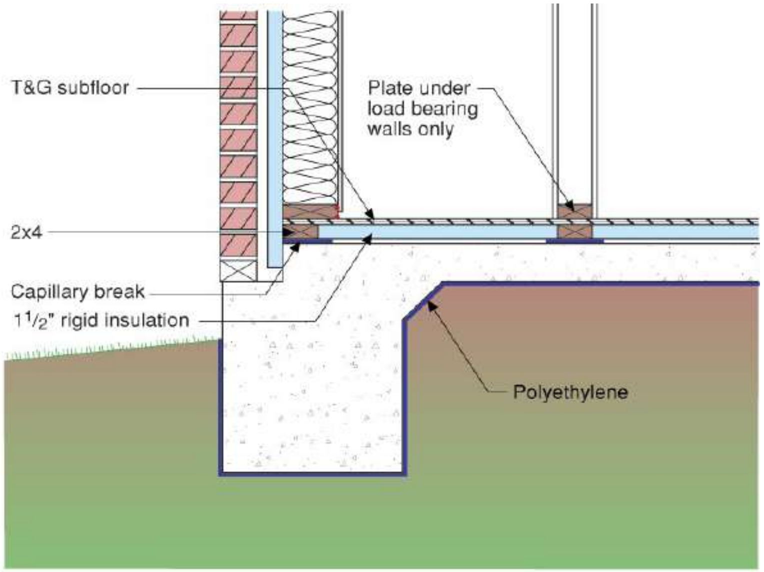

Roof flashing
Vent stack
Polyethylene vapor barrier
Concrete slab
Sealant at all penetrations in air barrier
Perforated drain pipe added to "T" in order to couple sub-slab pressure field to vent stack

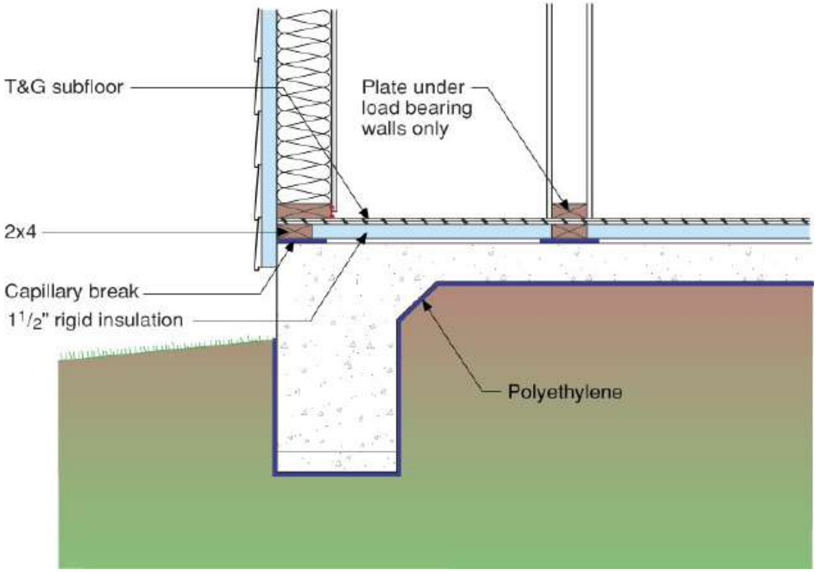

Cavity insulation
Gypsum board
Sealant, adhesive or gasket
Sill gasket
Masticed membrane strip
Rigid insulation as bond break material
Polyethylene vapor barrier
Cladding
Continuous exterior insulation
Rodent protection for continuous rigid insulation
For insect protection provide 3'-0" of mulch and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



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
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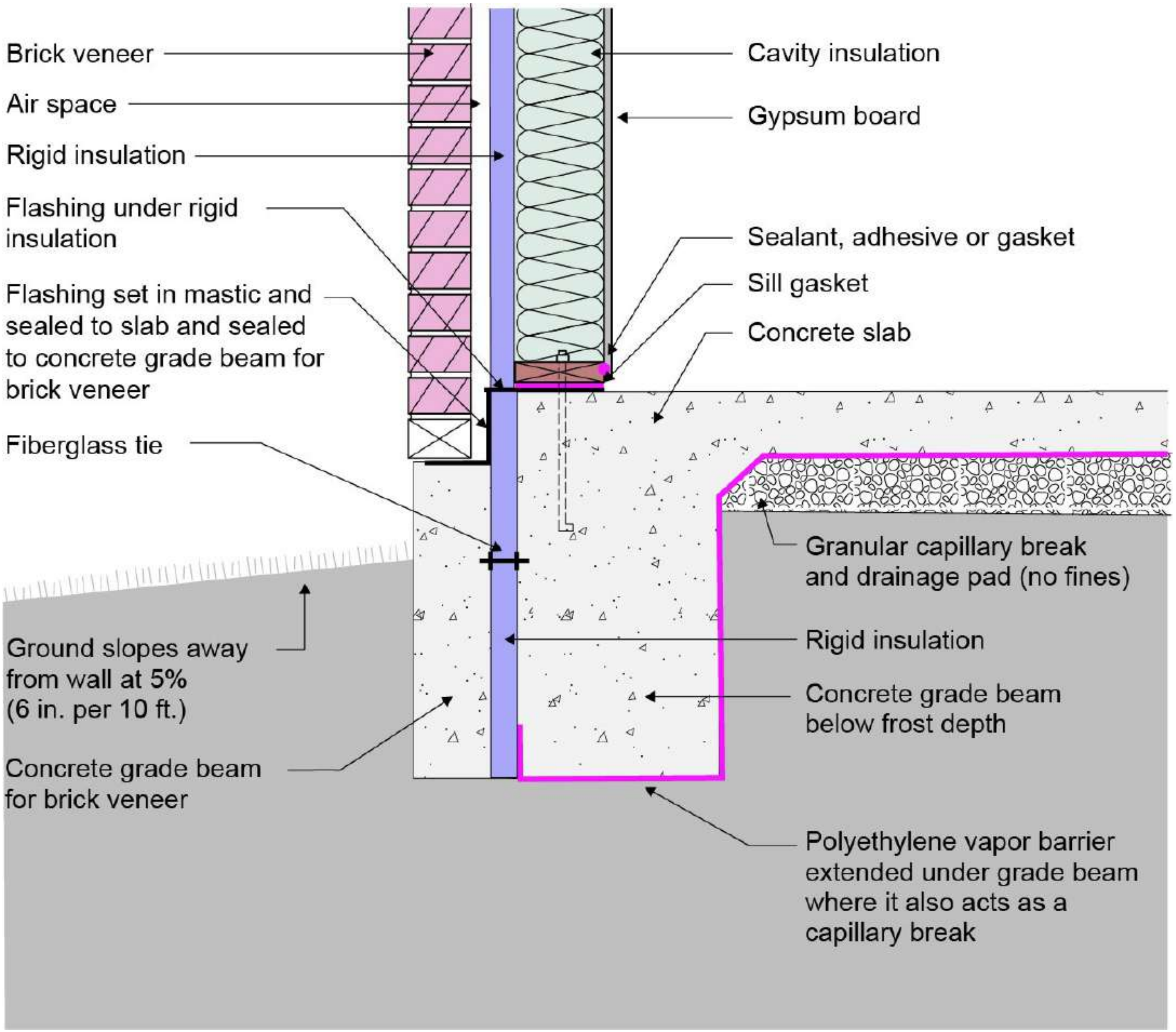
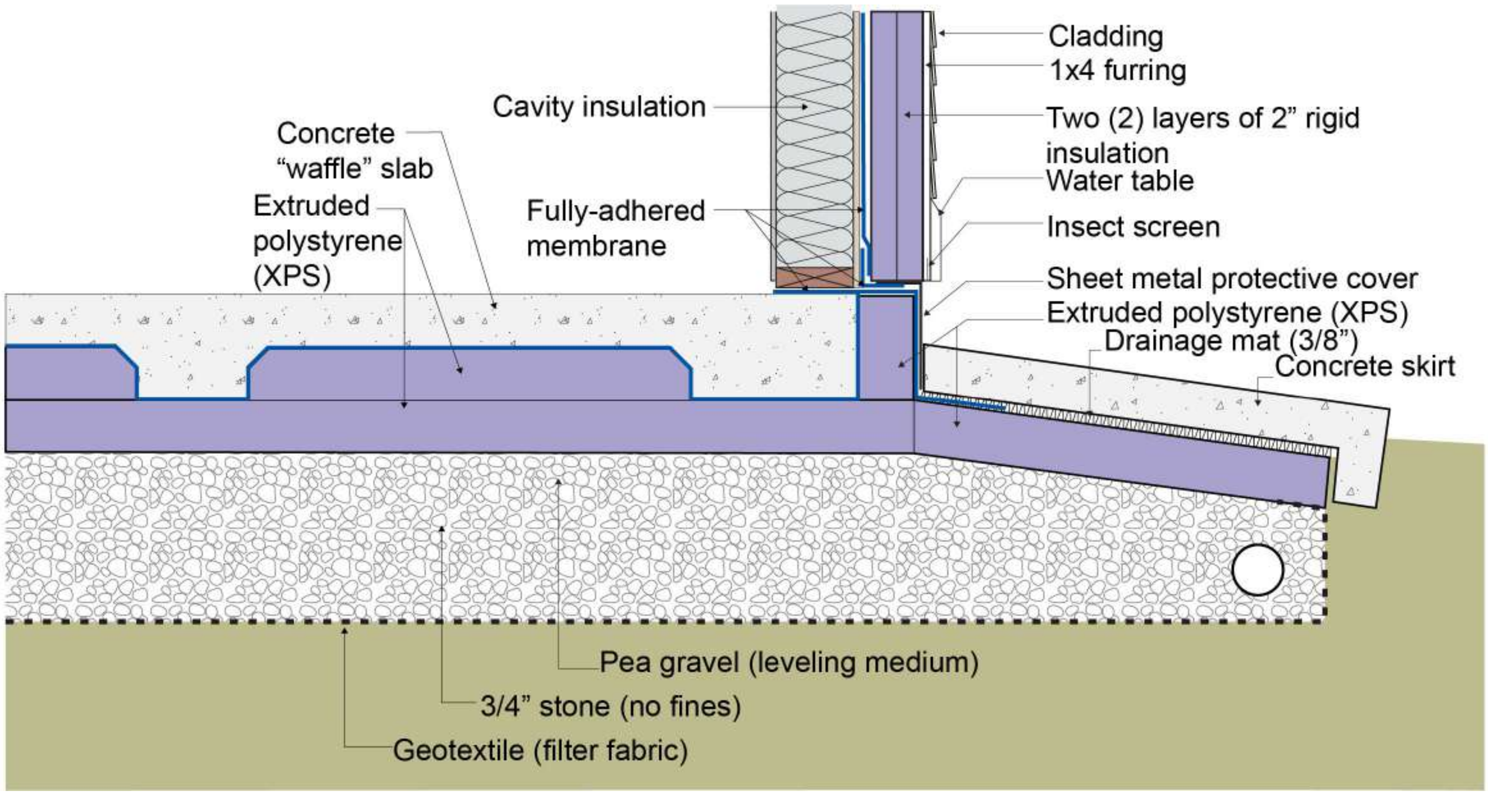

Brick veneer
Air space
Rigid insulation
Flashing under rigid insulation
Flashing set in mastic and sealed to slab and sealed to concrete grade beam for brick veneer
Fiberglass tie
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Concrete grade beam for brick veneer
Cavity insulation
Gypsum board
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)