

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

Building Science

Adventures In Building Science

www.buildingscience.com

What is a Building?

A Building is an Environmental Separator

- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and rigidity
- Be durable
- Be aesthetically pleasing
- Be economical

Arrhenius Equation

For Every 10 Degree K Rise
Reaction Rate Doubles

$$k = Ae^{-E_a/(RT)}$$

Damage Functions

Water

Heat

Ultra-violet Radiation

2nd Law of Thermodynamics

Heat Flow Is From Warm To Cold

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Air Flow Is From A Higher Pressure to a
Lower Pressure

Gravity Acts Down

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Vapor Diffusion

Thermodynamic Potential



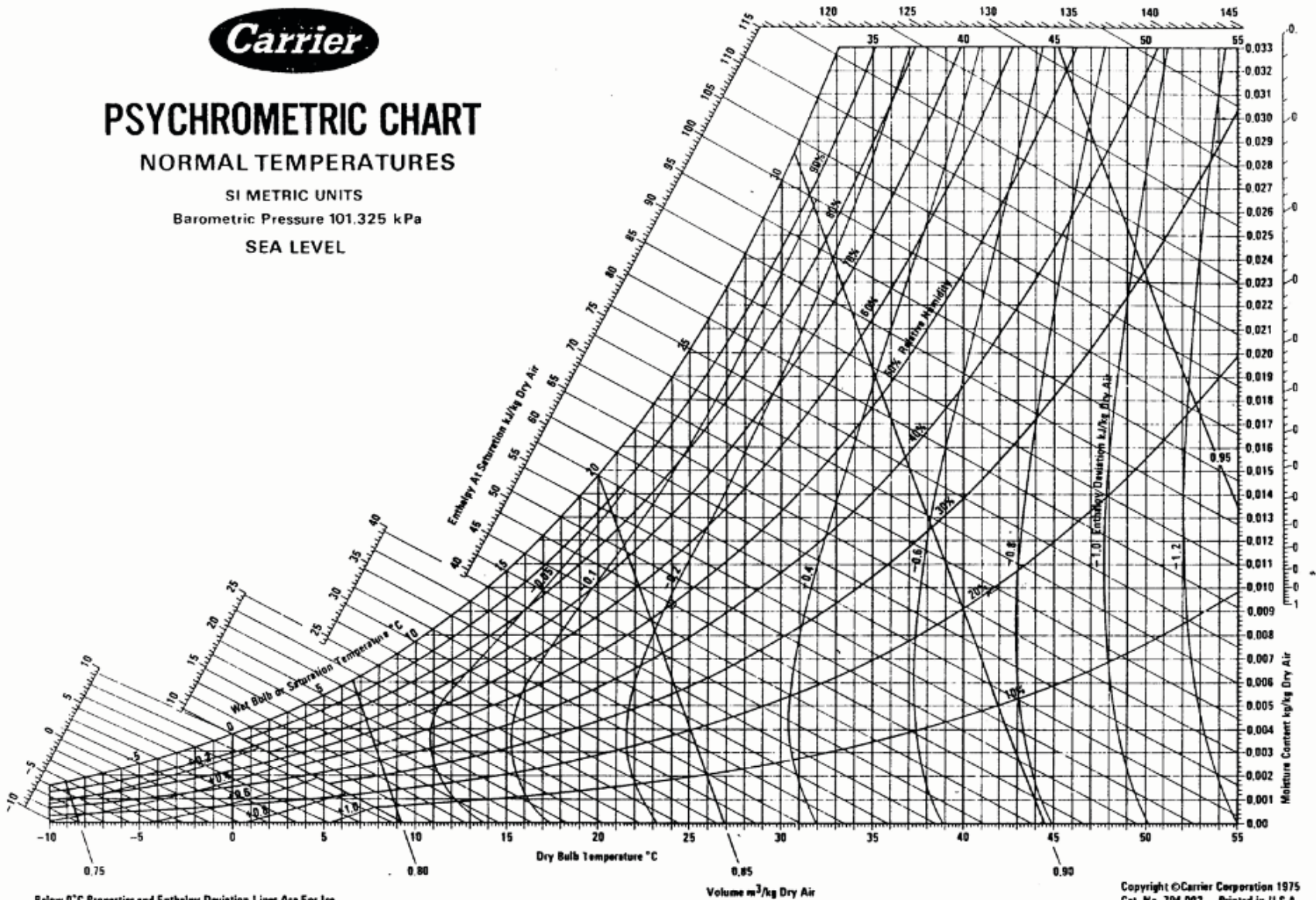
PSYCHROMETRIC CHART

NORMAL TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101.325 kPa

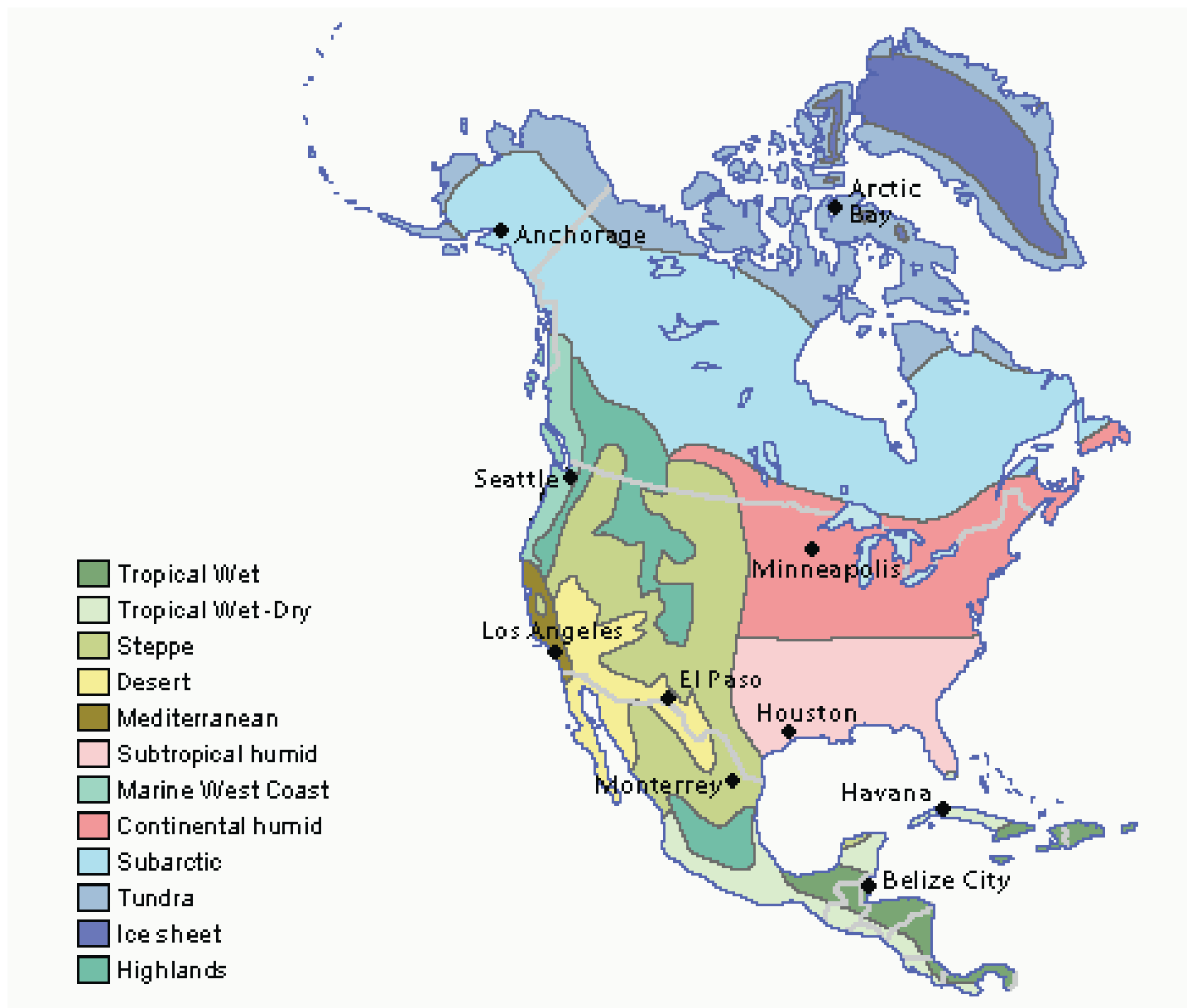
SEA LEVEL



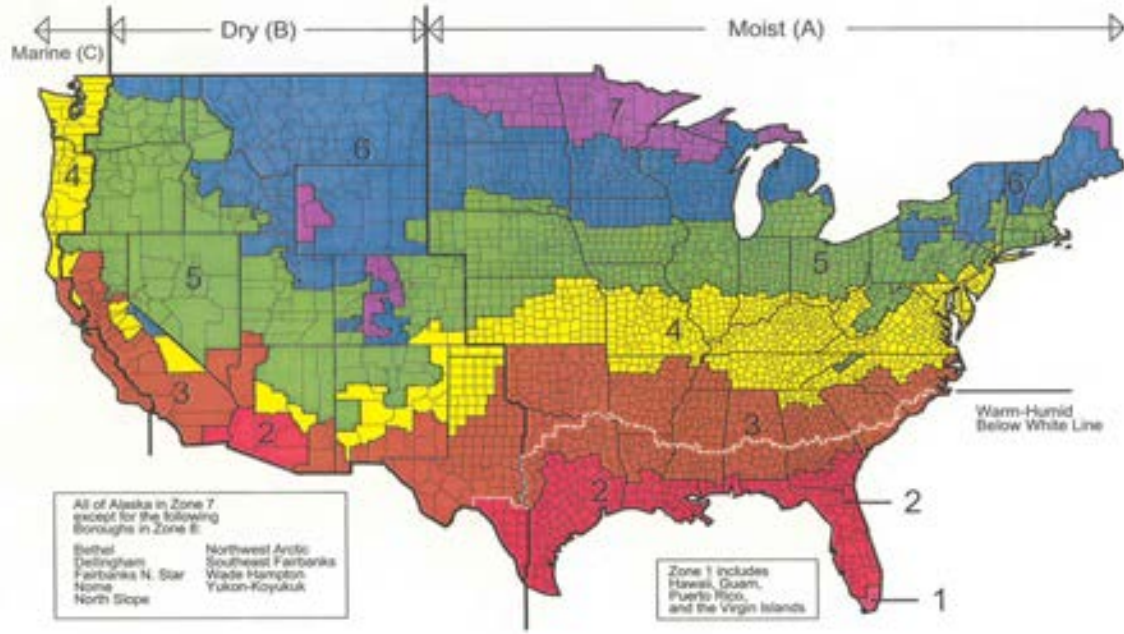
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice

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Map of DOE's Proposed Climate Zones

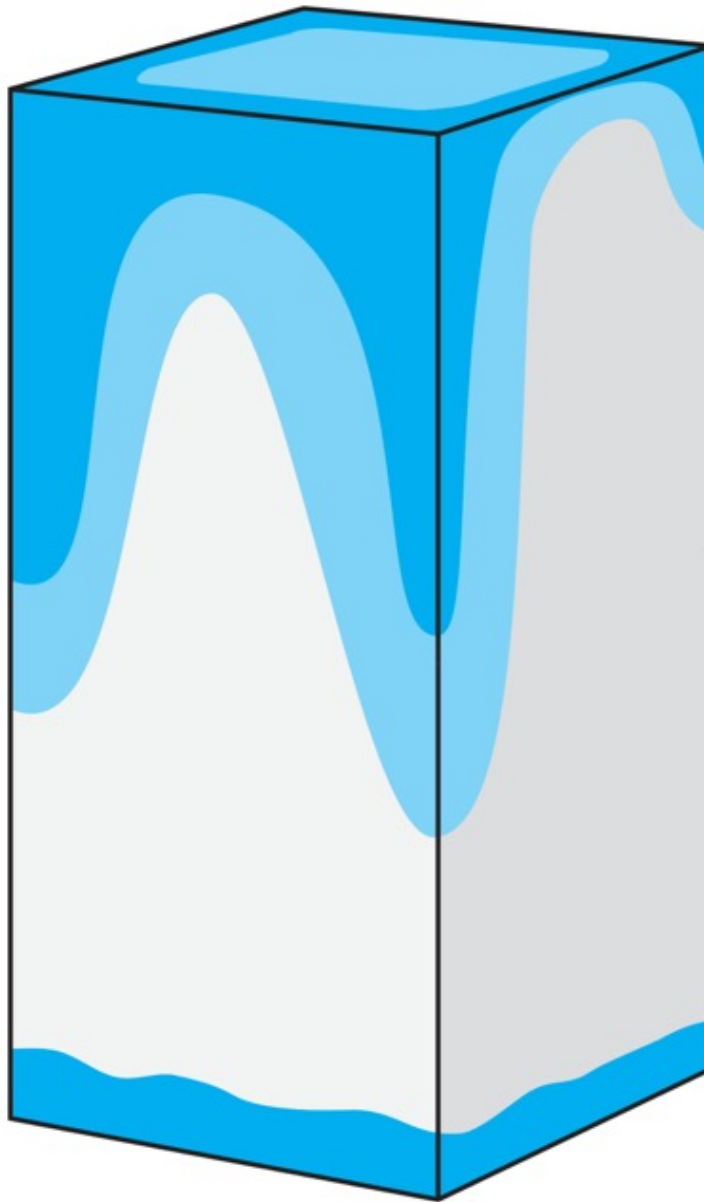


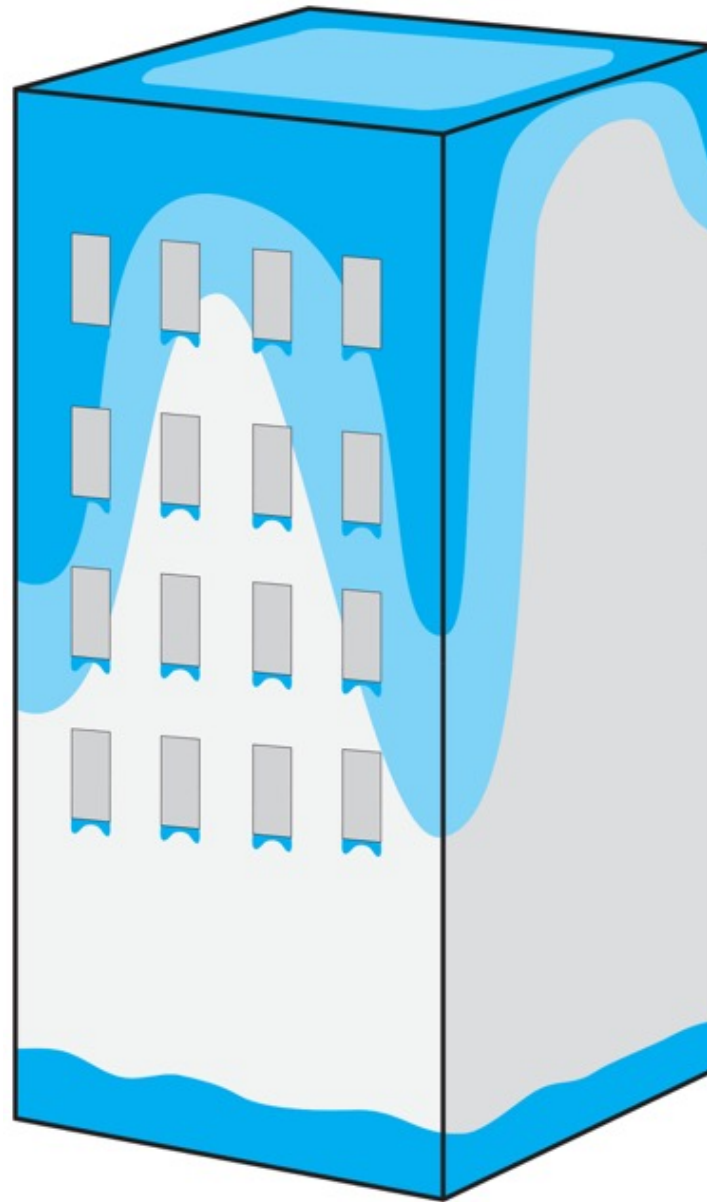
March 24, 2003



Exposure

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



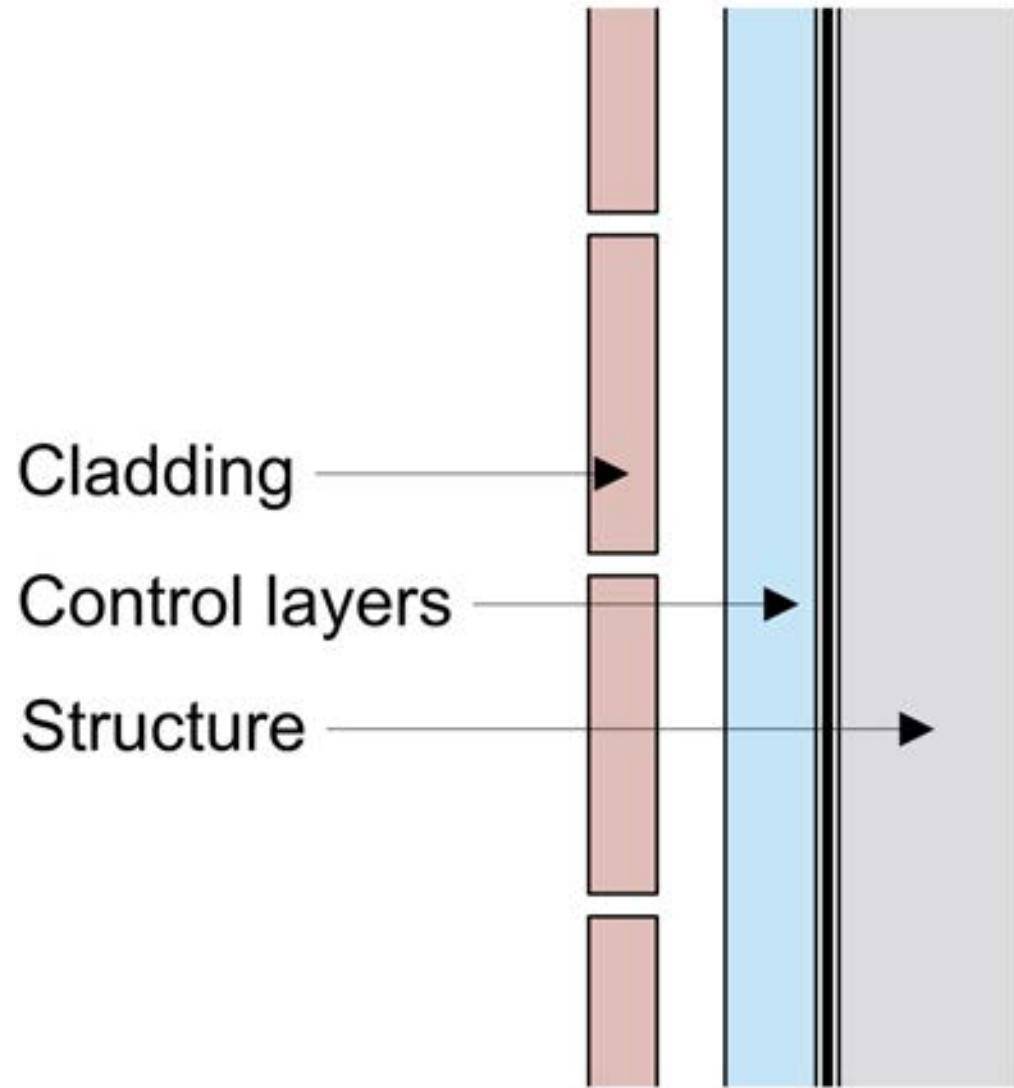


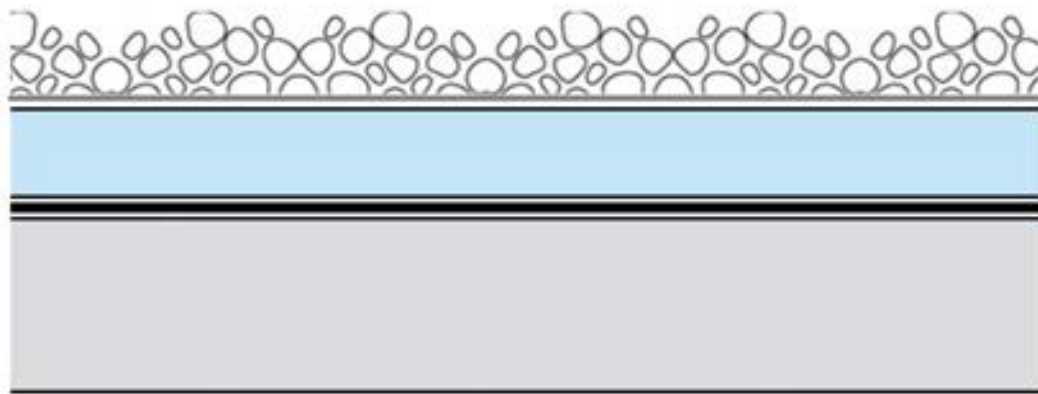
Water Control Layer

Air Control Layer

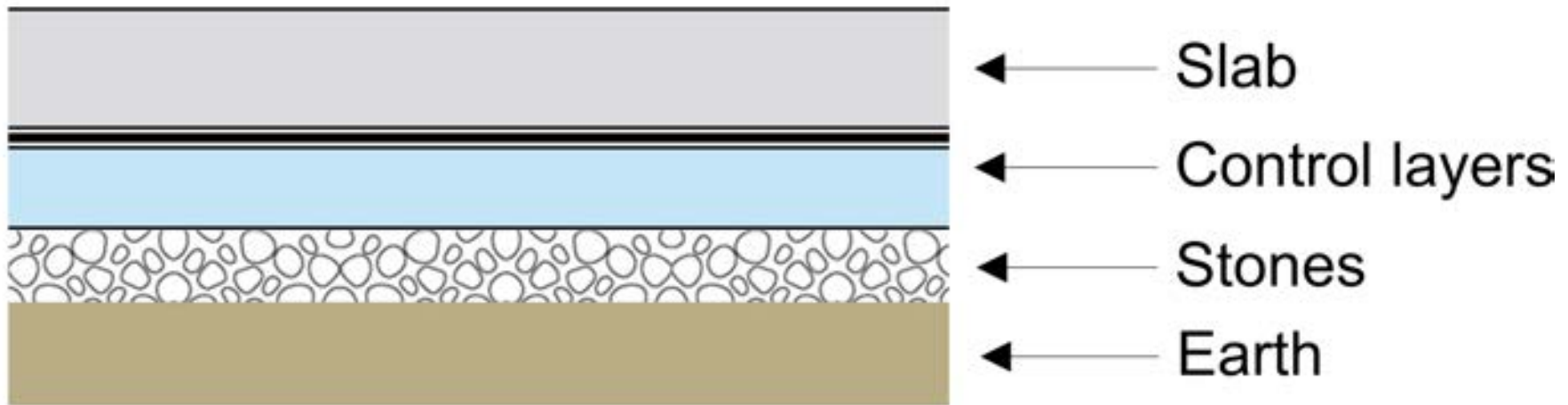
Vapor Control Layer

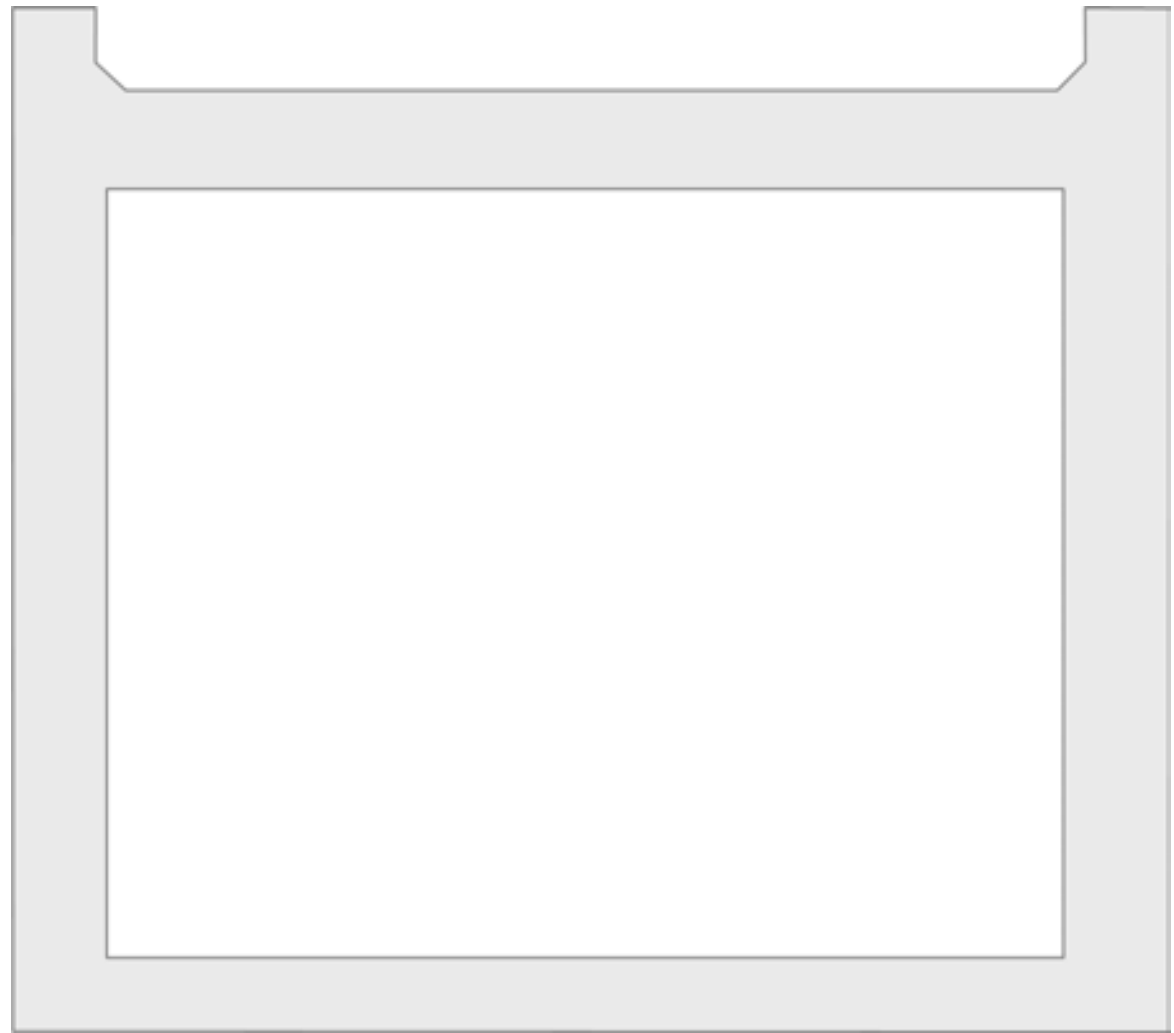
Thermal Control Layer



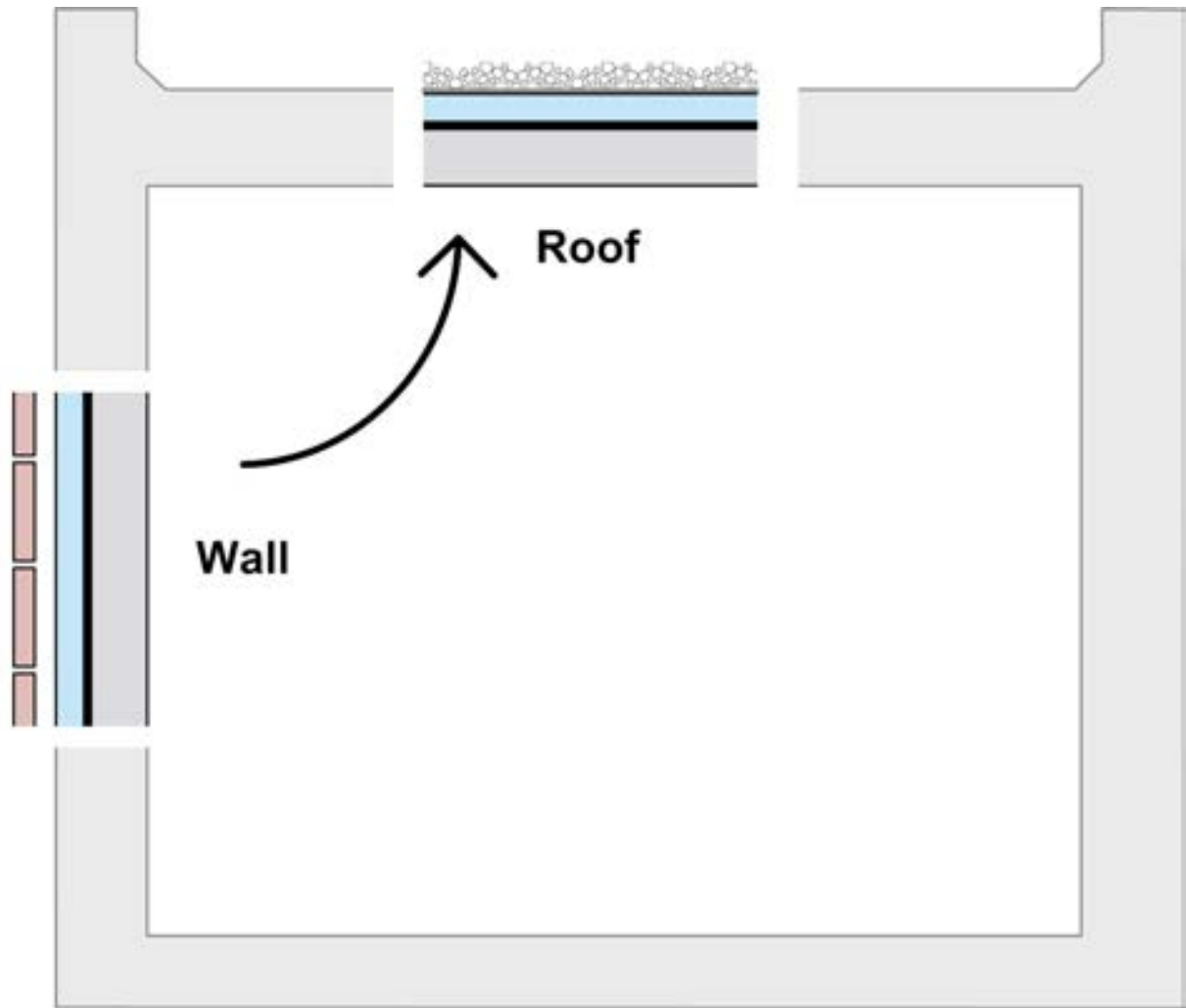


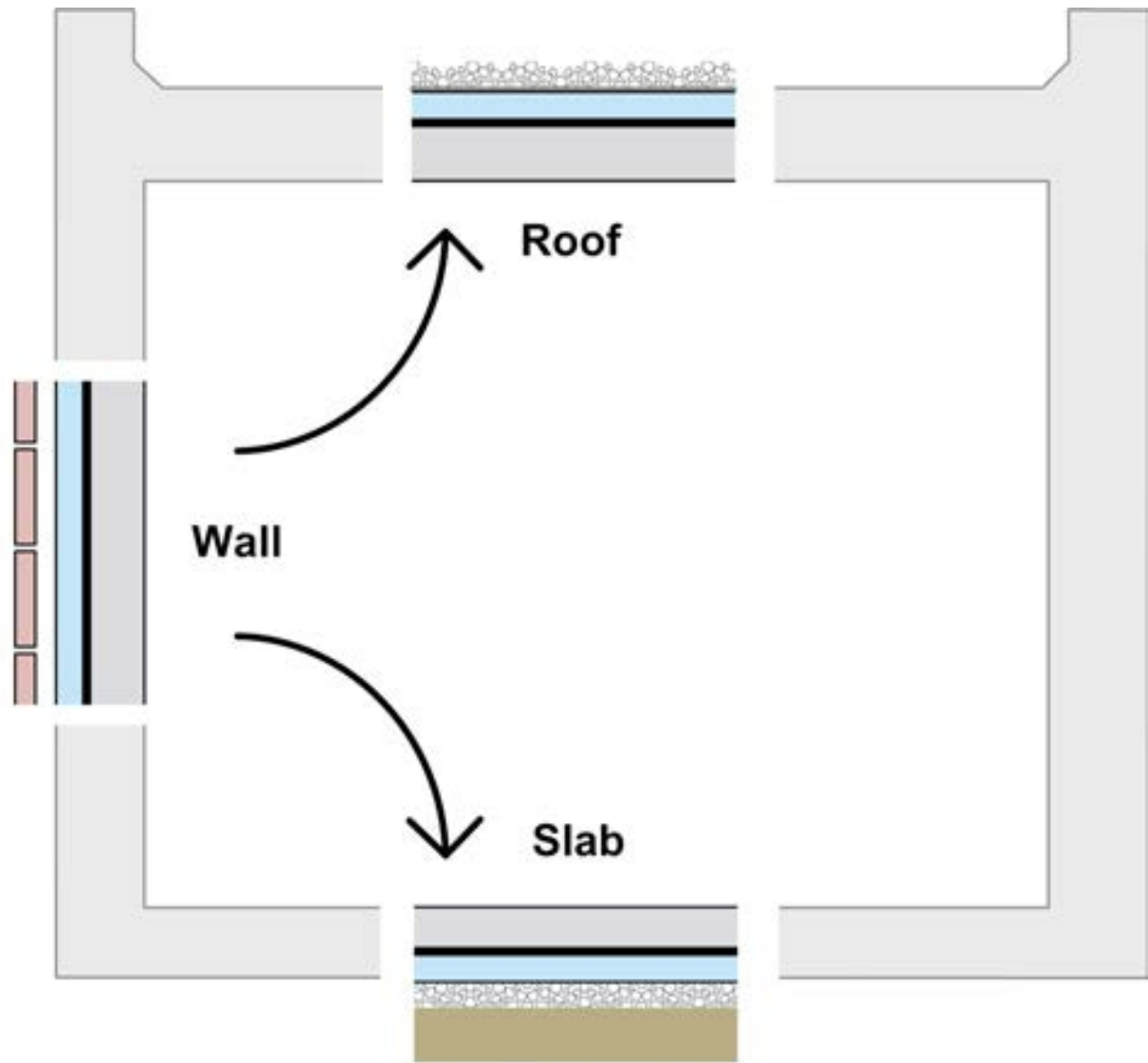
- ← Ballast
- ← Filter fabric
- ← Control layers
- ← Roof structure

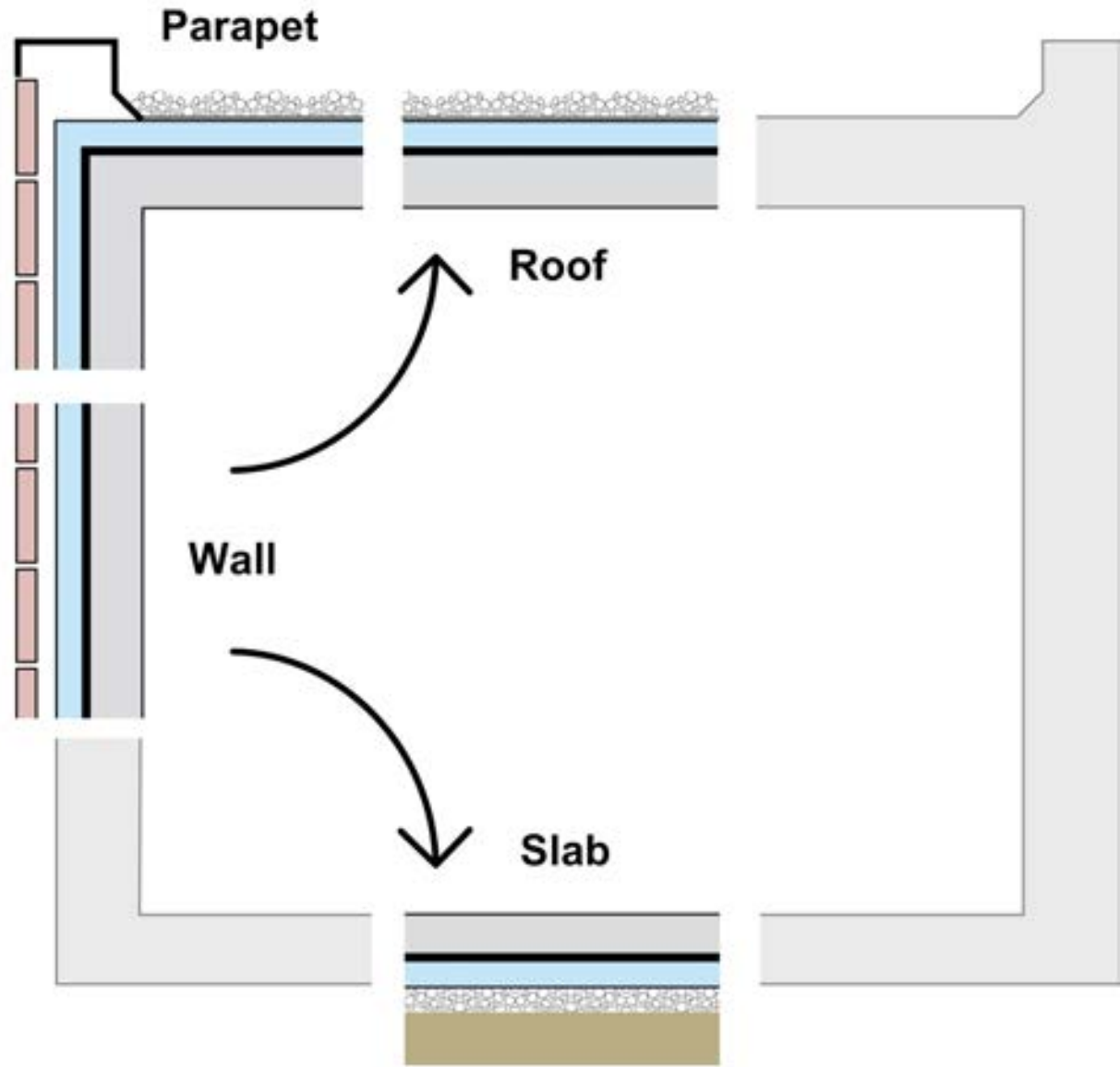


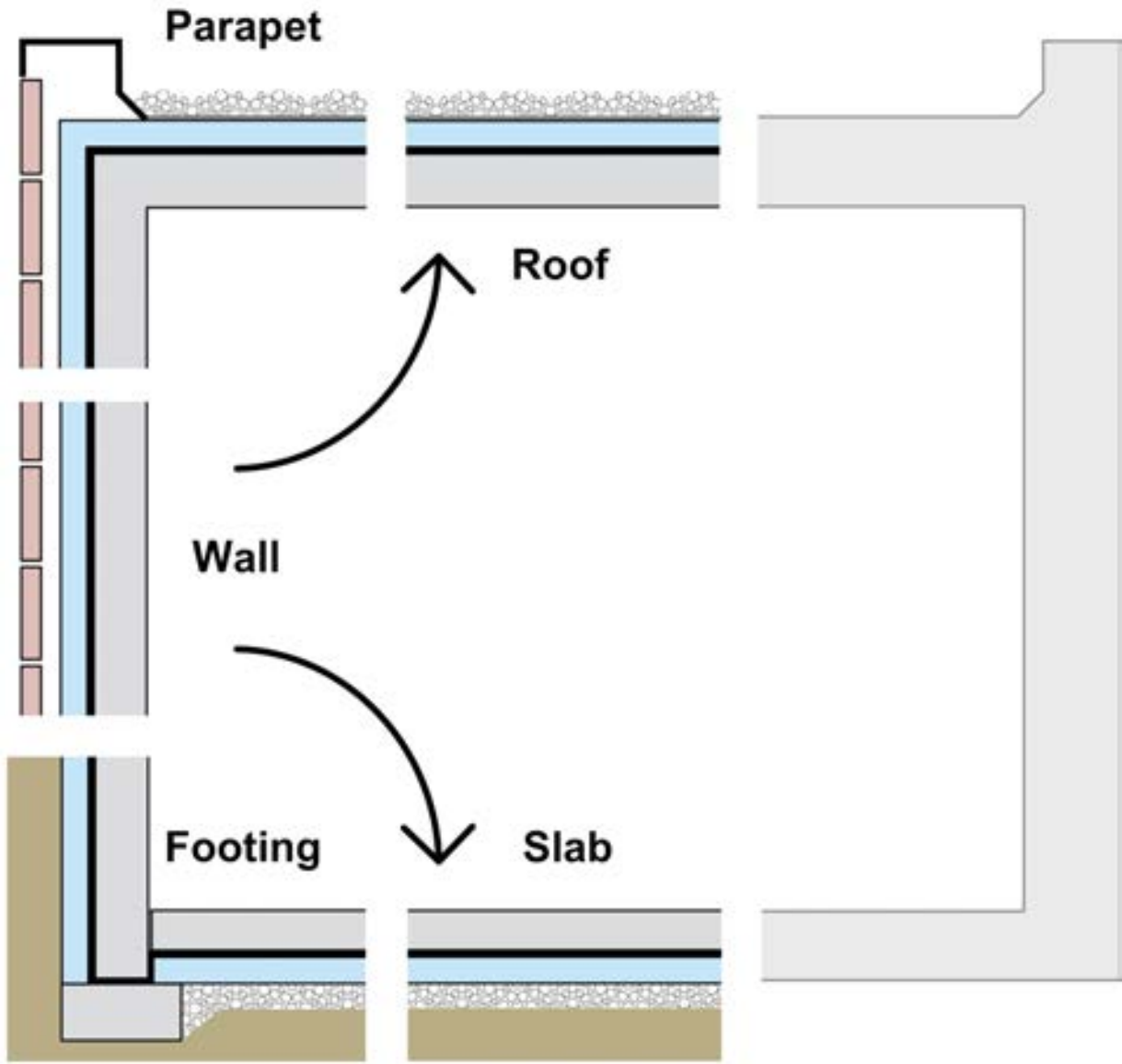


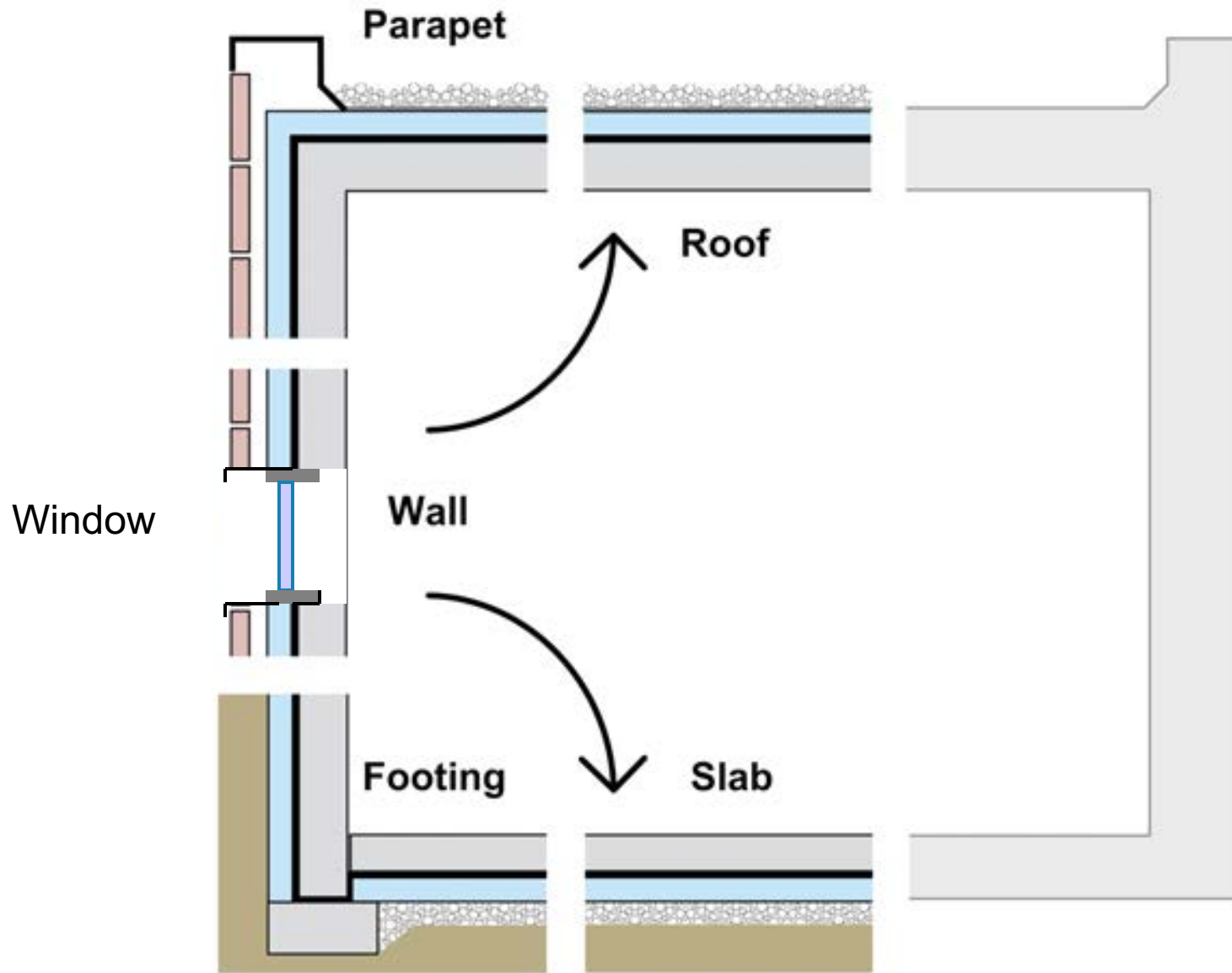




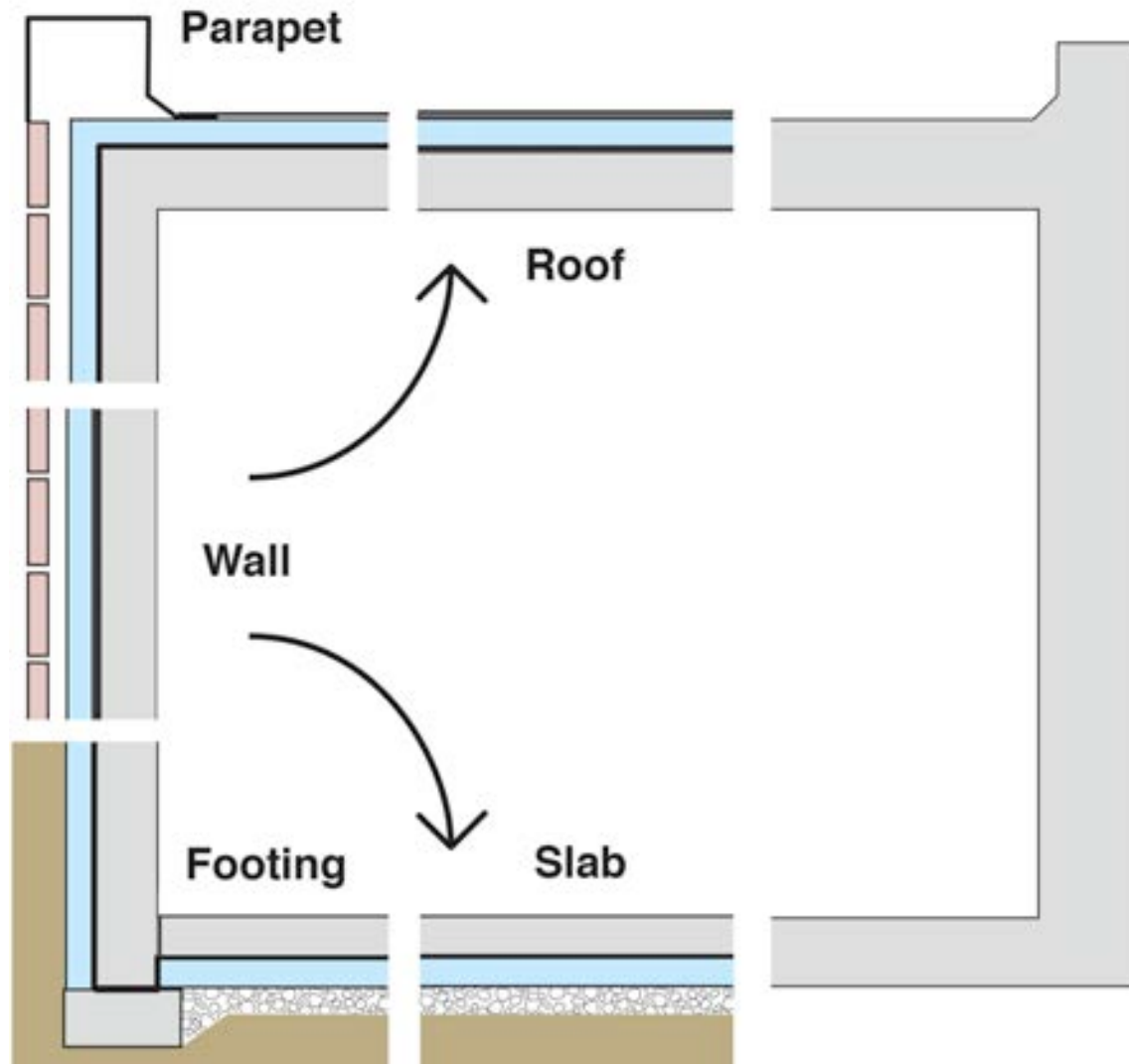


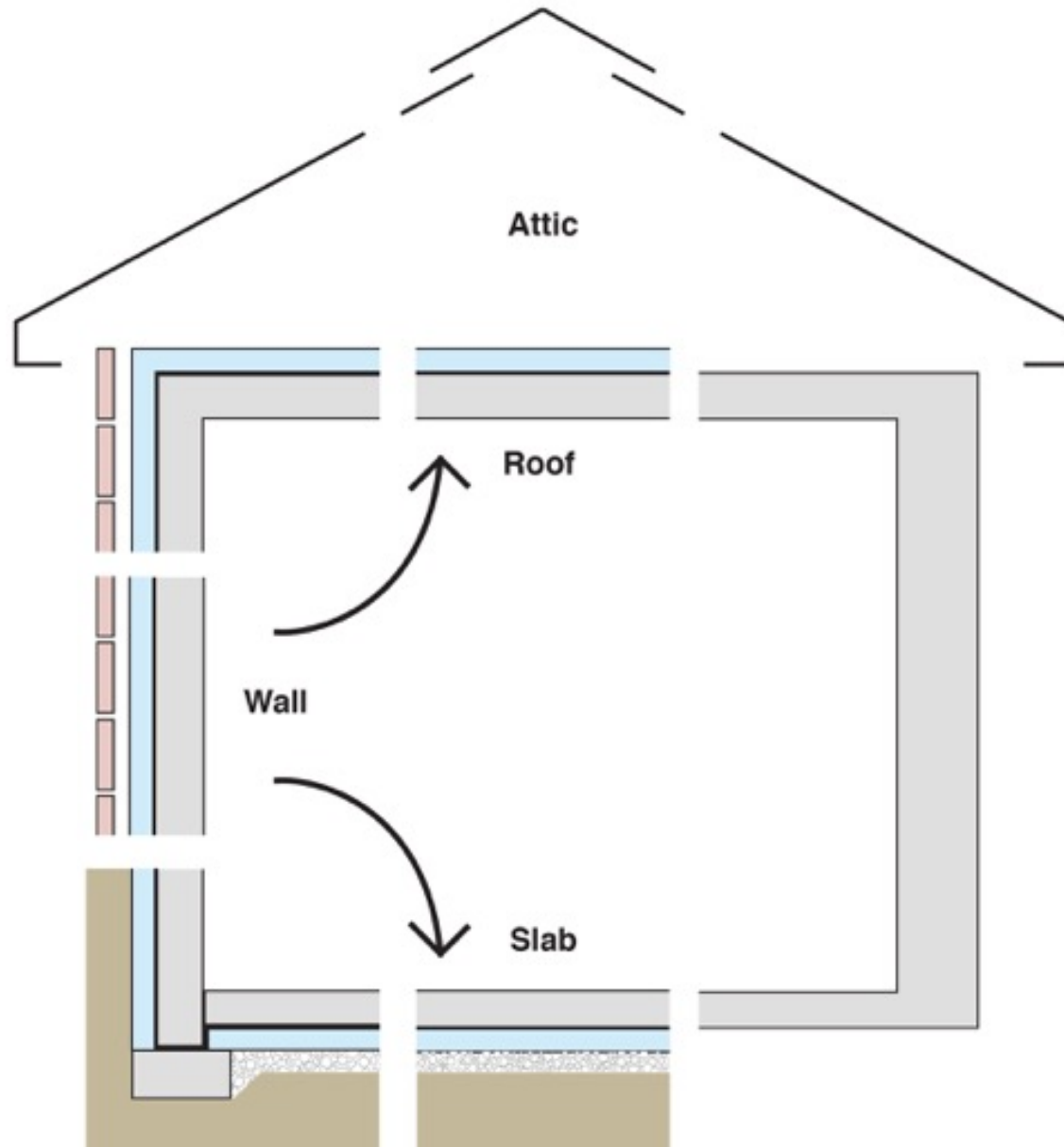


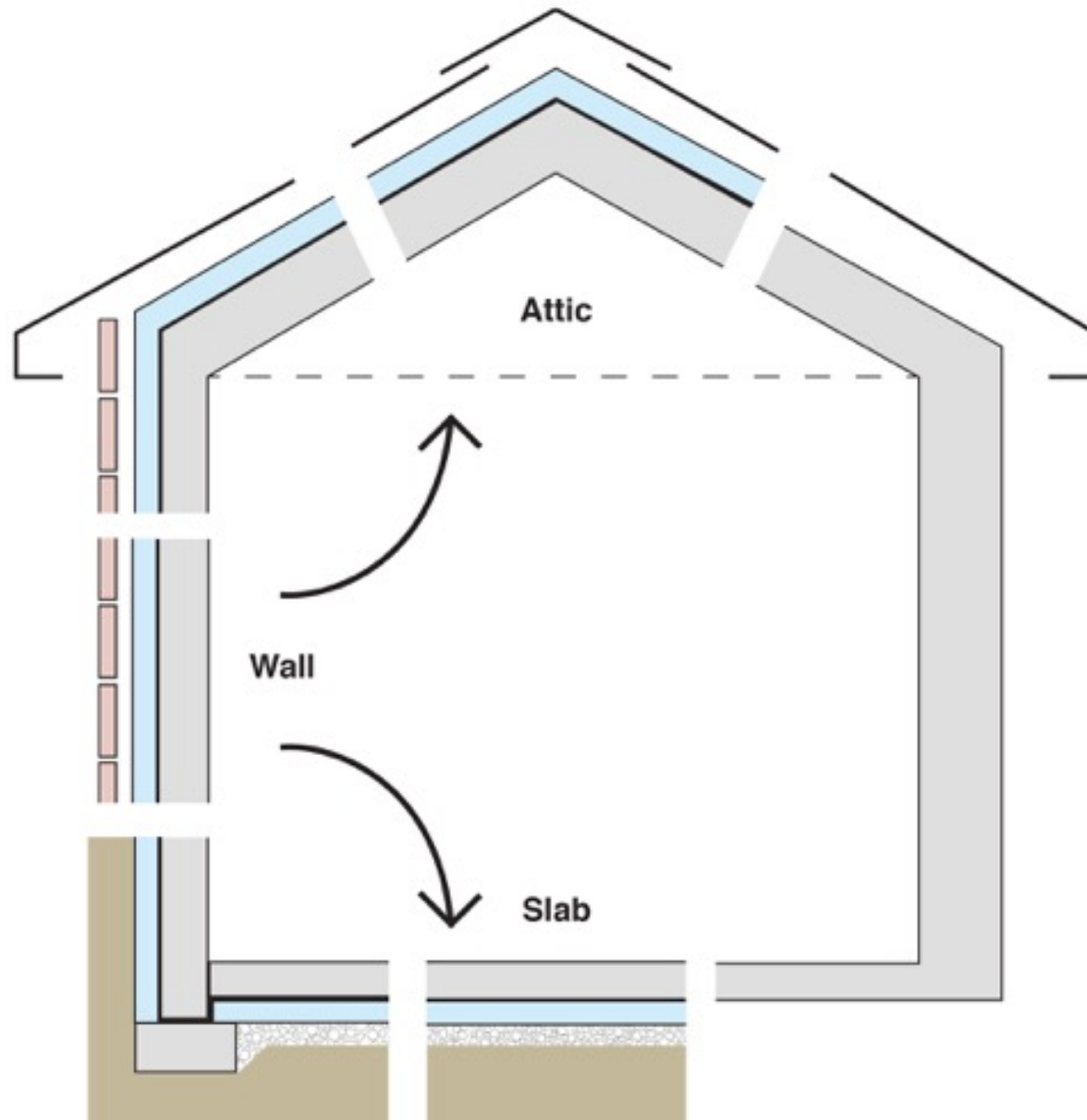


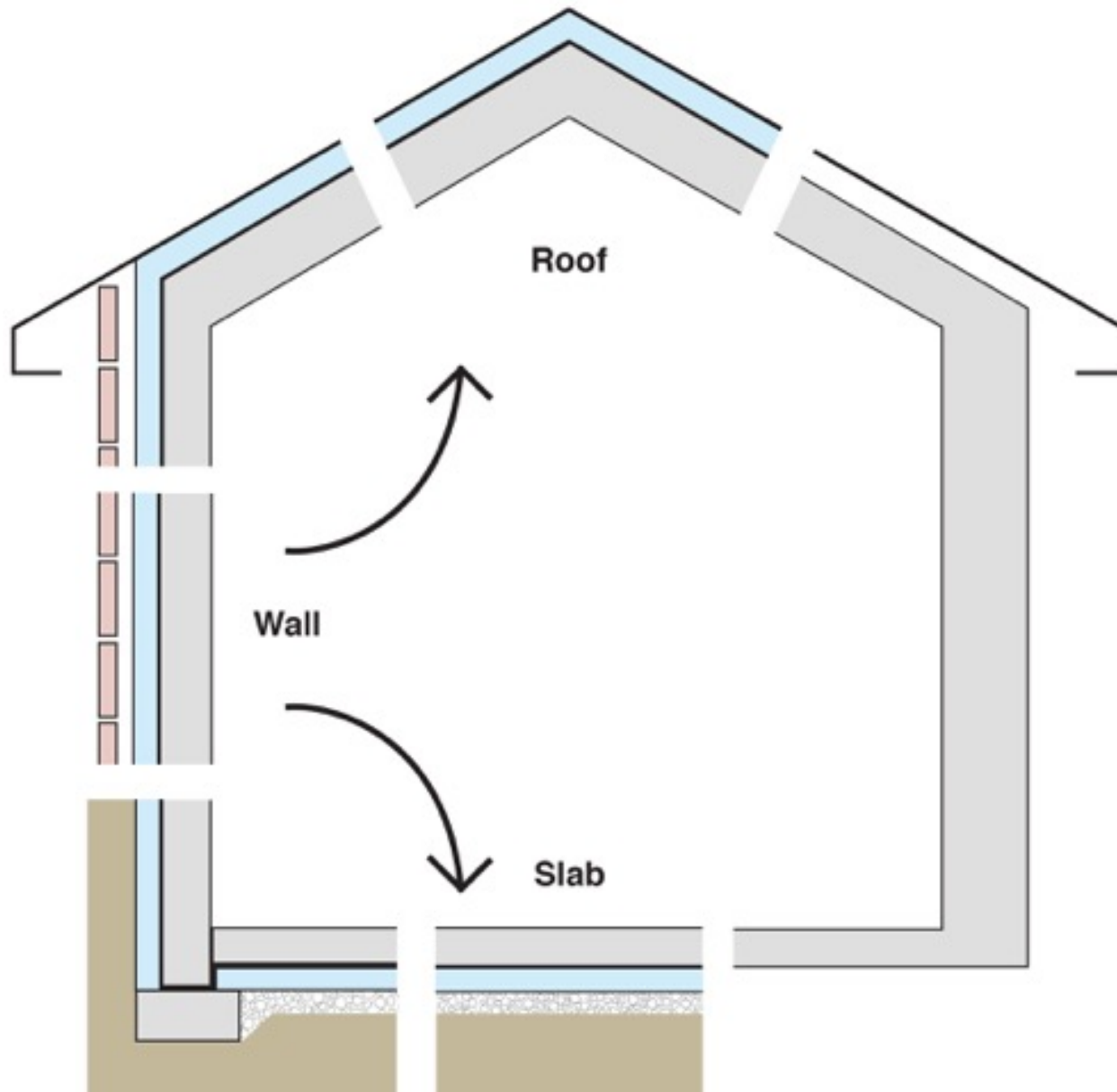


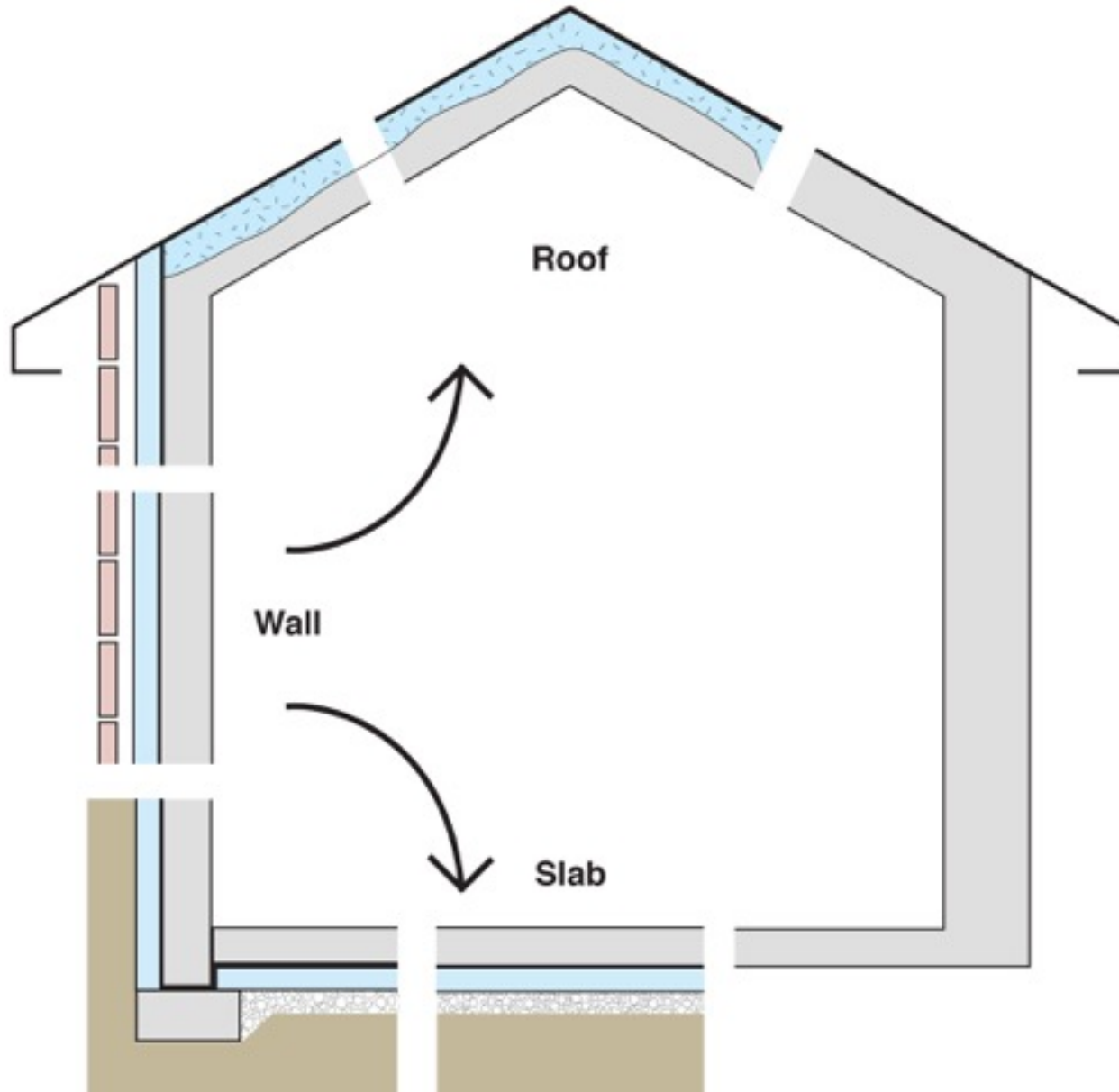




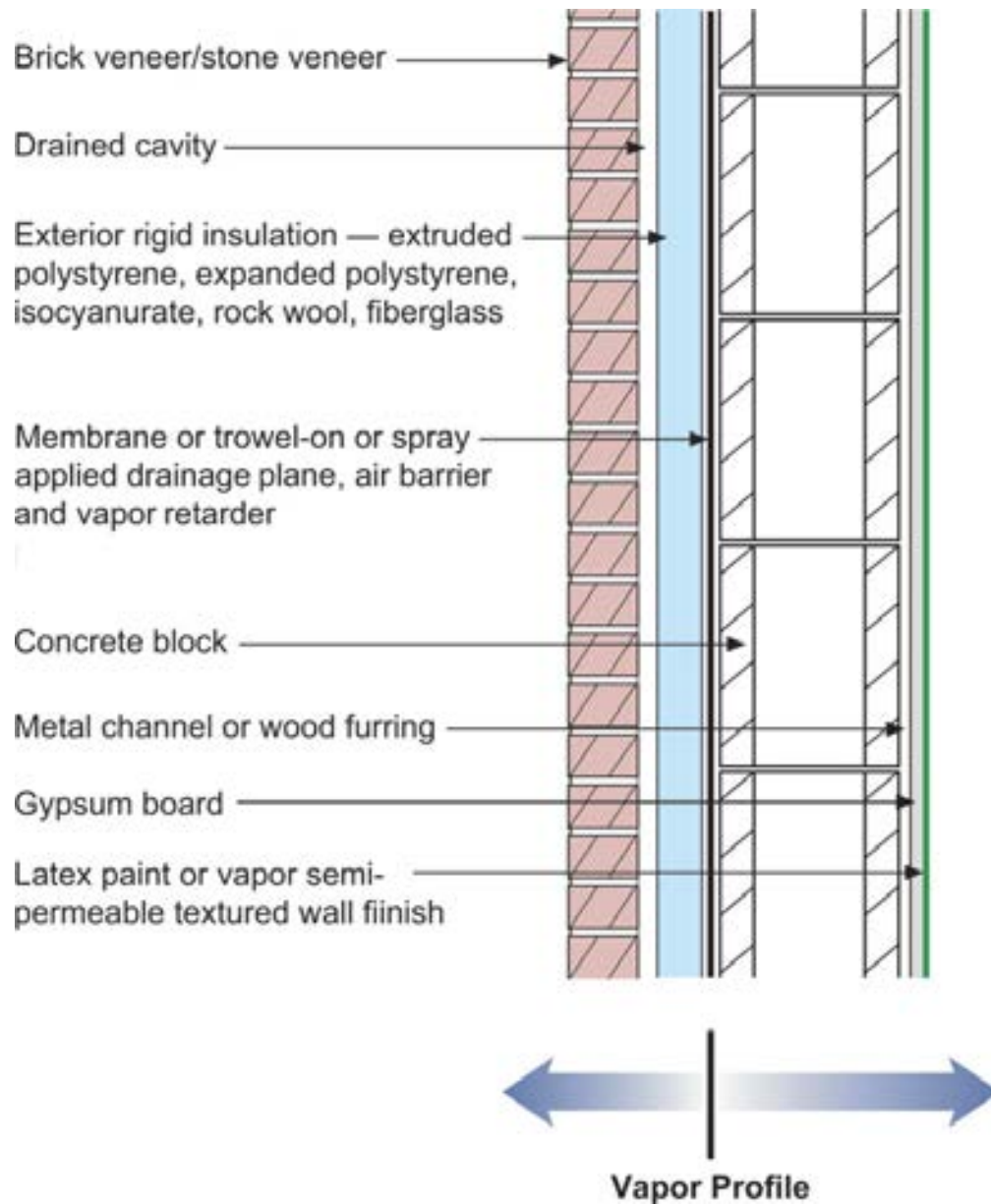


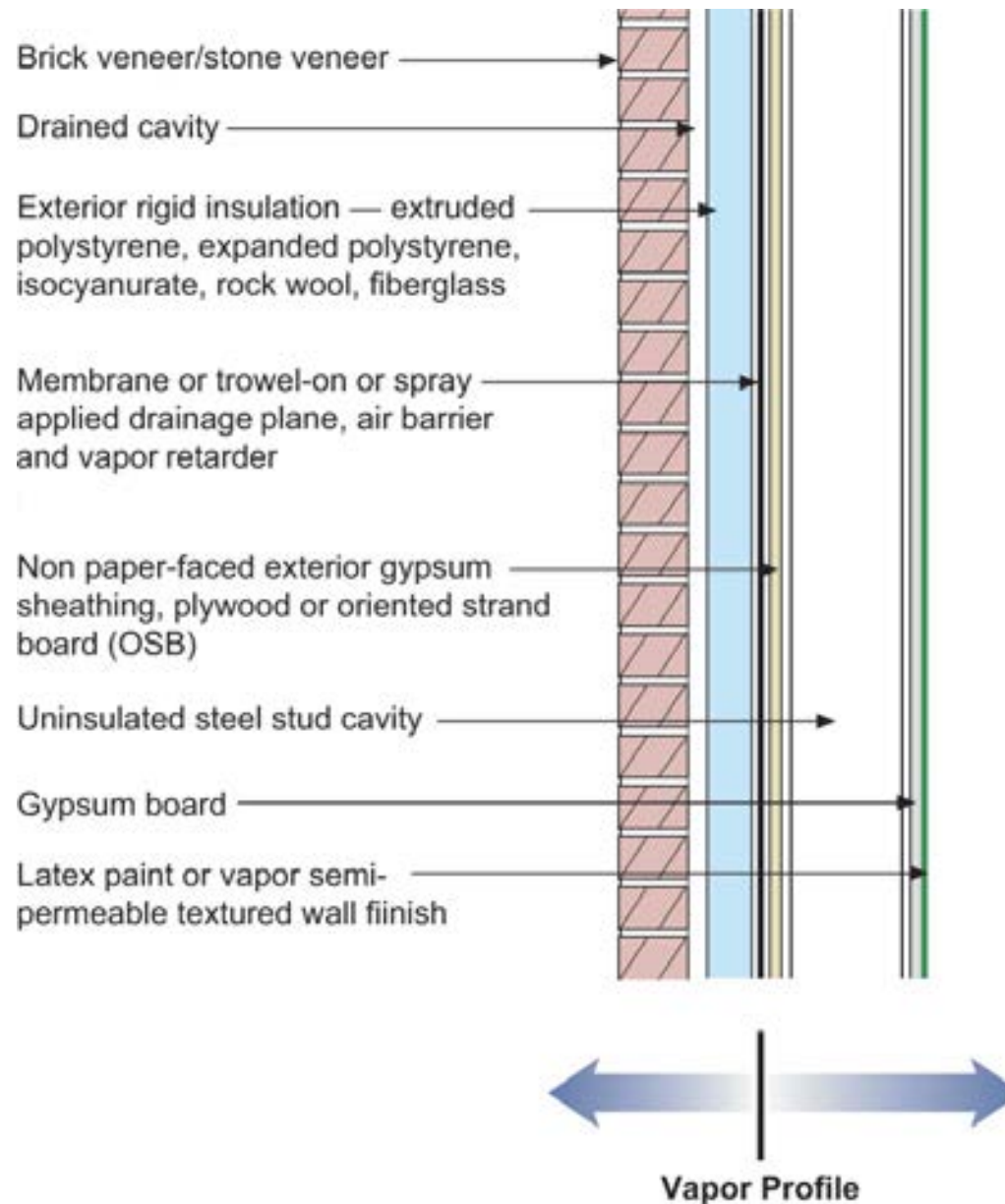


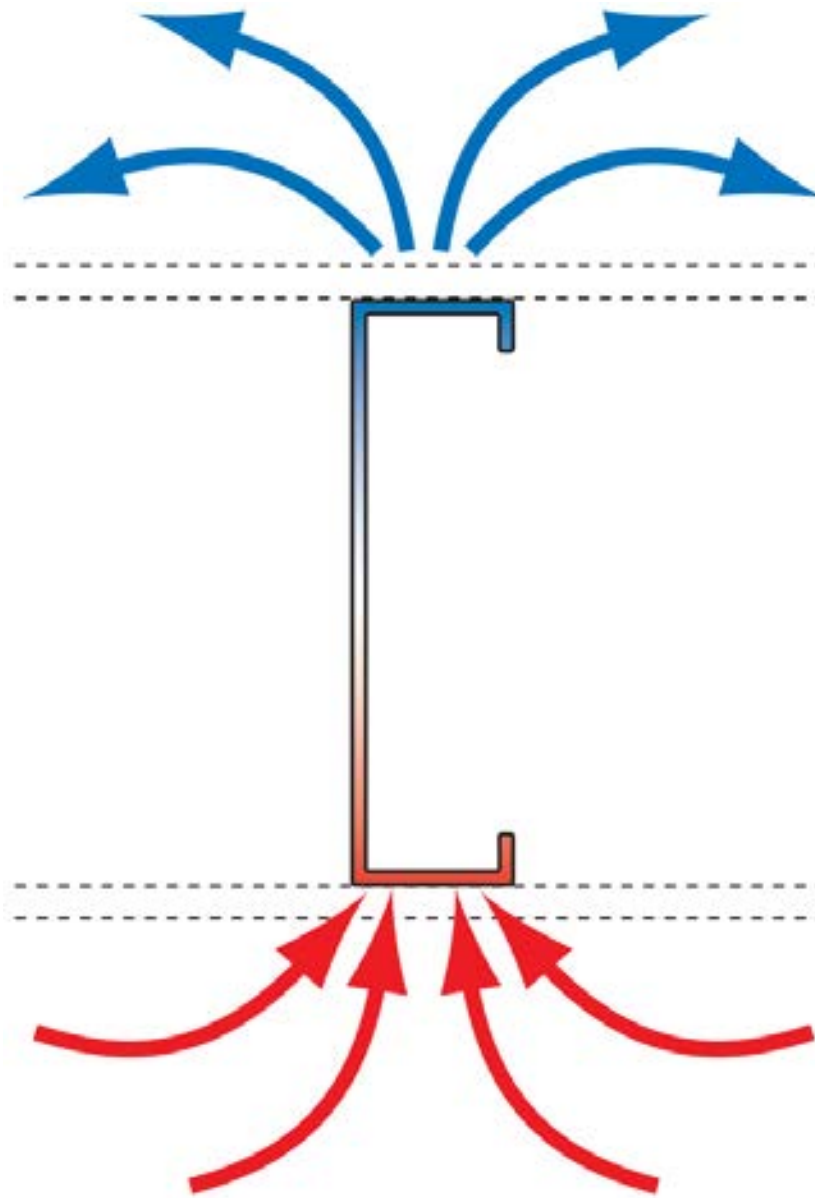




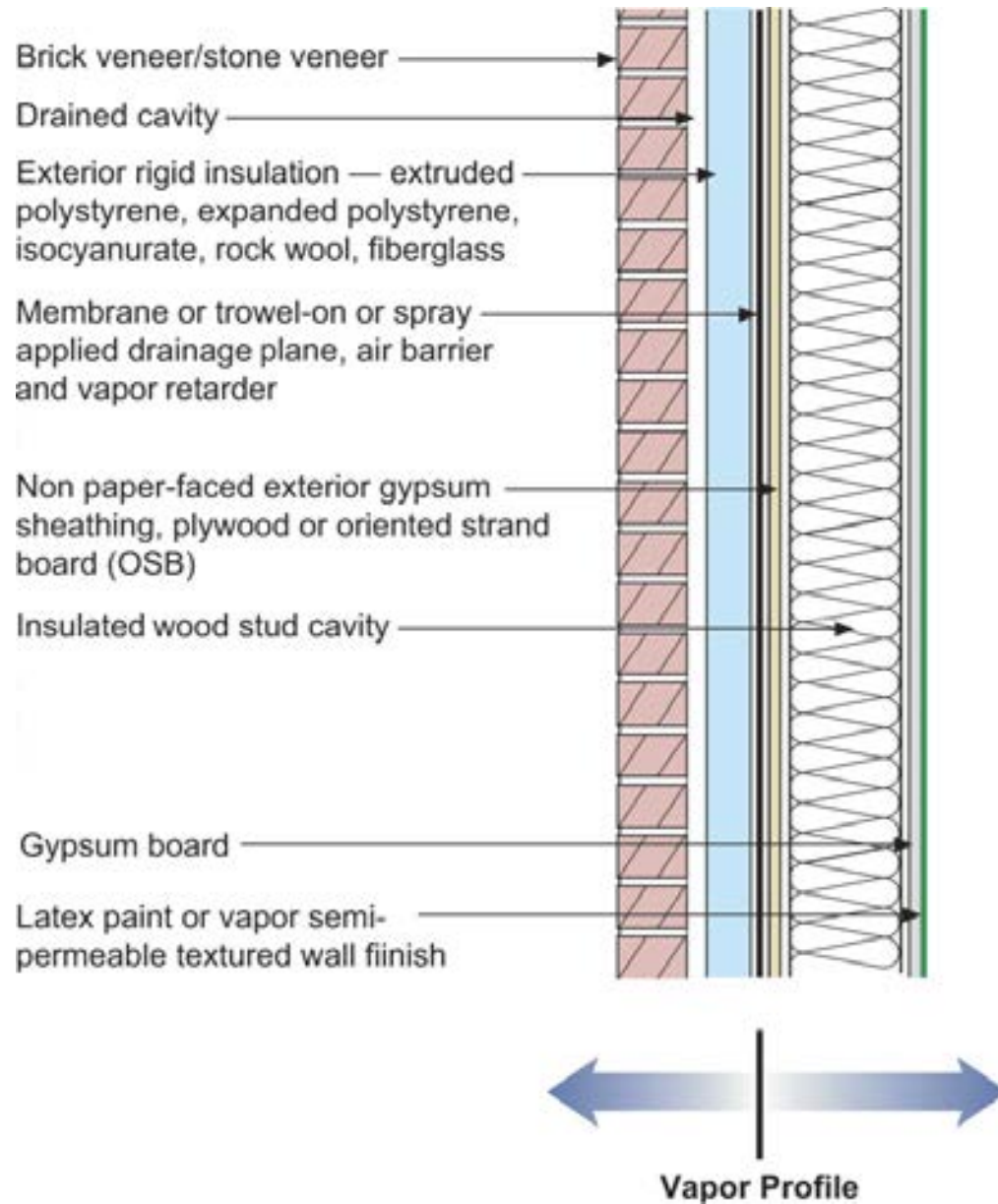
Configurations of the Perfect Wall







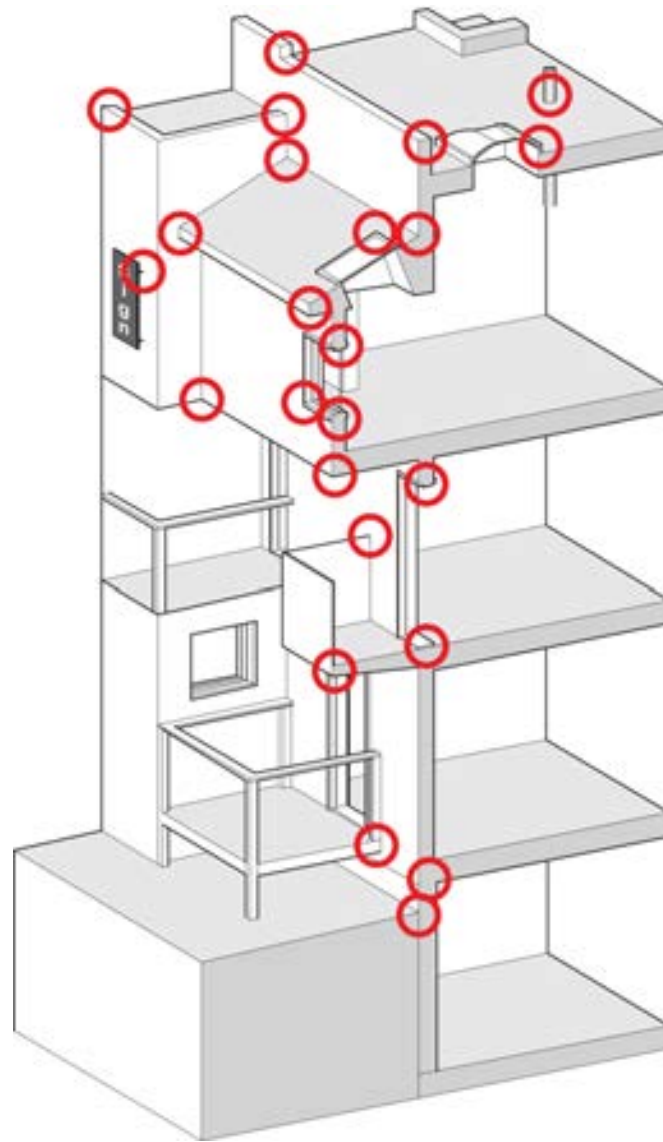




Commercial Enclosure: Simple Layers



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



























































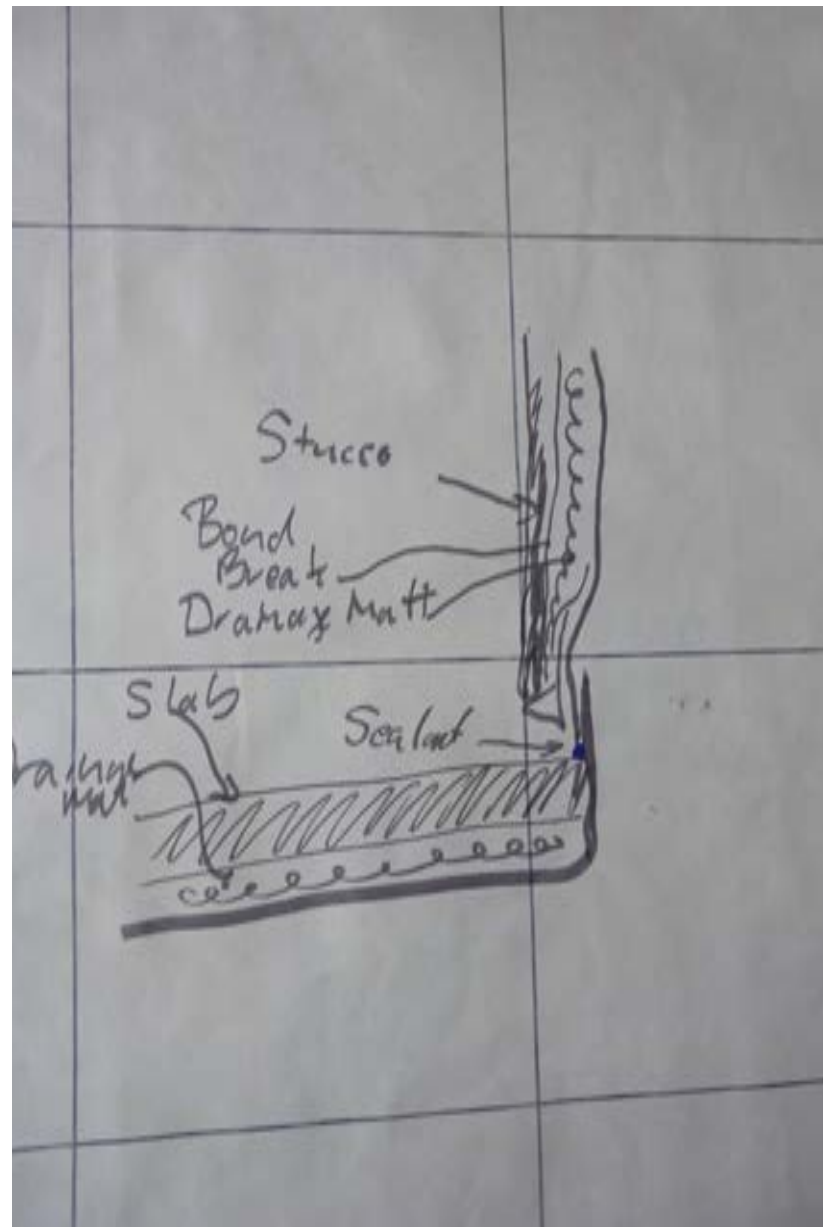
































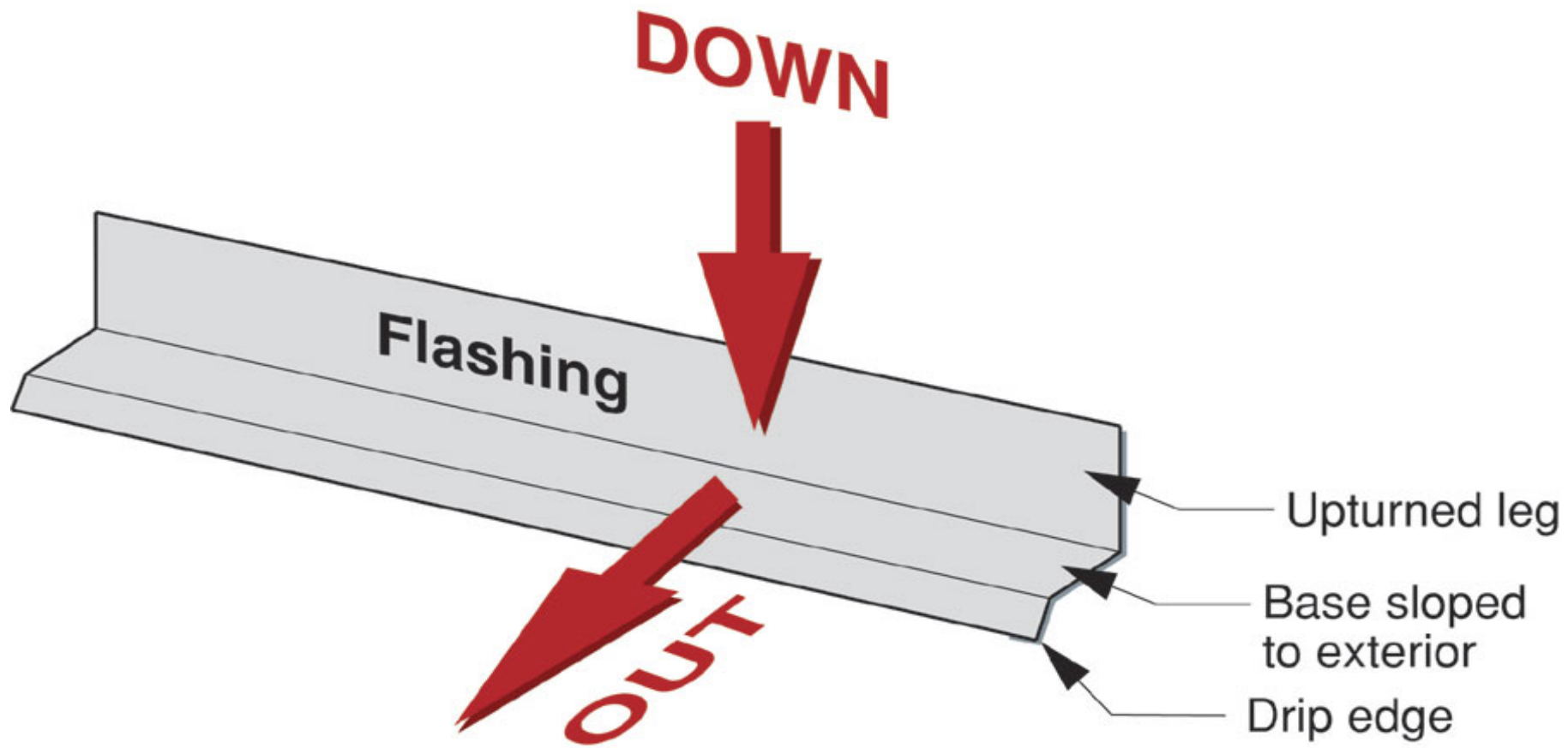


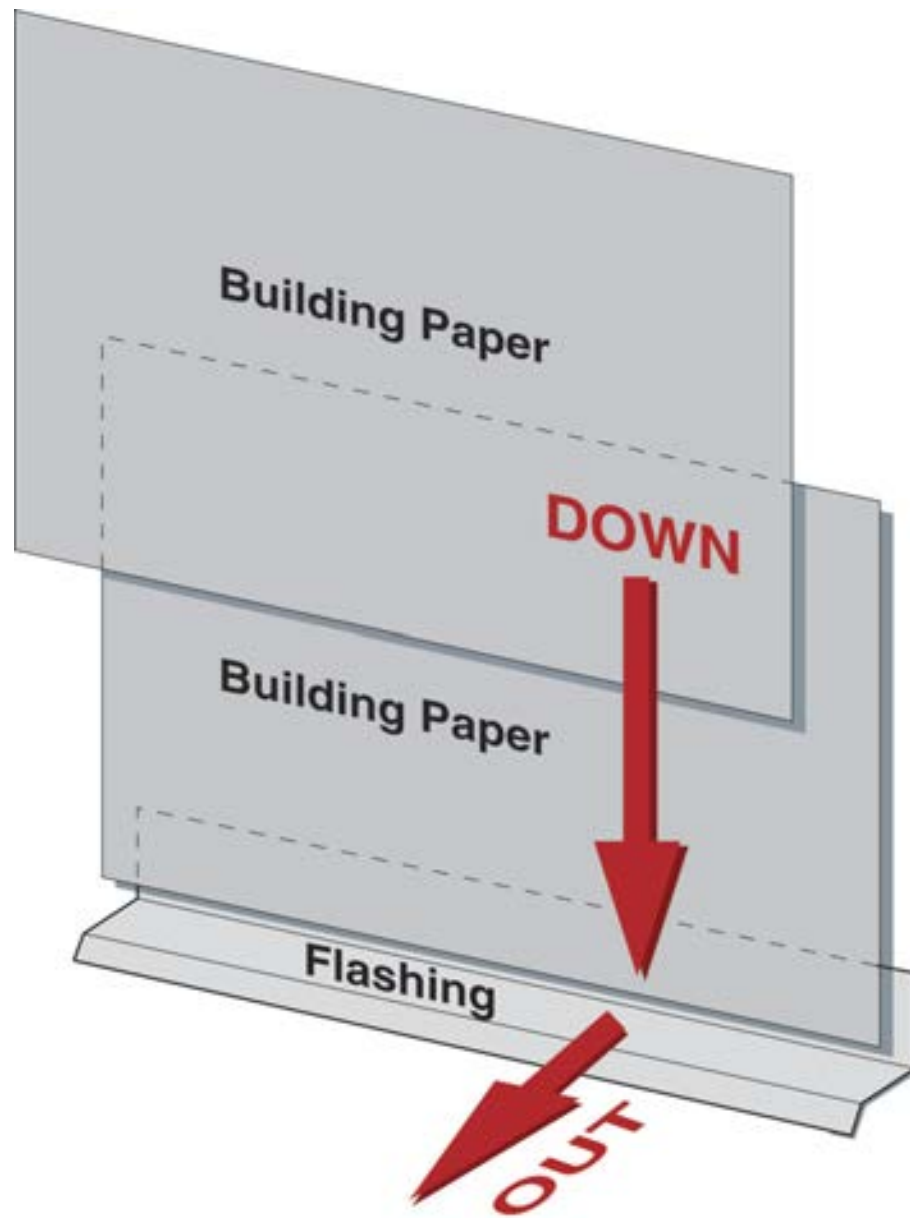


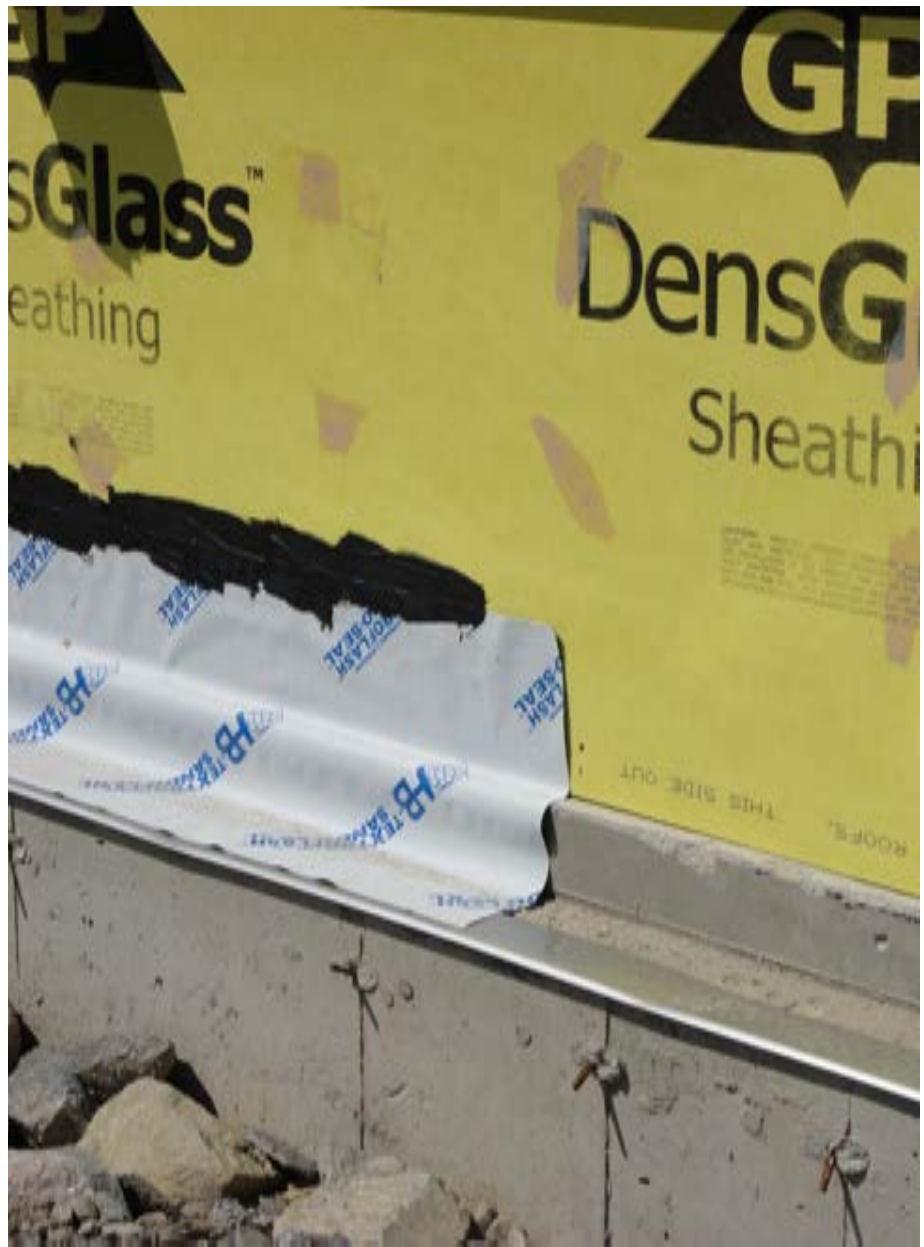






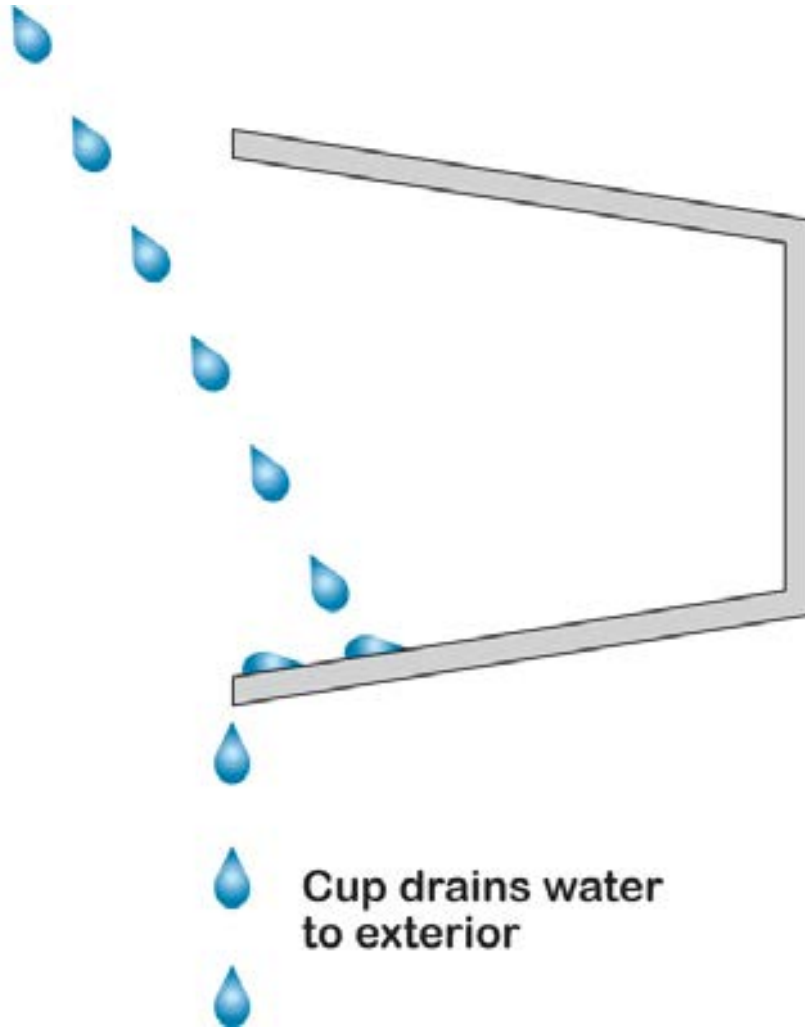








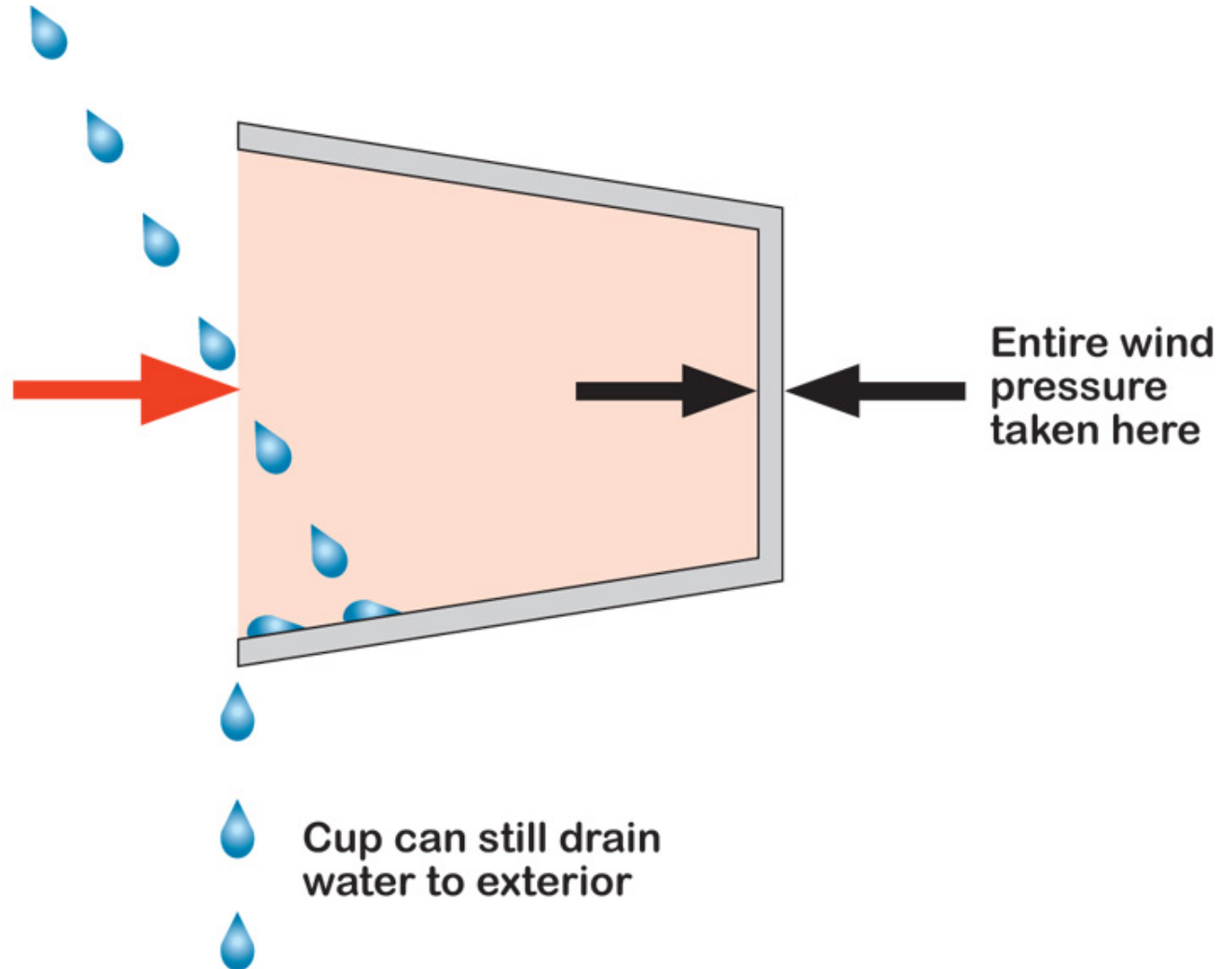
Rain enters cup
due to momentum
("kinetic energy")



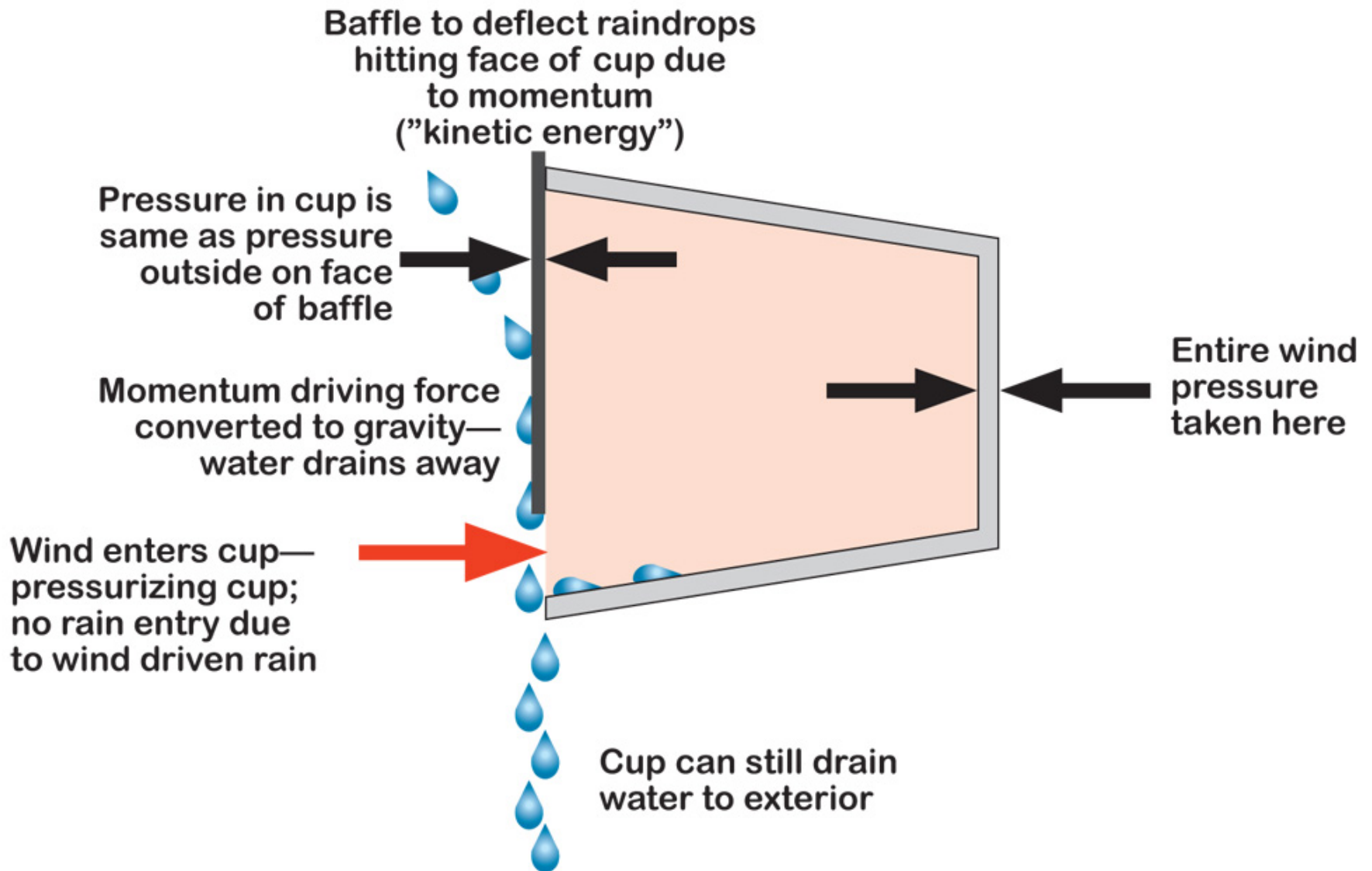
Cup drains water
to exterior

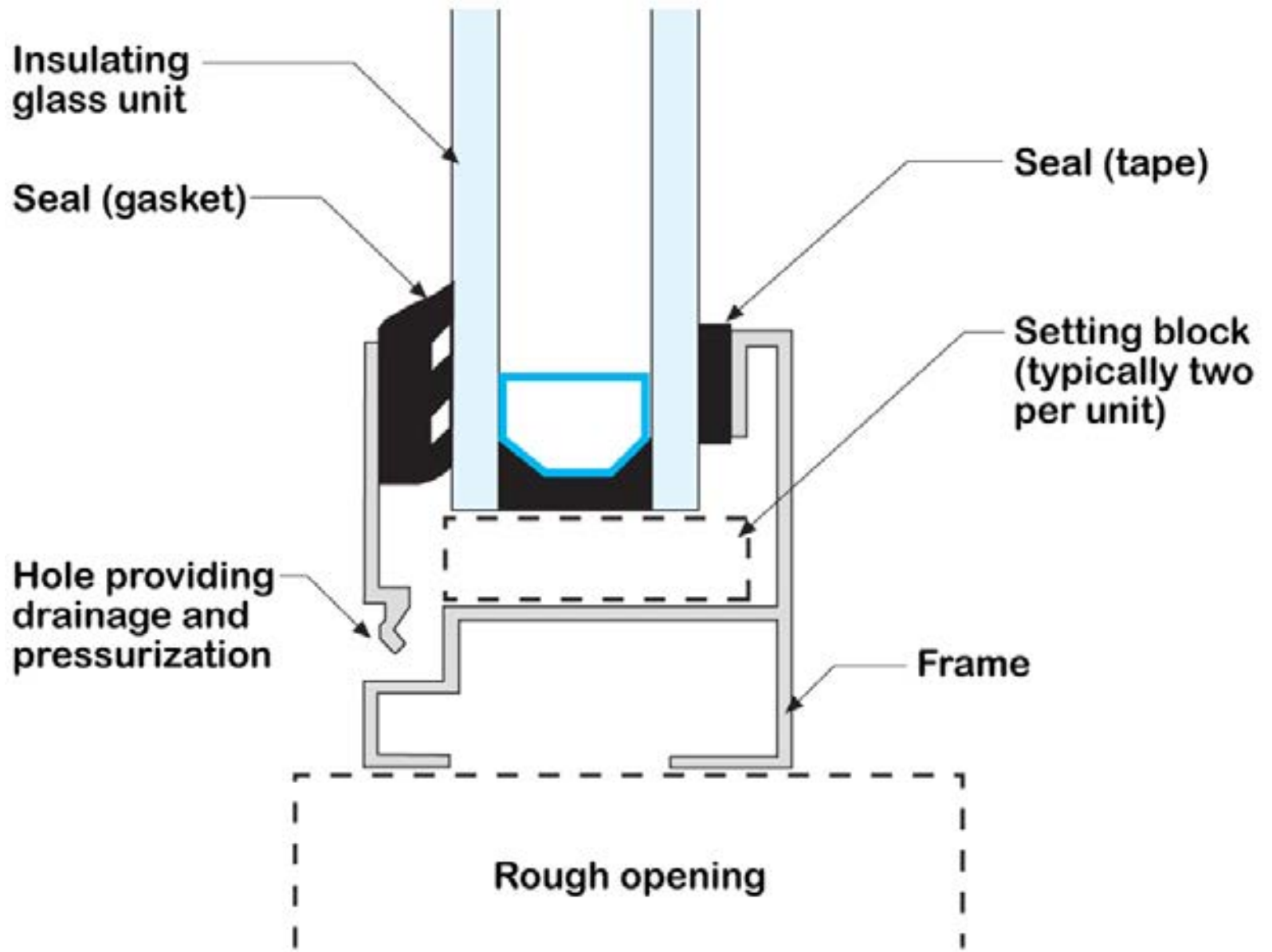
Rain enters cup due to momentum ("kinetic energy")

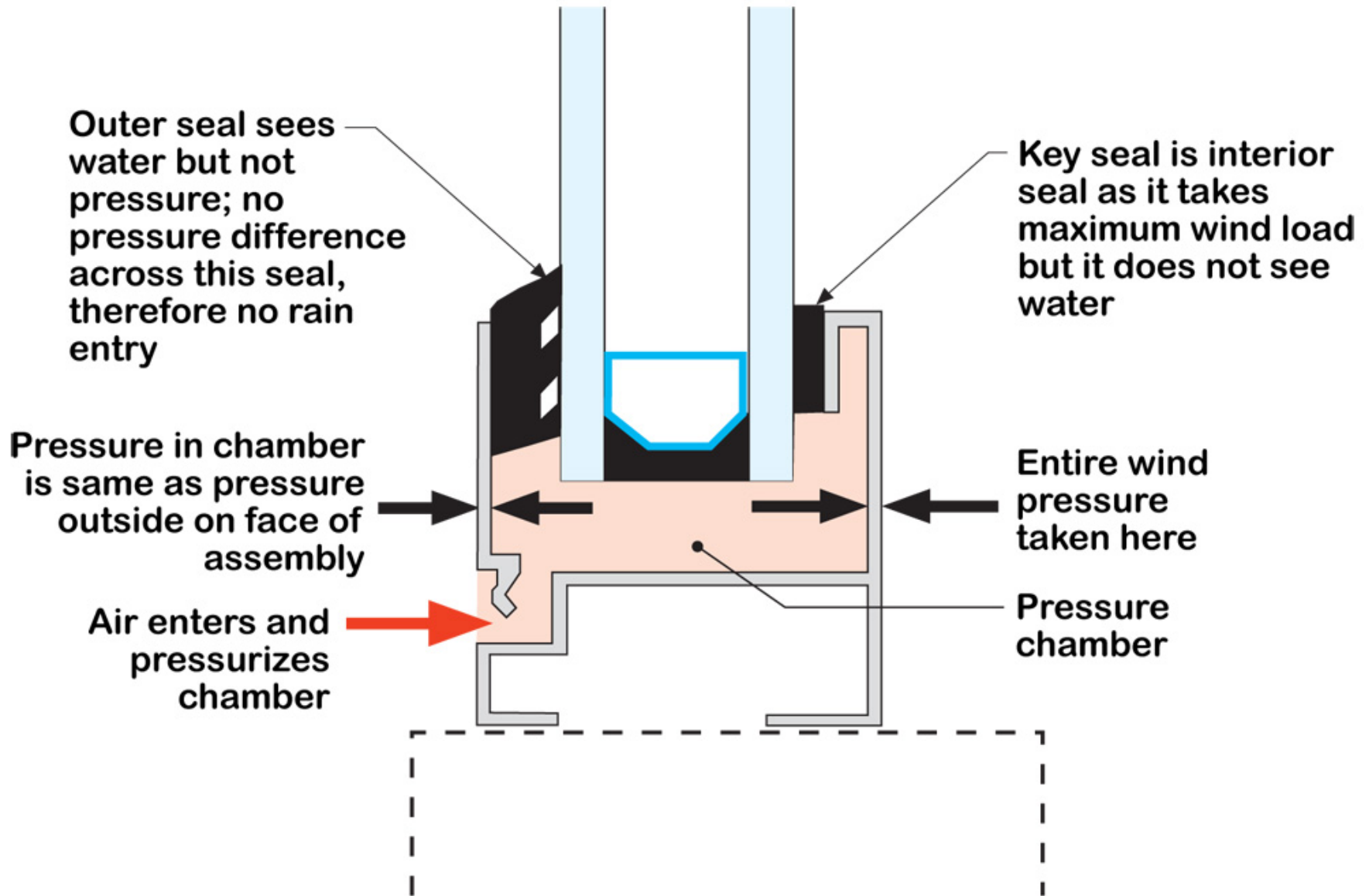
Wind enters cup—pressurizing cup; no rain entry due to wind driven rain

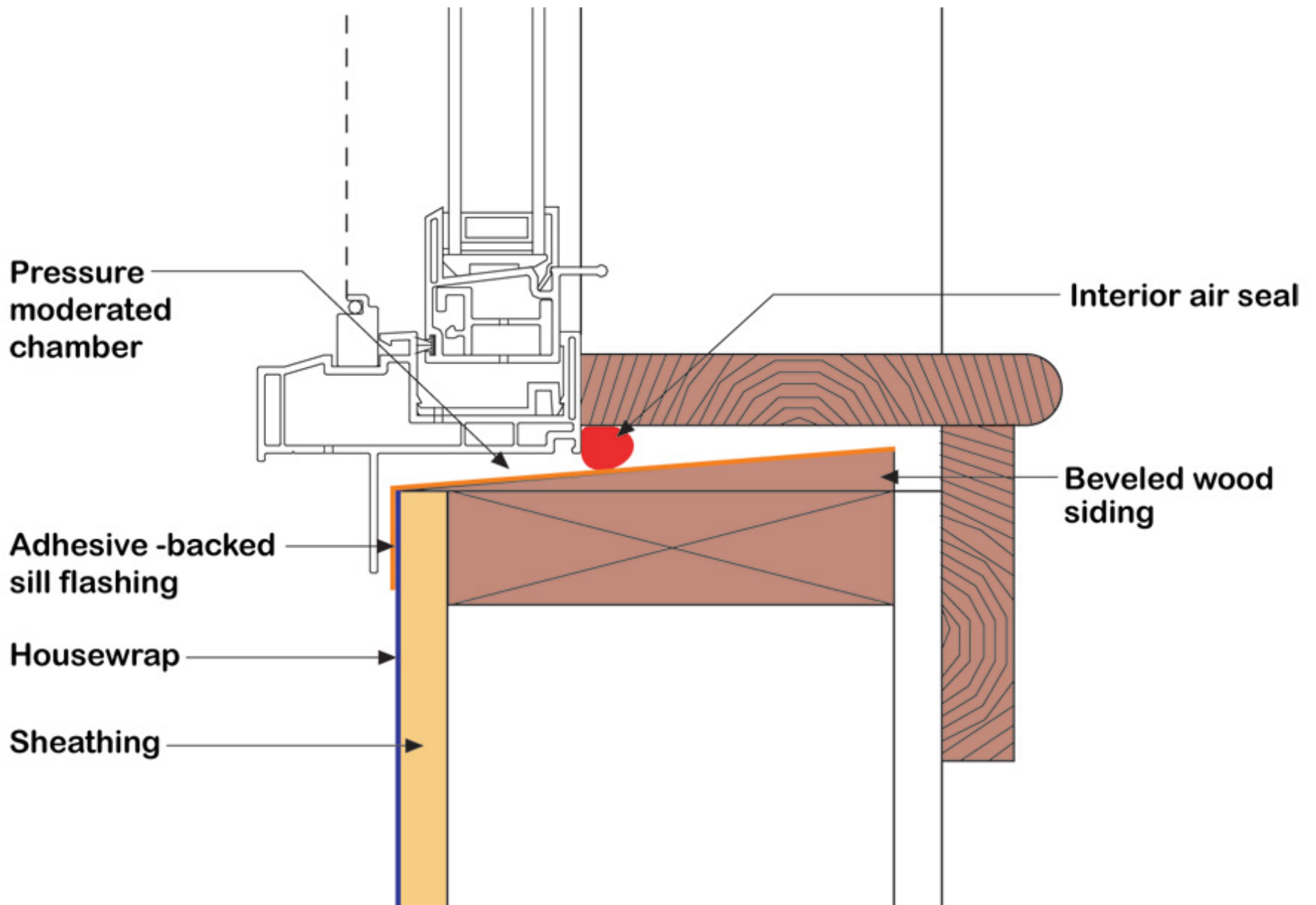


Cup can still drain water to exterior









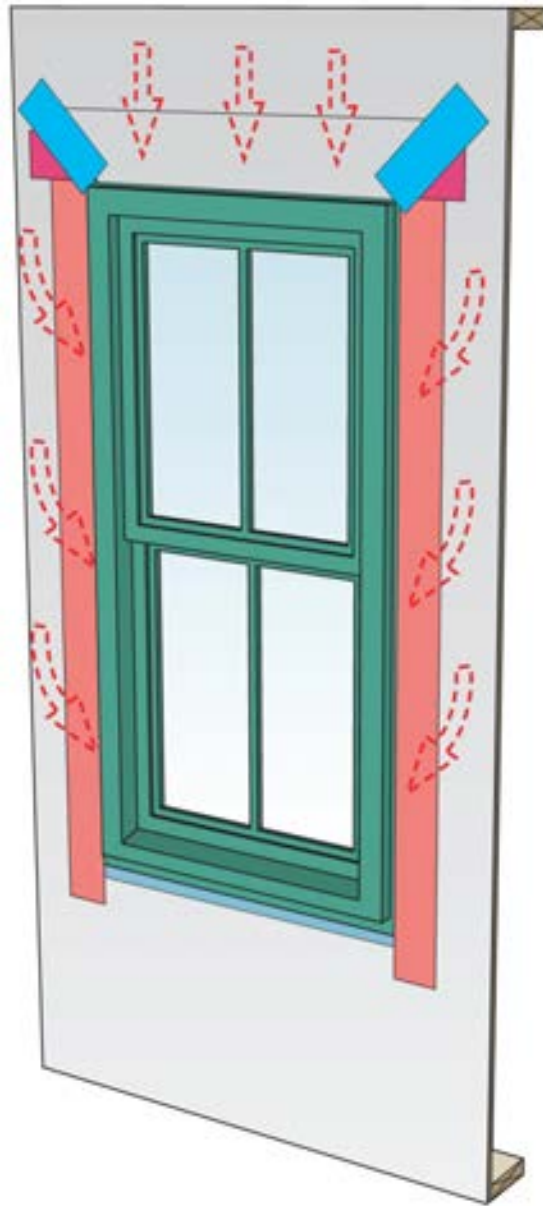


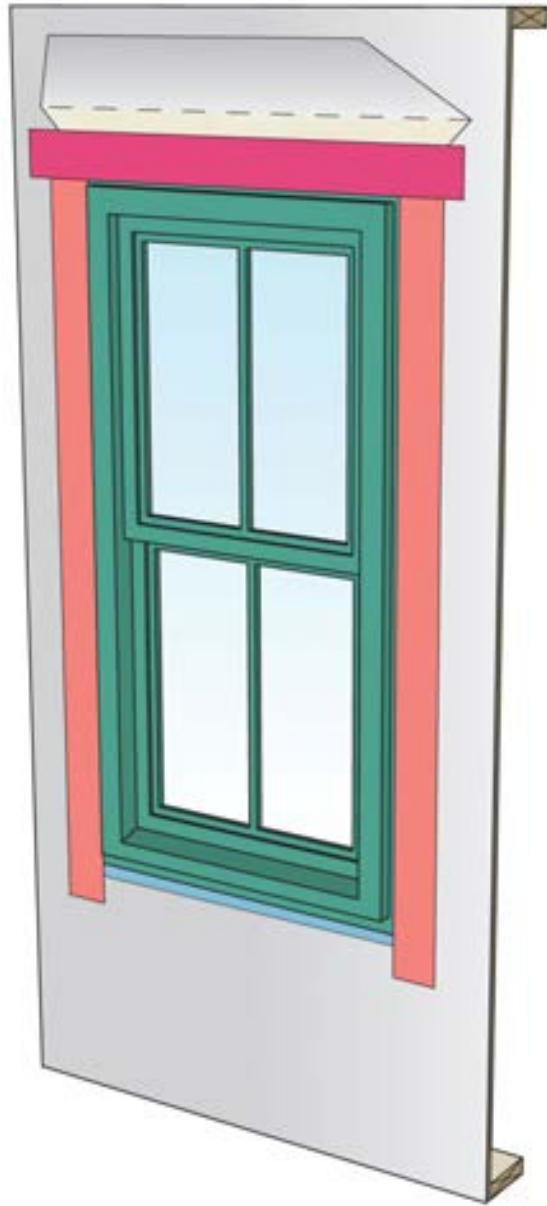




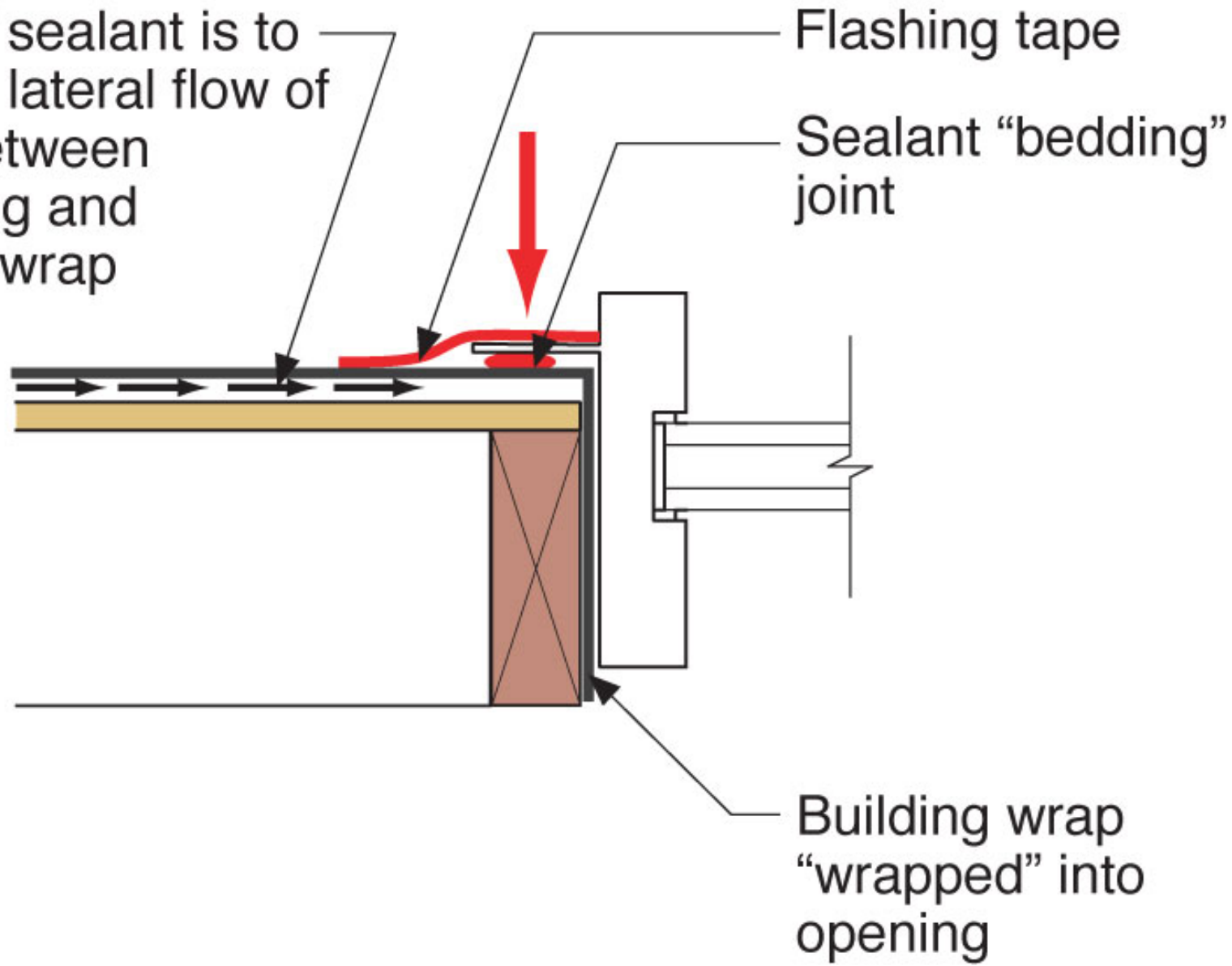


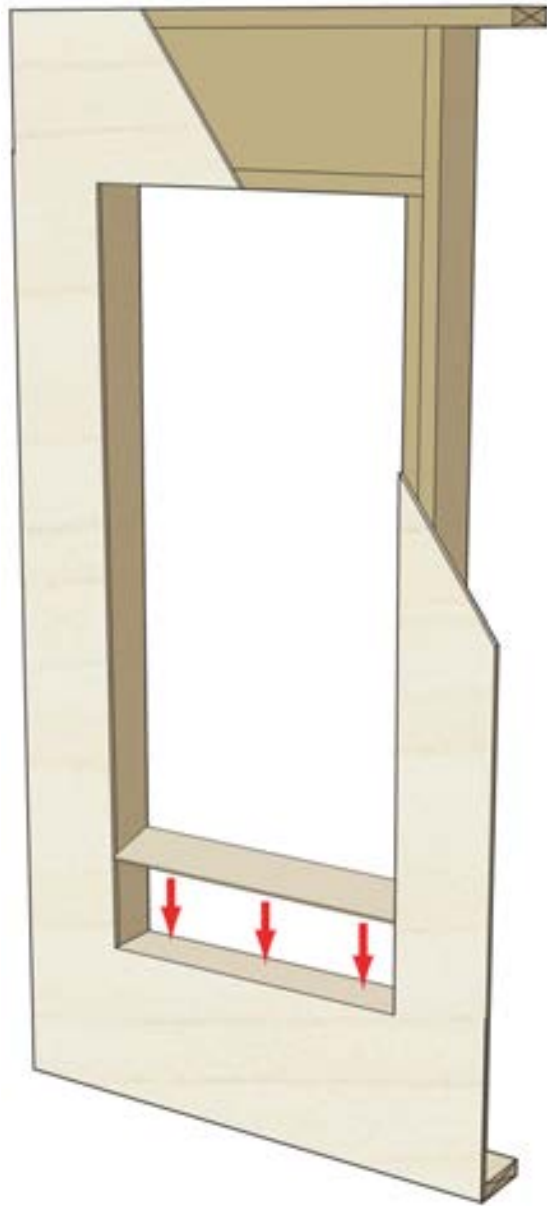


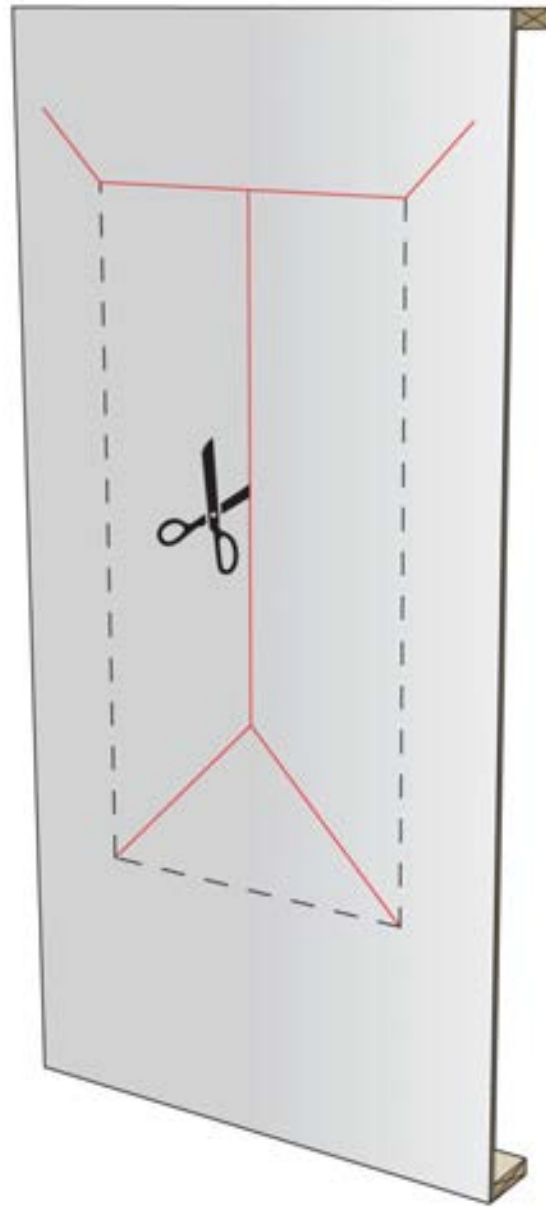


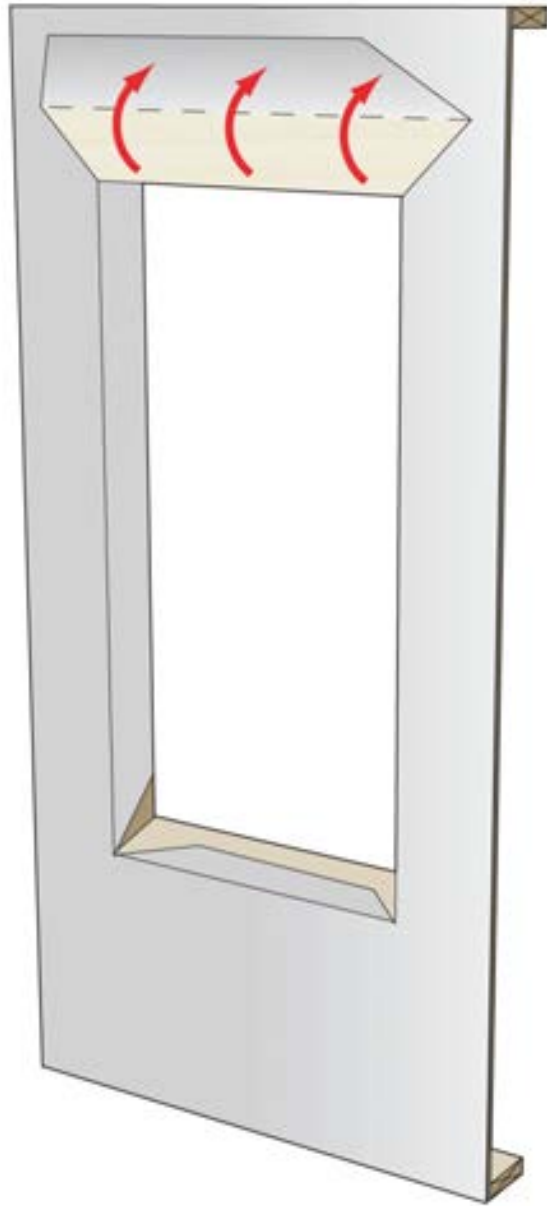


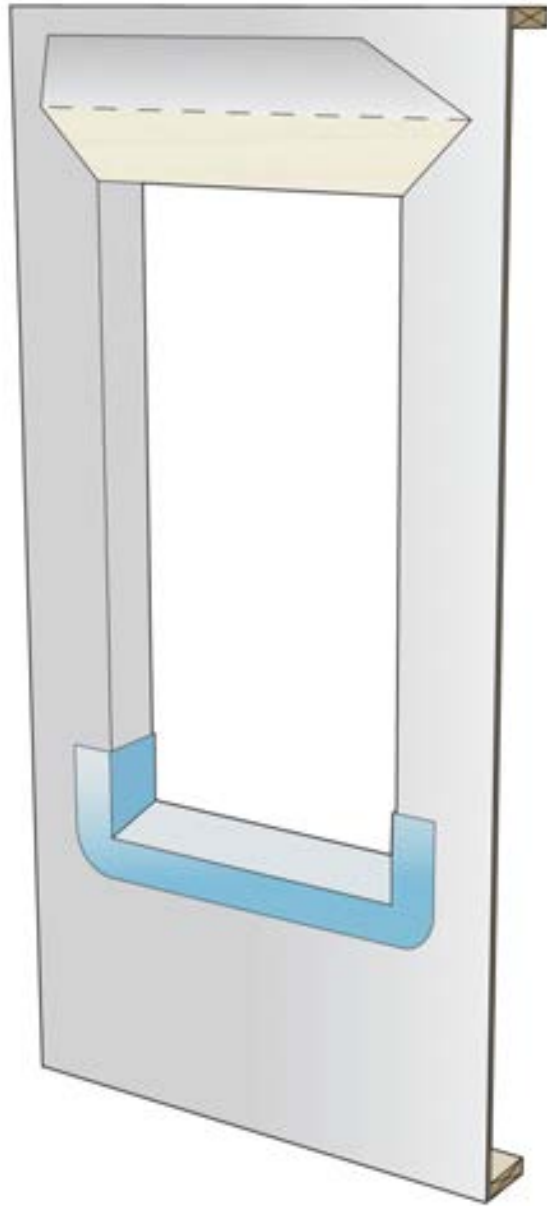
Intent of sealant is to limit this lateral flow of water between sheathing and building wrap

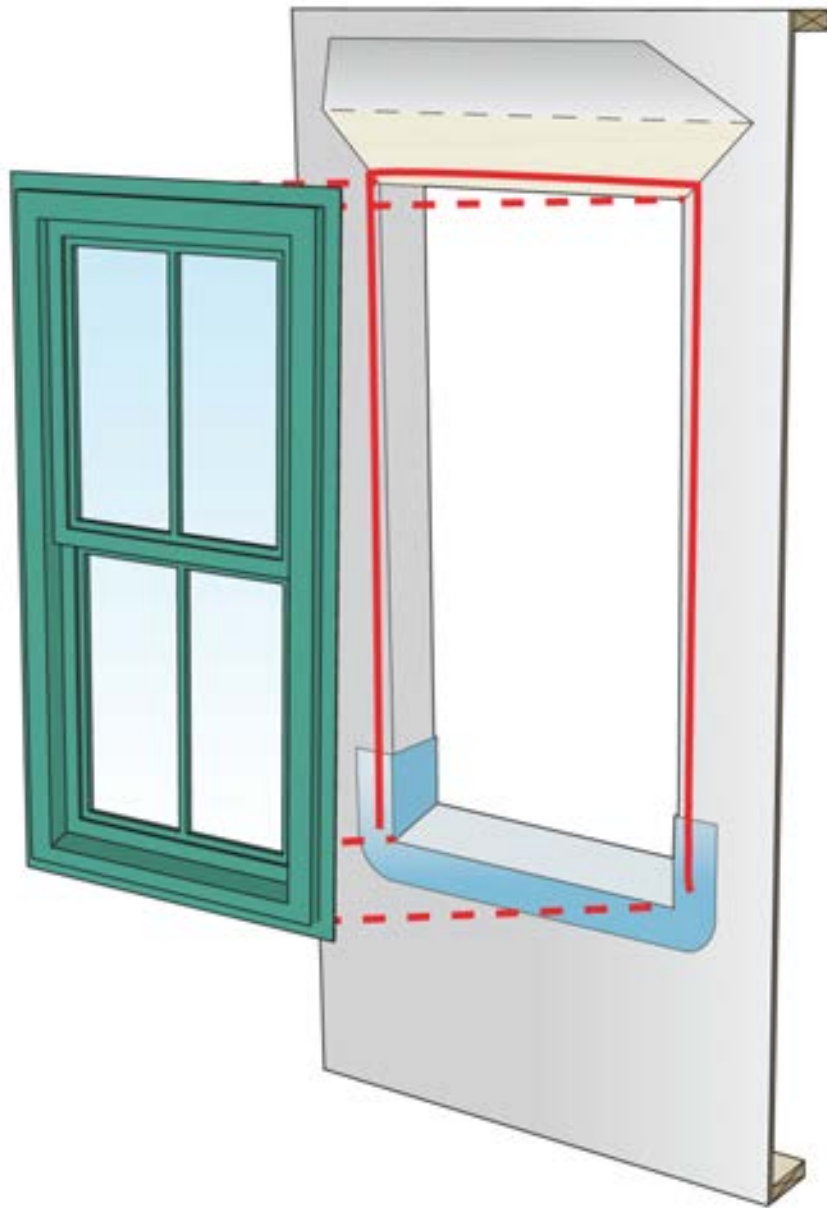


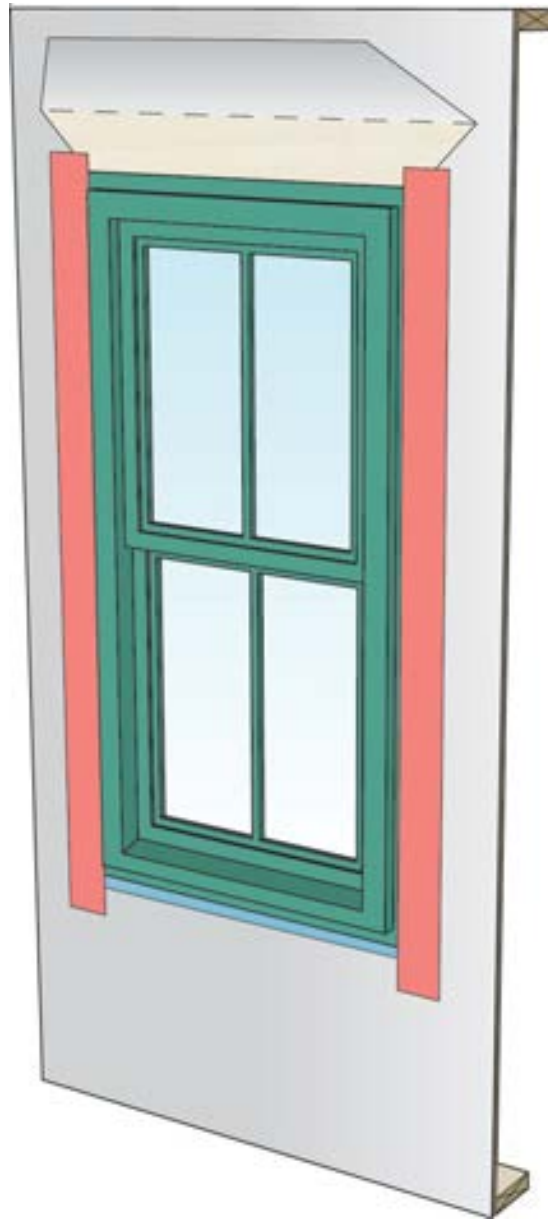


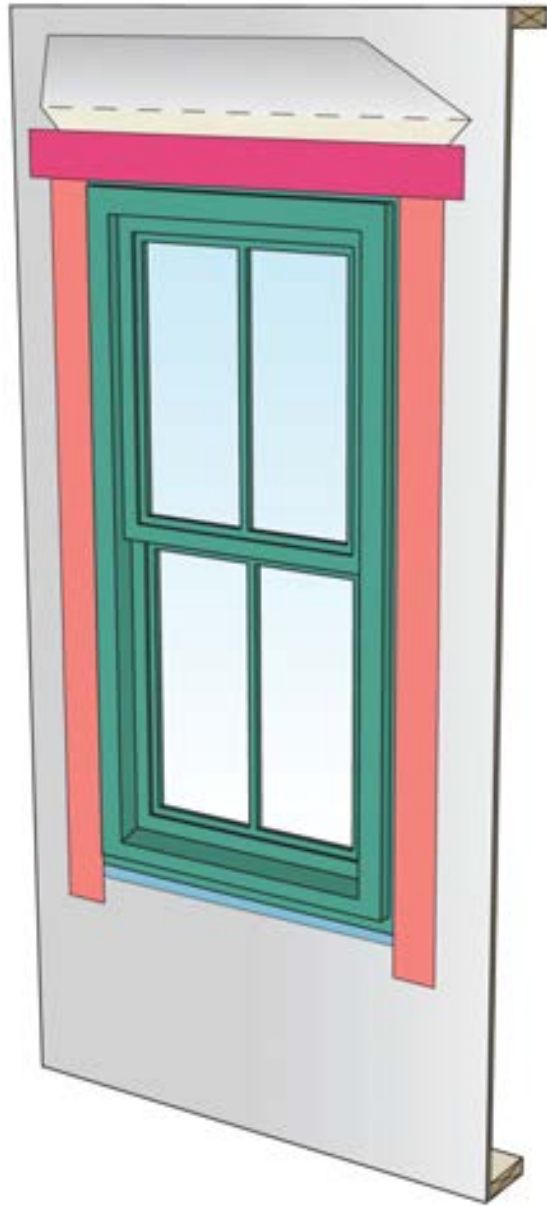


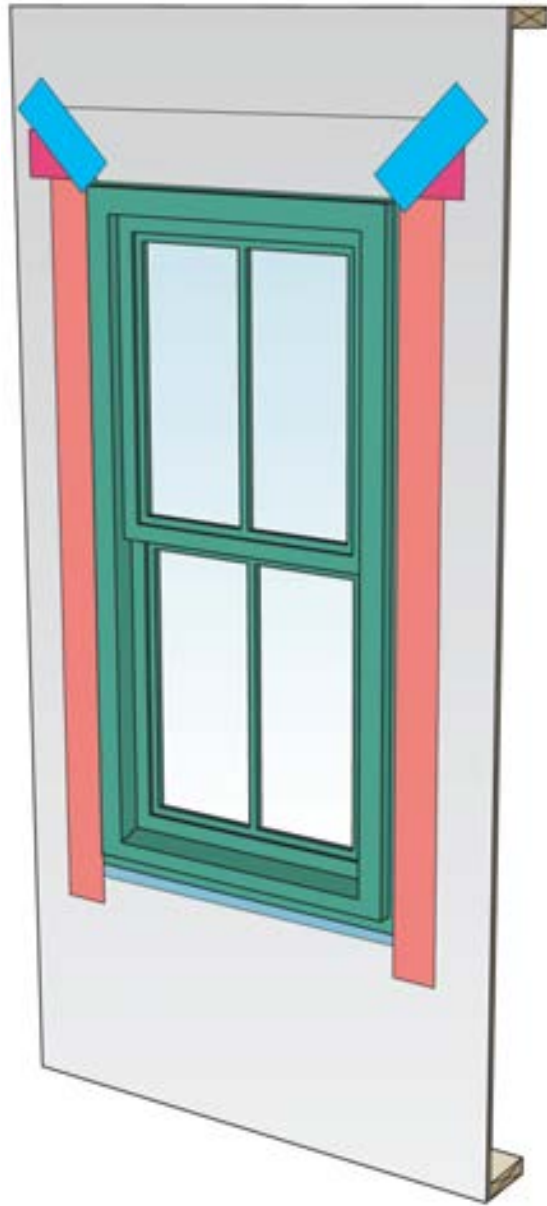


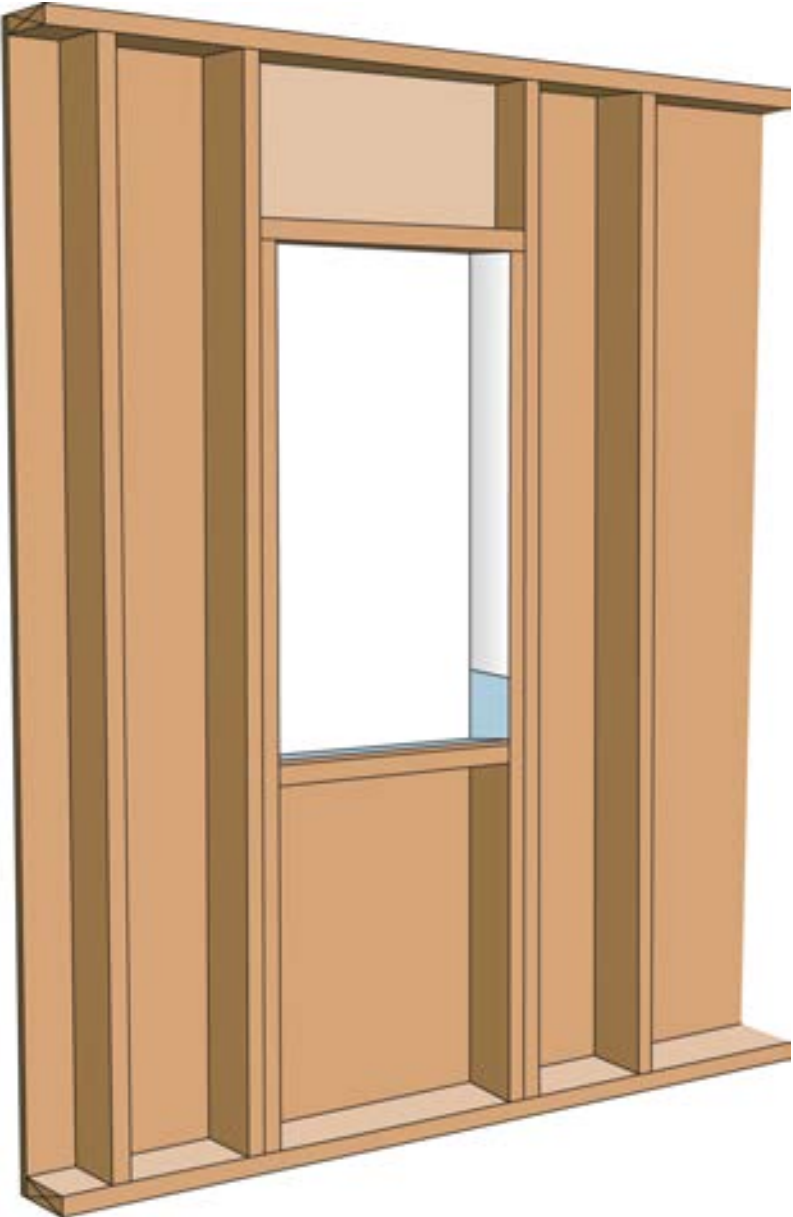




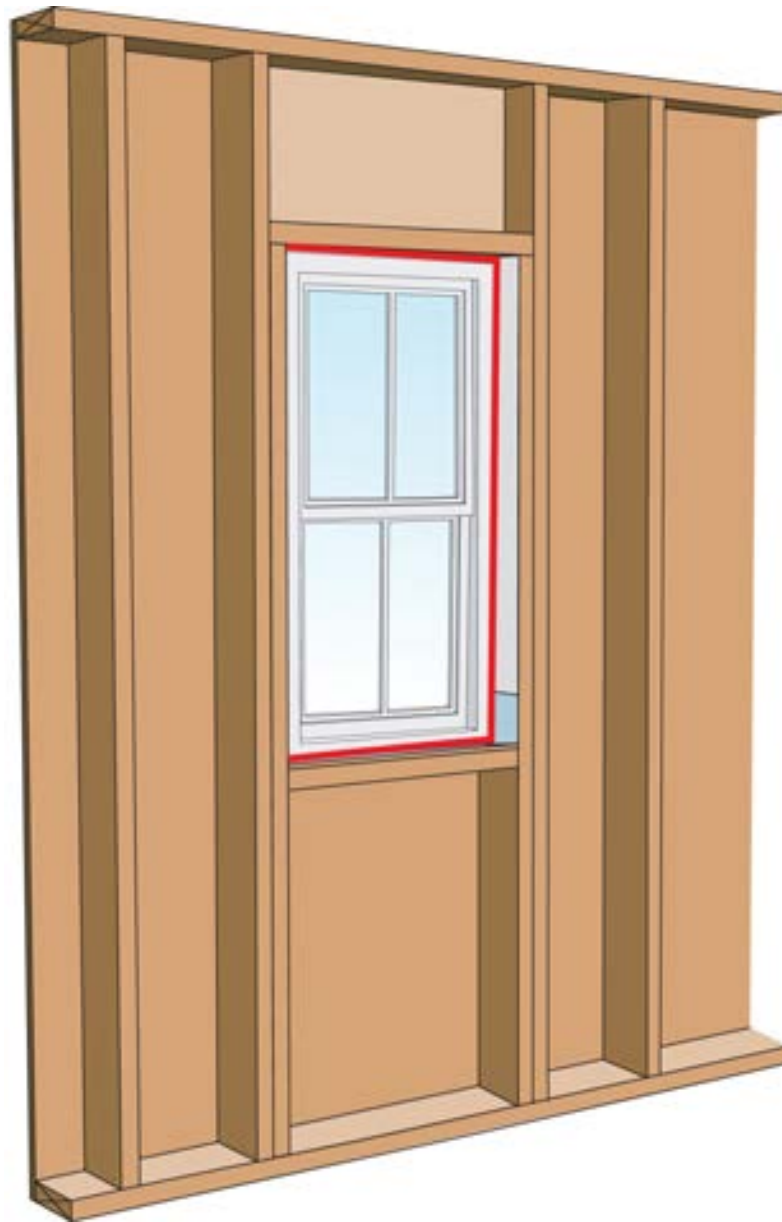




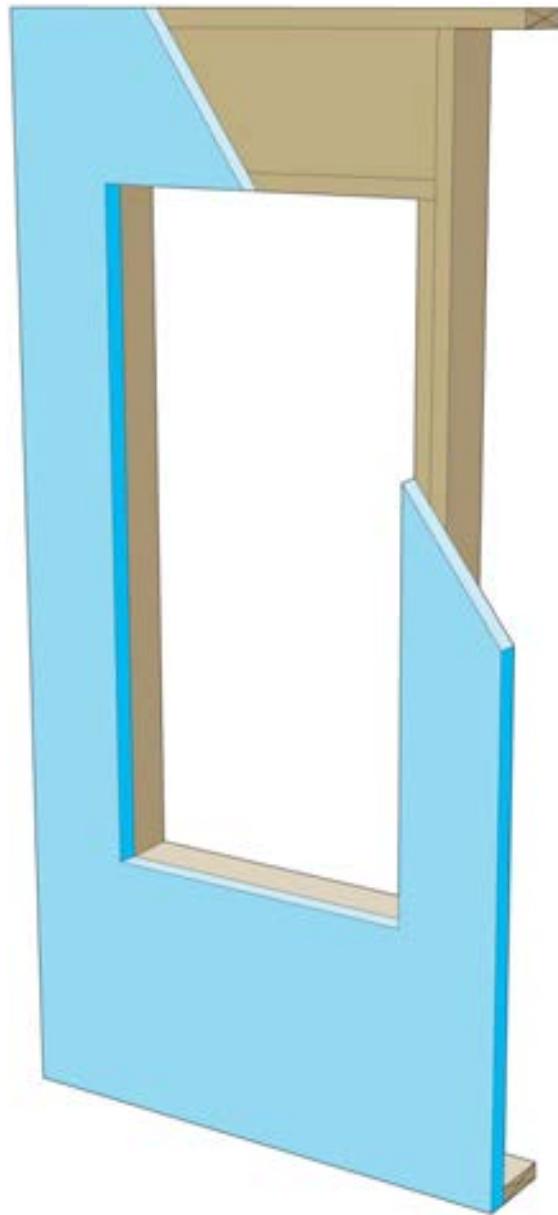


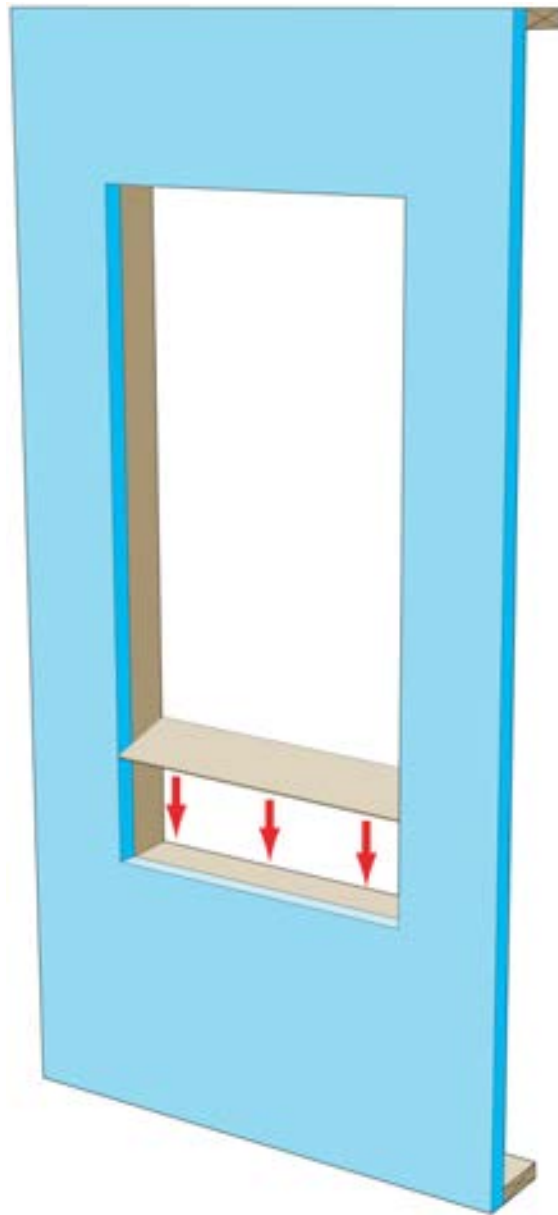


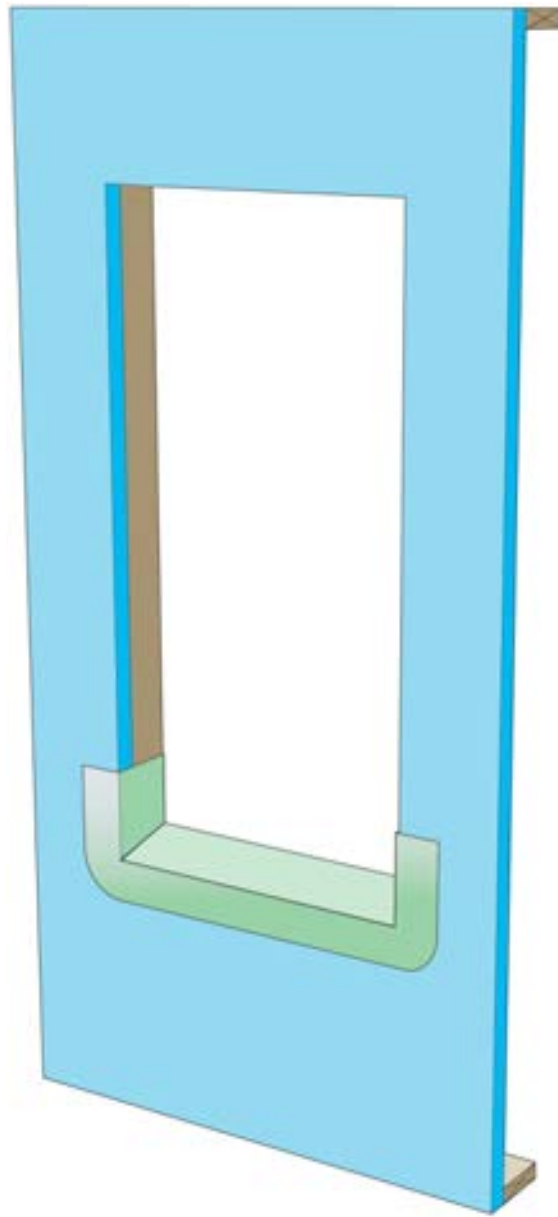


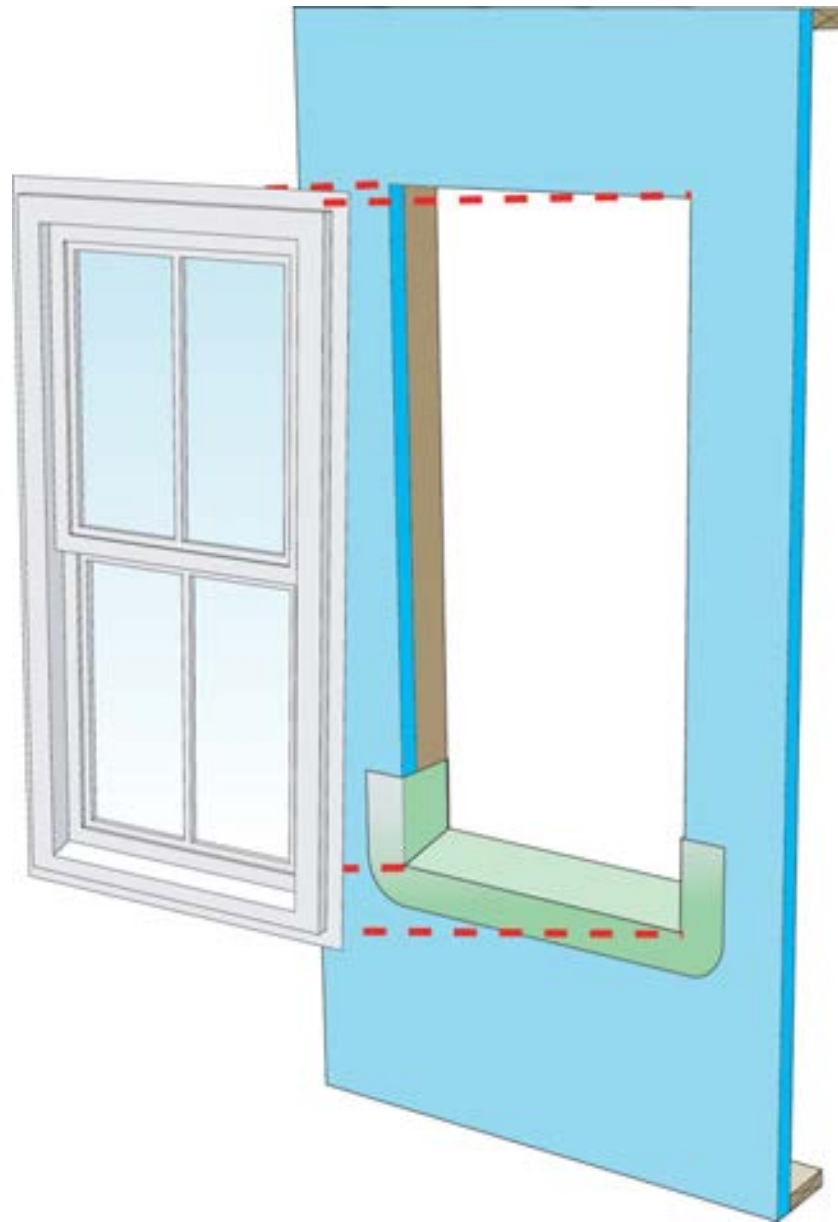








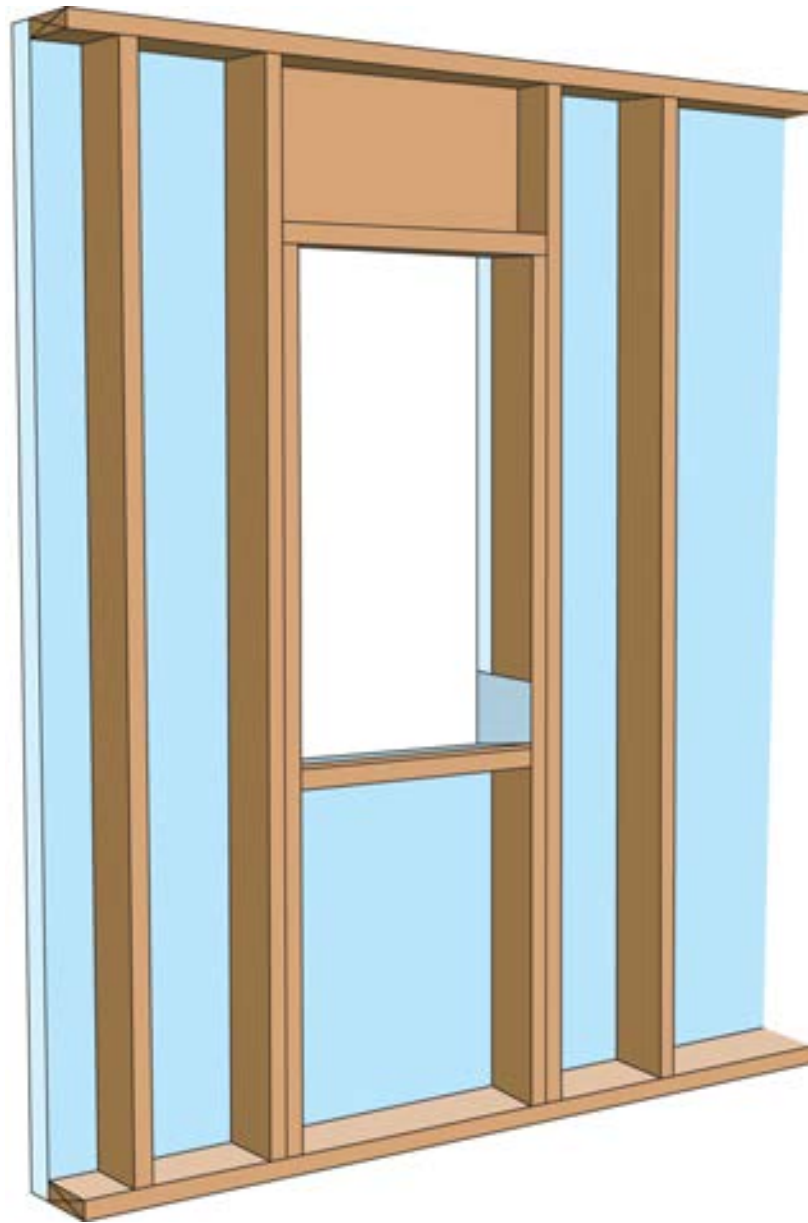


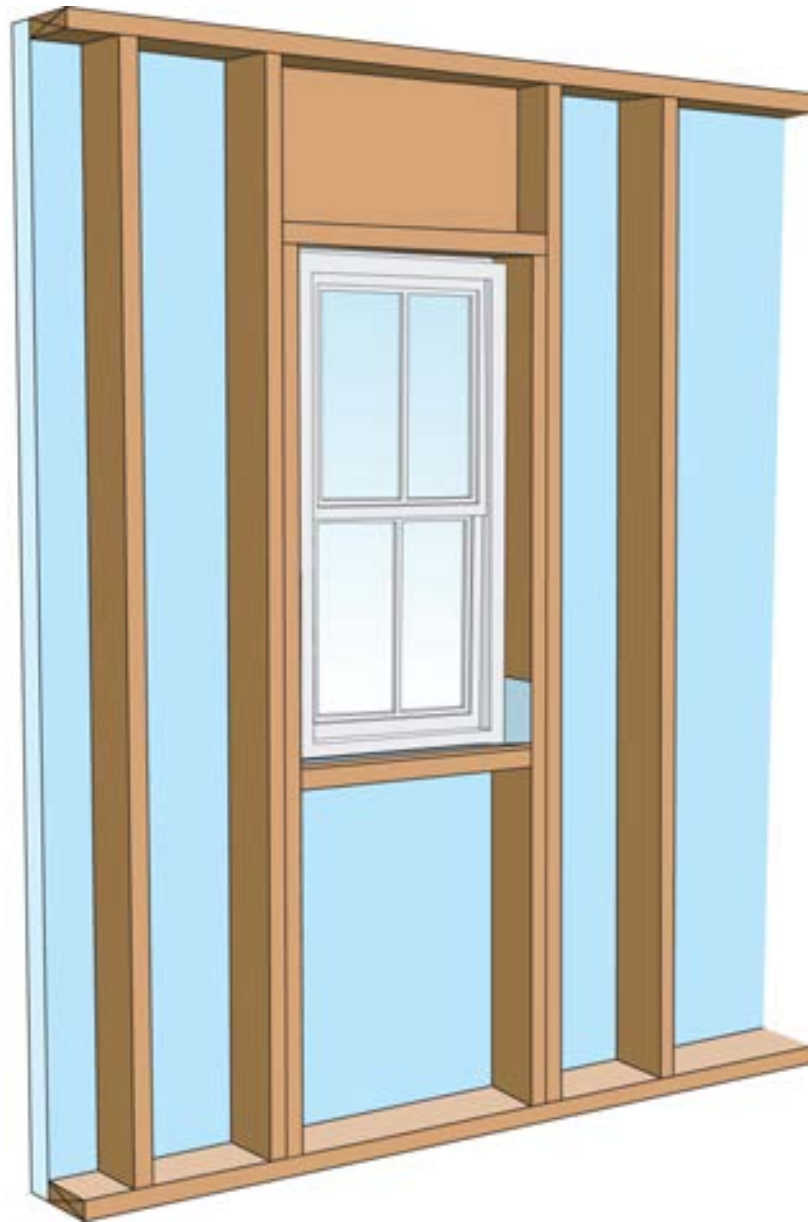


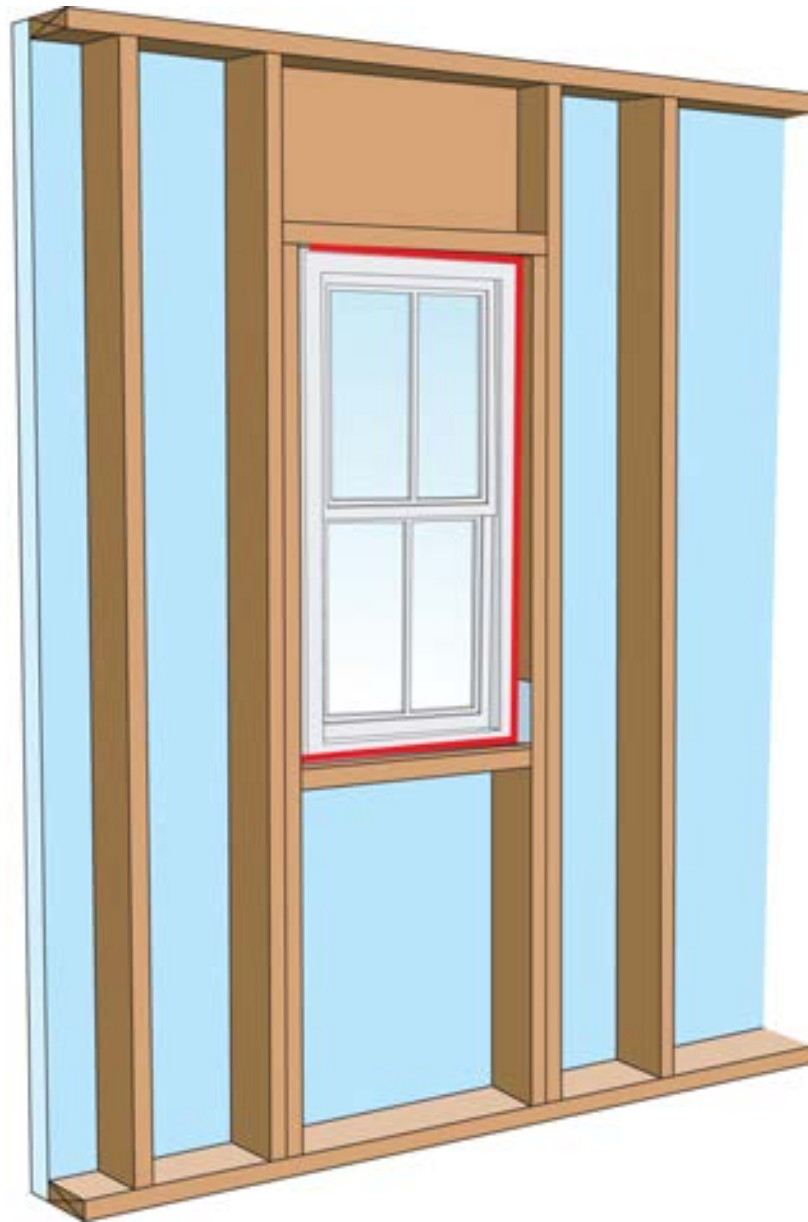






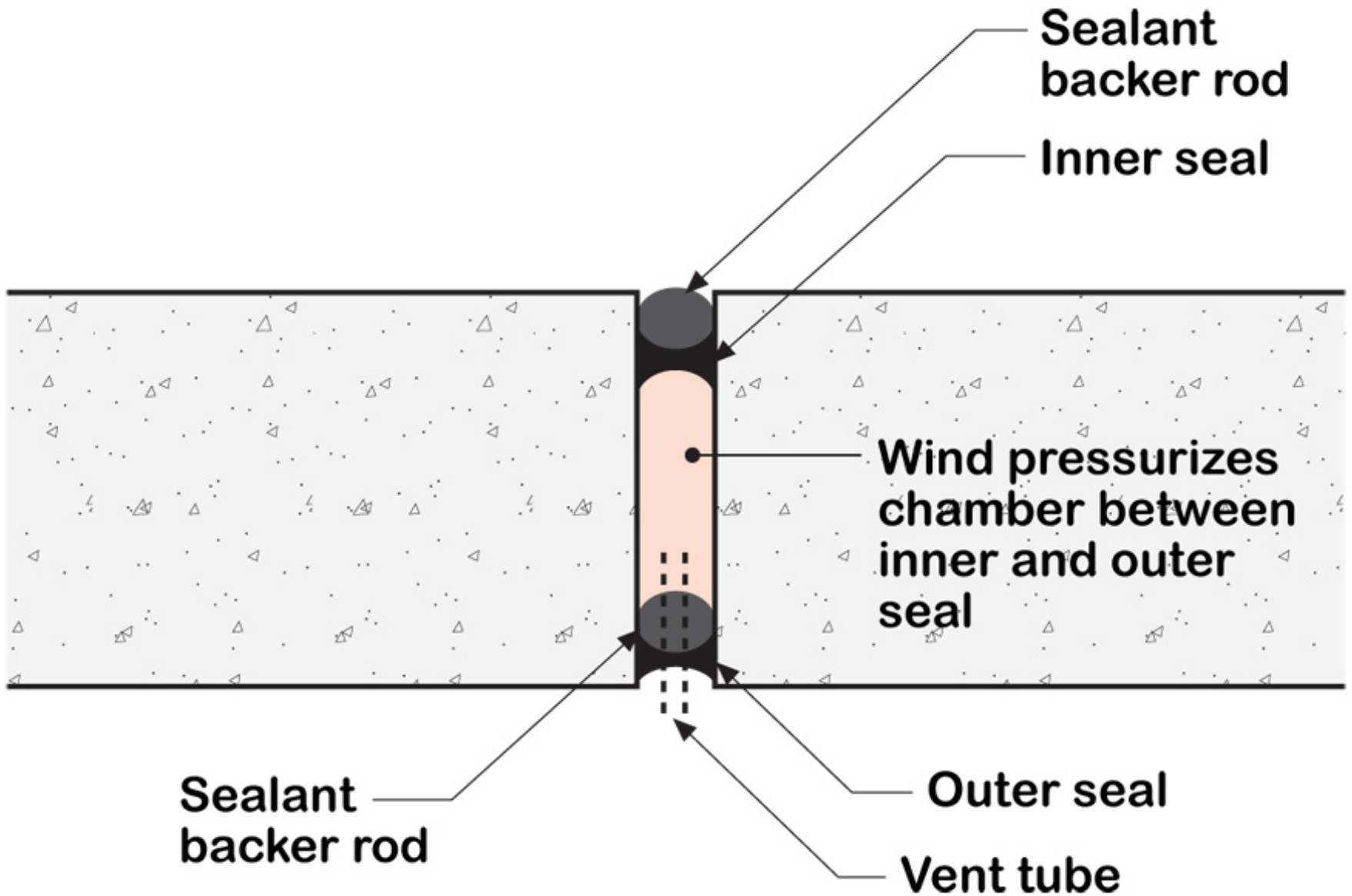


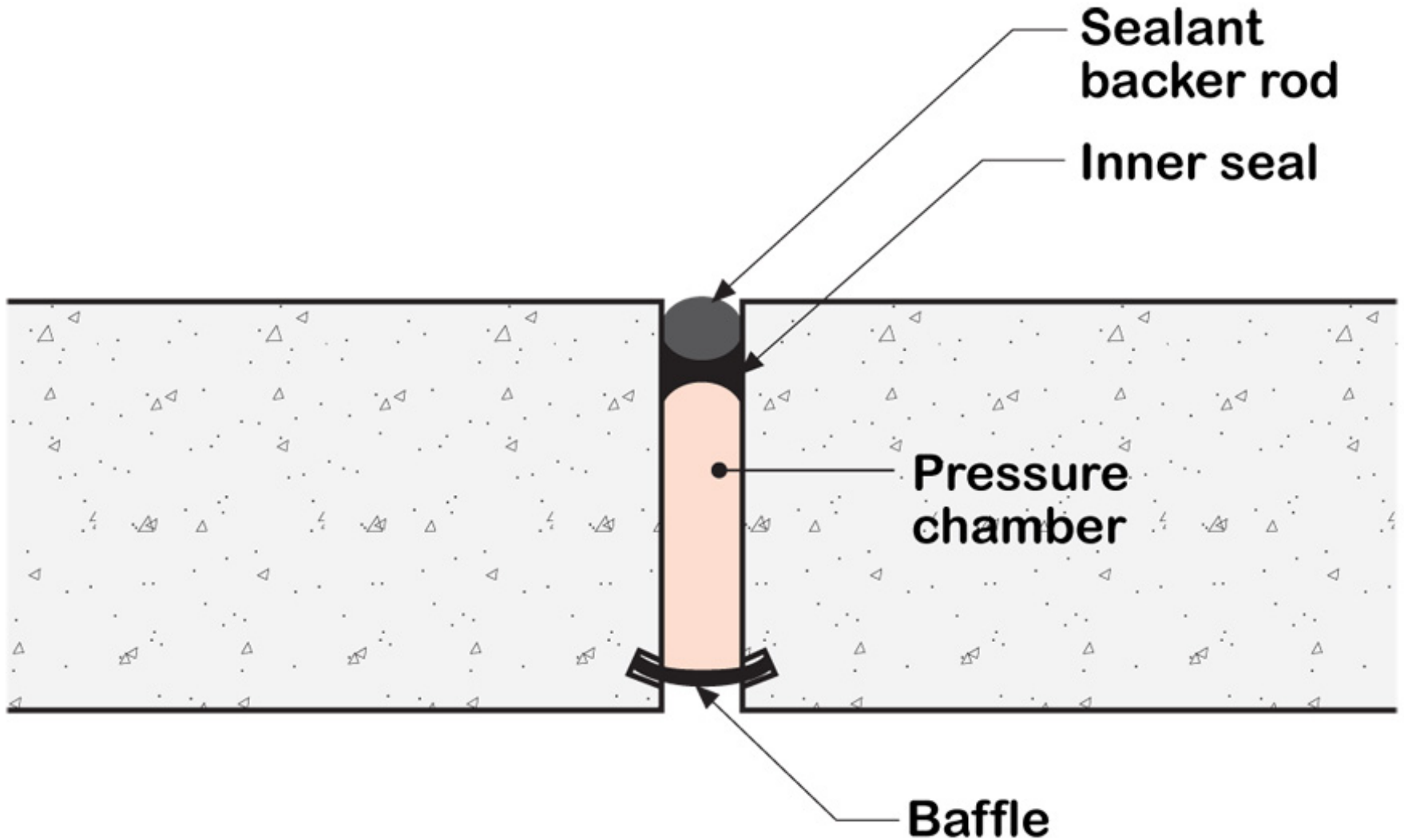


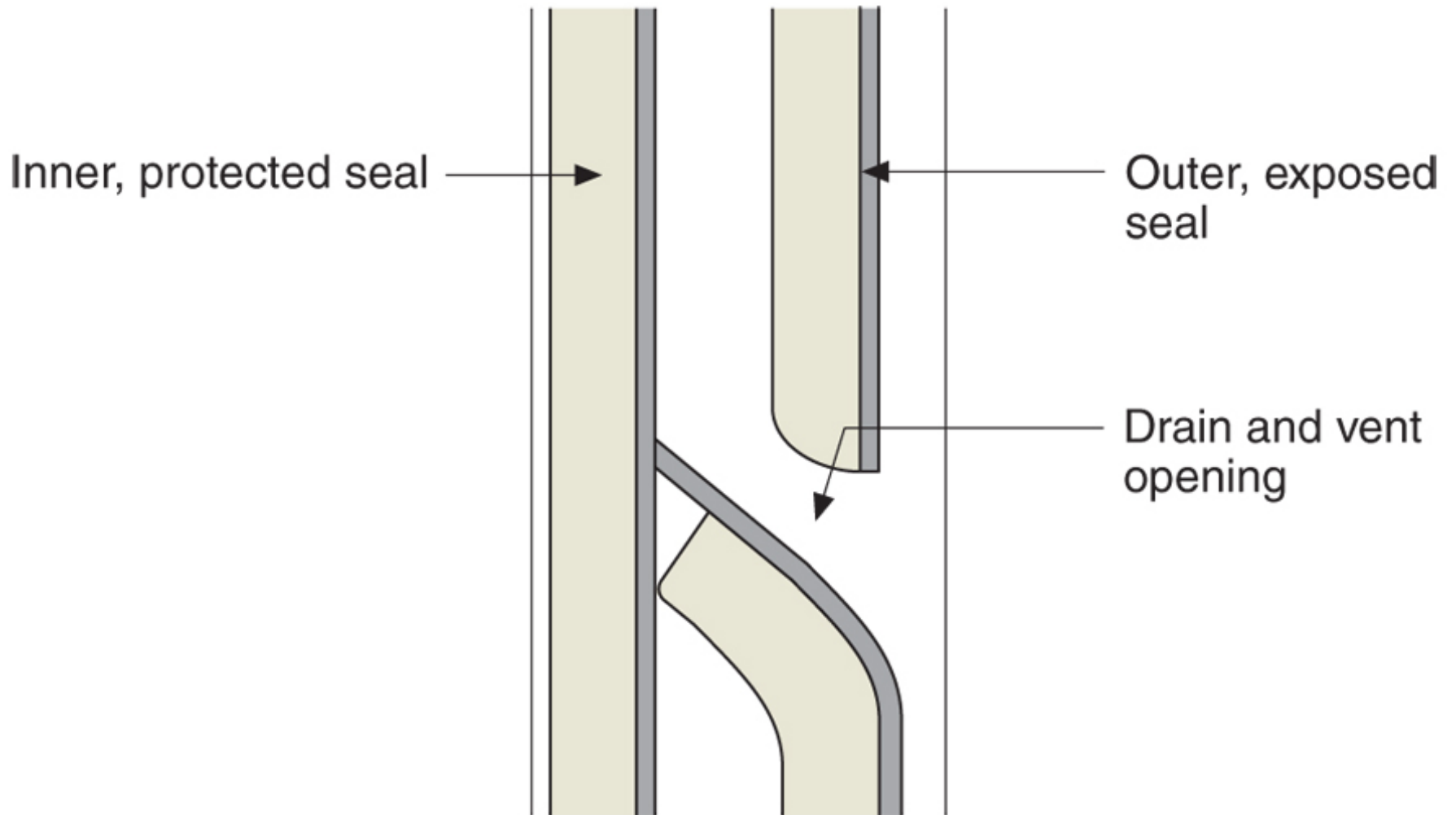


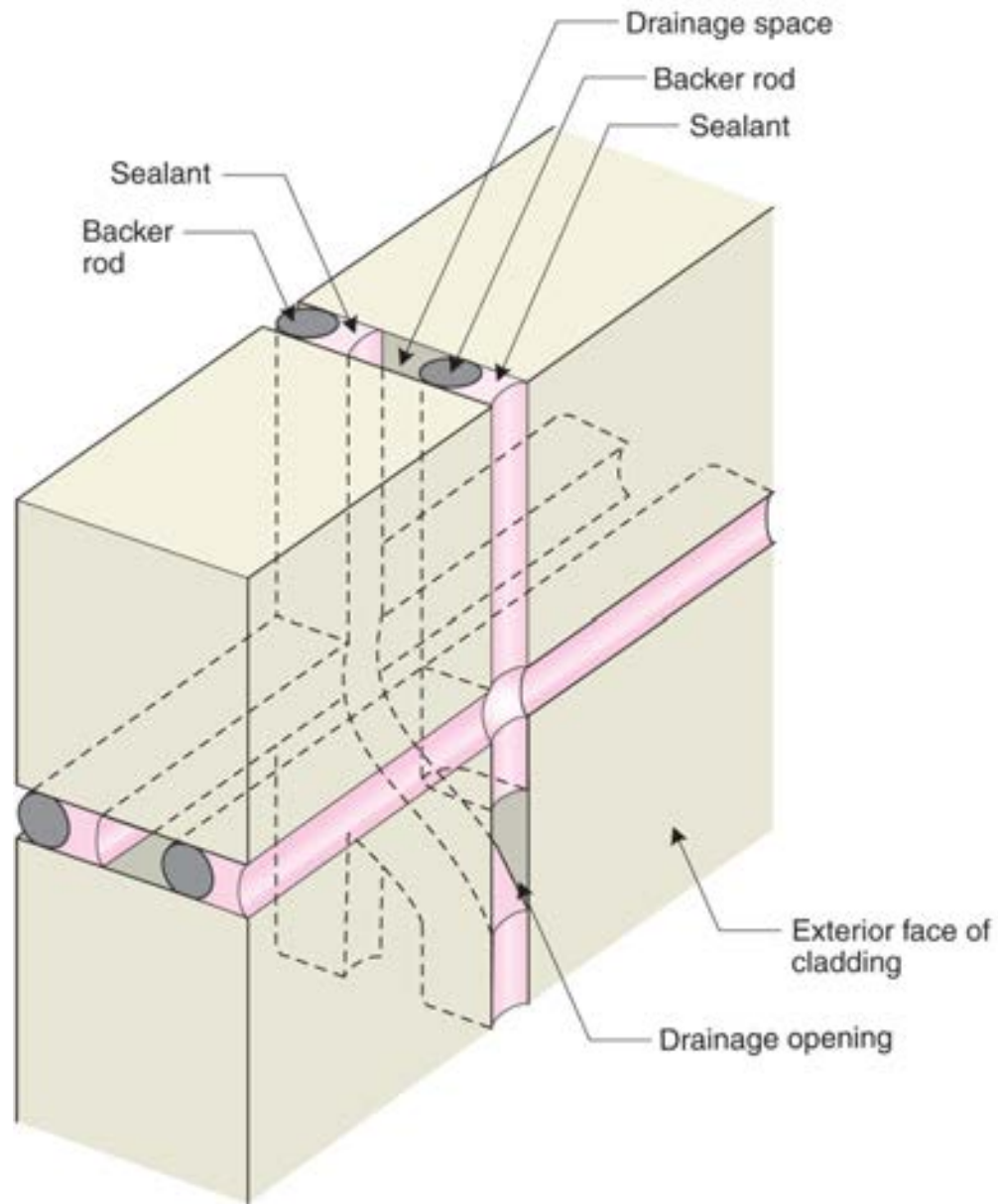












Life is Tough Enough As it Is...

Life is Tough Enough As it Is...
It's Harder When You Are Stupid

Don't Do Stupid Things

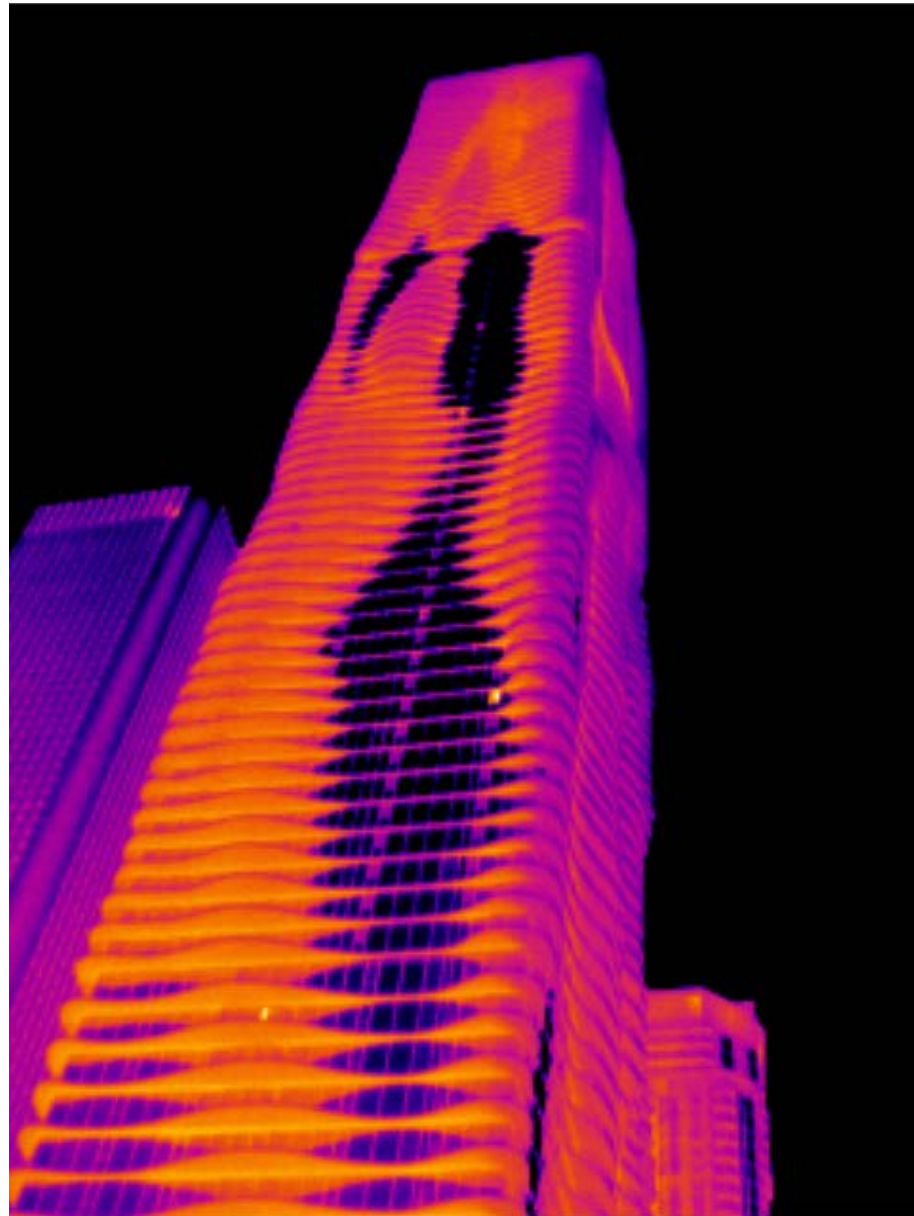


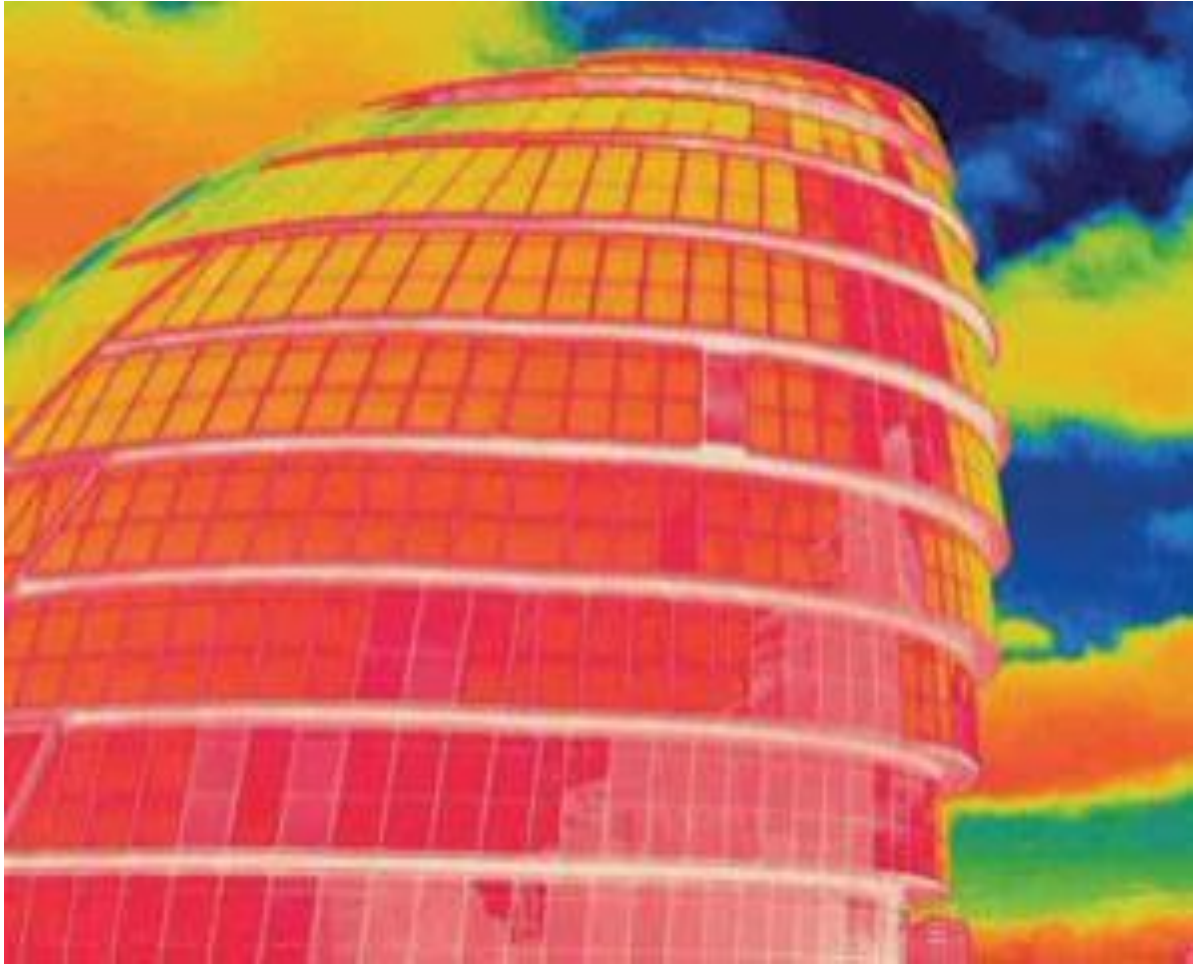






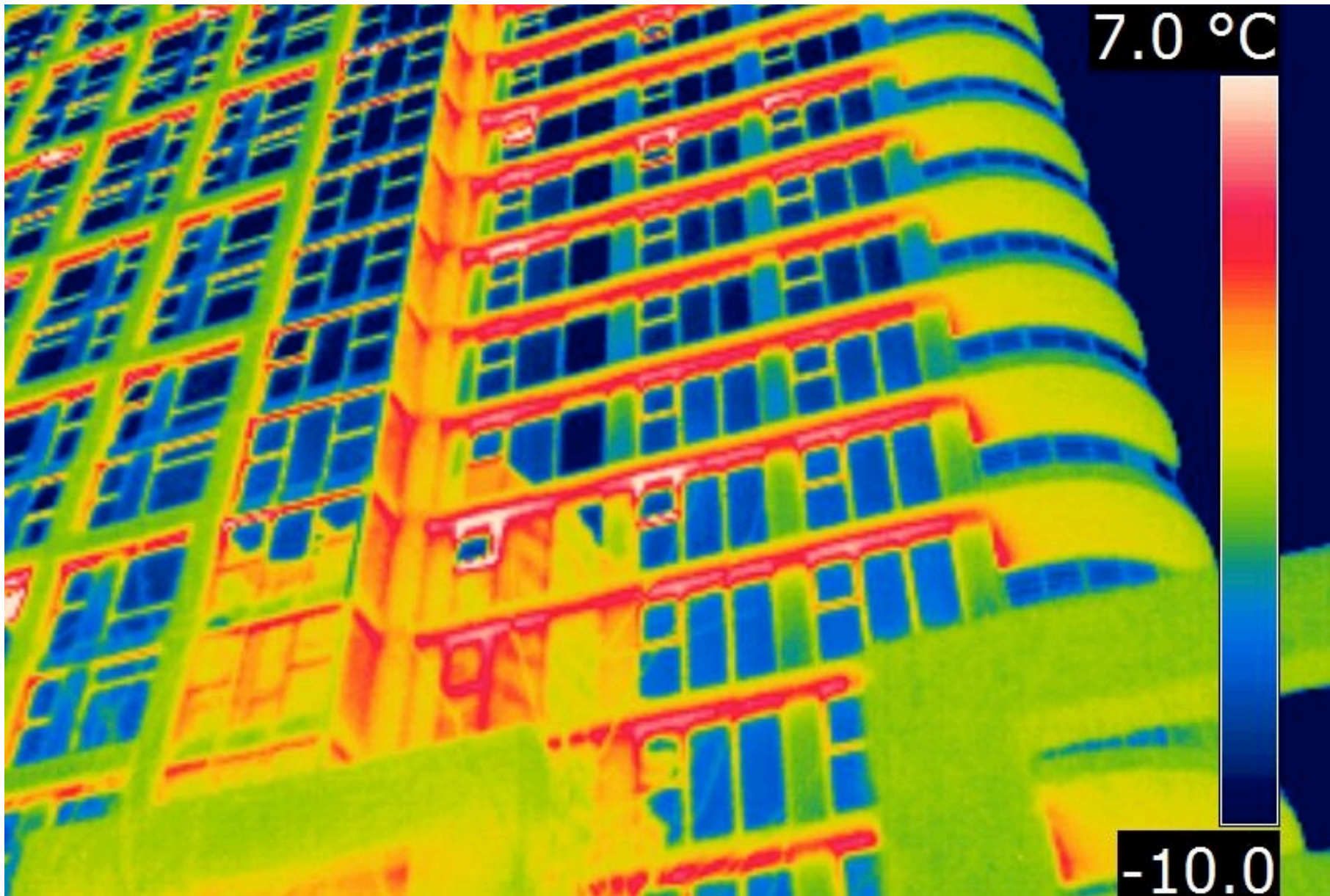


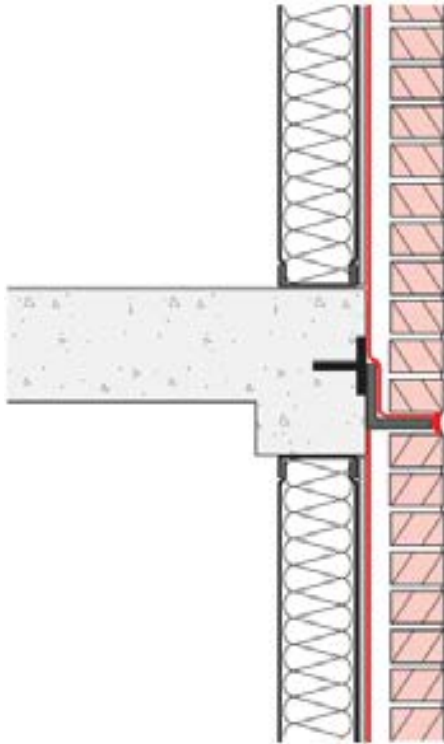




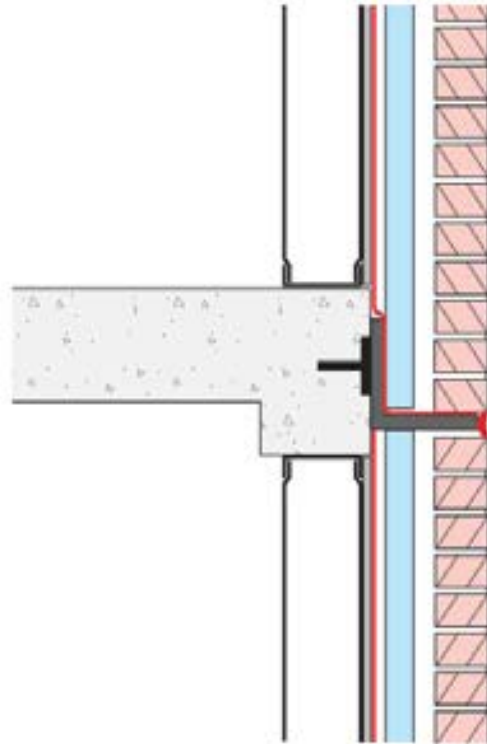




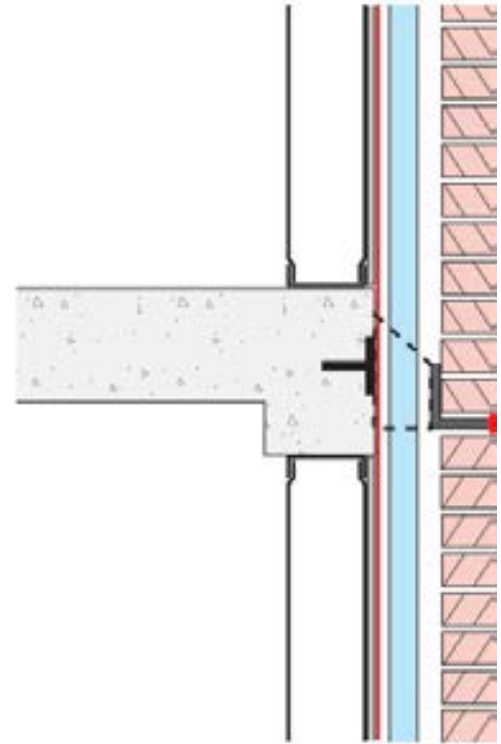




“The Ugly”



“The Bad”



“The Good”

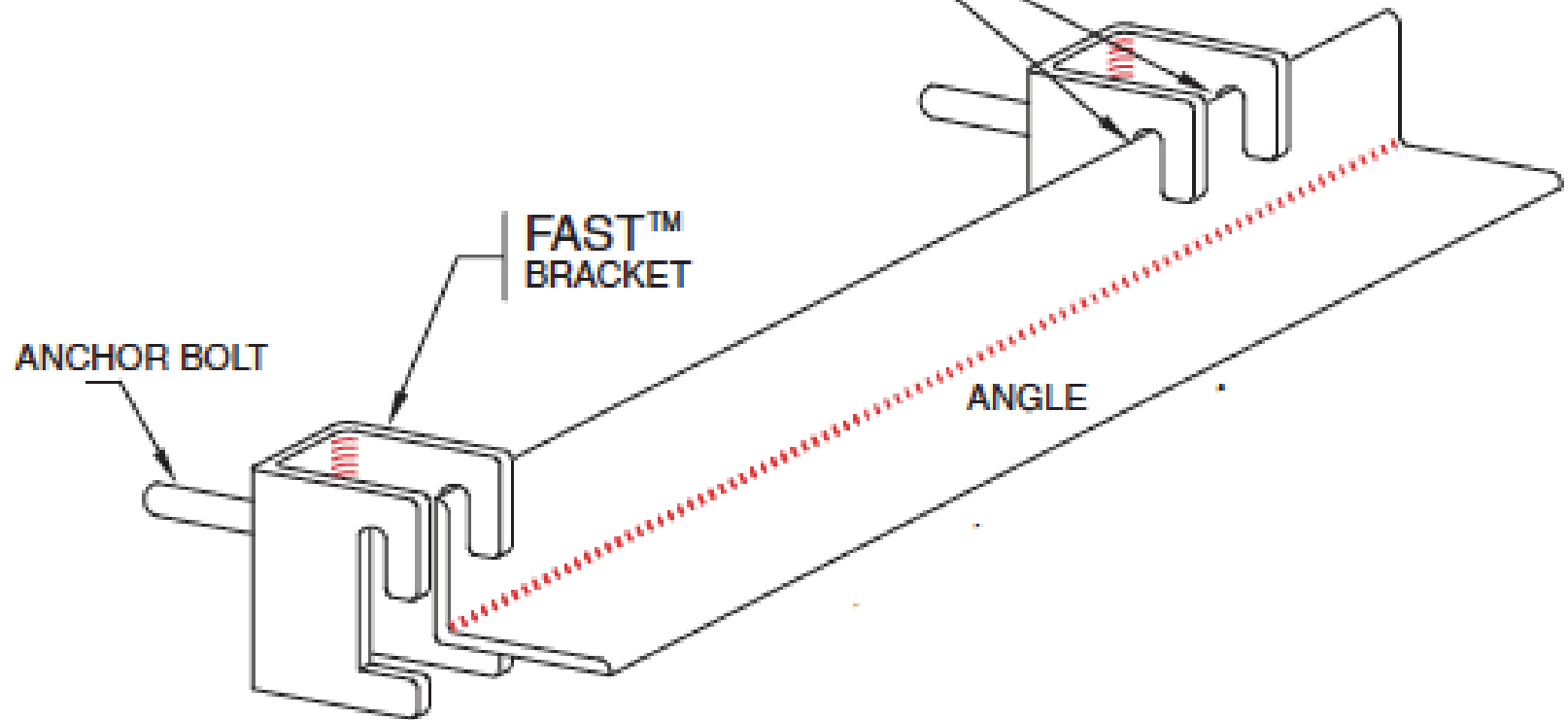




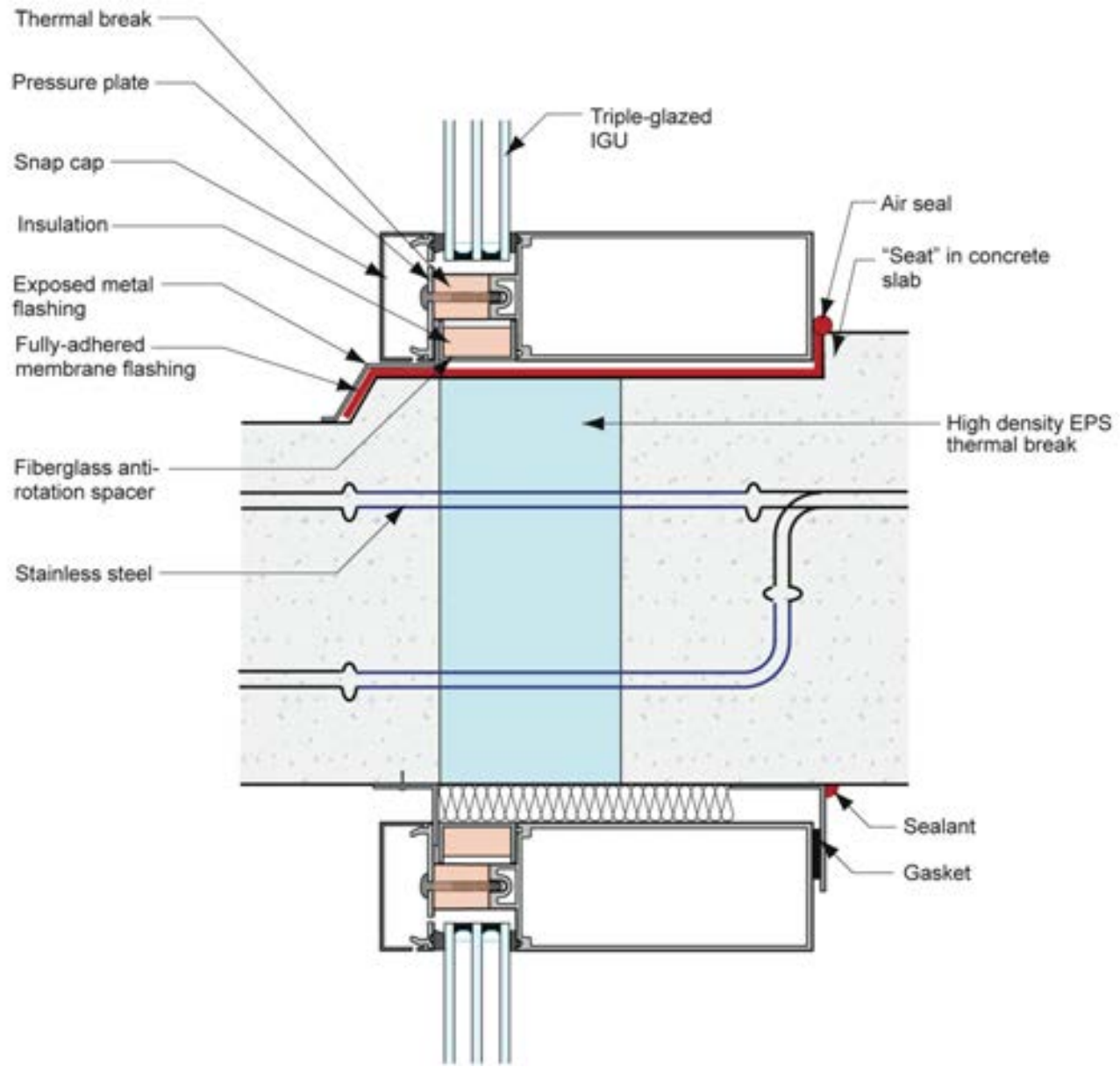


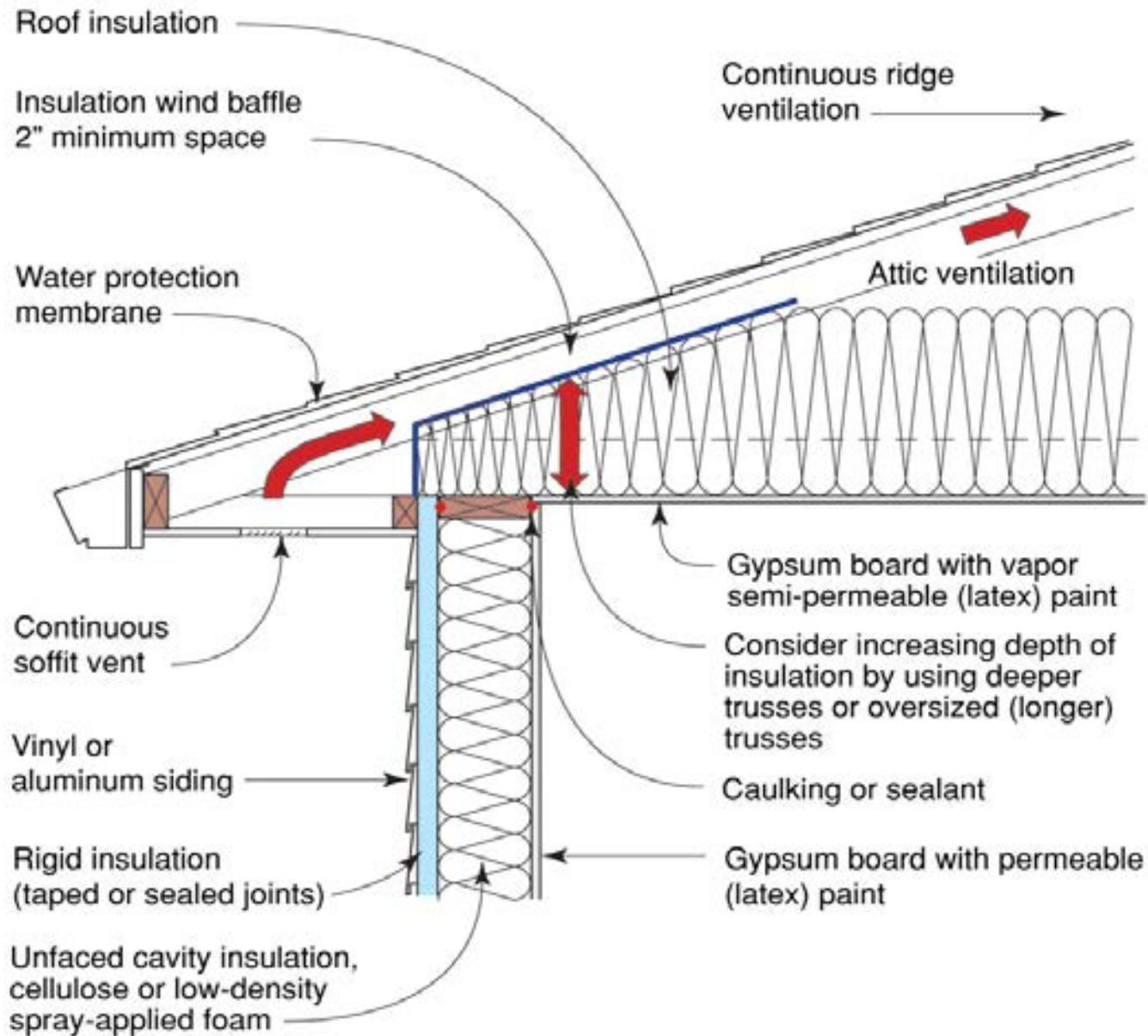


WEDGE SHIMS INSERTED BEHIND/FRONT OF ANGLE TO ENSURE DIRECT BEARING ON BRACKET AND PROVIDE LEVEL (IF NECESSARY)

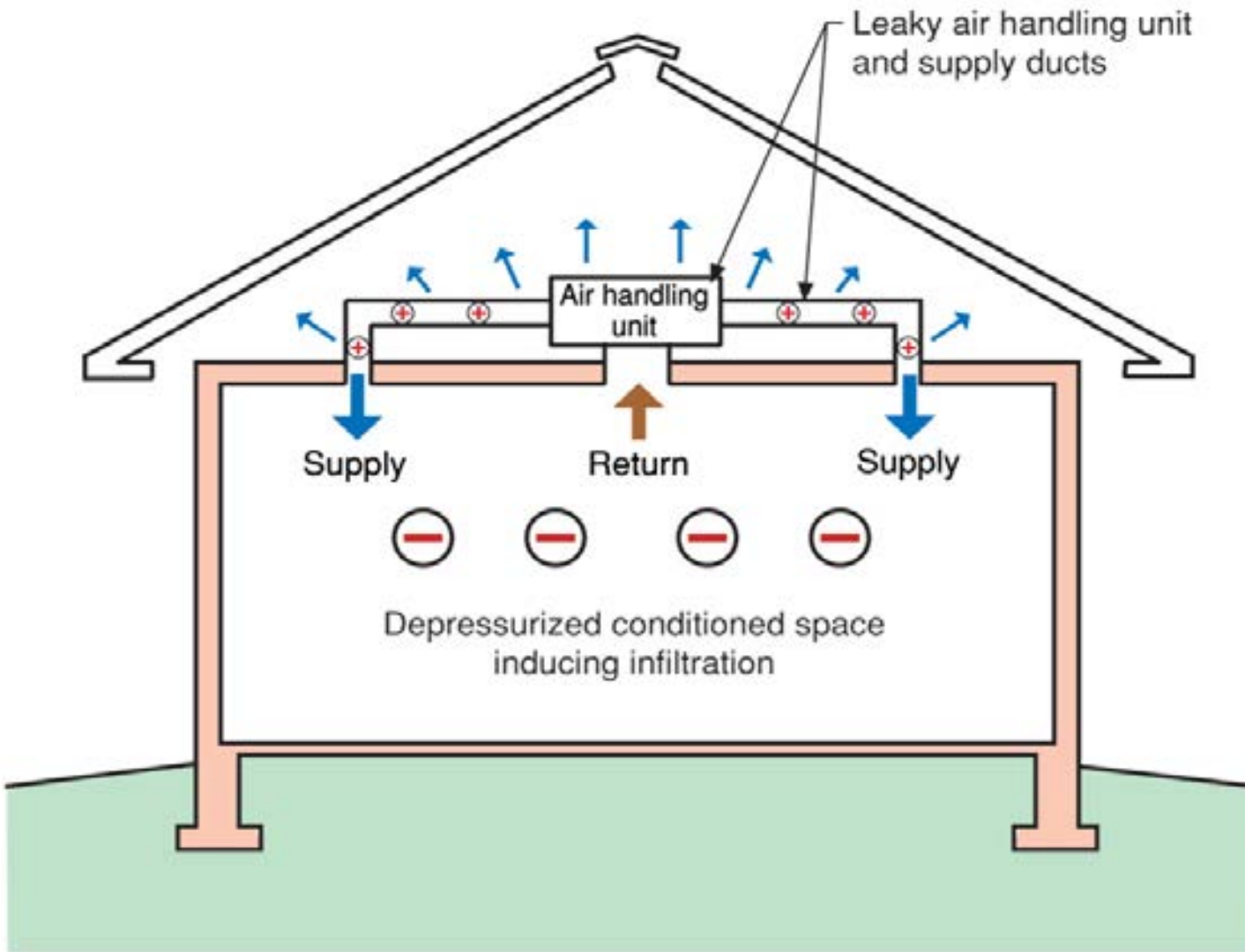












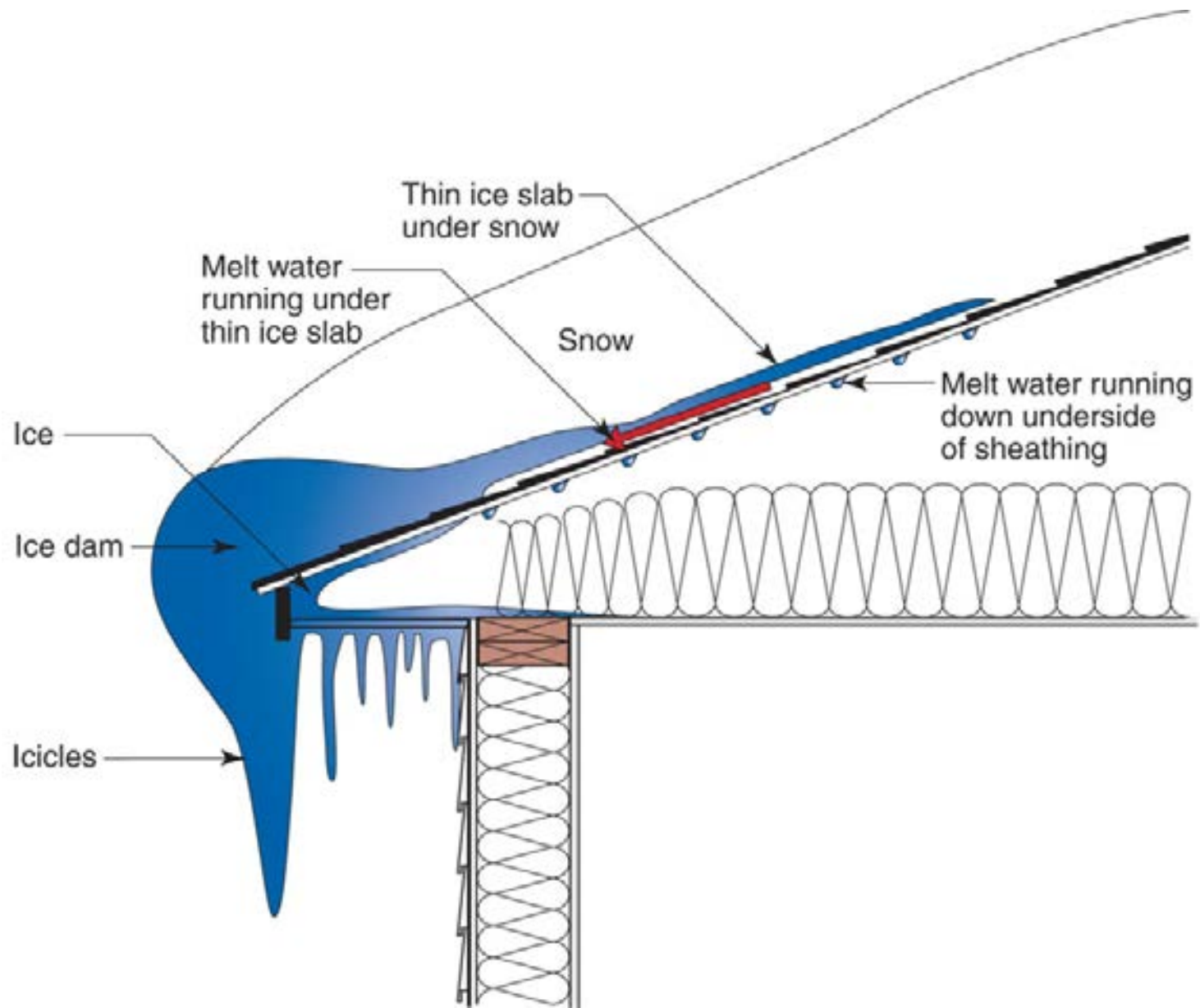
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.









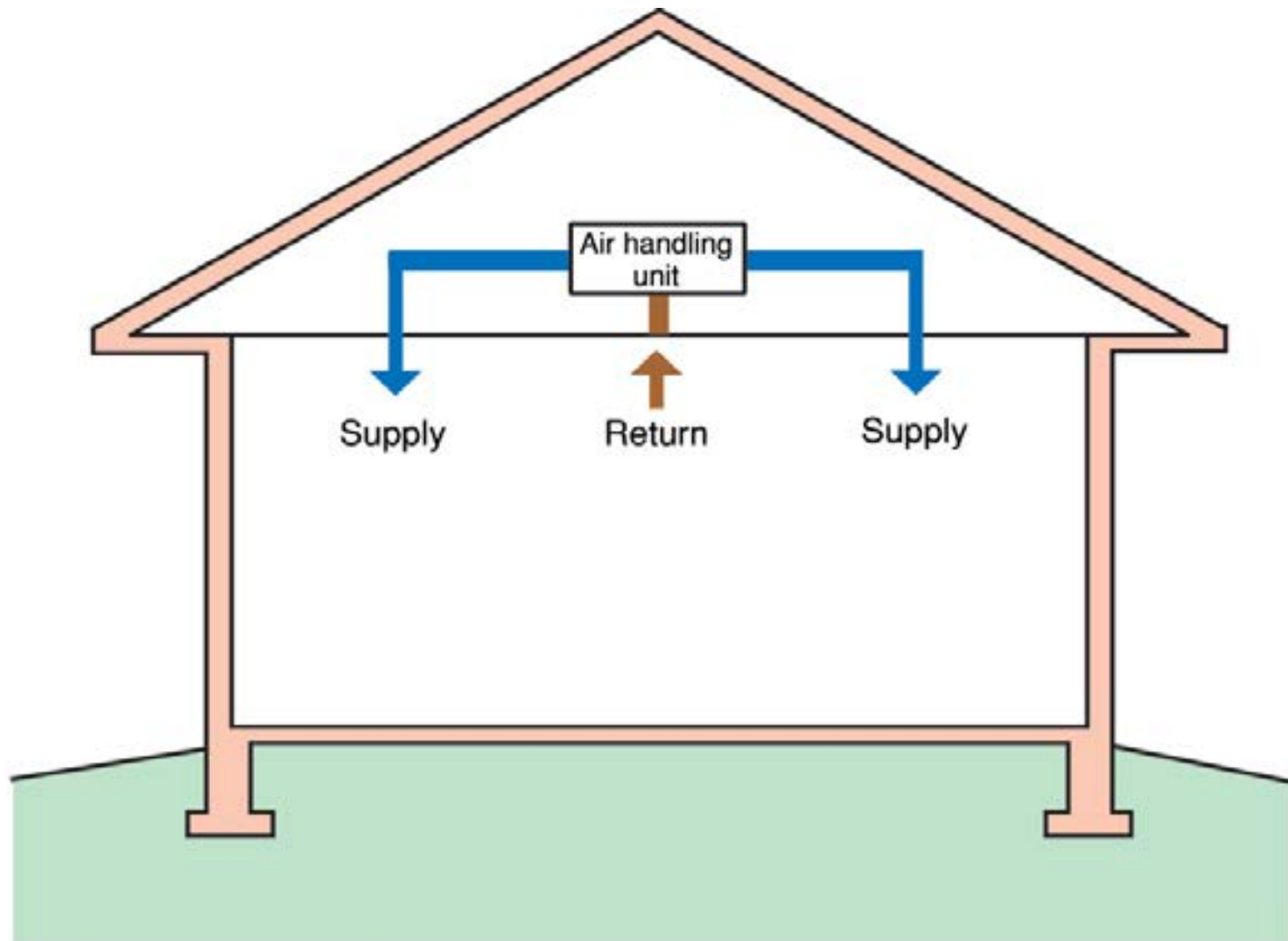




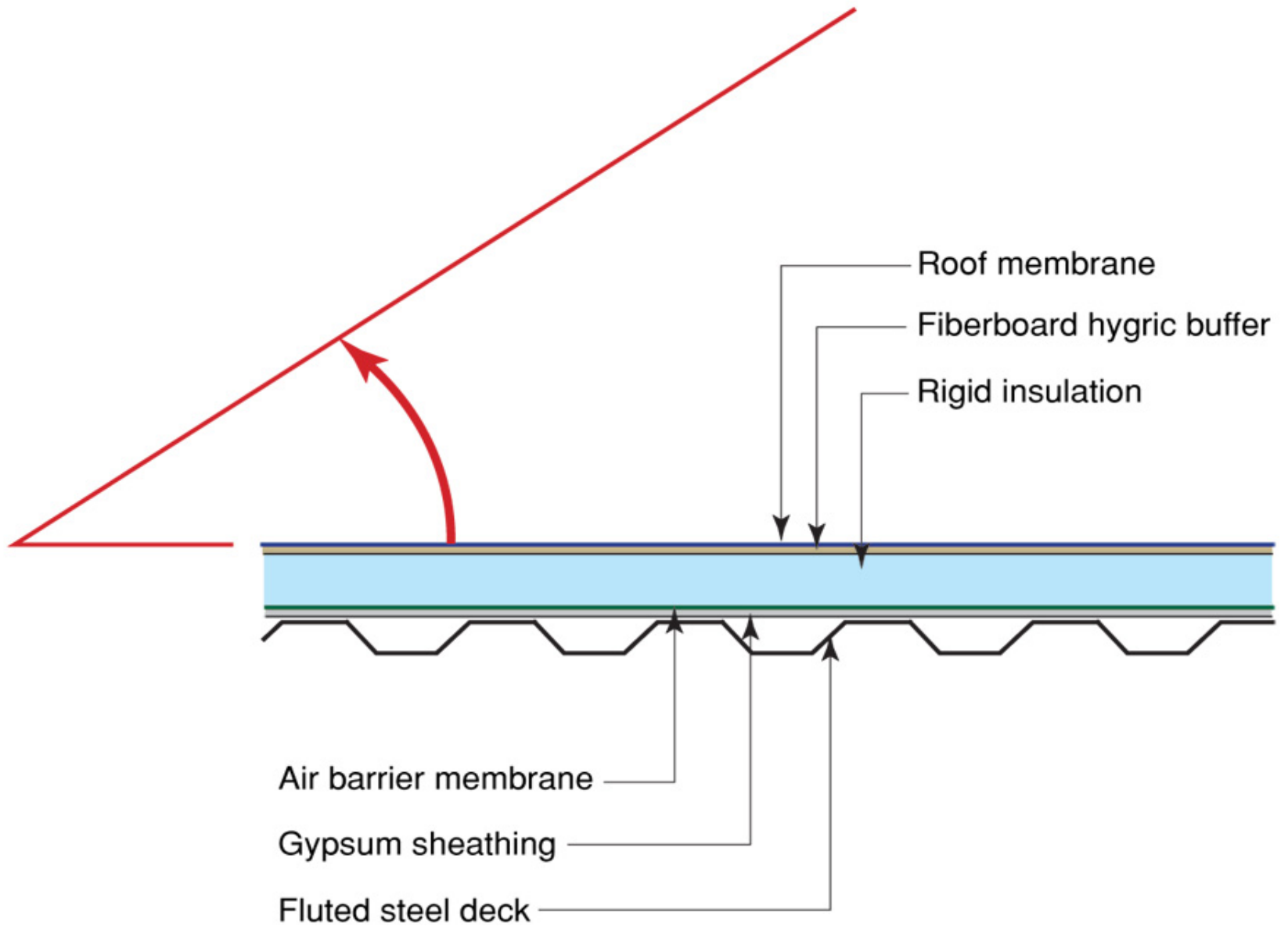


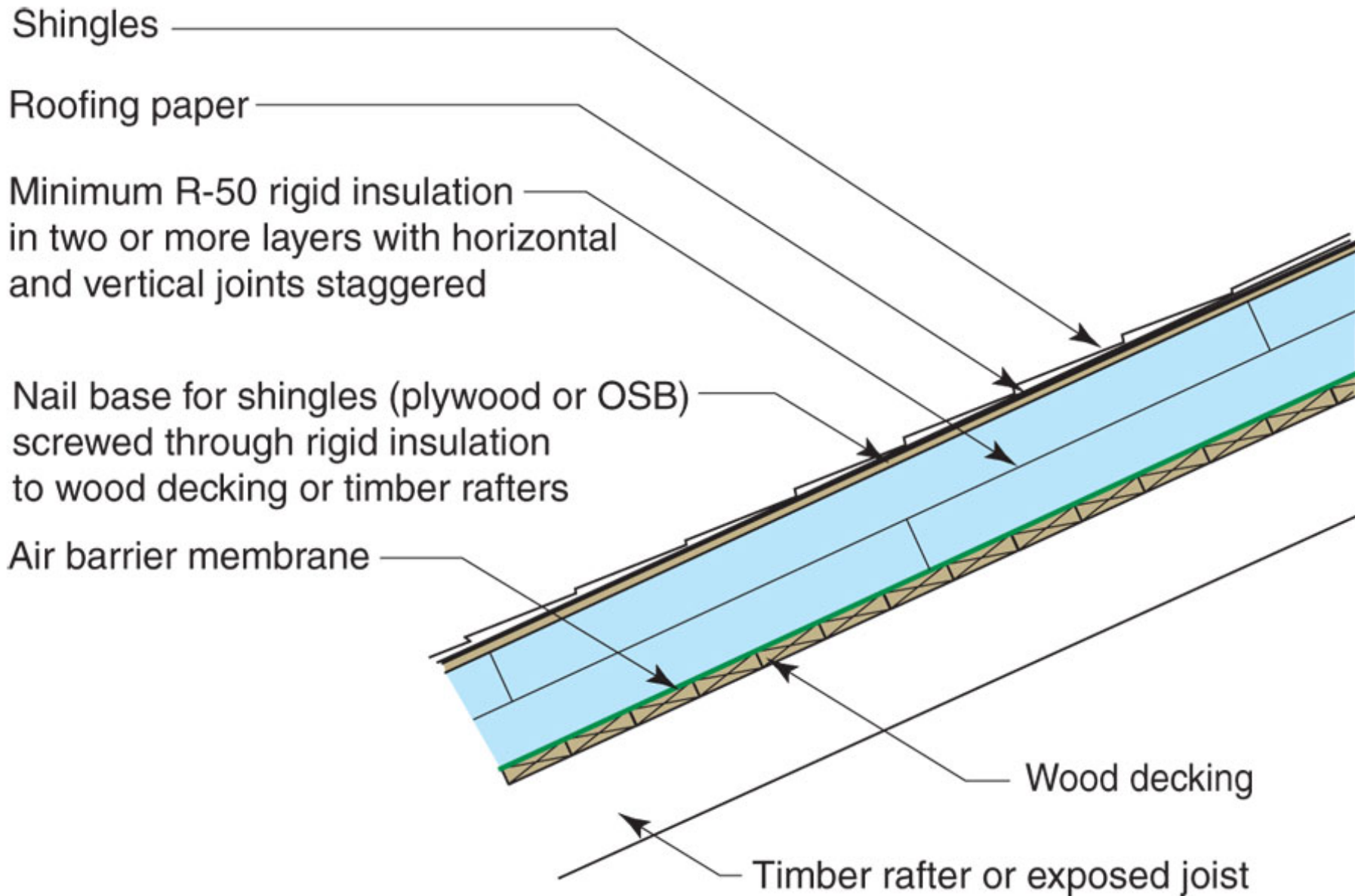


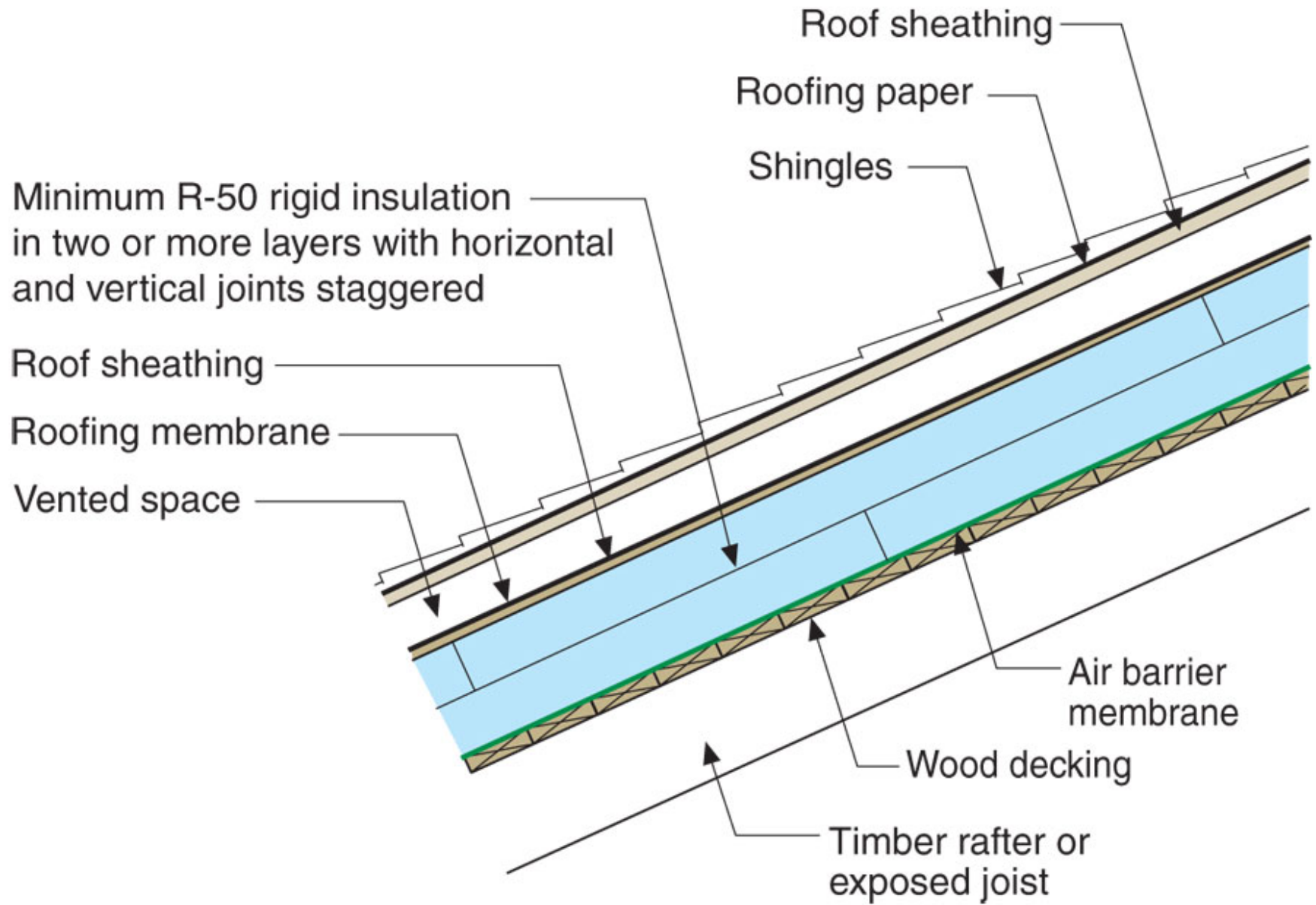


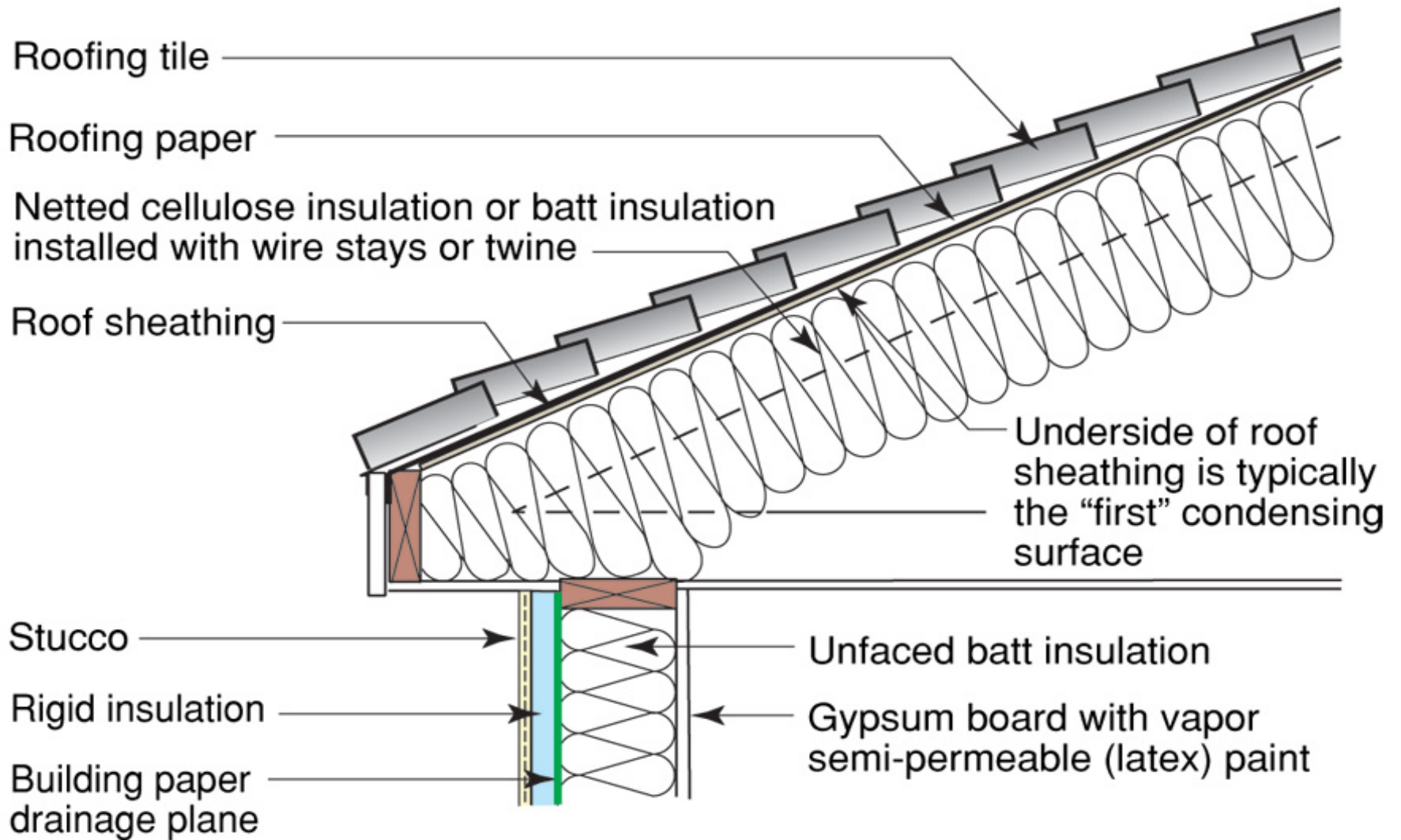


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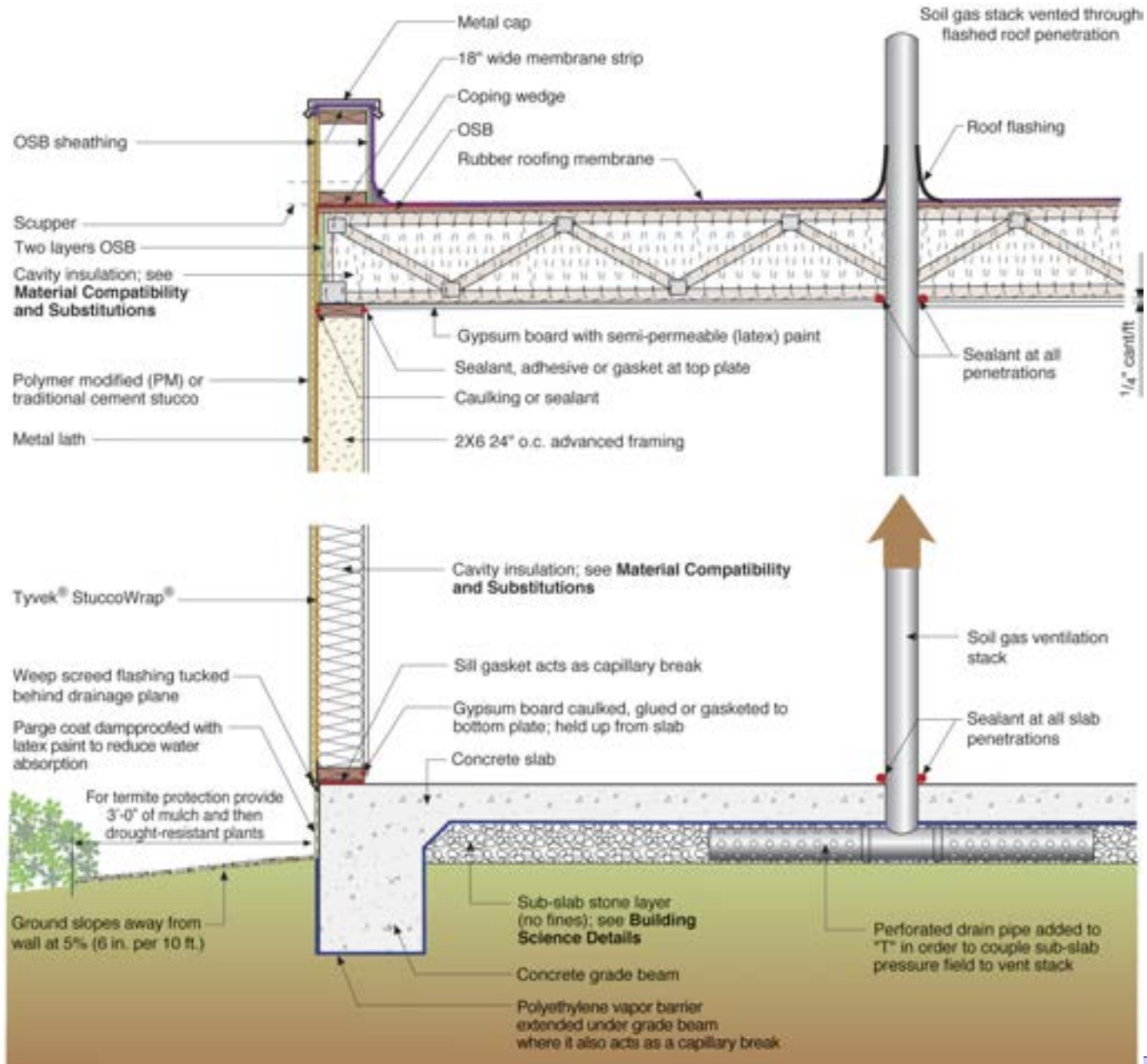


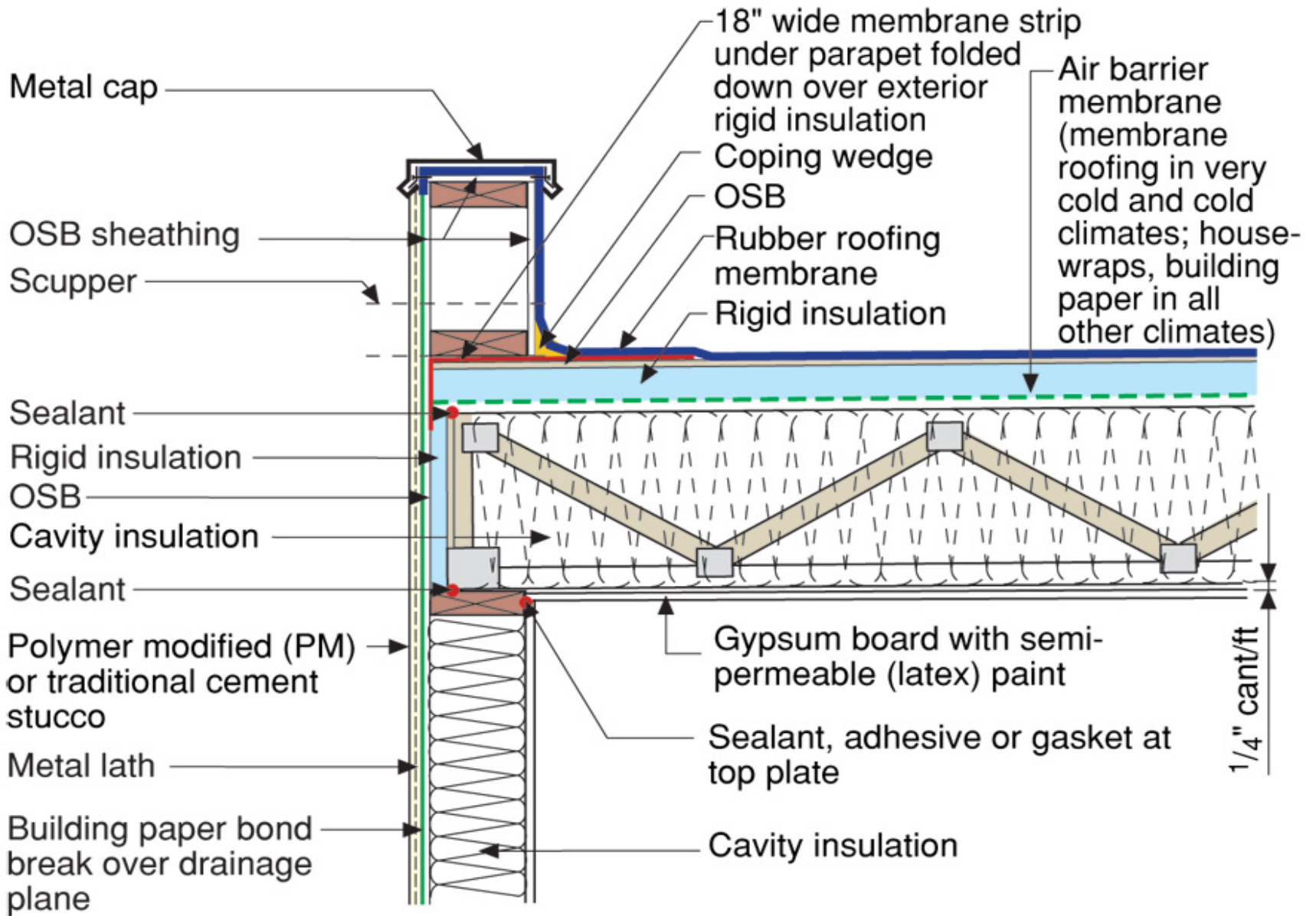


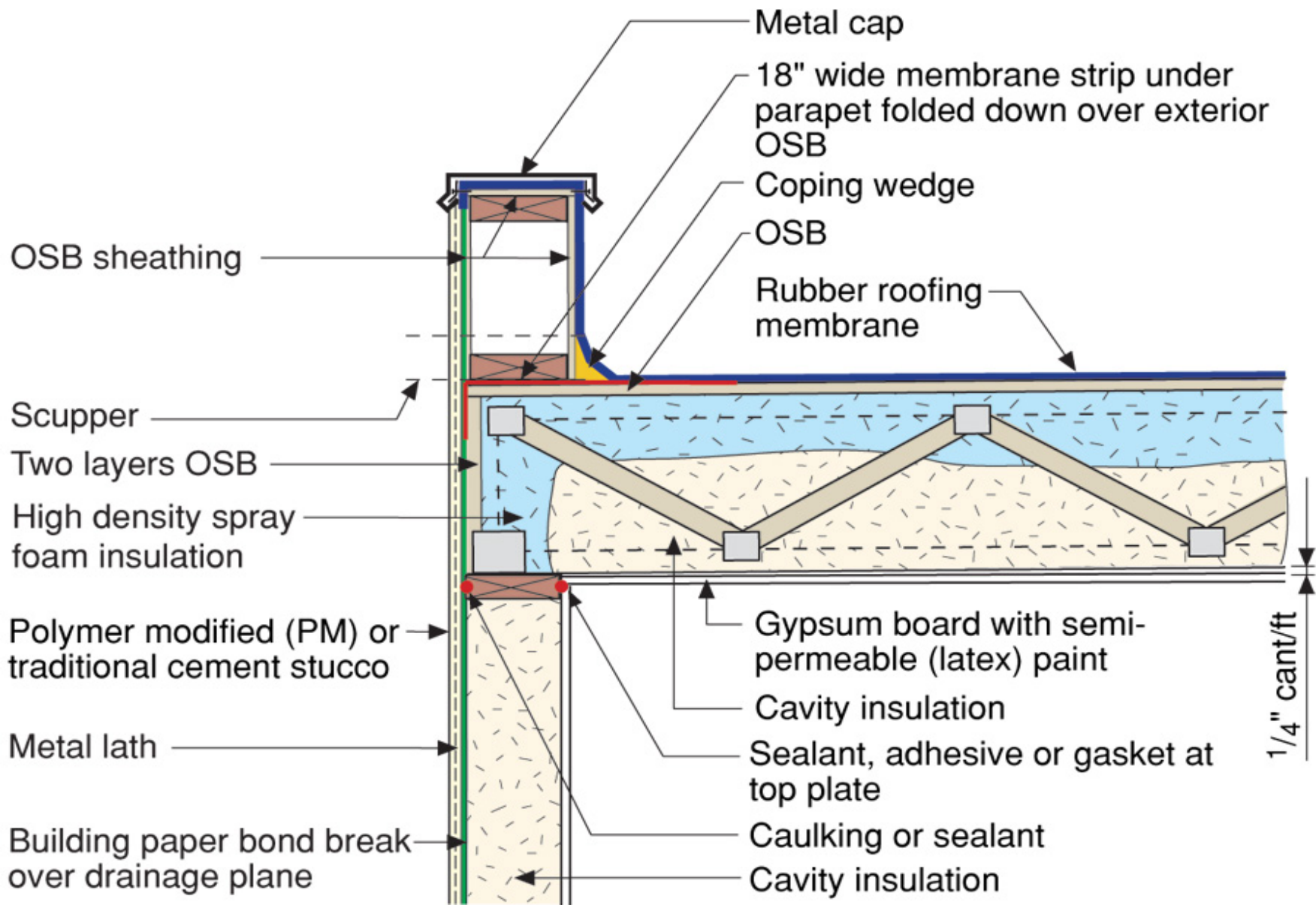




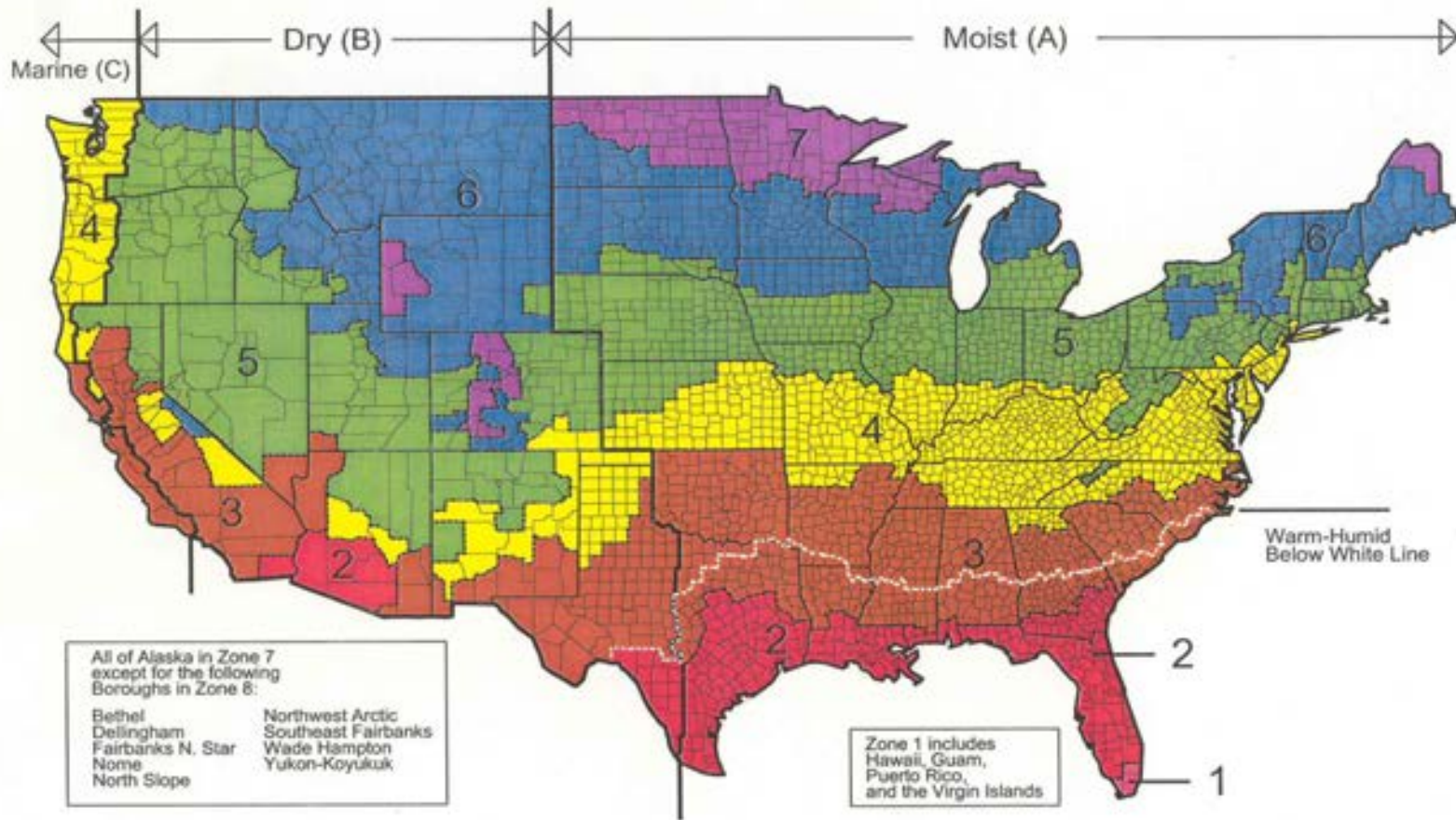




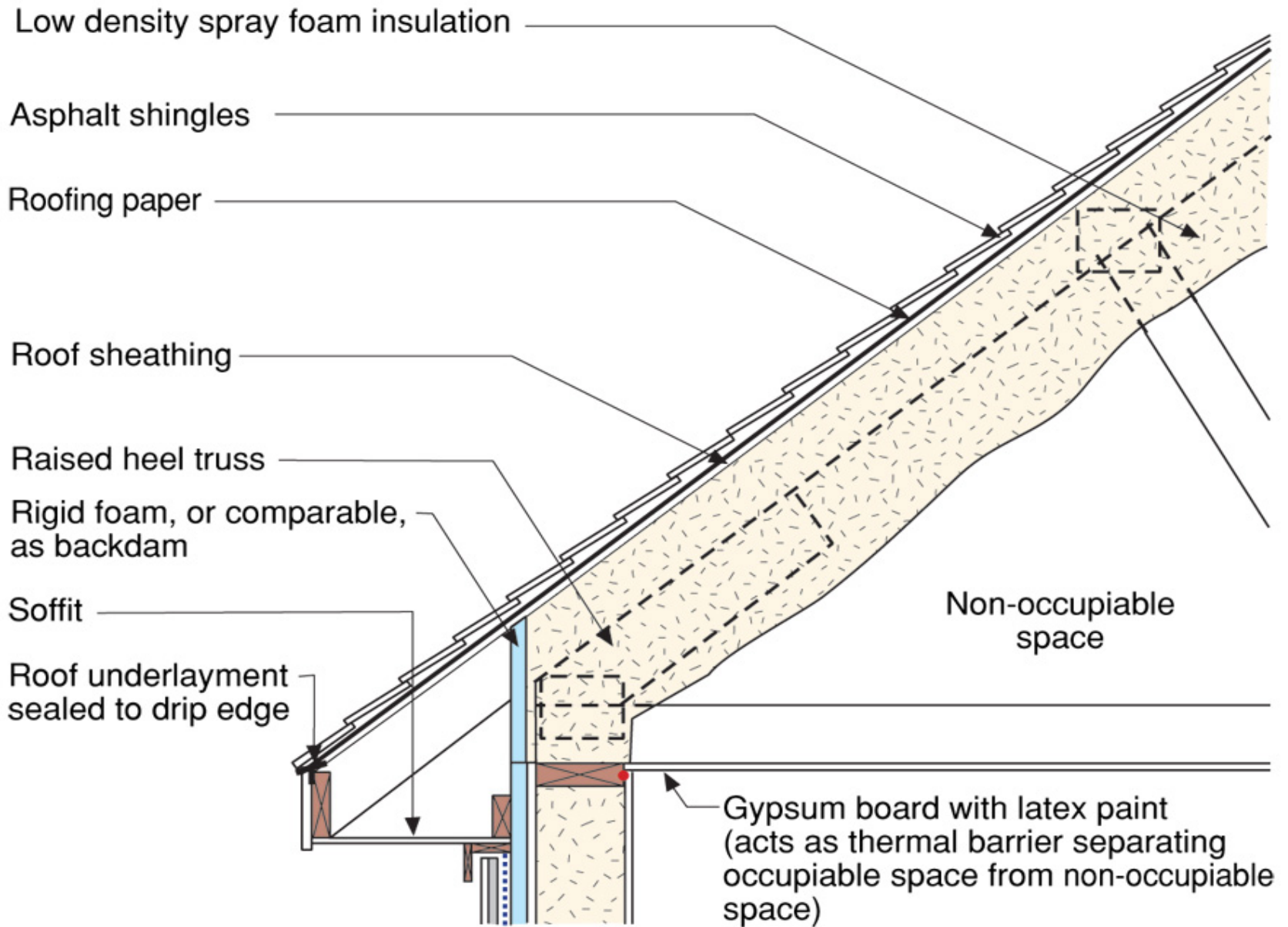




Map of DOE's Proposed Climate Zones



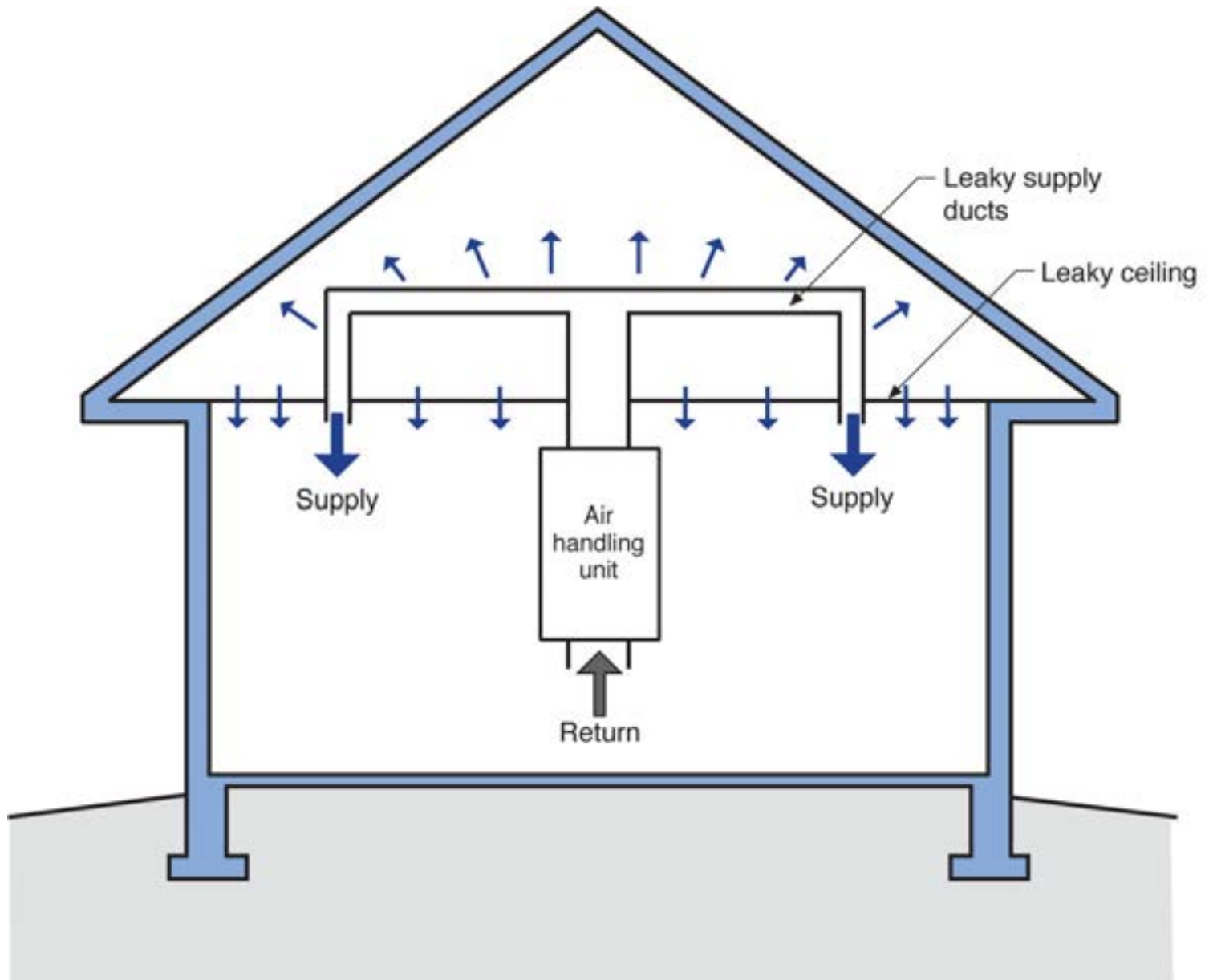
March 24, 2003

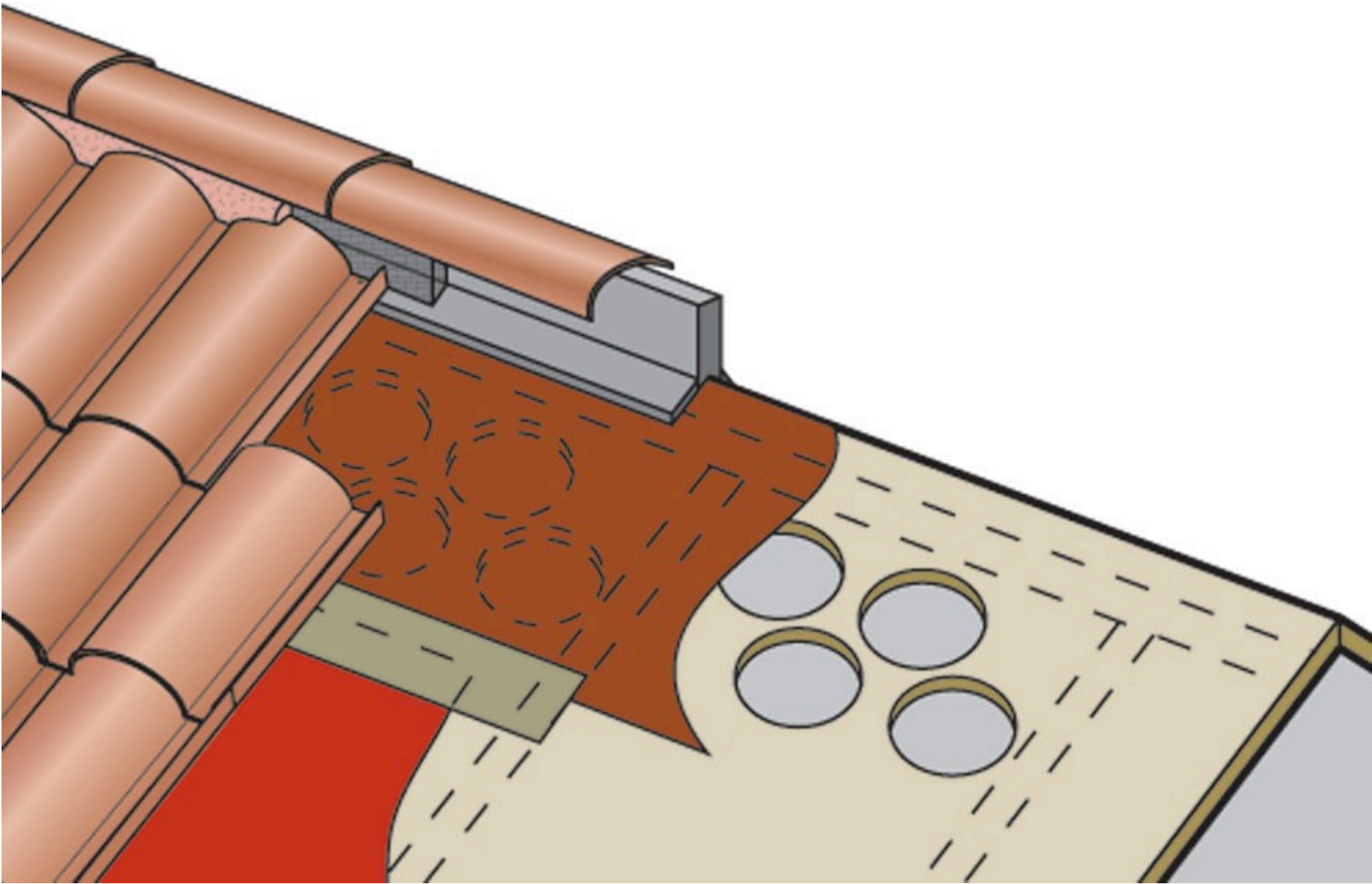


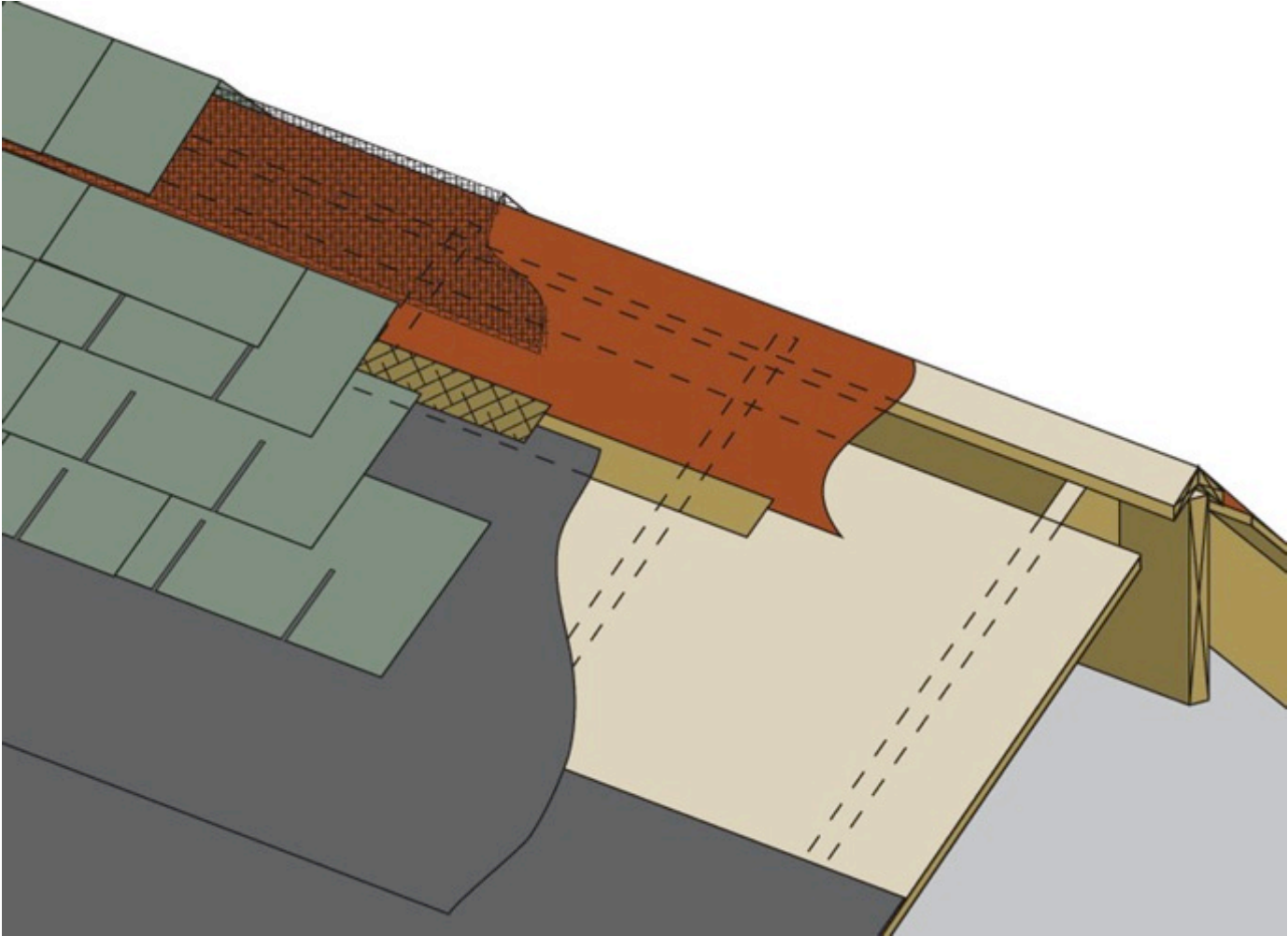








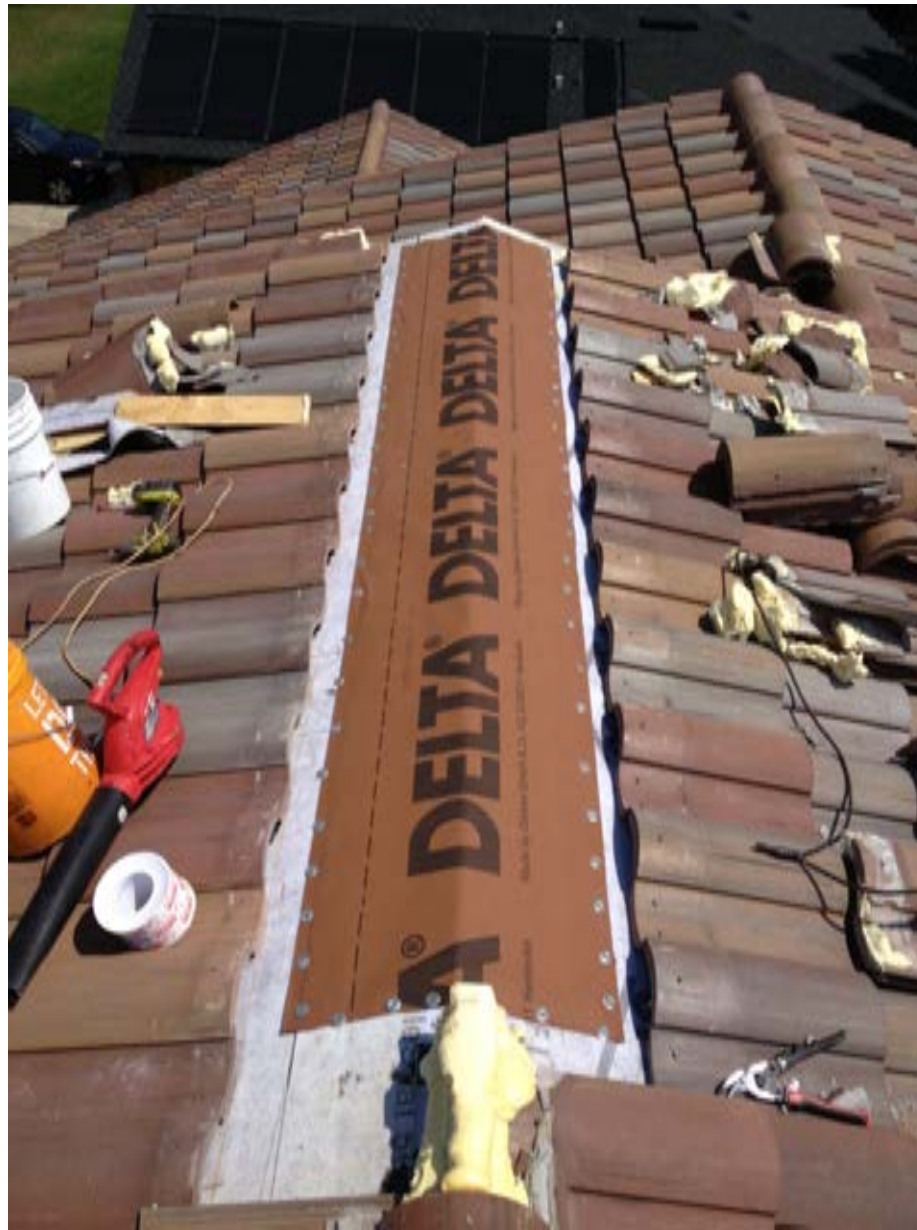


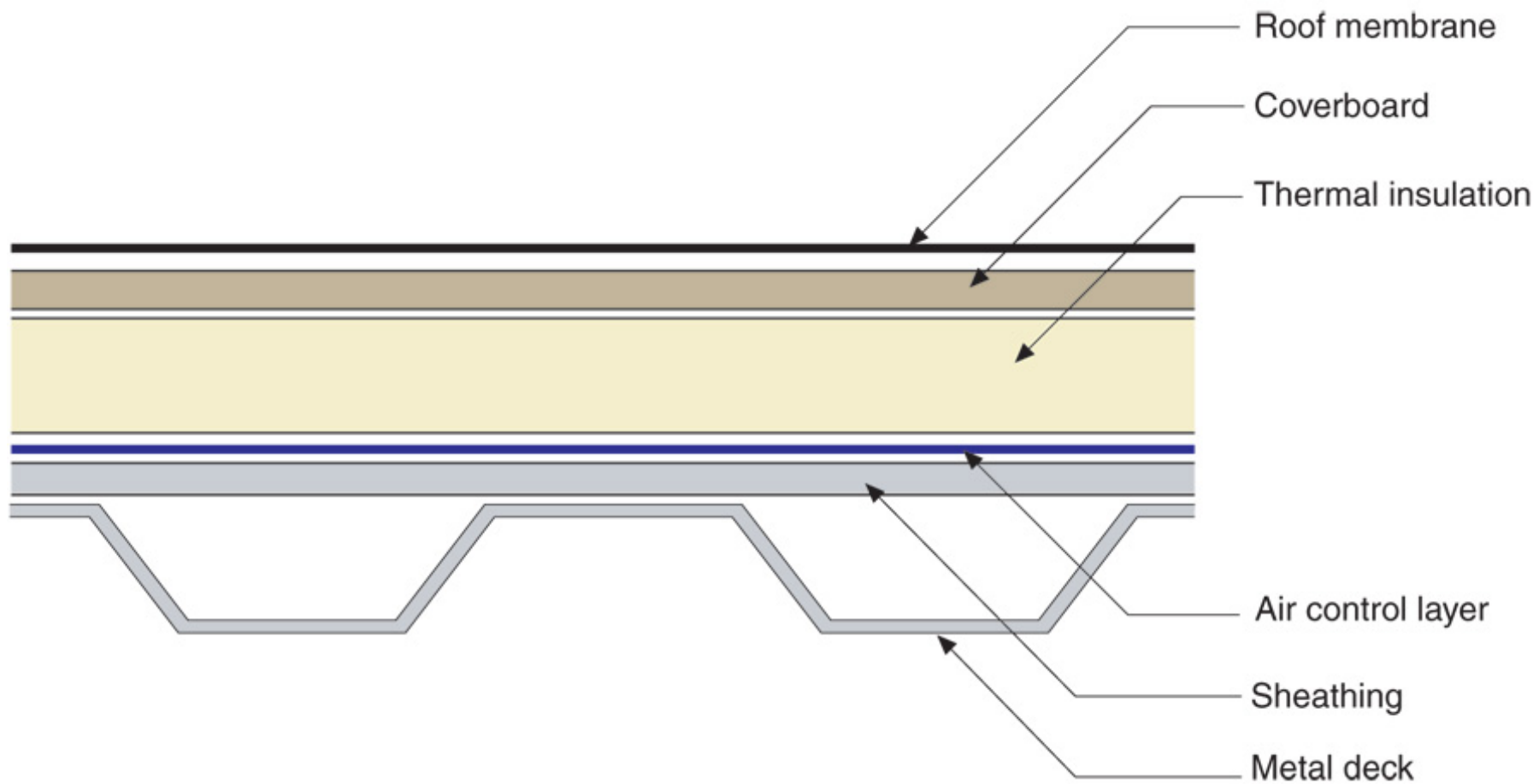


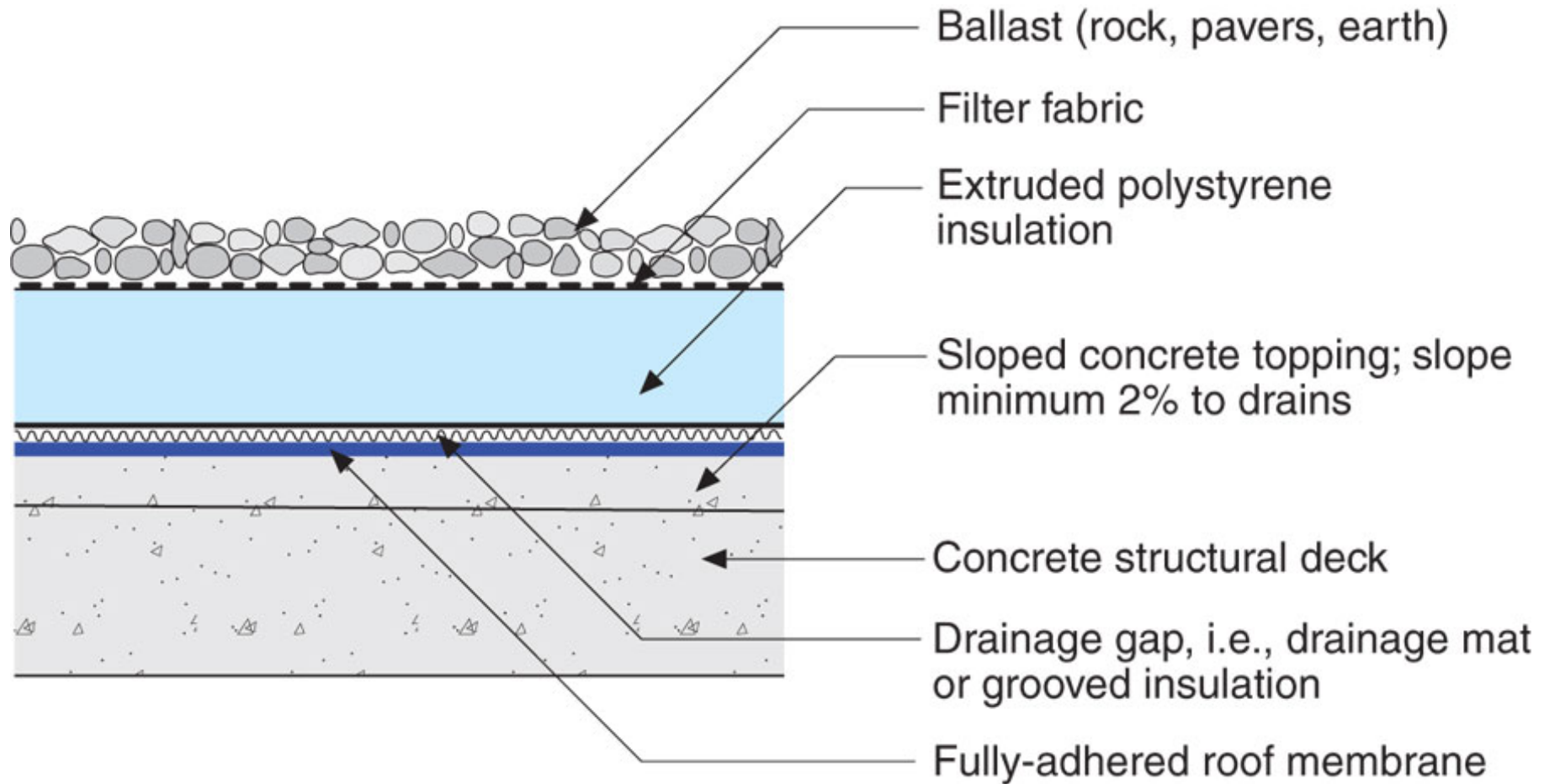


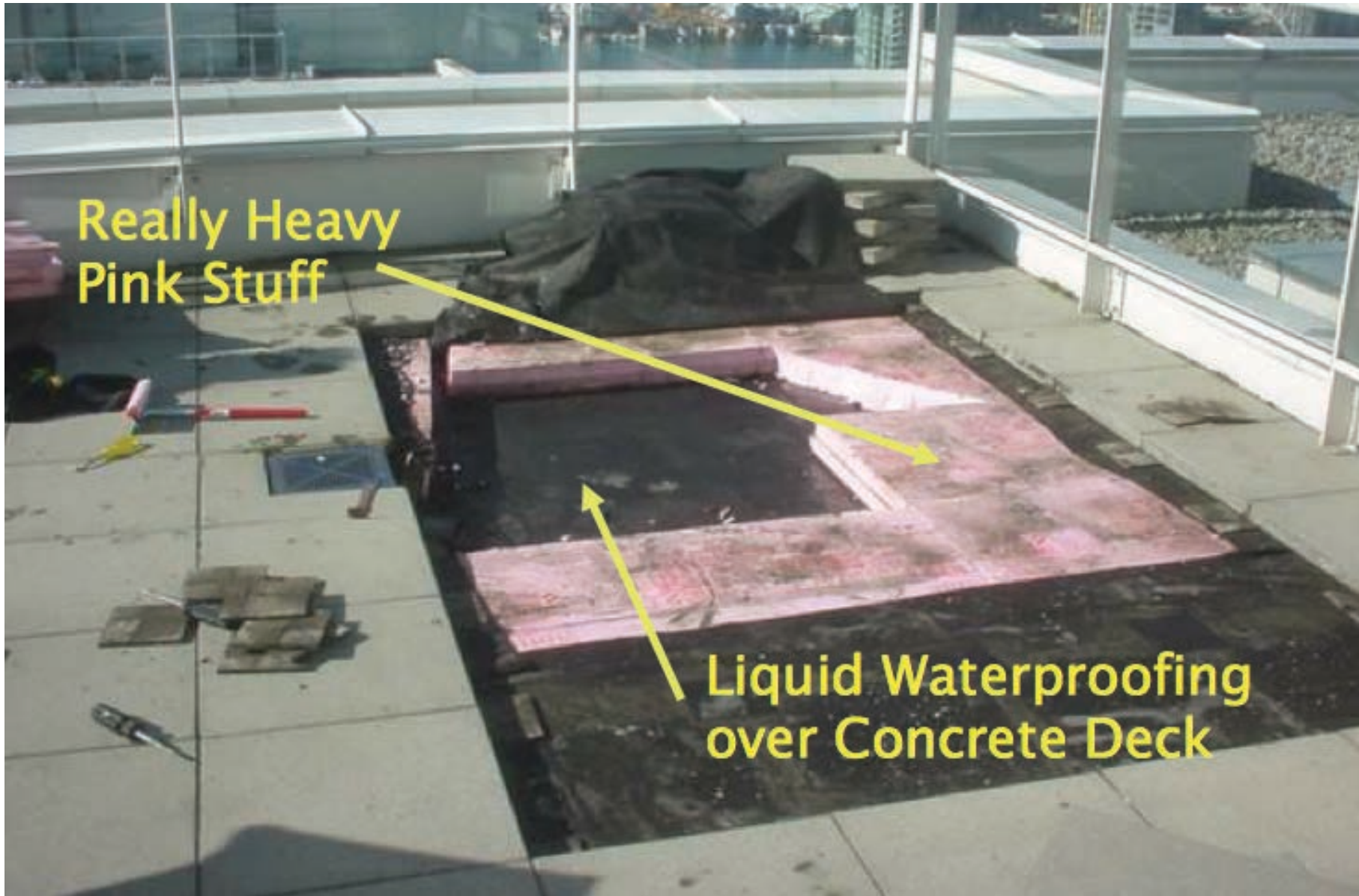






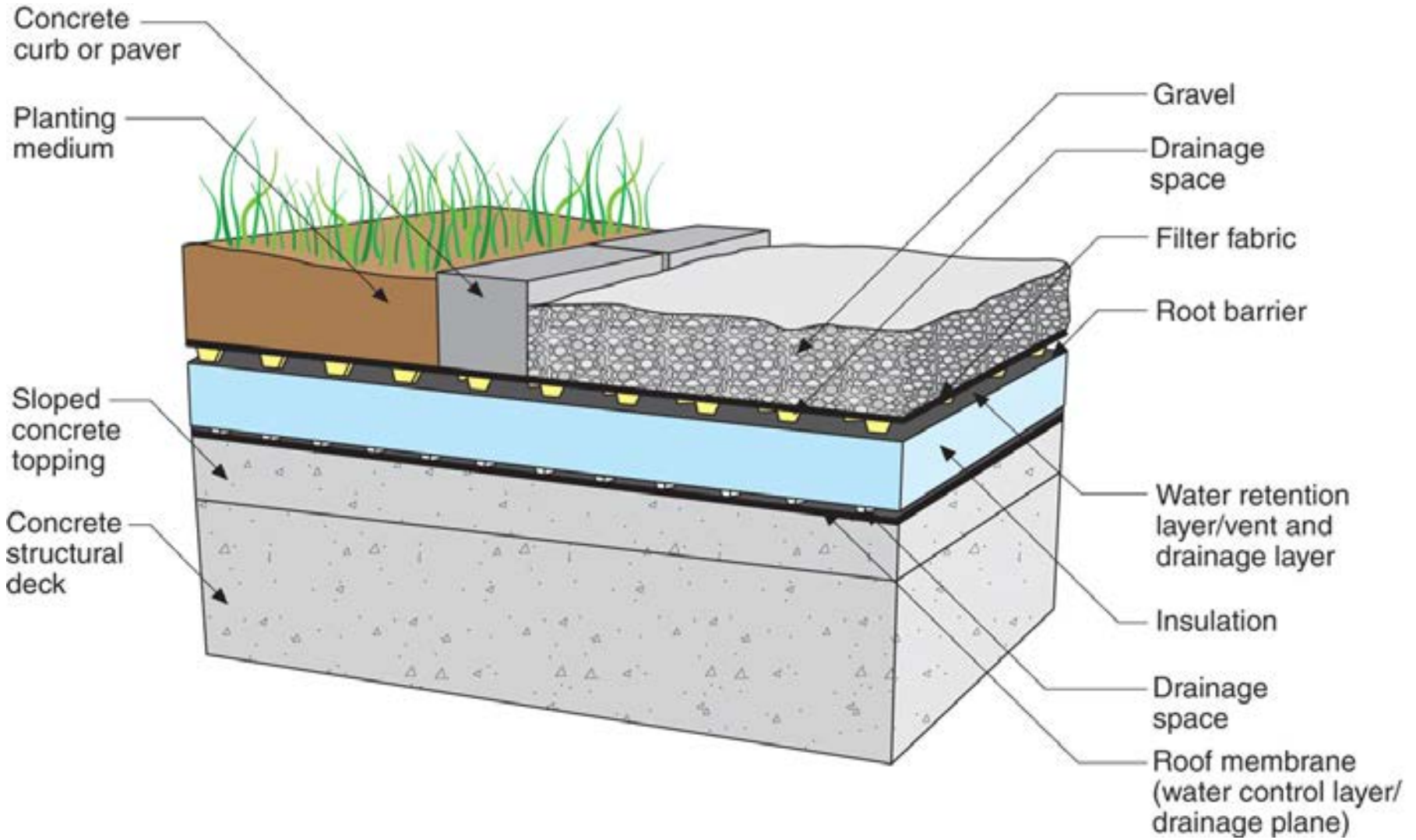




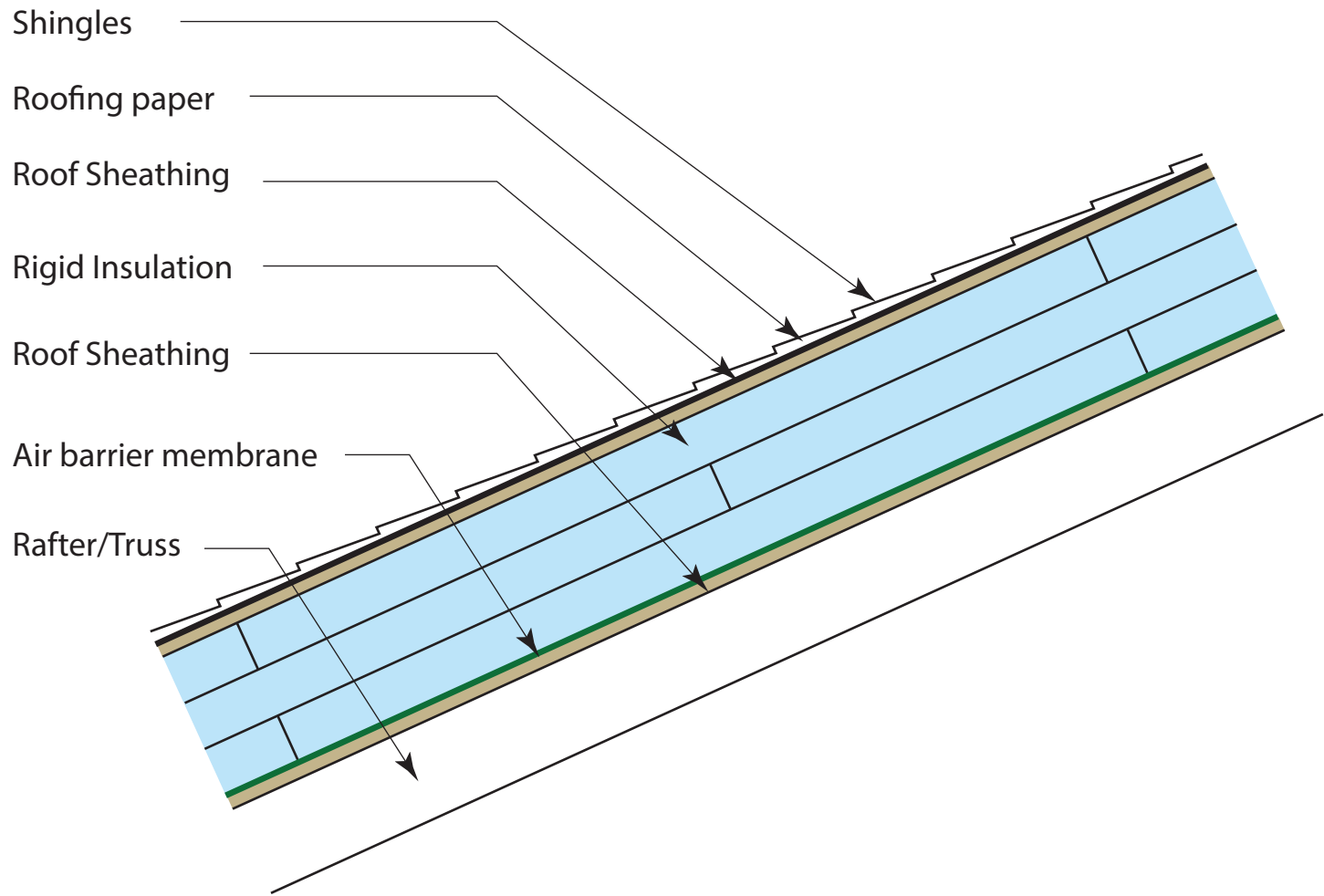


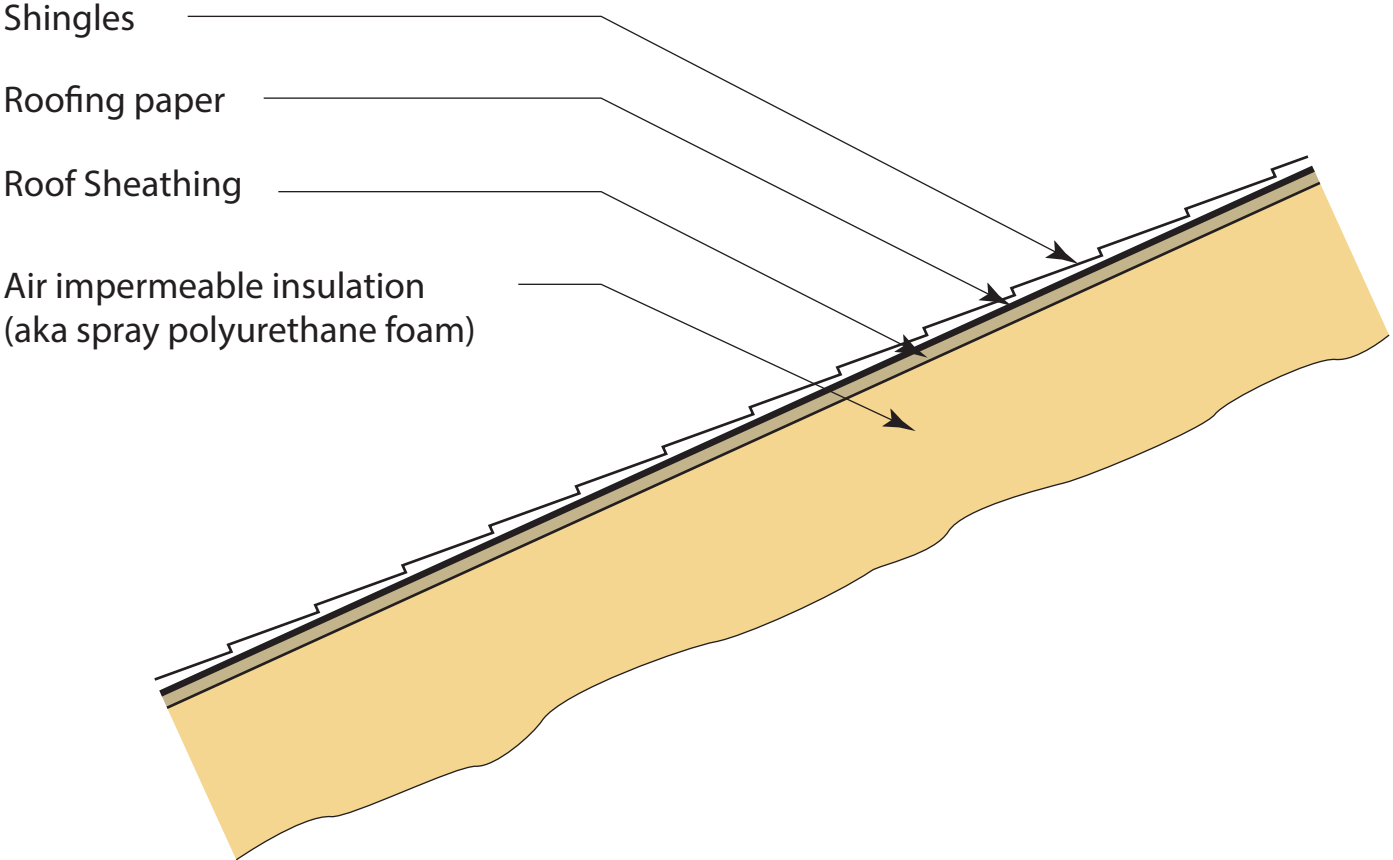
Really Heavy
Pink Stuff

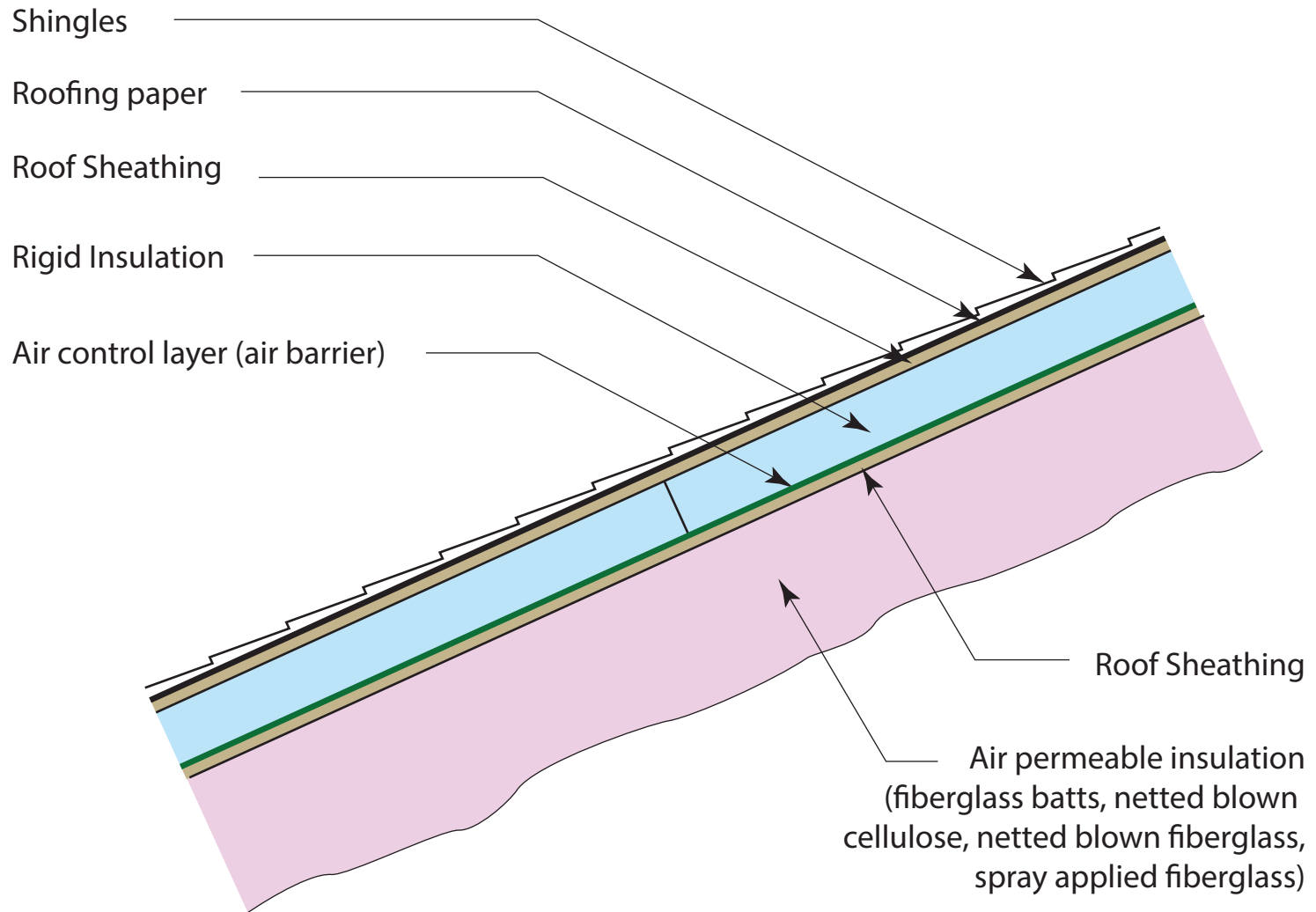
Liquid Waterproofing
over Concrete Deck









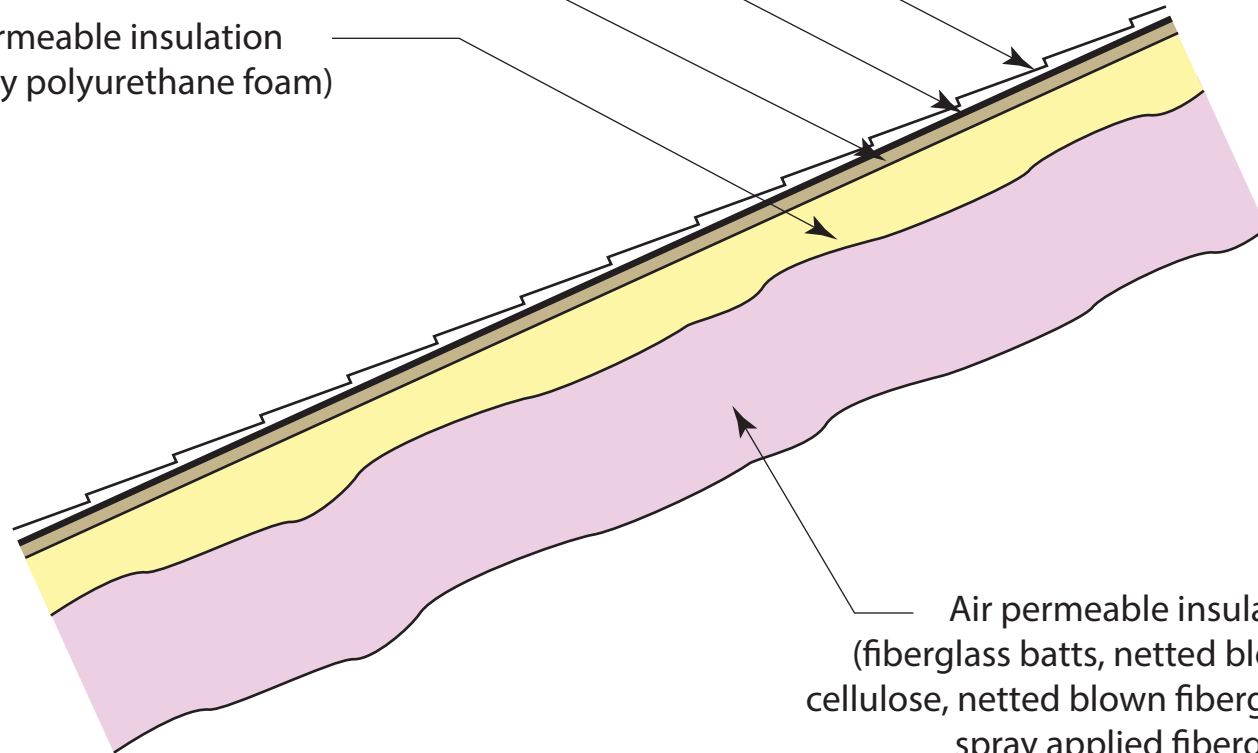


Shingles

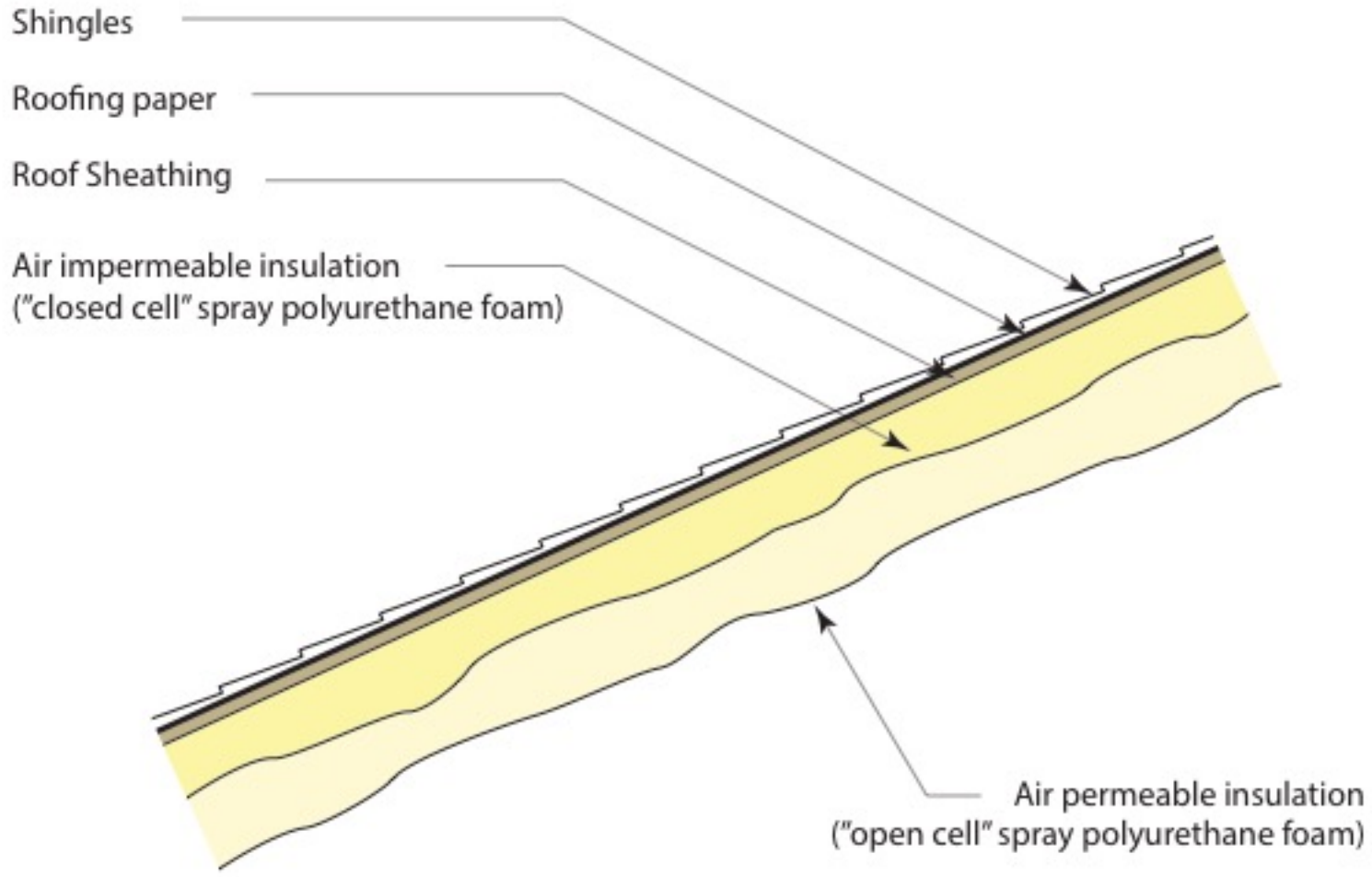
Roofing paper

Roof Sheathing

Air impermeable insulation
(aka spray polyurethane foam)



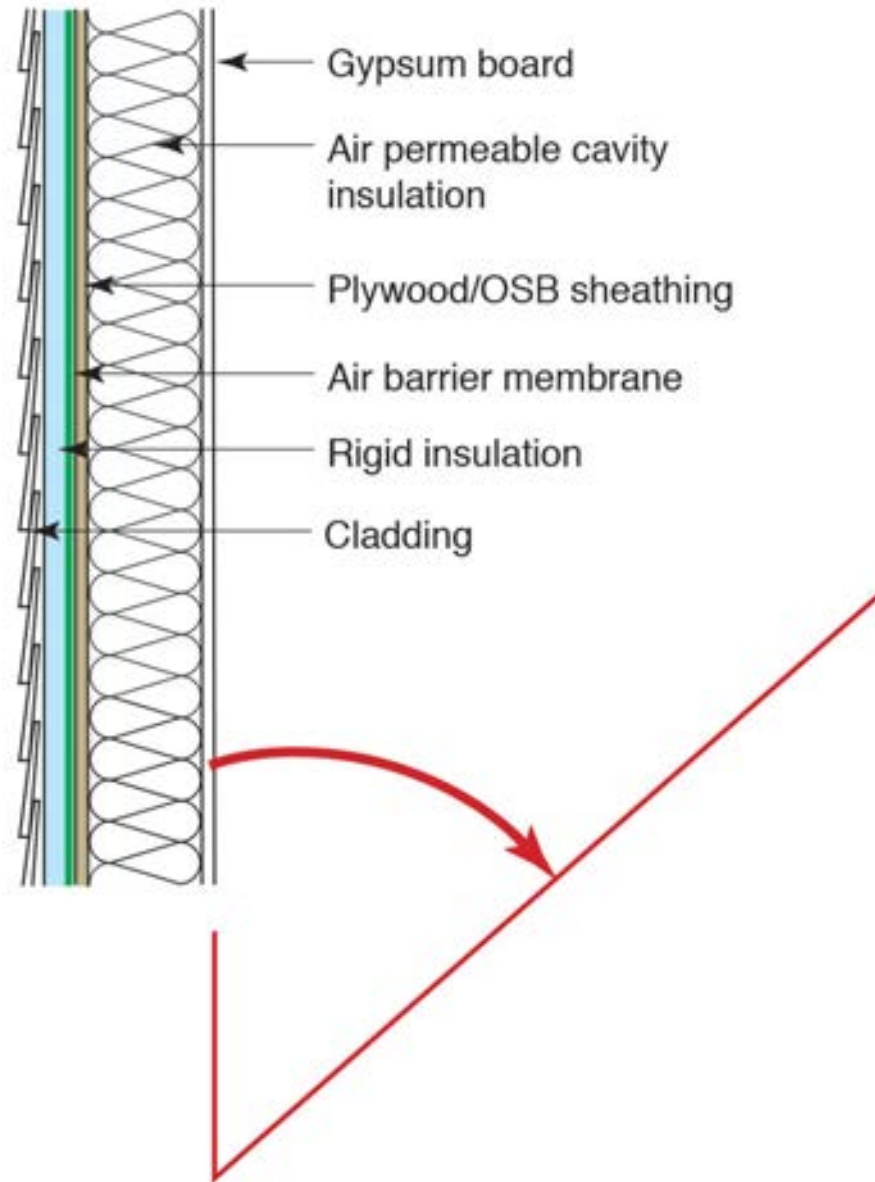
Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass)

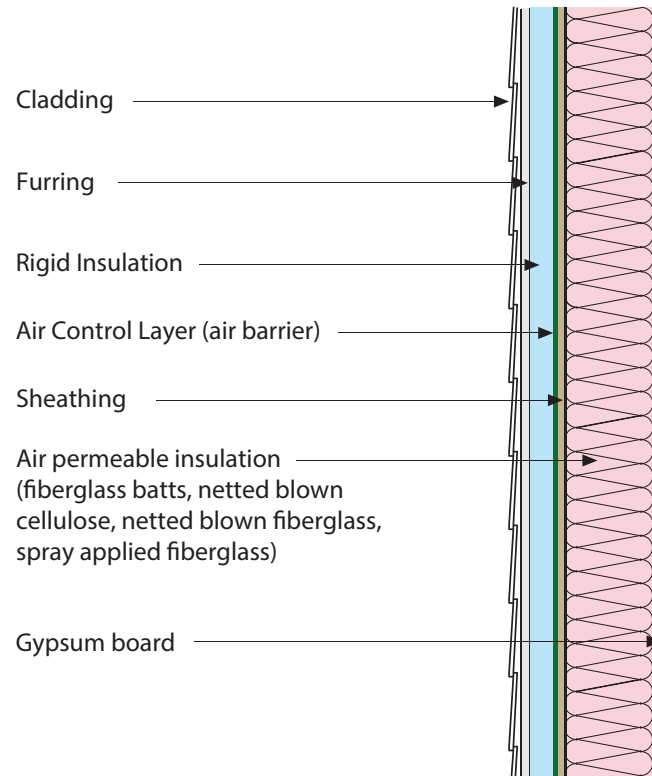


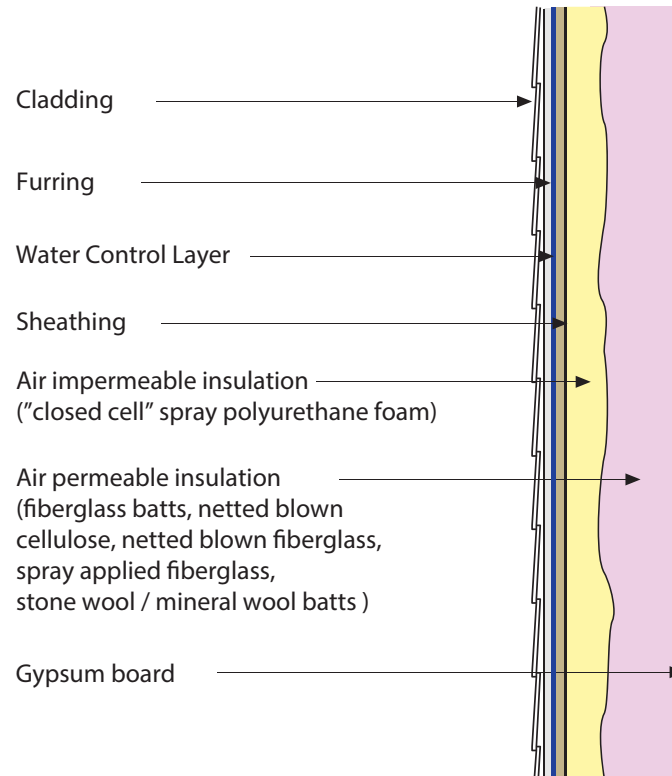
Insulation for Condensation Control*

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







Insulation for Condensation Control*

Climate Zone	Rigid Board or Air Impermeable Insulation	Code Required R-Value	Ratio of Rigid Board Insulation or Air Impermeable 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