

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

Building Science

Adventures In Building Science

www.buildingscience.com

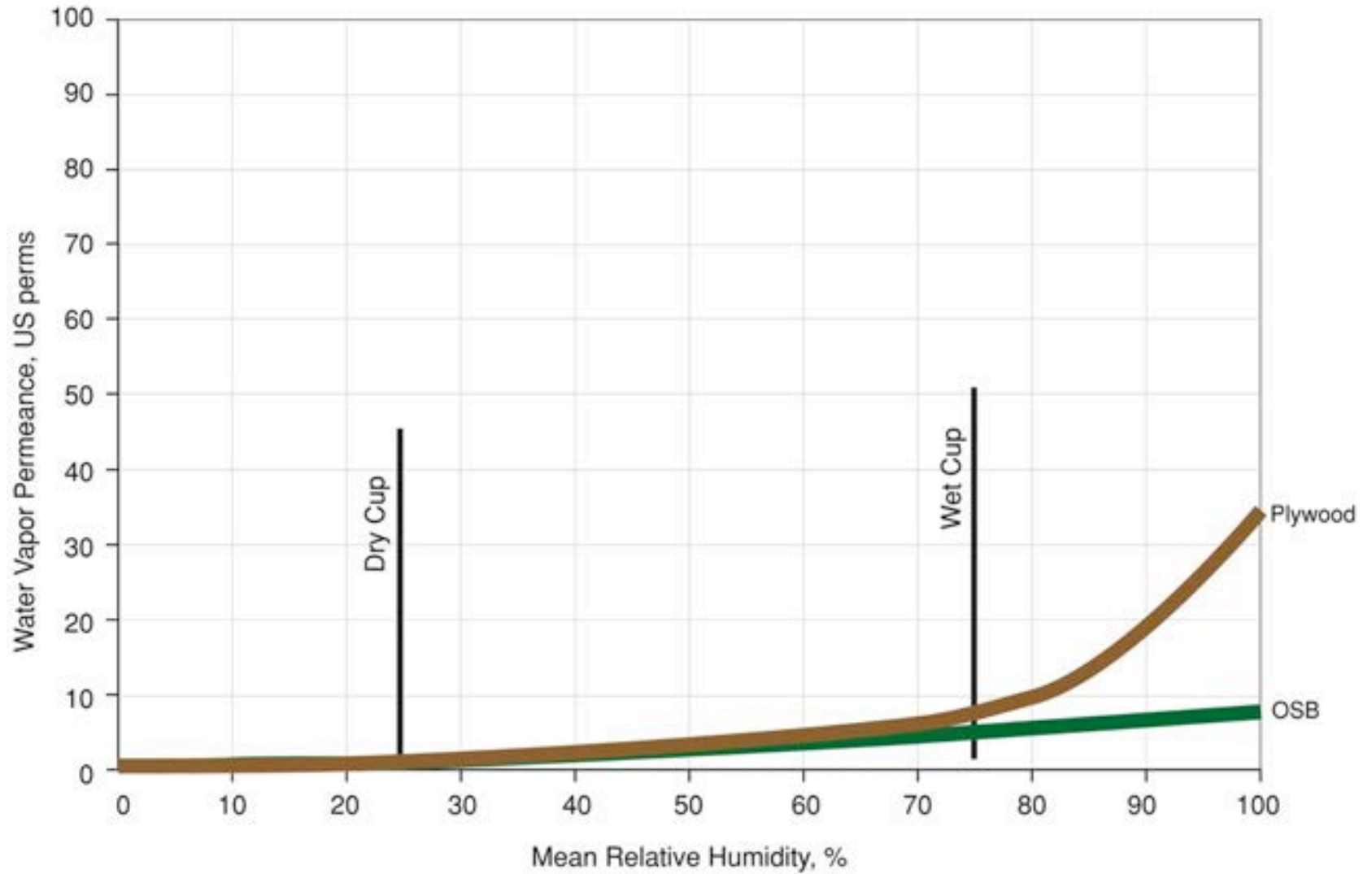
What is a Building?

A Building is an Environmental Separator

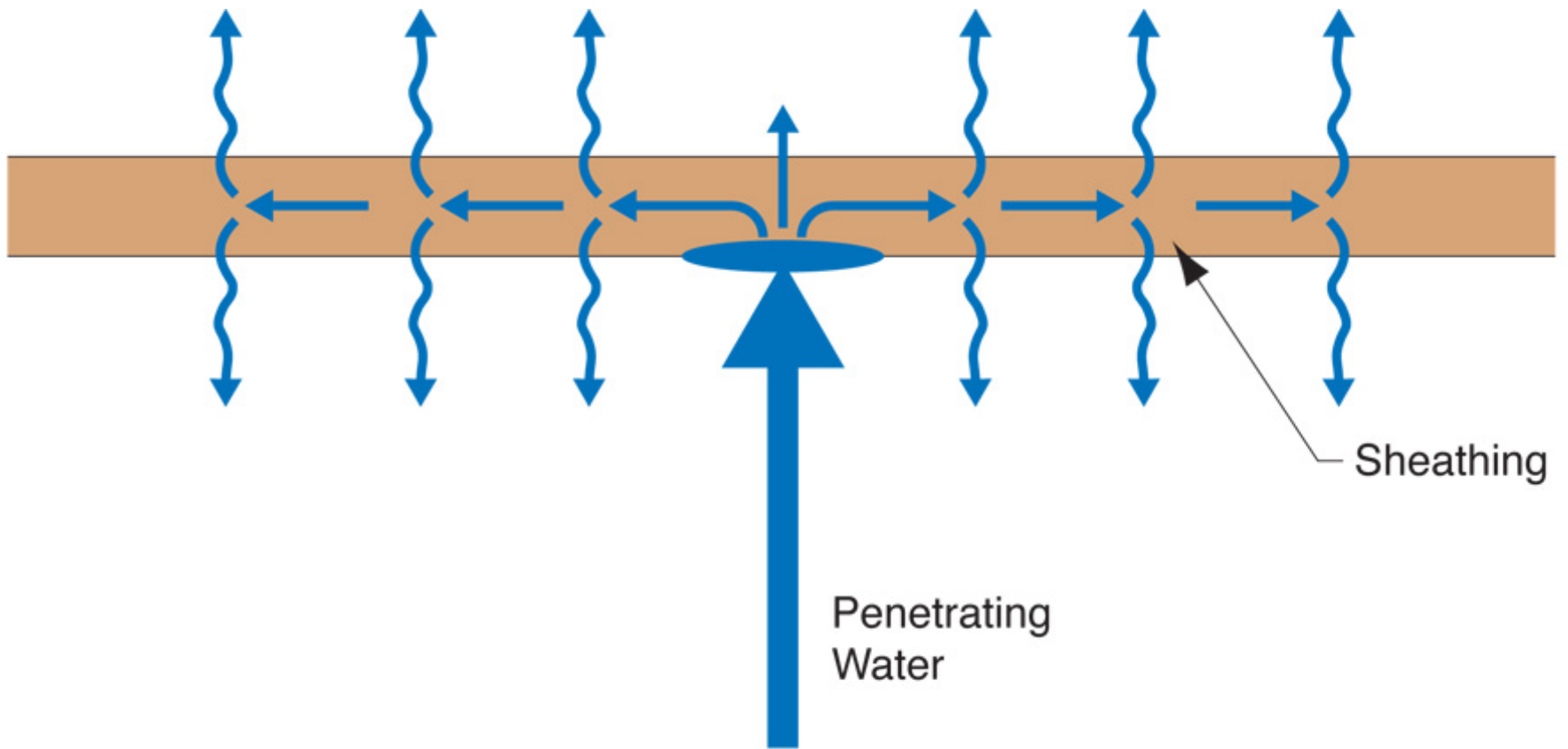


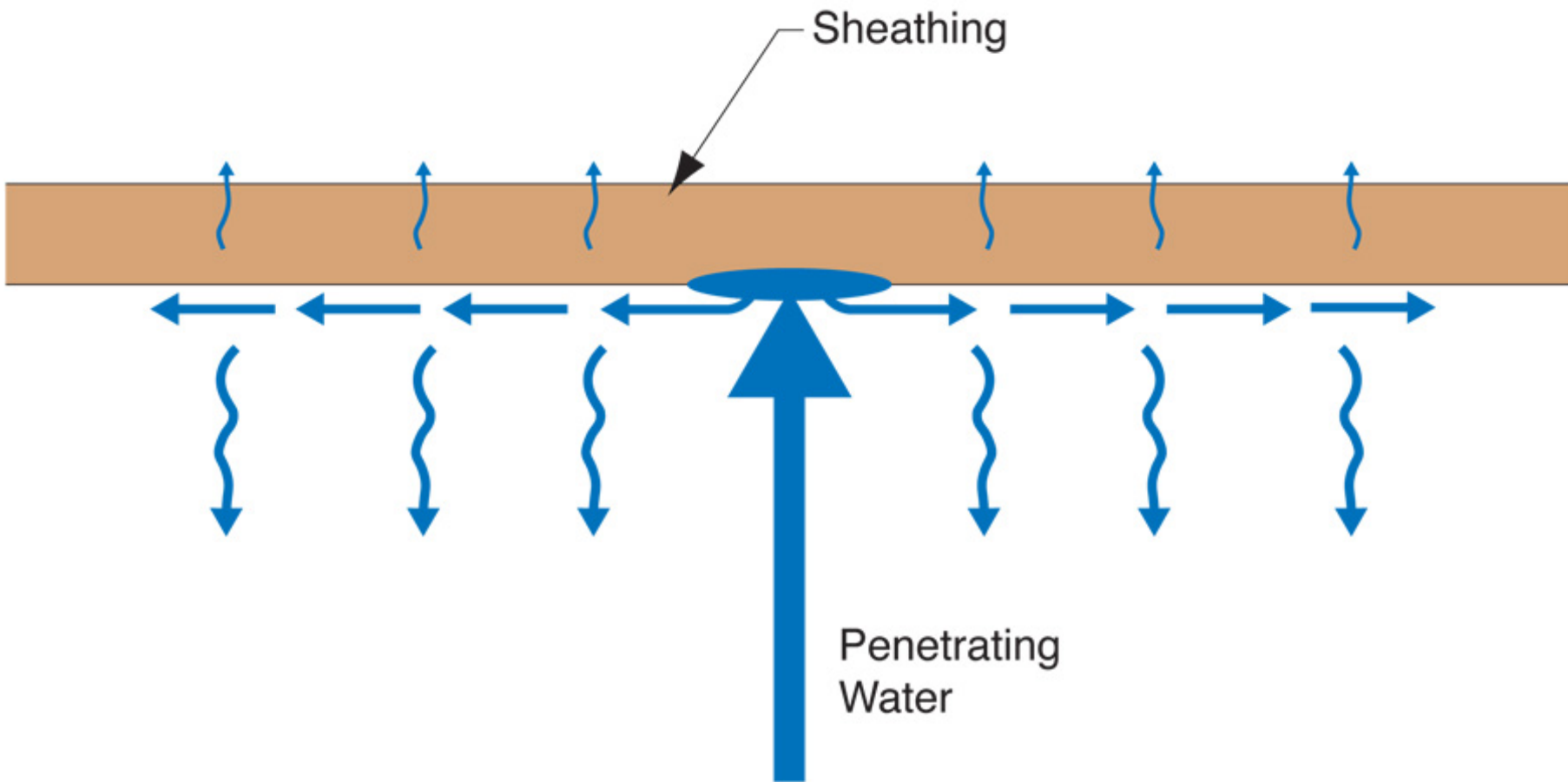


Water Vapor Permeance of Sheathing Materials









- 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



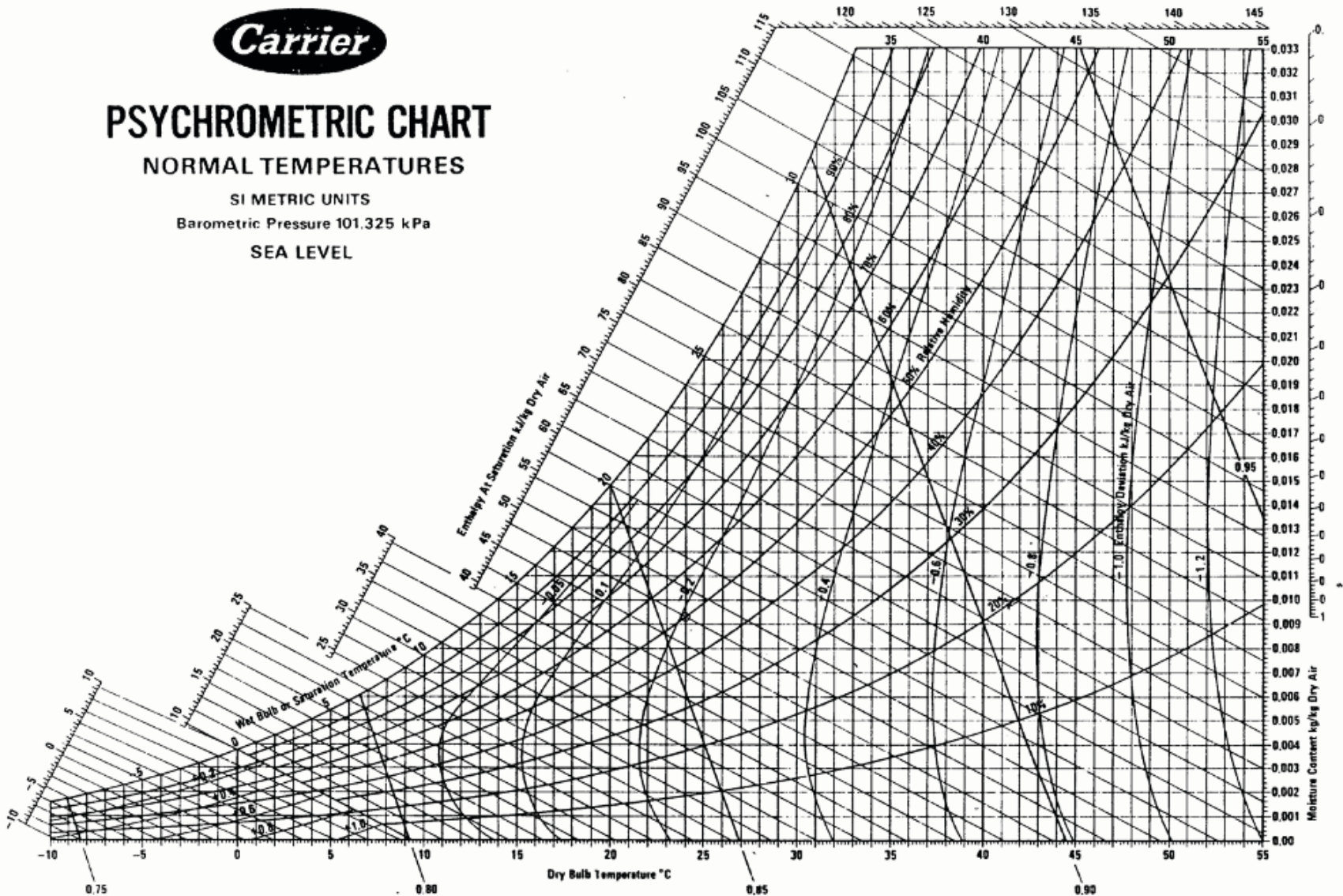
PSYCHROMETRIC CHART

NORMAL TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101.325 kPa

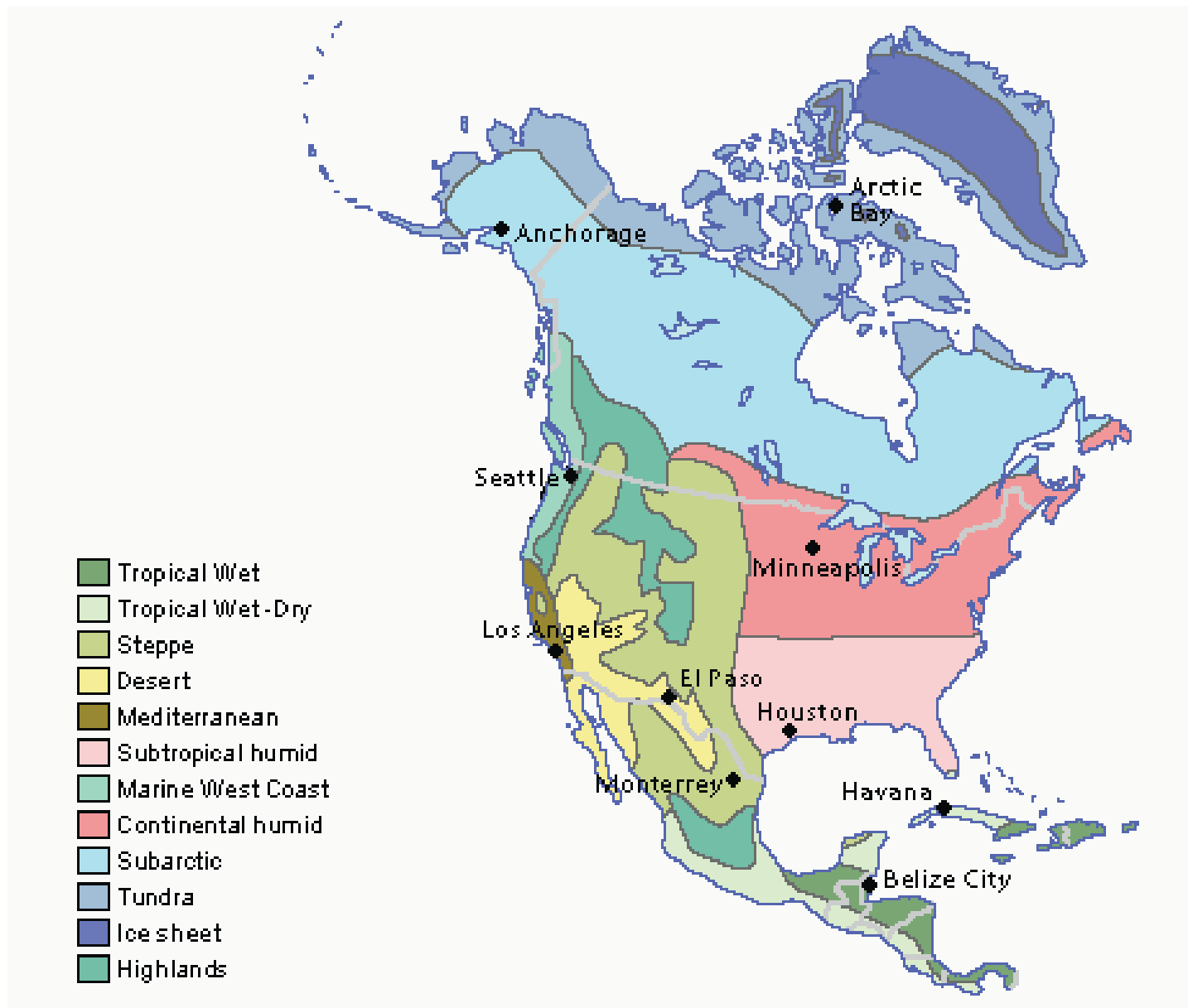
SEA LEVEL



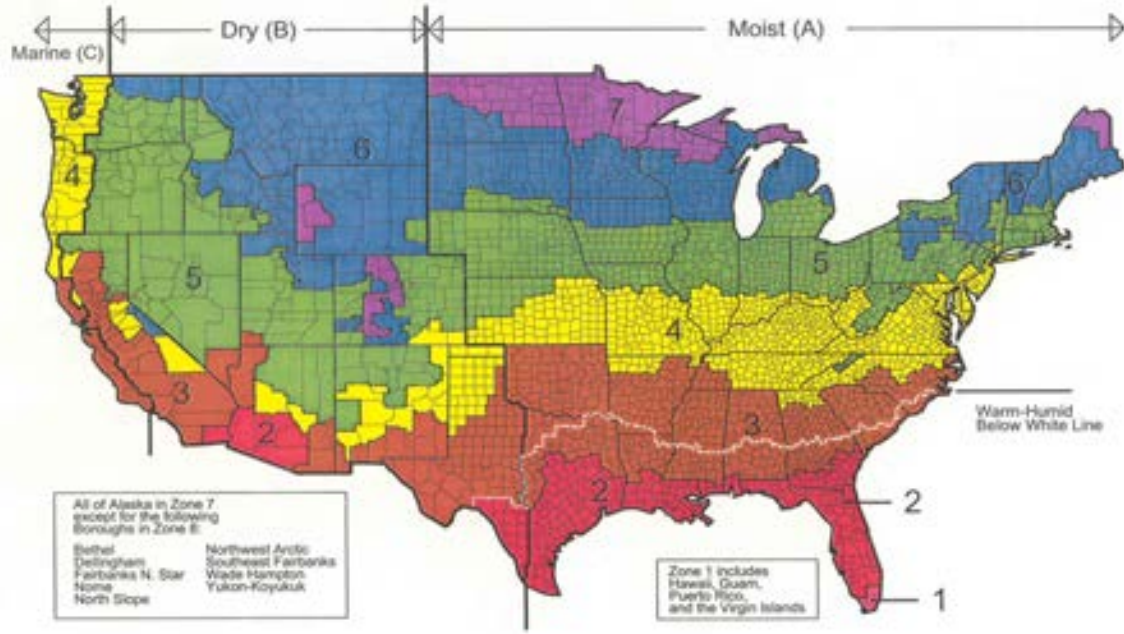
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice

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Map of DOE's Proposed Climate Zones

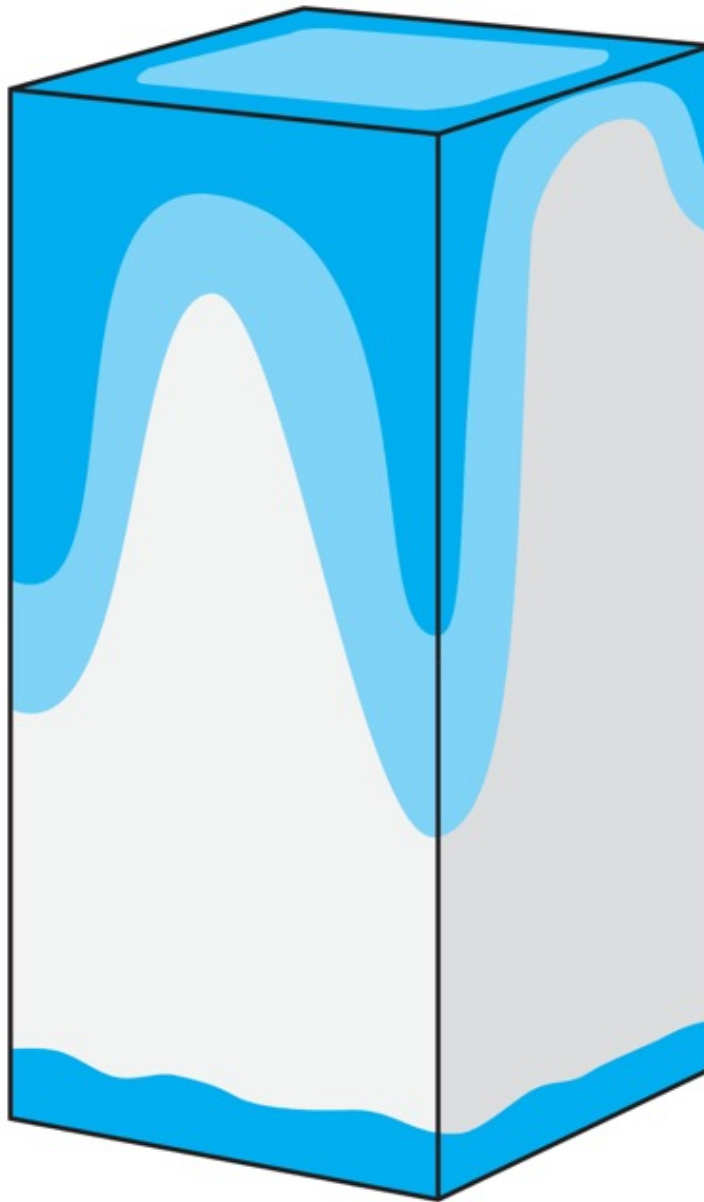


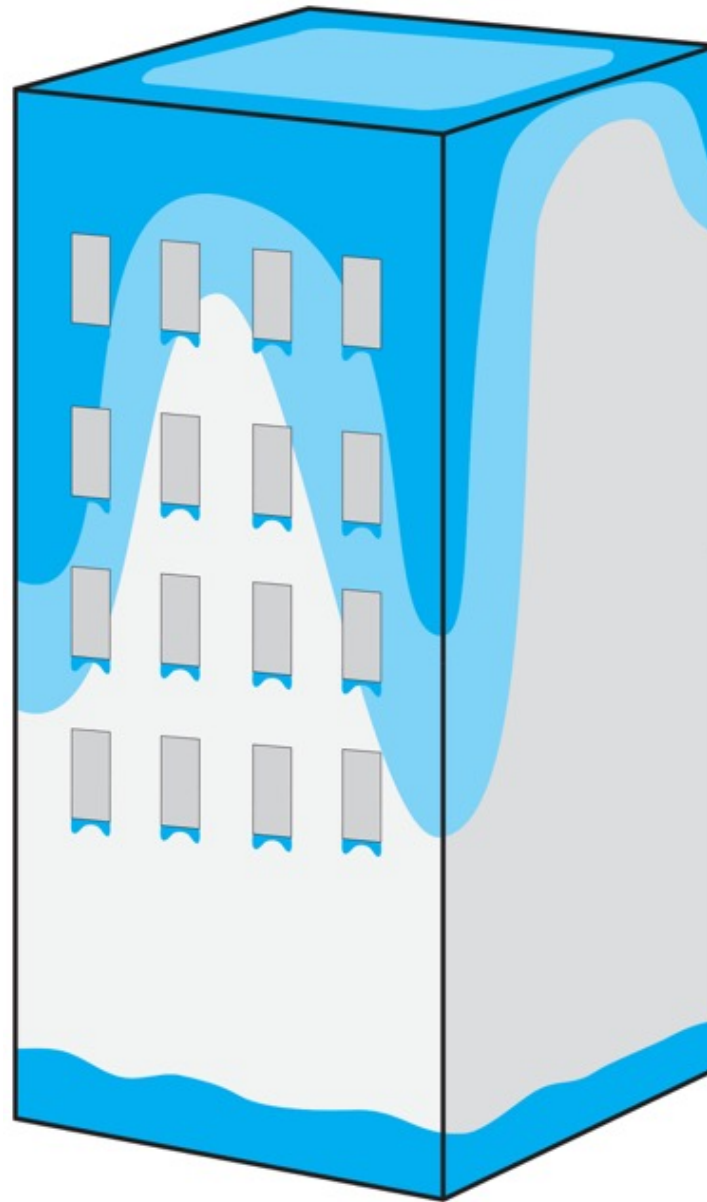
March 24, 2003



Exposure

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



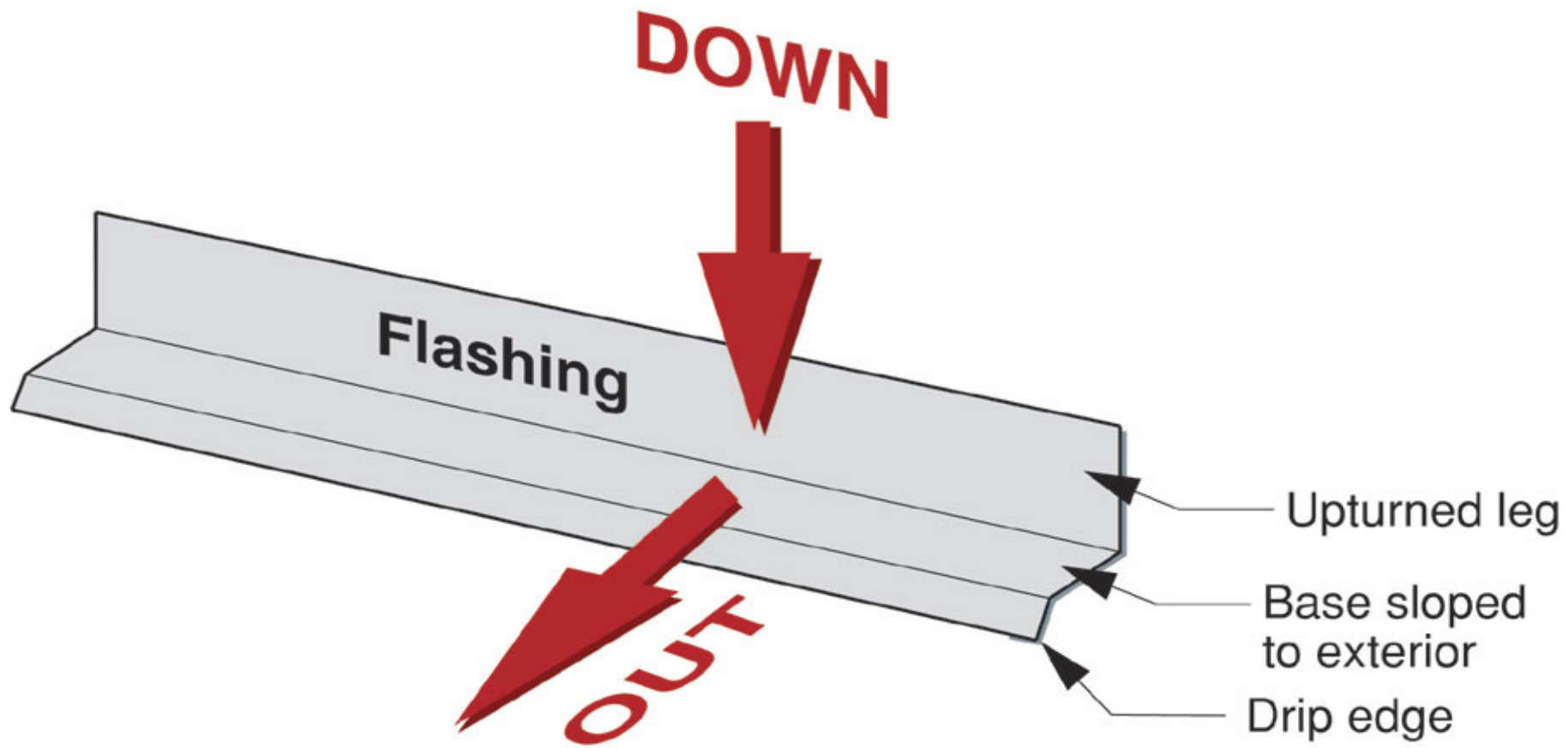


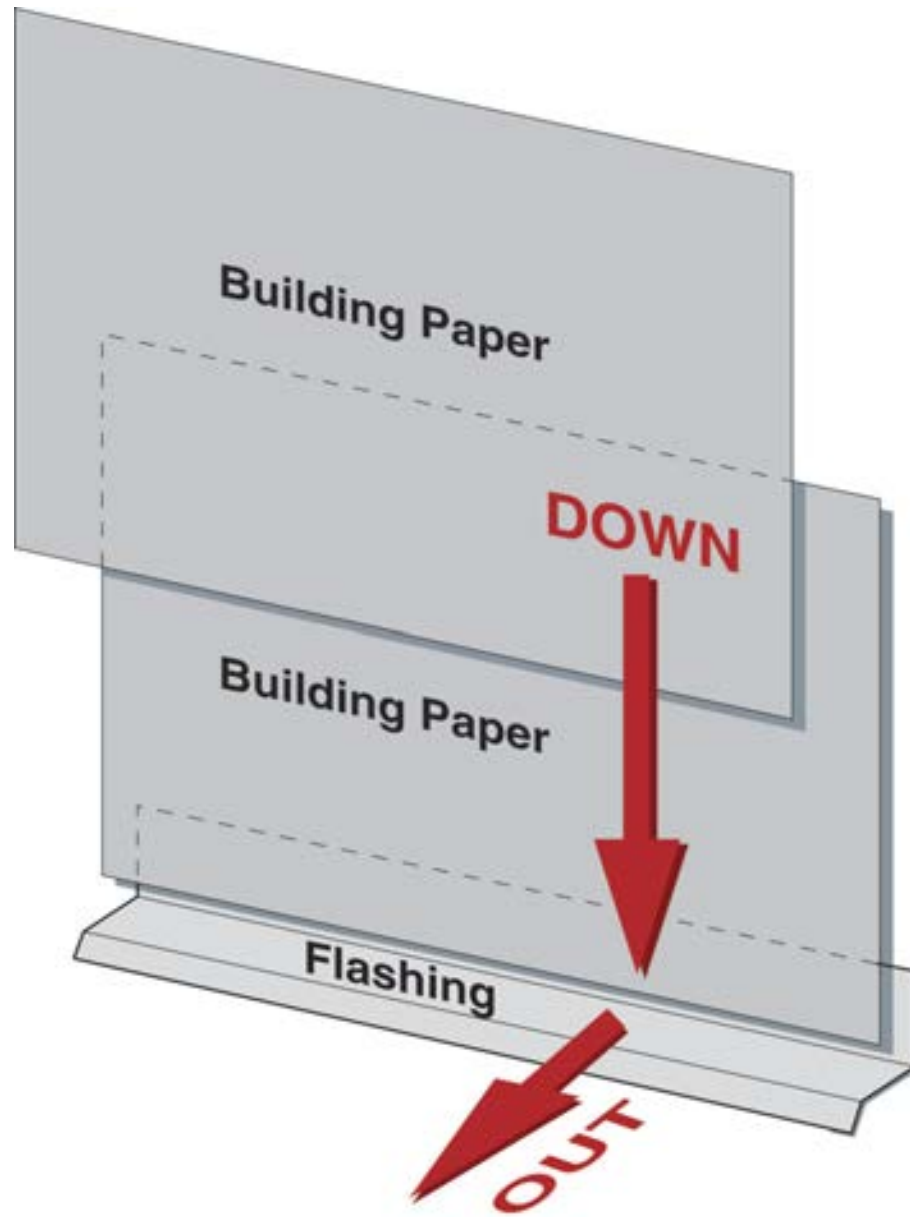


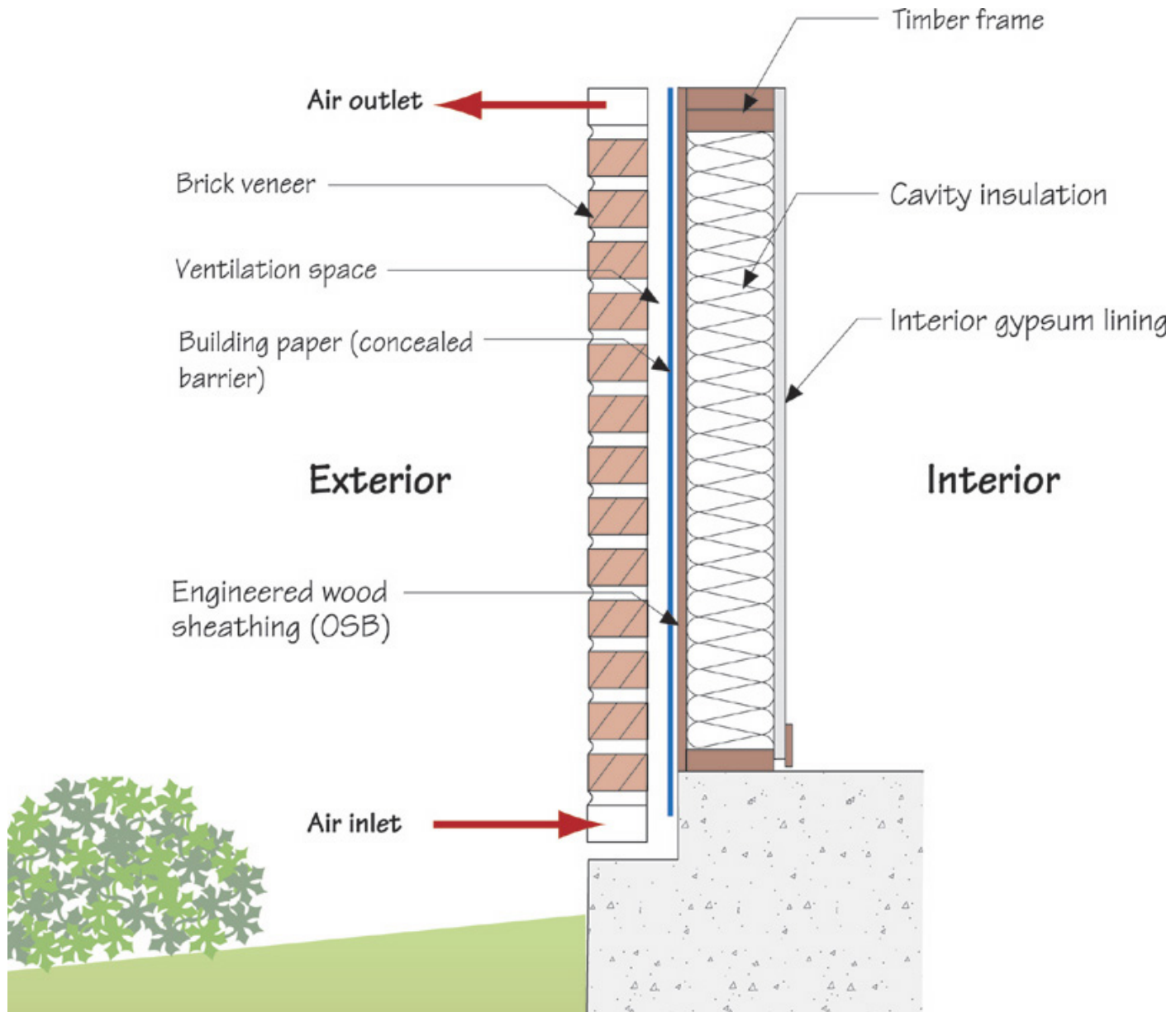


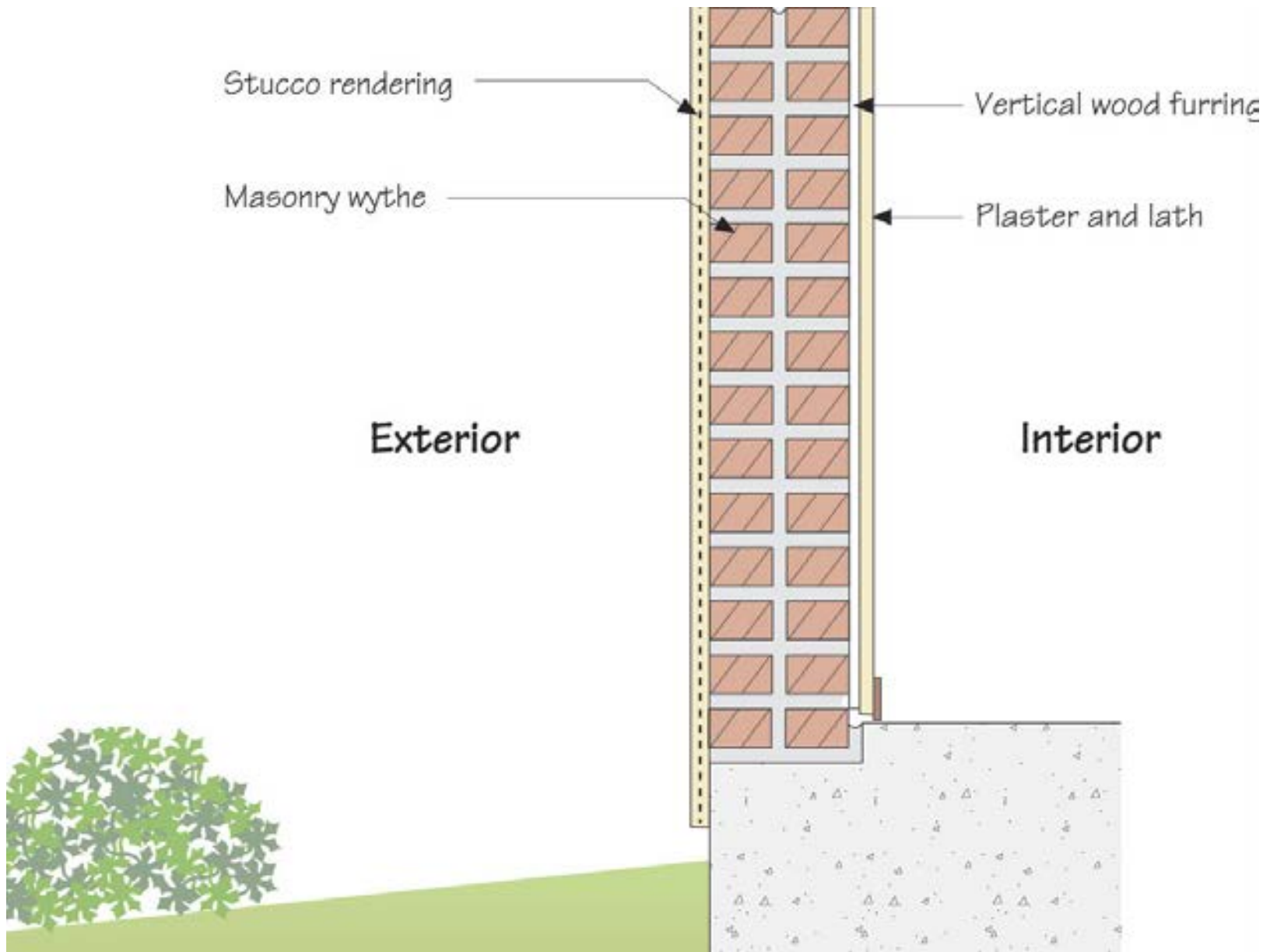










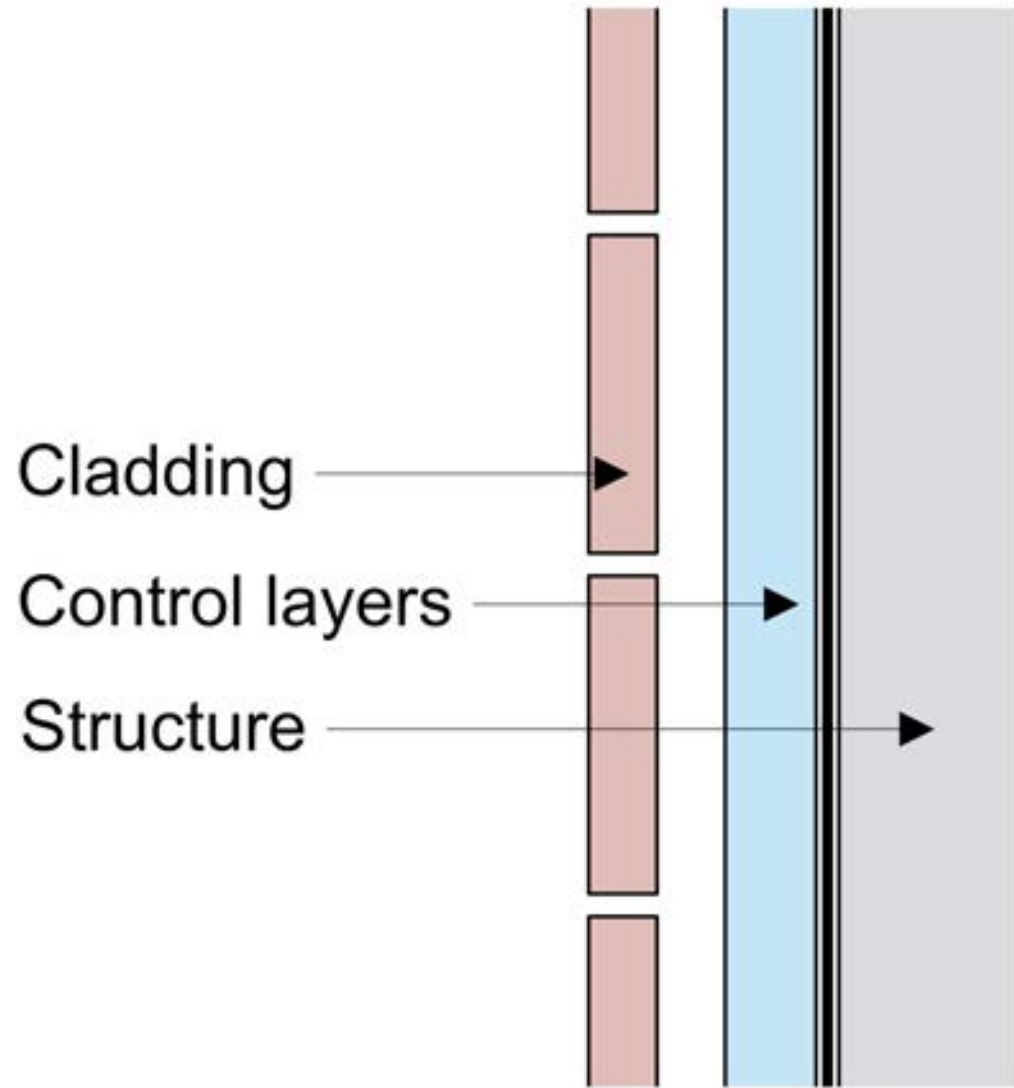


Water Control Layer

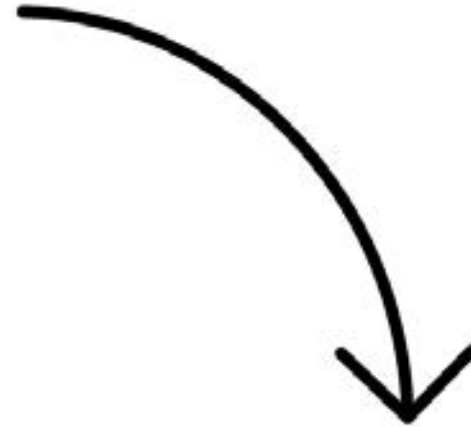
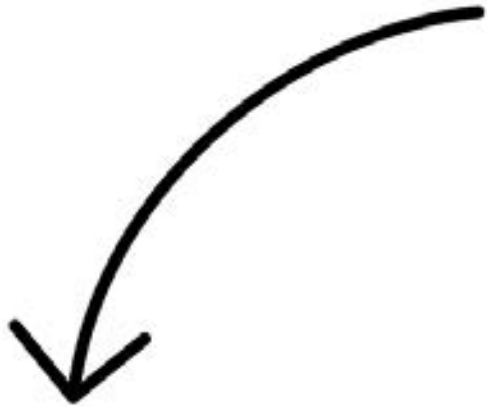
Air Control Layer

Vapor Control Layer

Thermal Control Layer



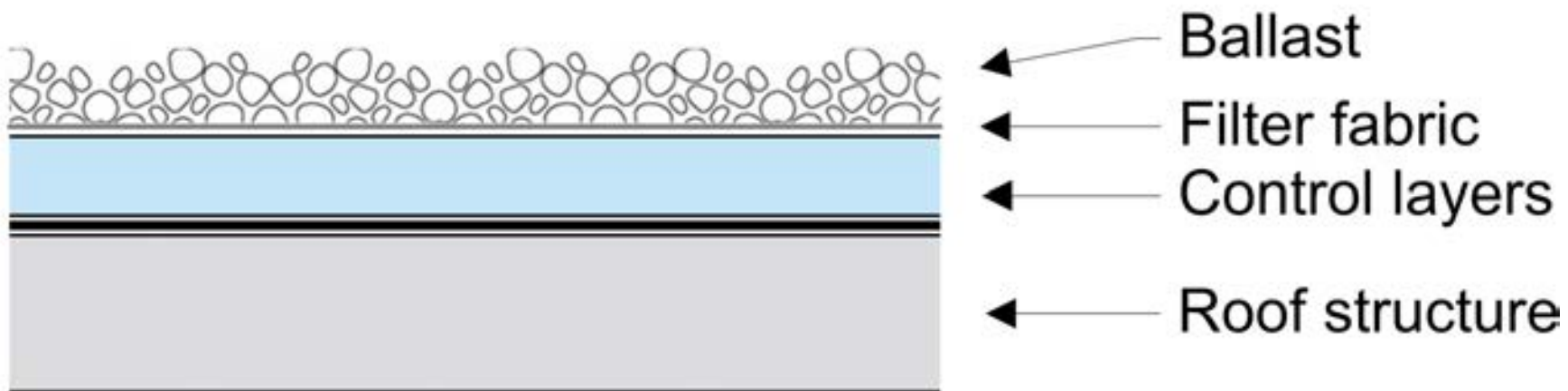
Wall

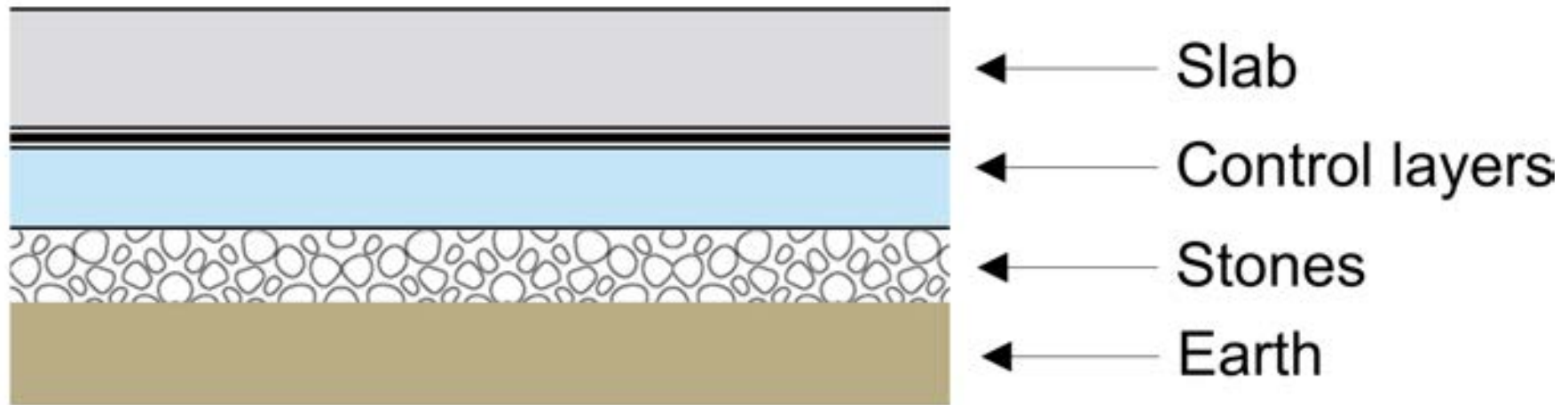


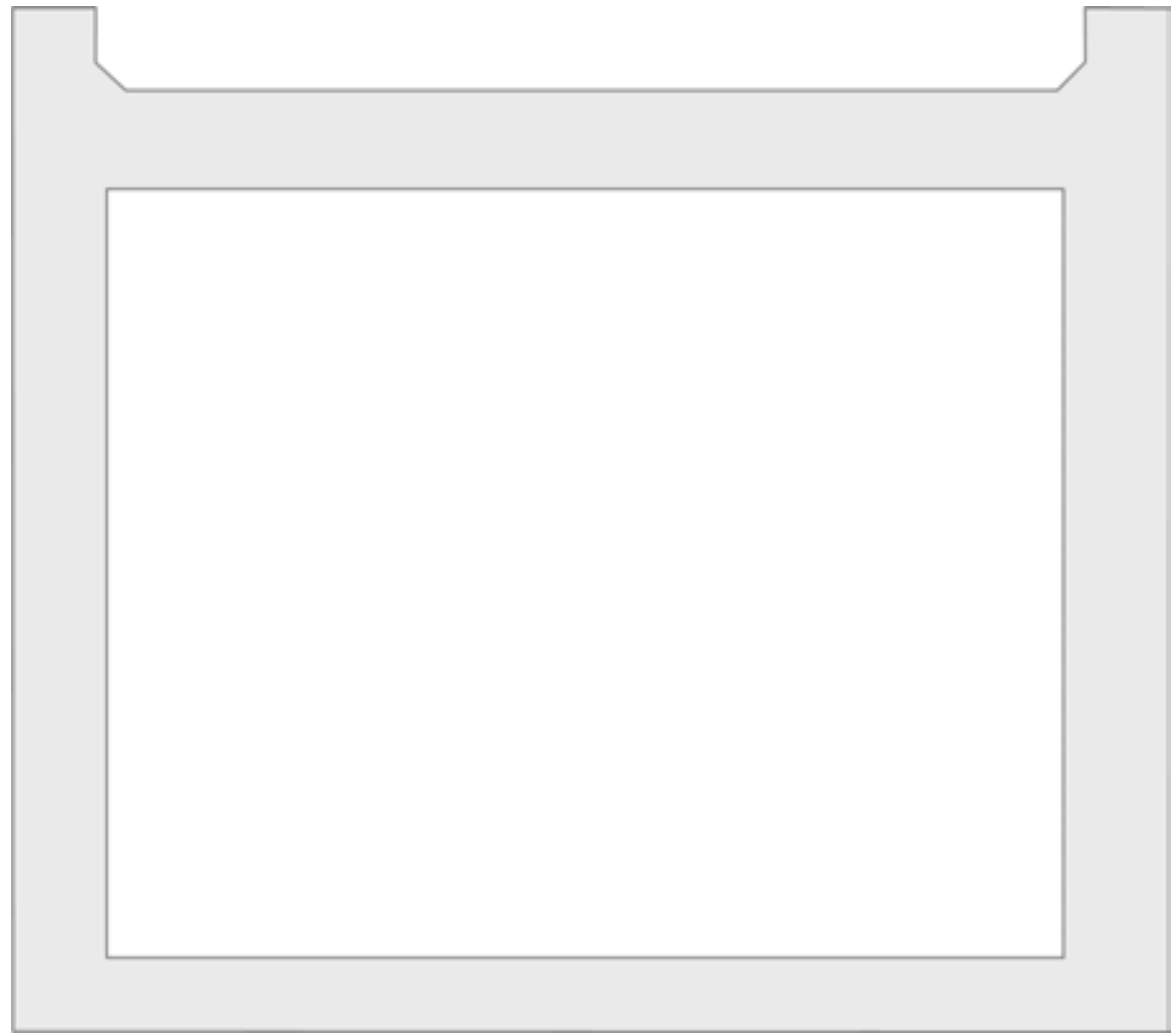
Slab



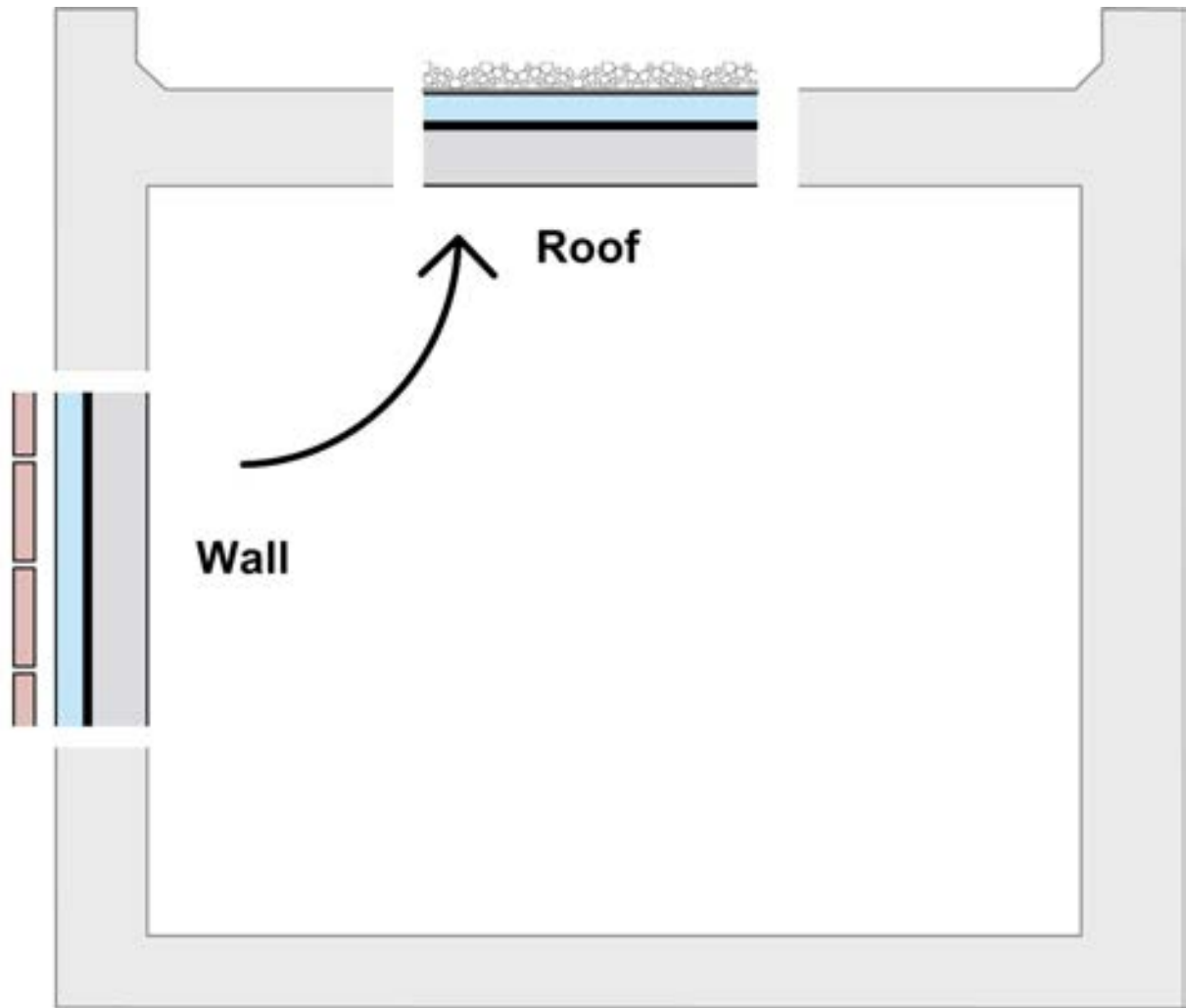
Roof

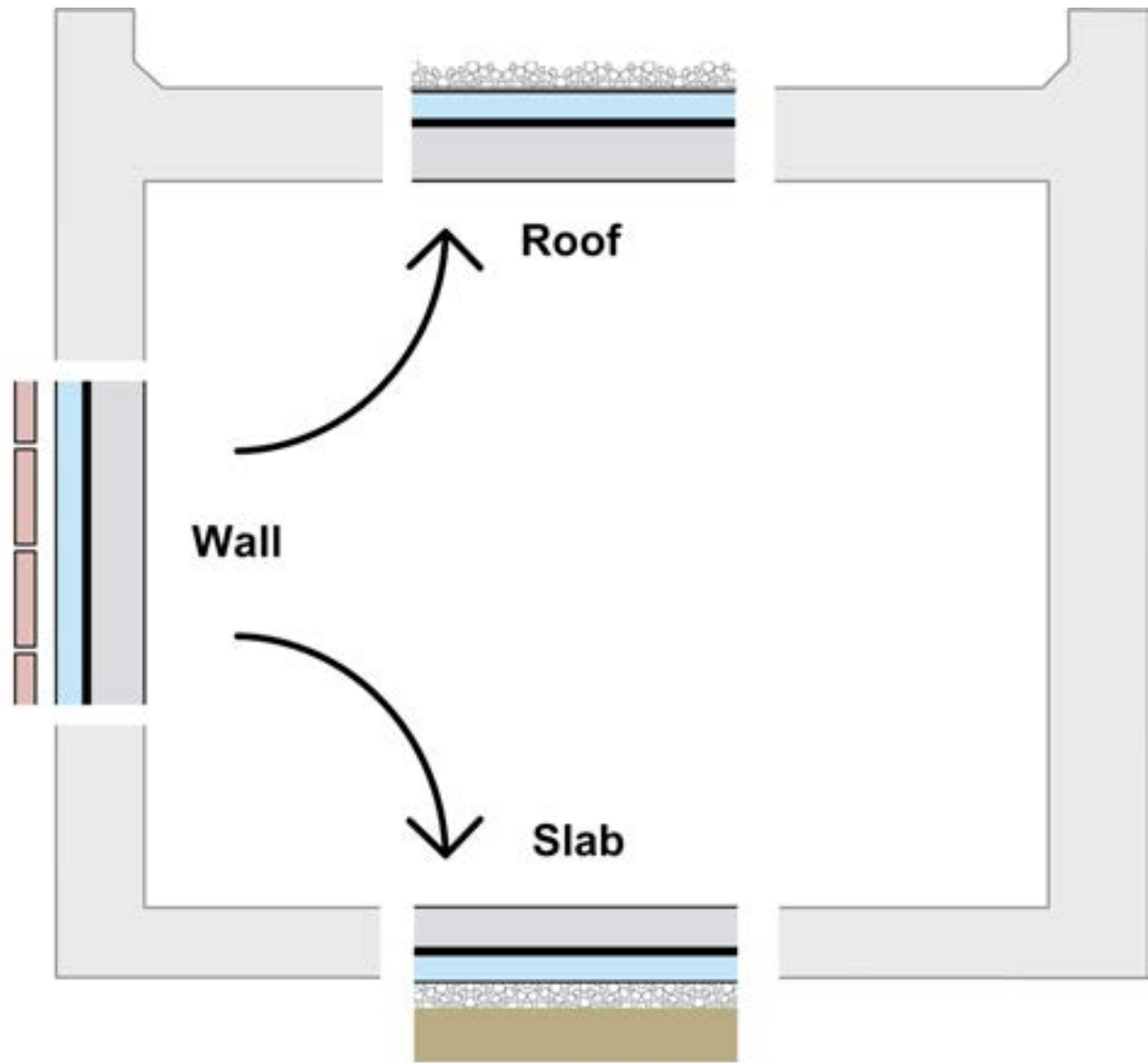


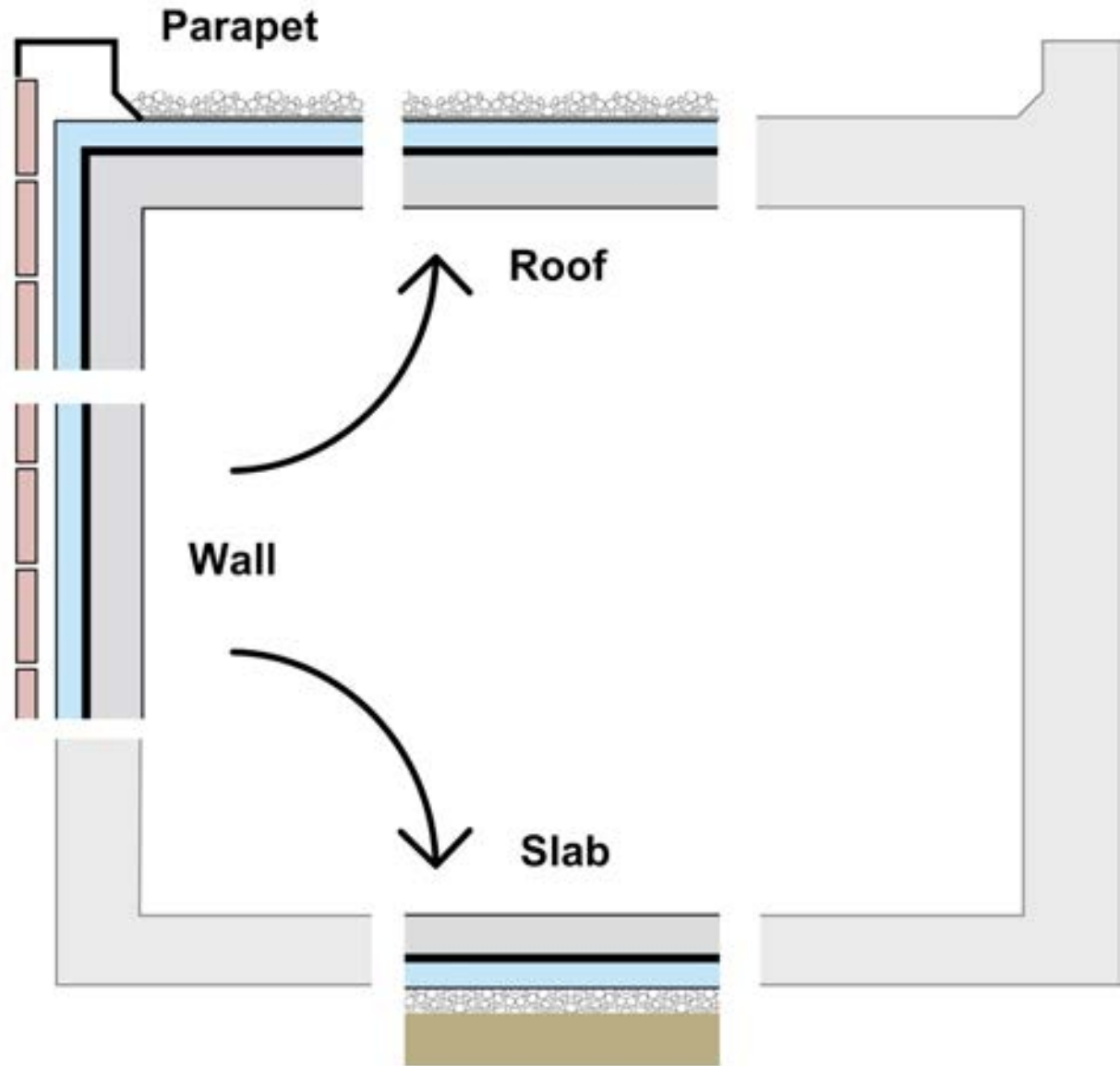


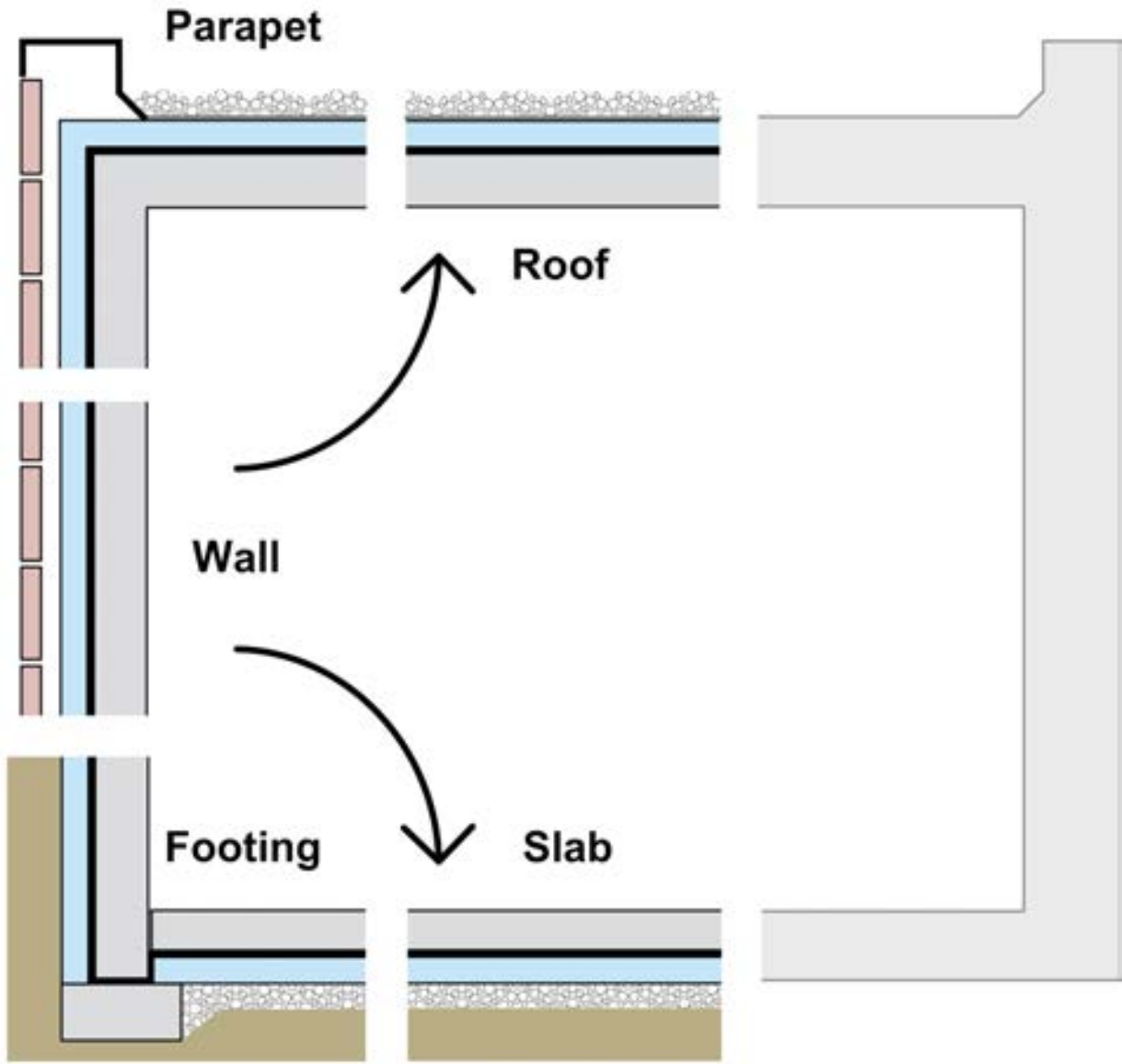


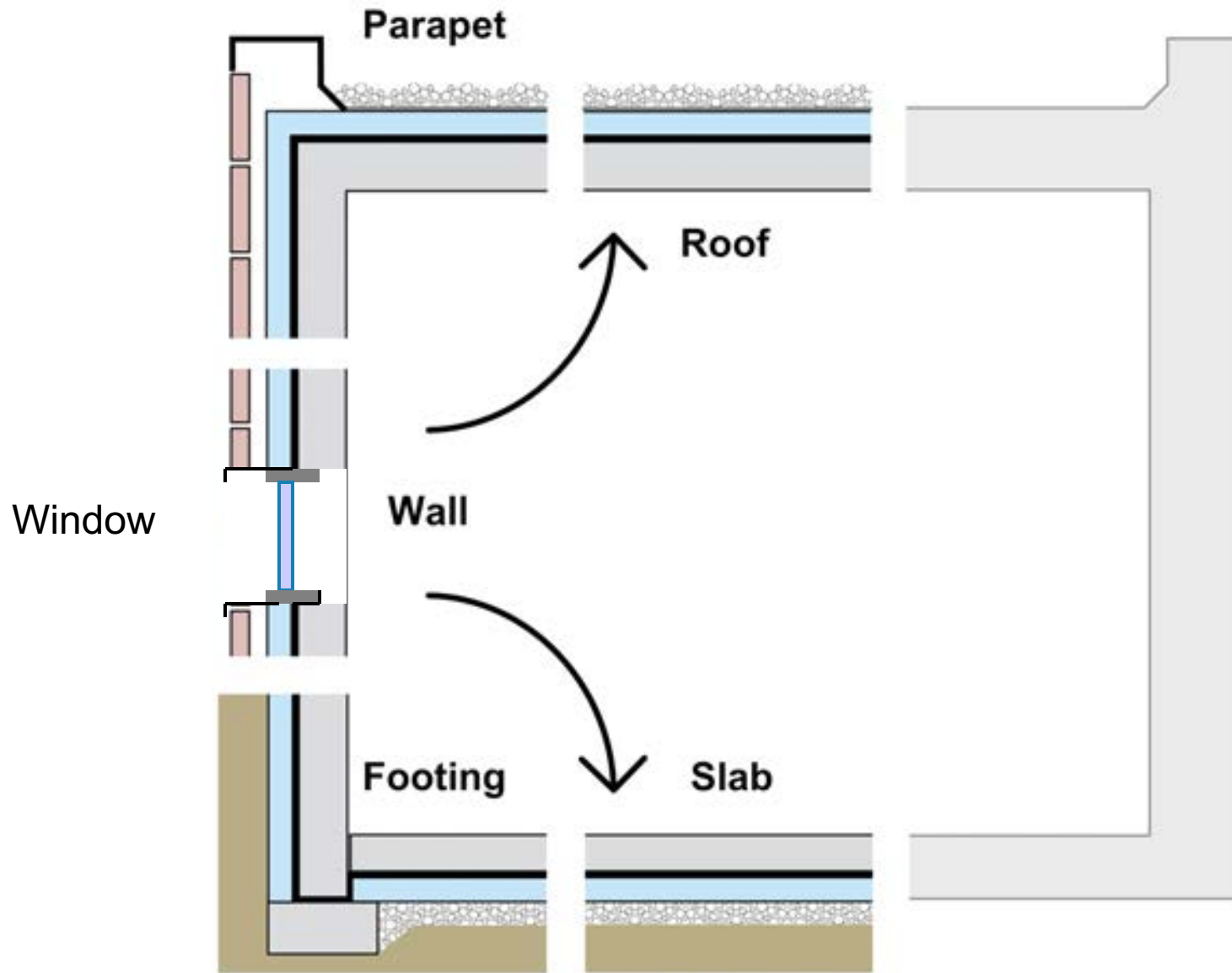




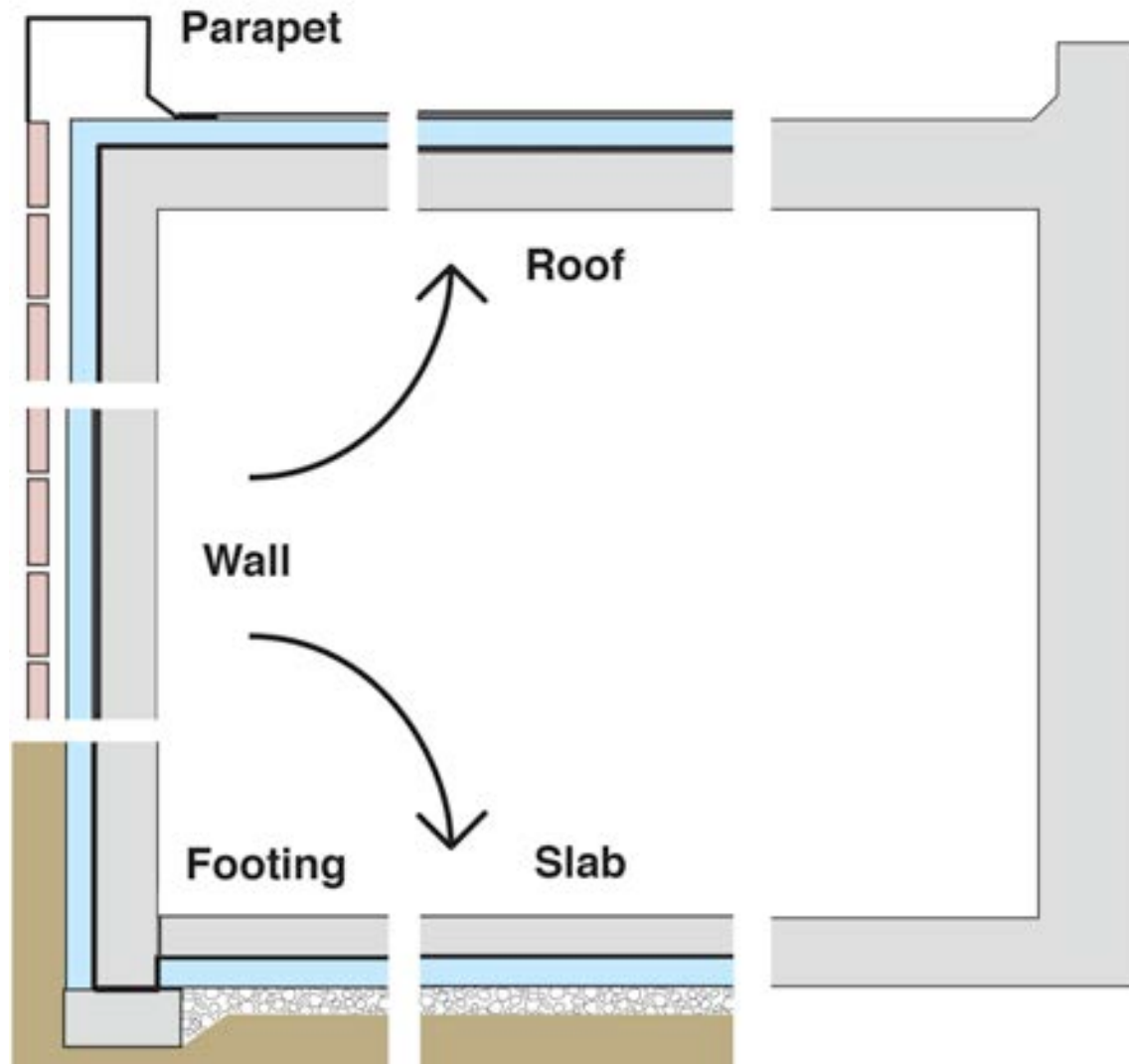


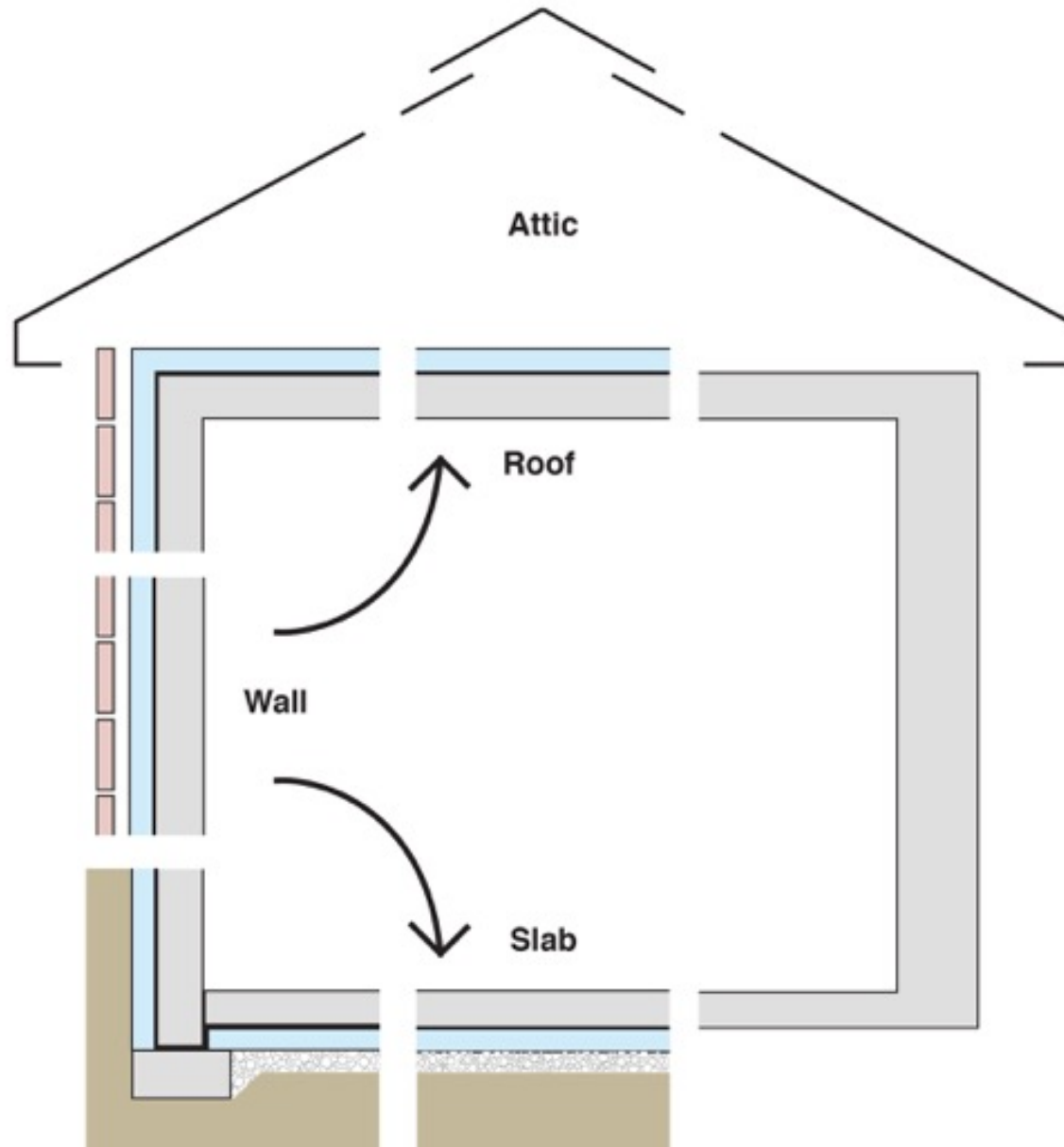


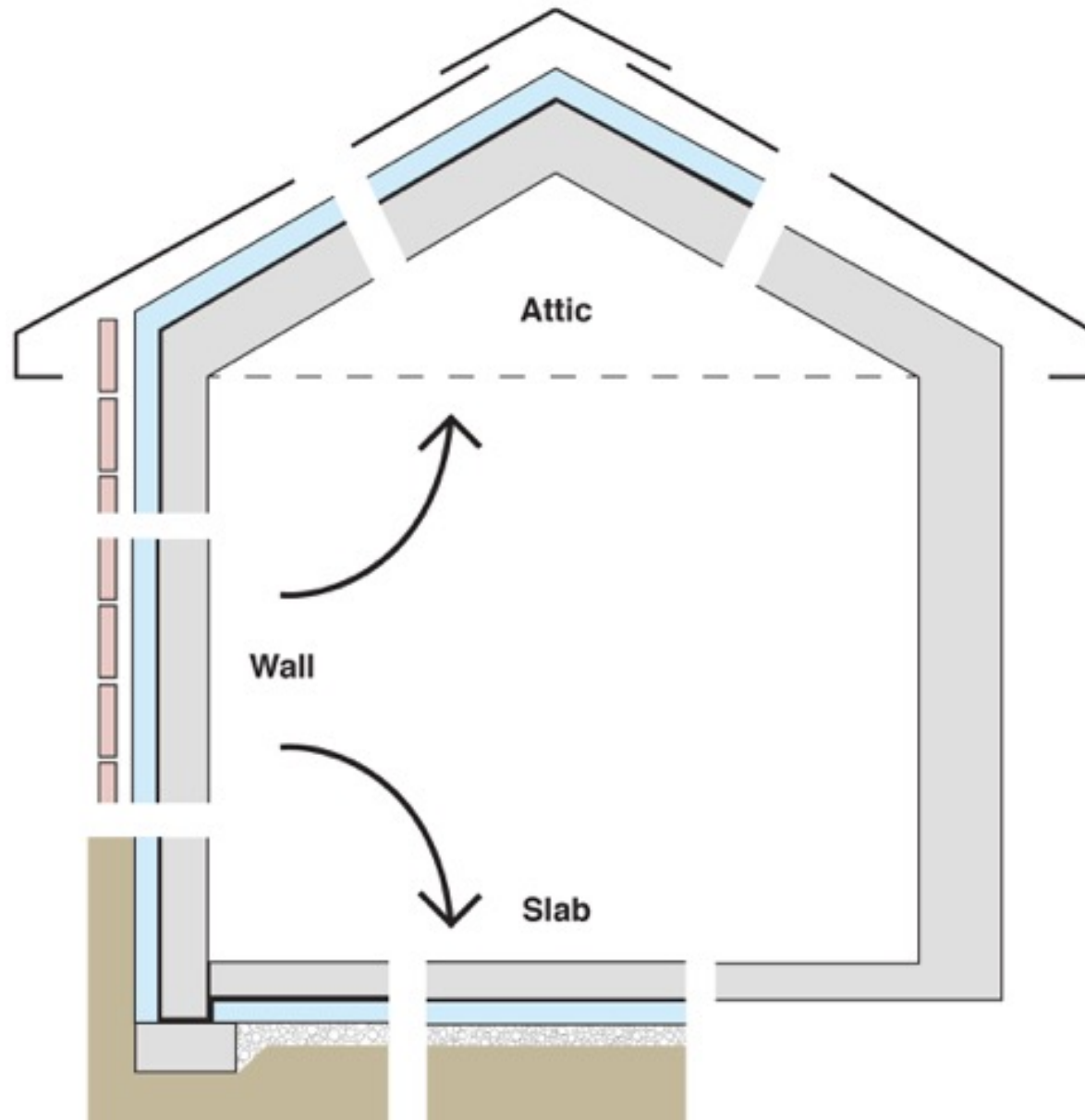


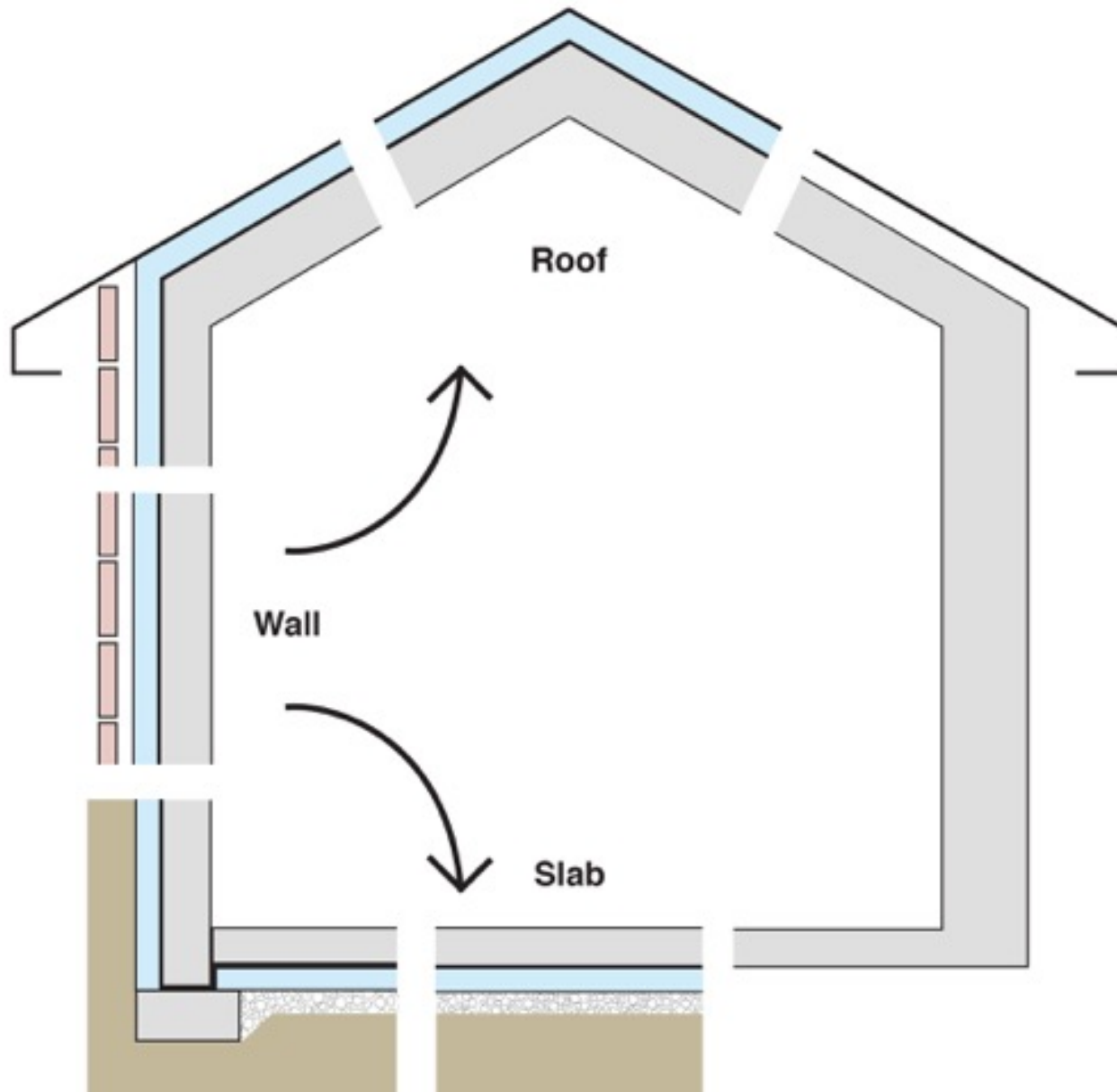


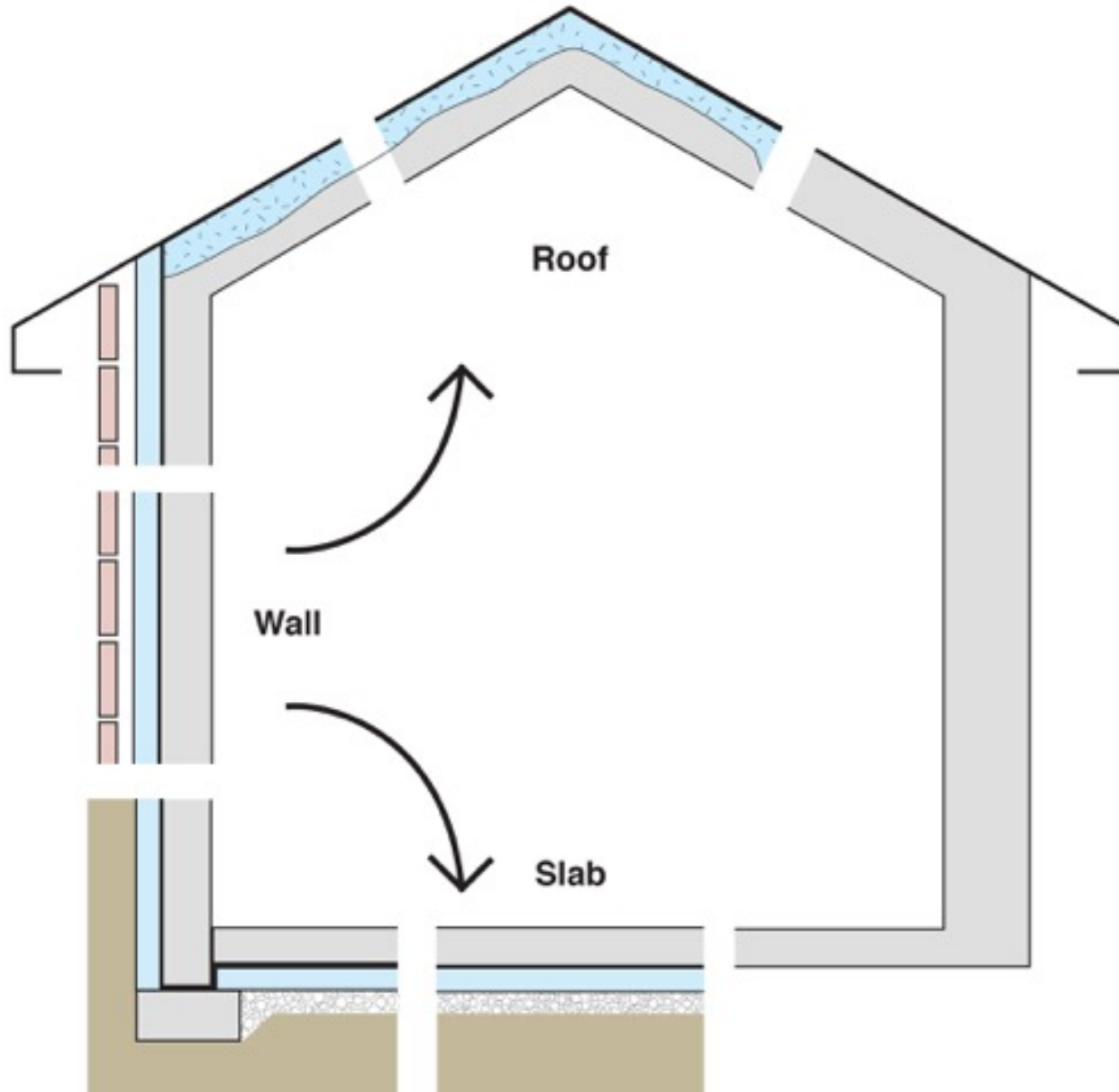




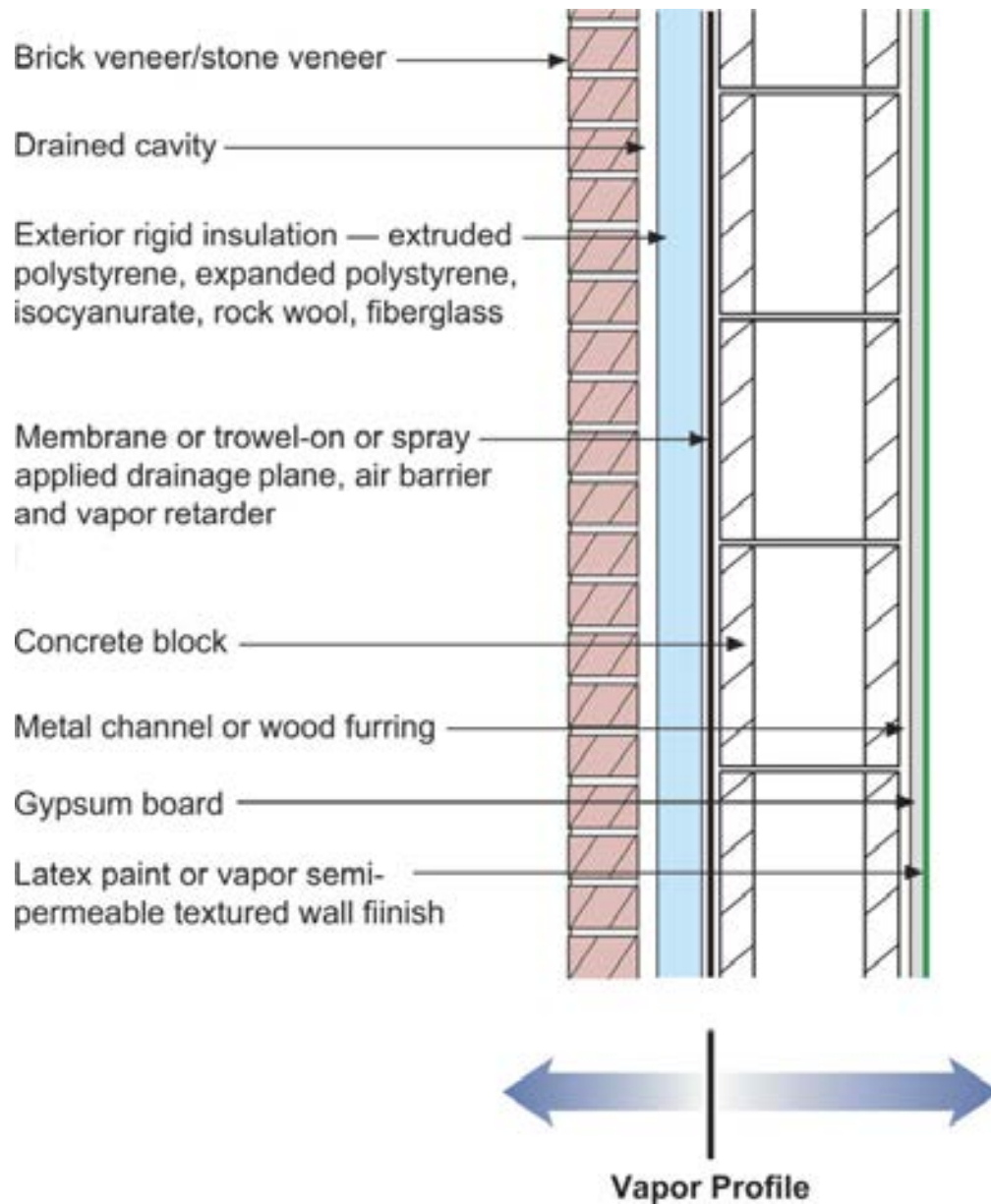


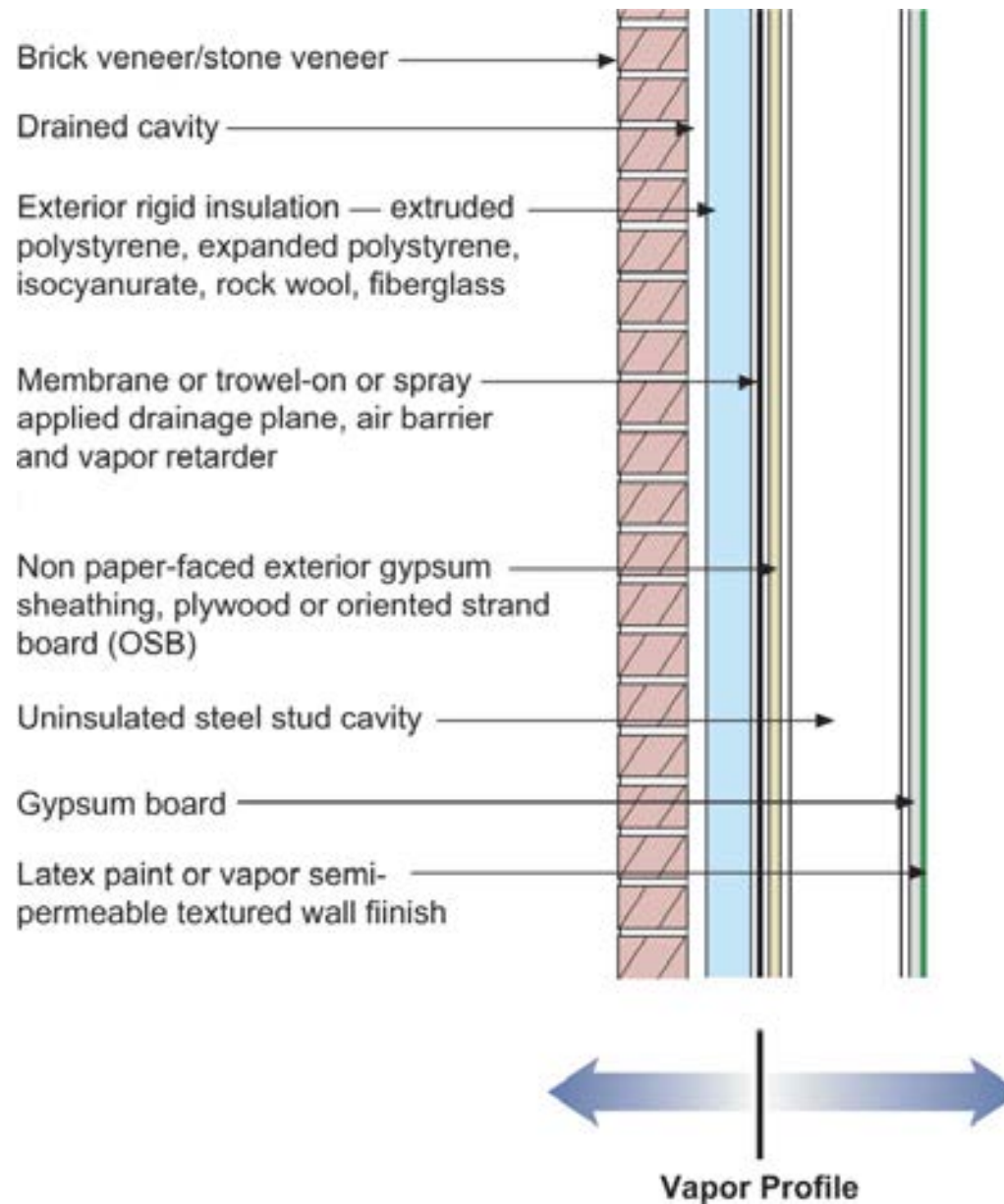


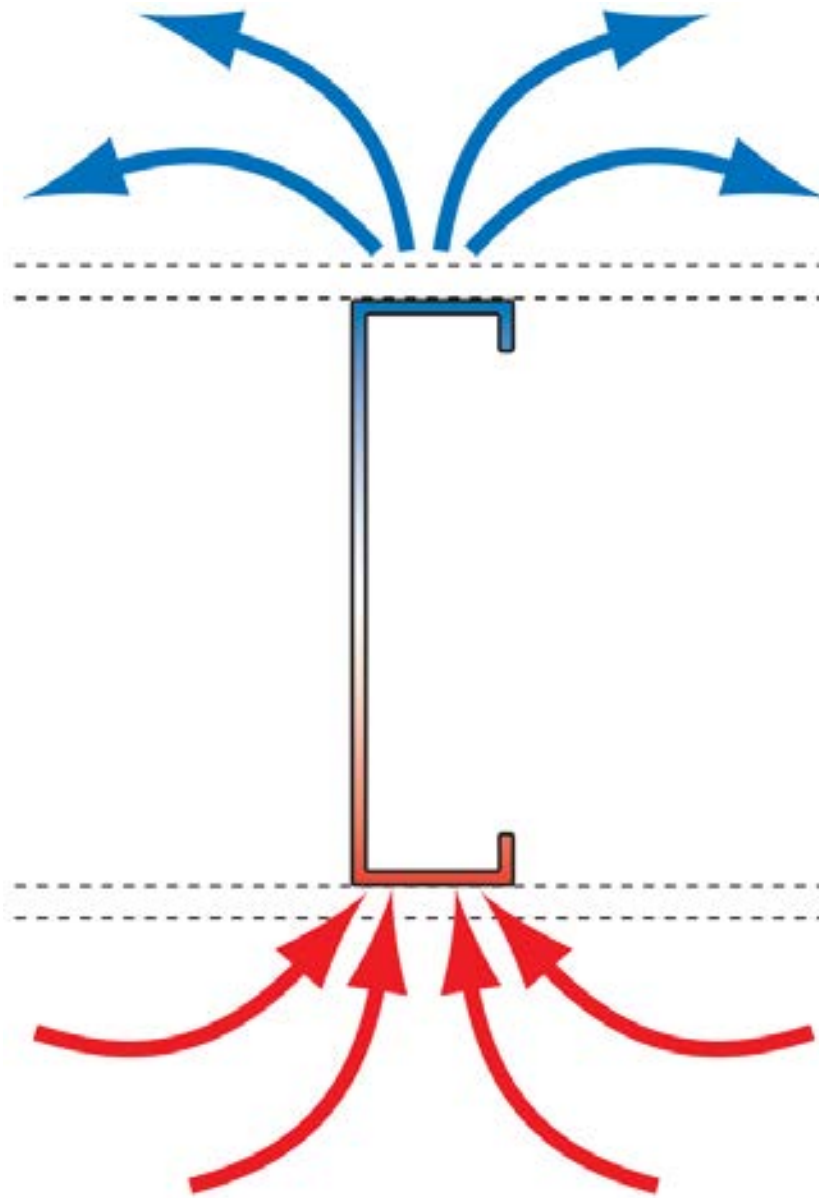




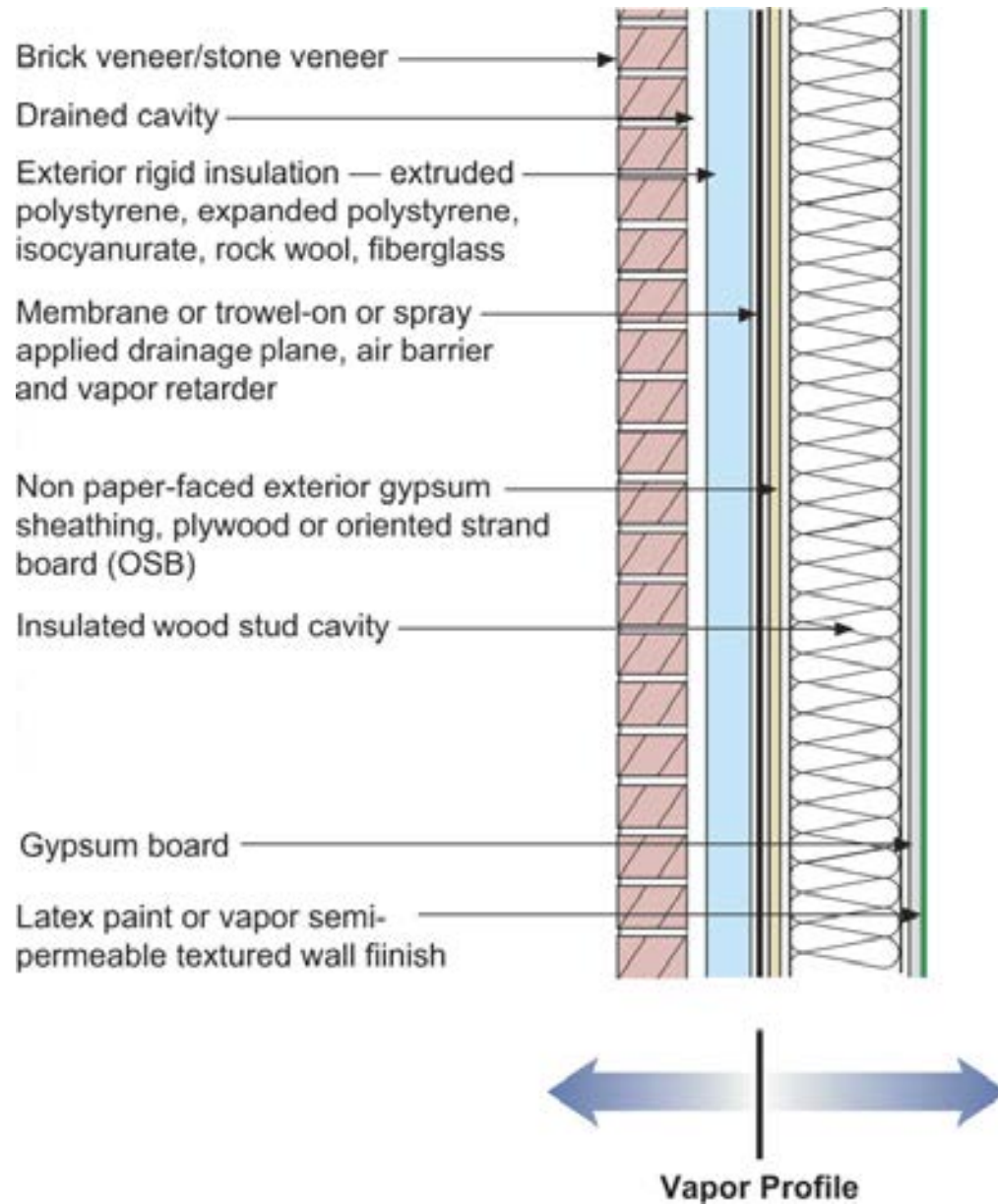
Configurations of the Perfect Wall

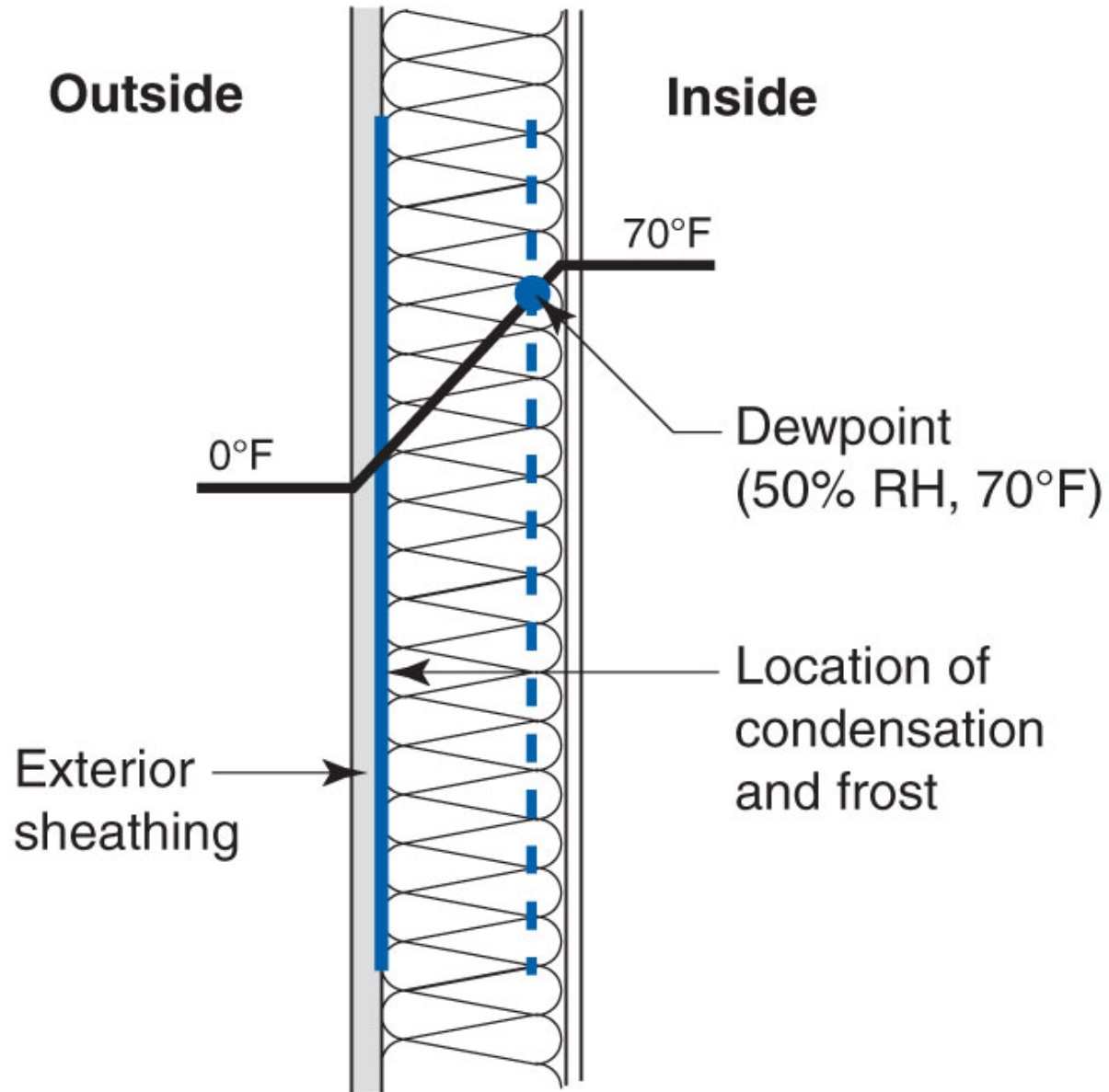




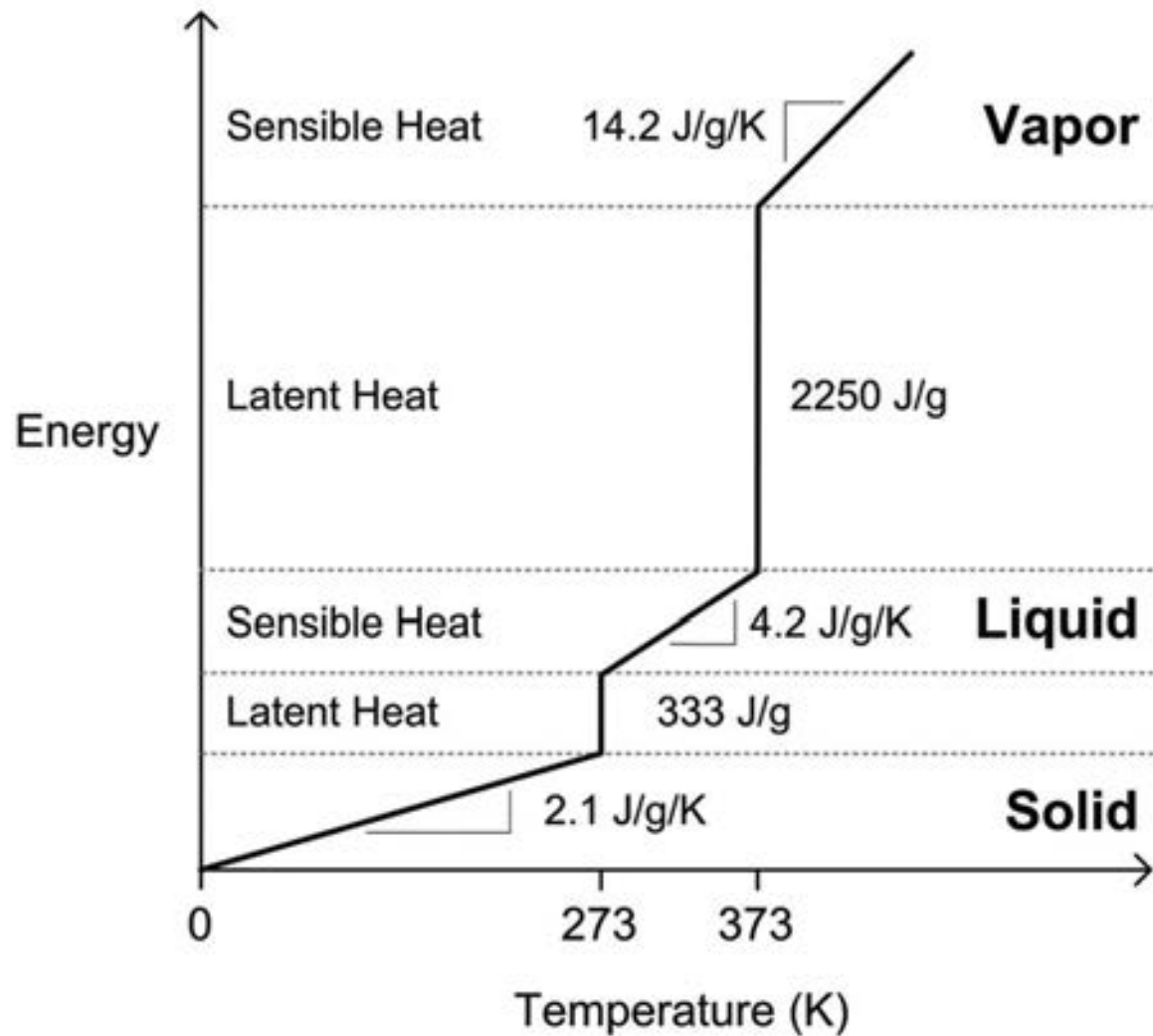






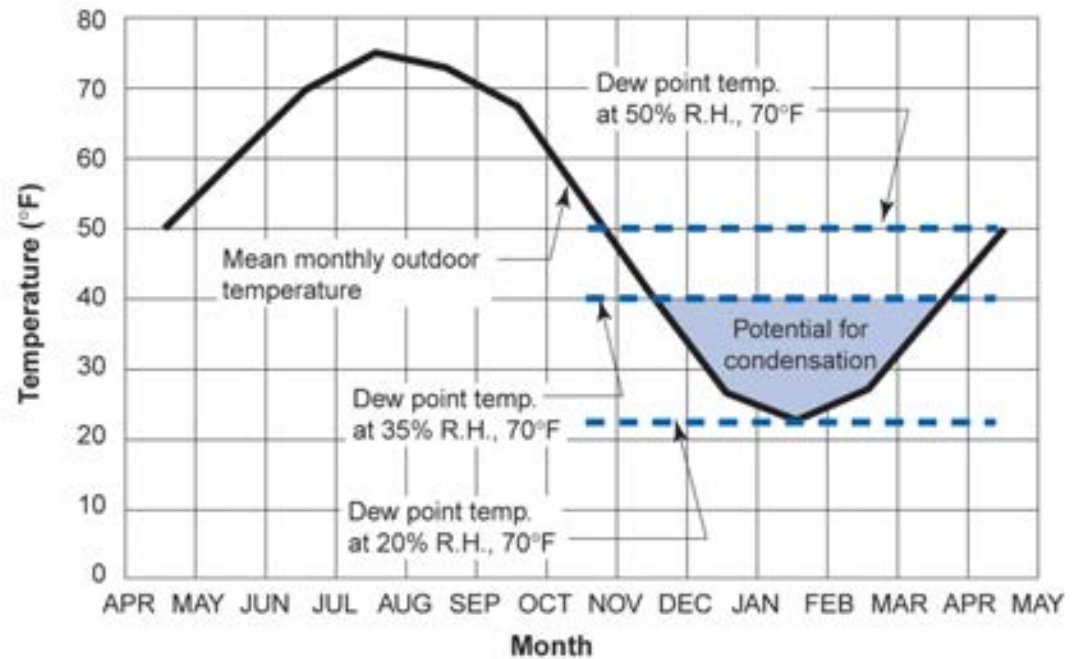
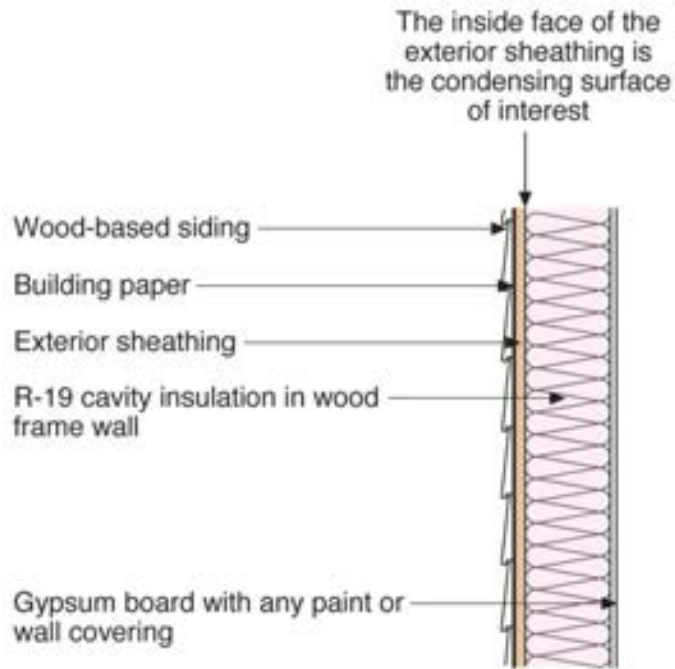


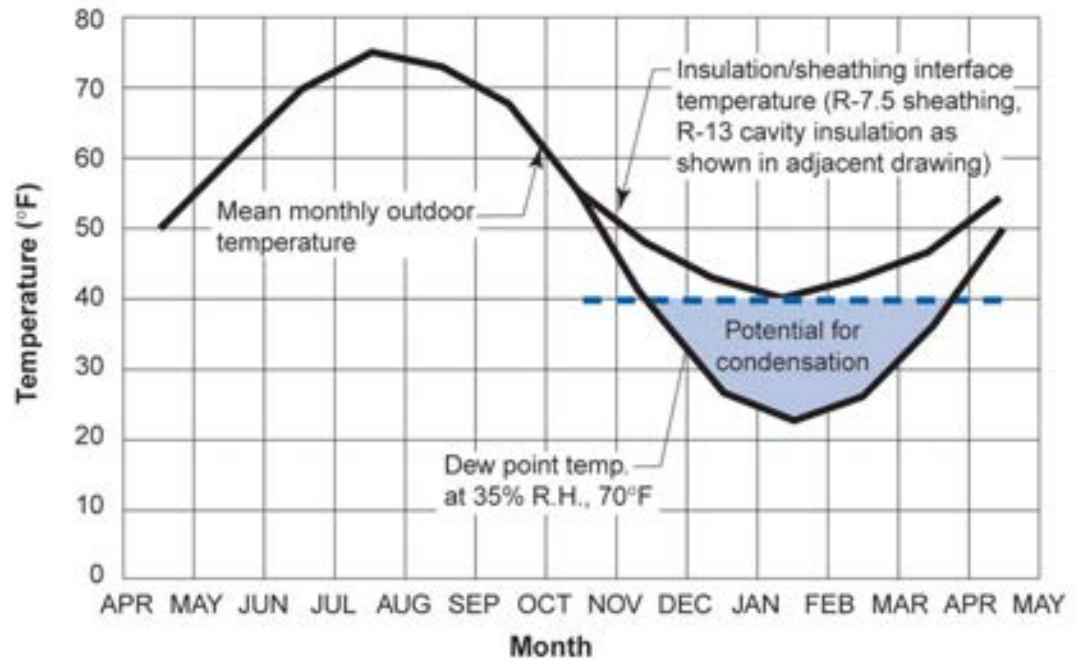
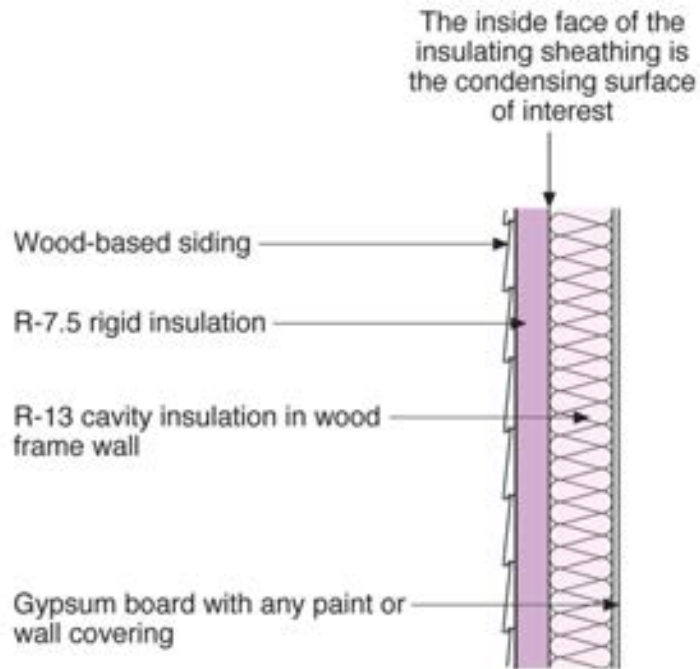




Simple linearized energy-temperature relation for water
 From Straube & Burnett, 2005







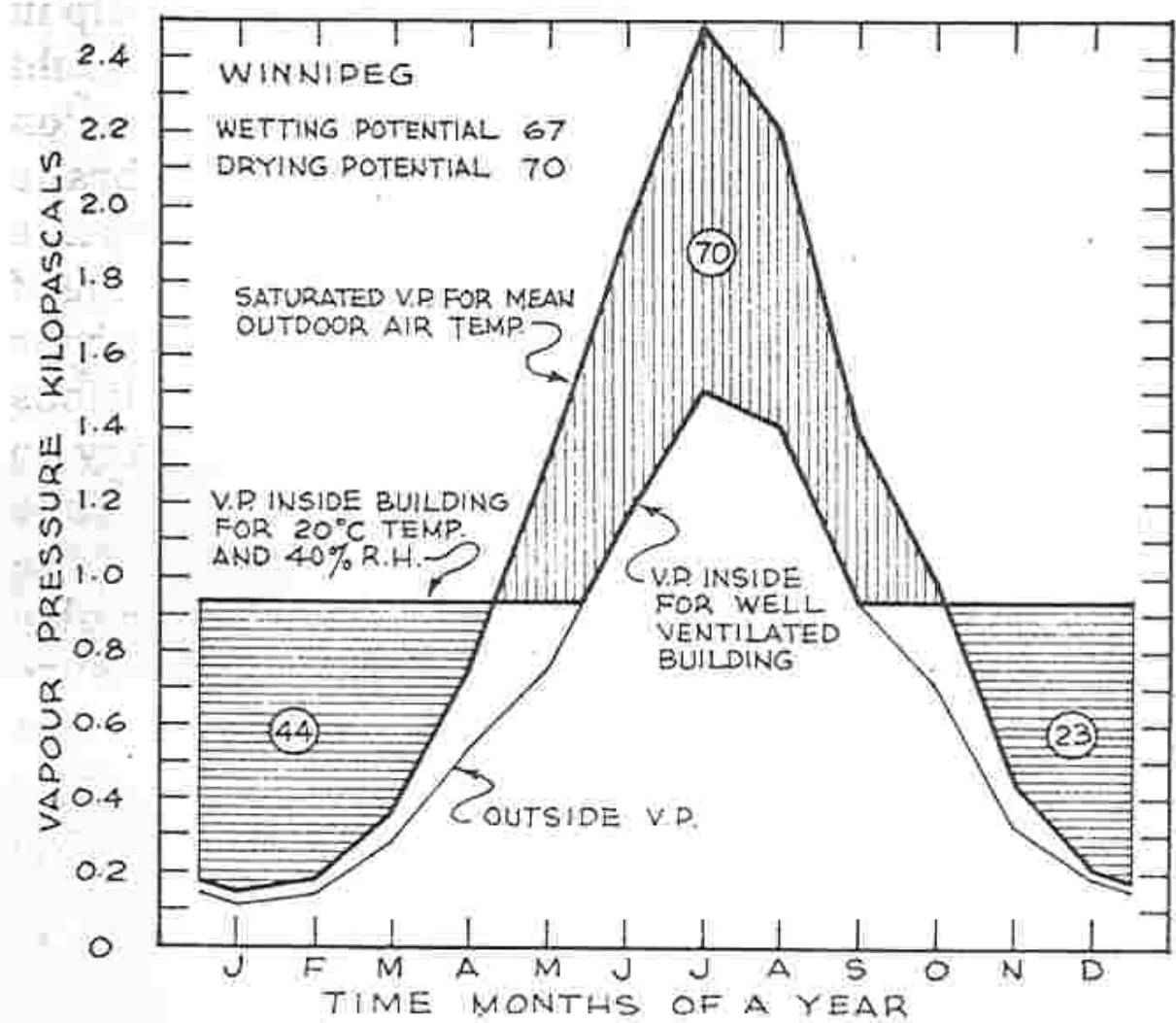
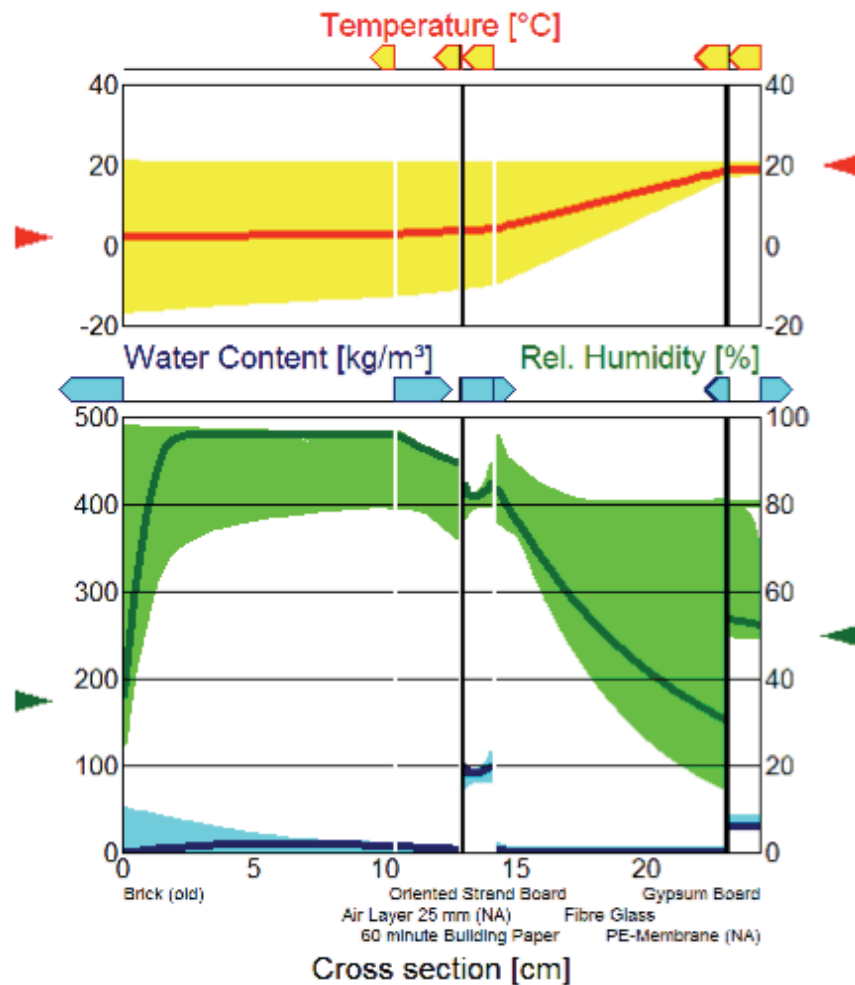


Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.



WUFI® 3.3 Pro. IBP
Run

16 Feb
2001

100%

Run

Stop

Pause

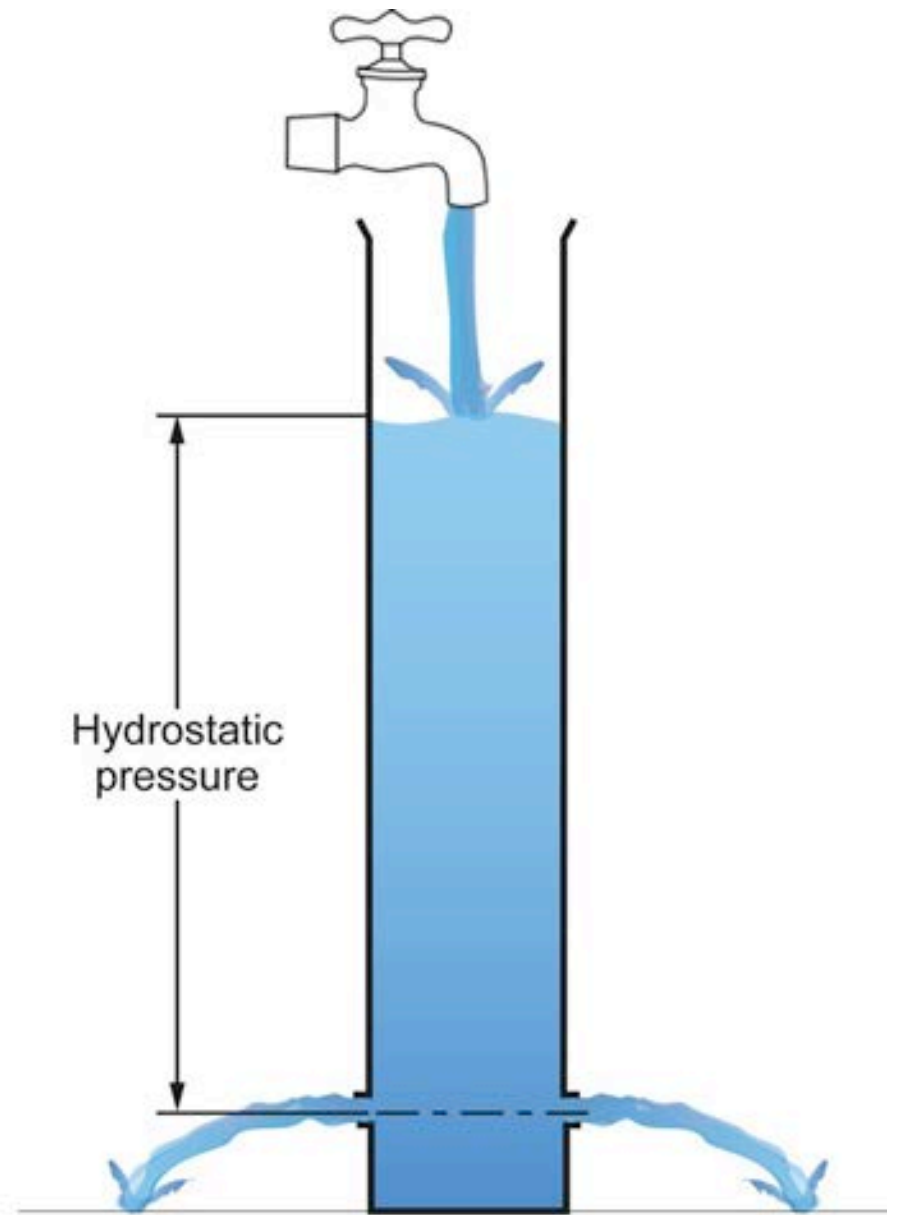
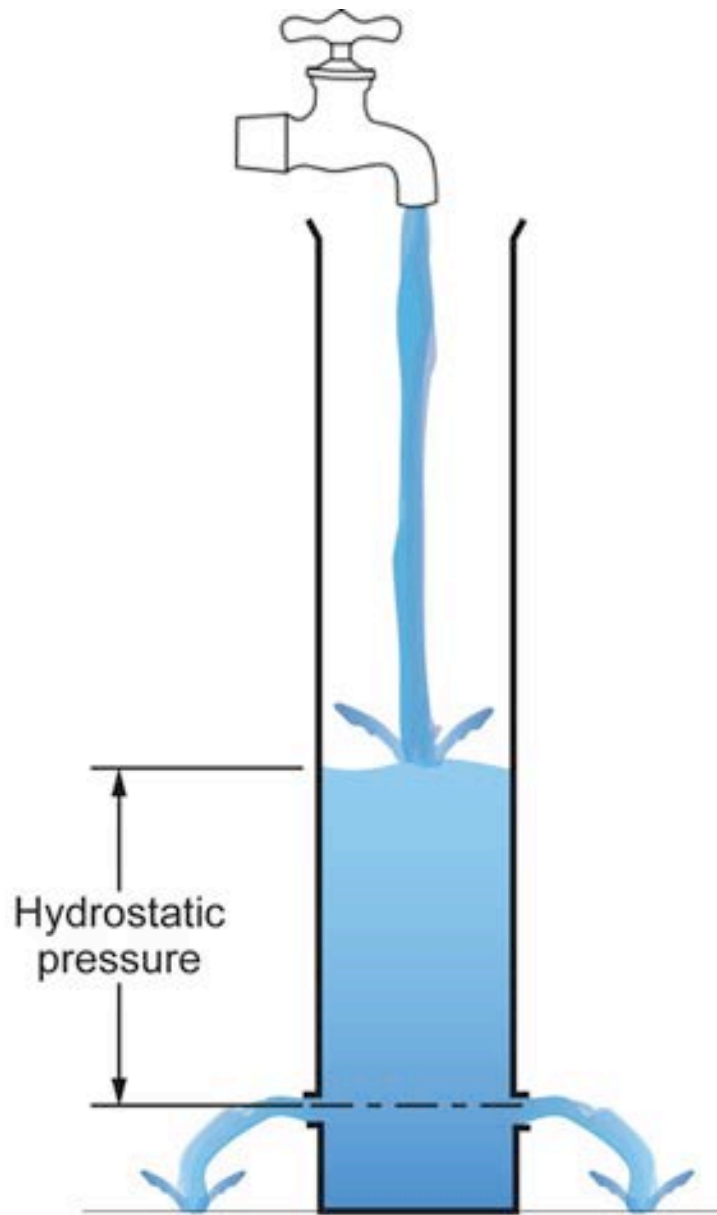
100%

100%

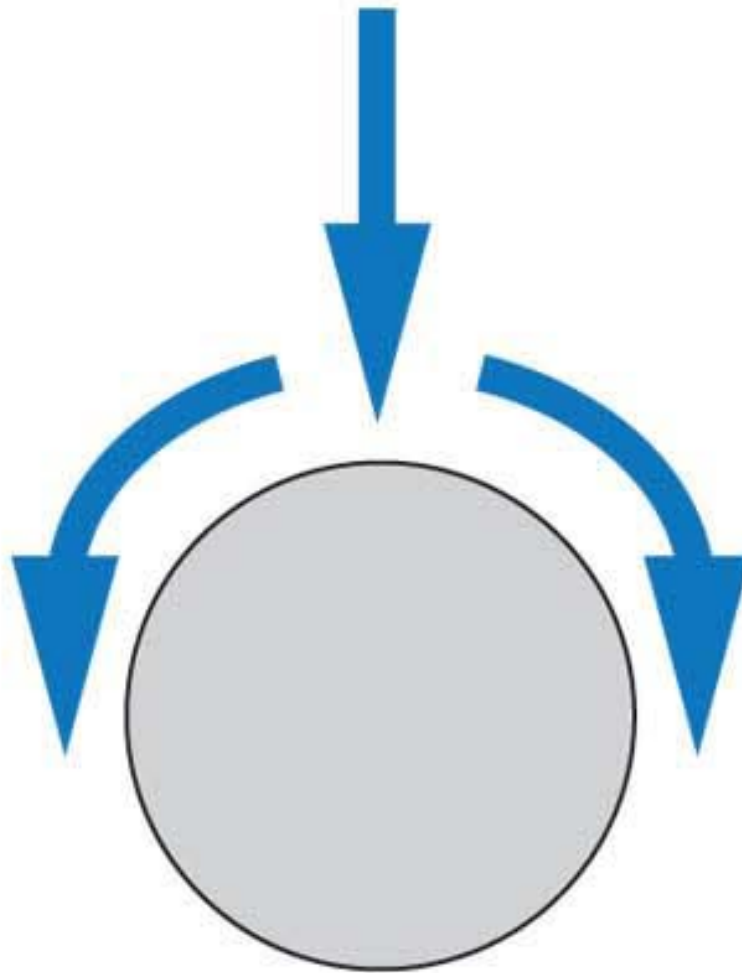
Insulation for Condensation Control*

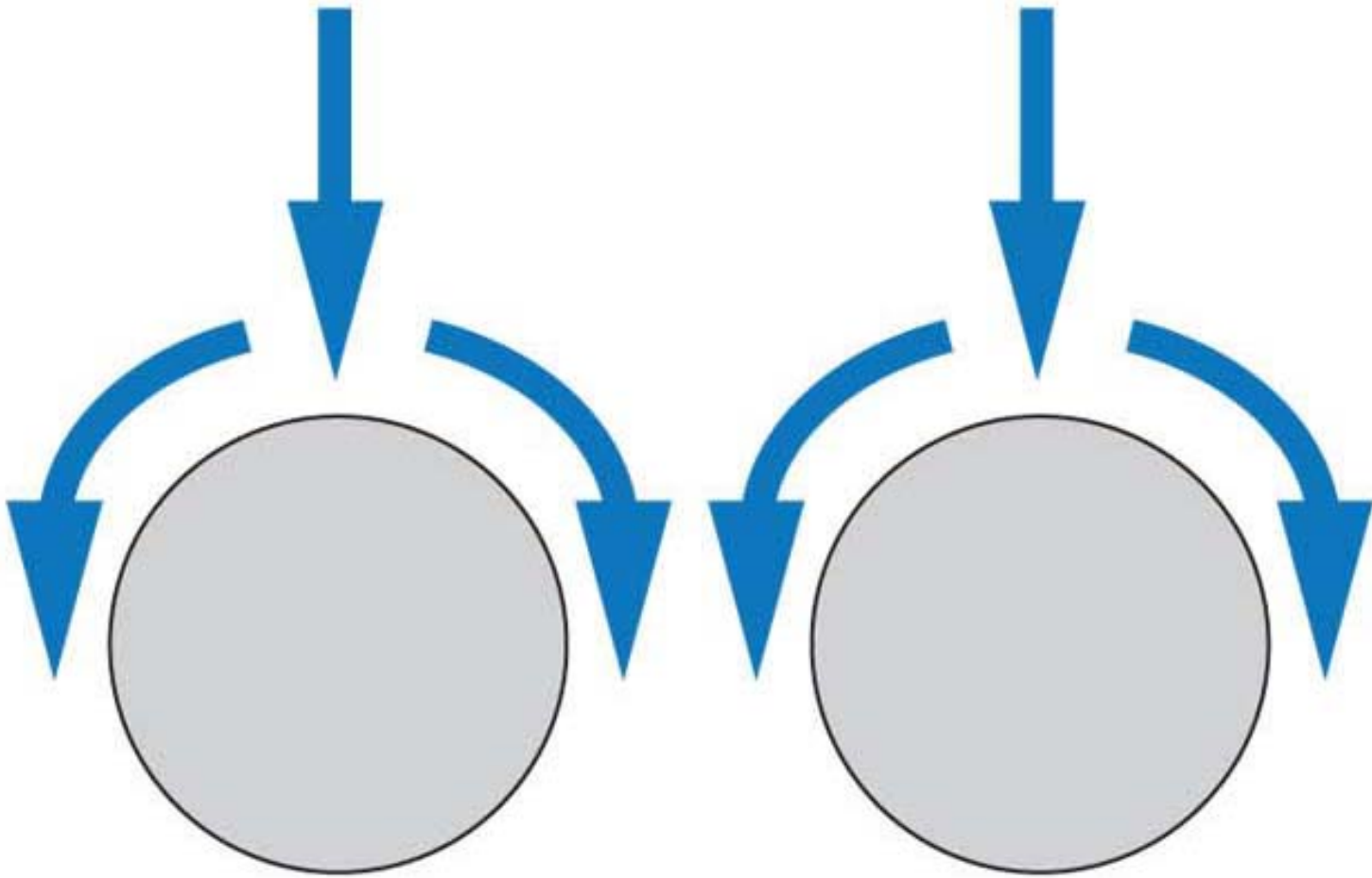
Climate Zone	Rigid Board or Air Impermeable Insulation	Total Cavity Insulation	Total Wall Assembly Insulation	Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value
4C	R-2.5	R-13	R-15.5	15%
	R-3.75	R-20	R-23.75	15%
5	R-5	R-13	R-18	30%
	R-7.5	R-20	R-27.5	30%
6	R-7.5	R-13	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%

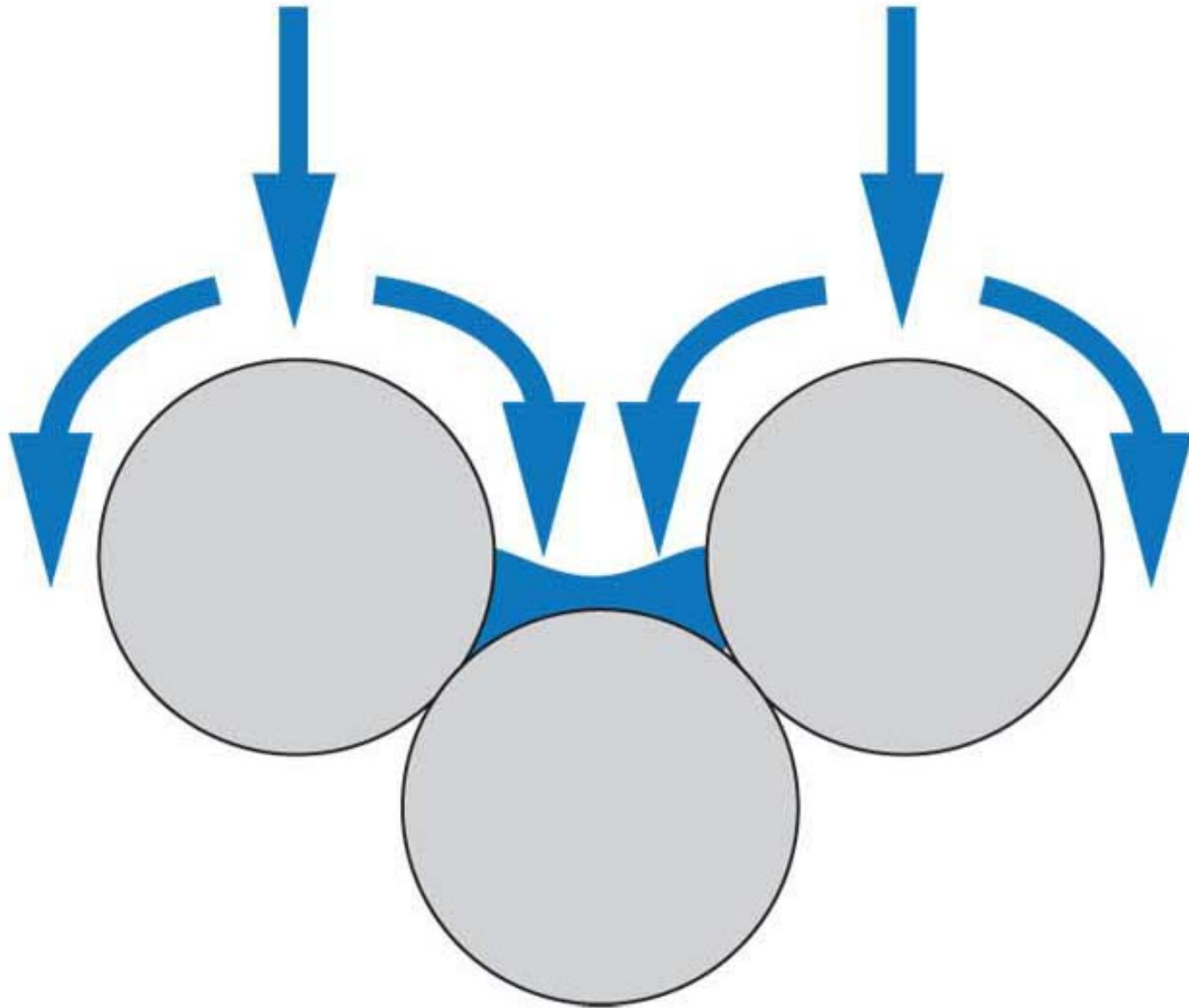
*Adapted from Table R 702.1 2015 International Residential Code



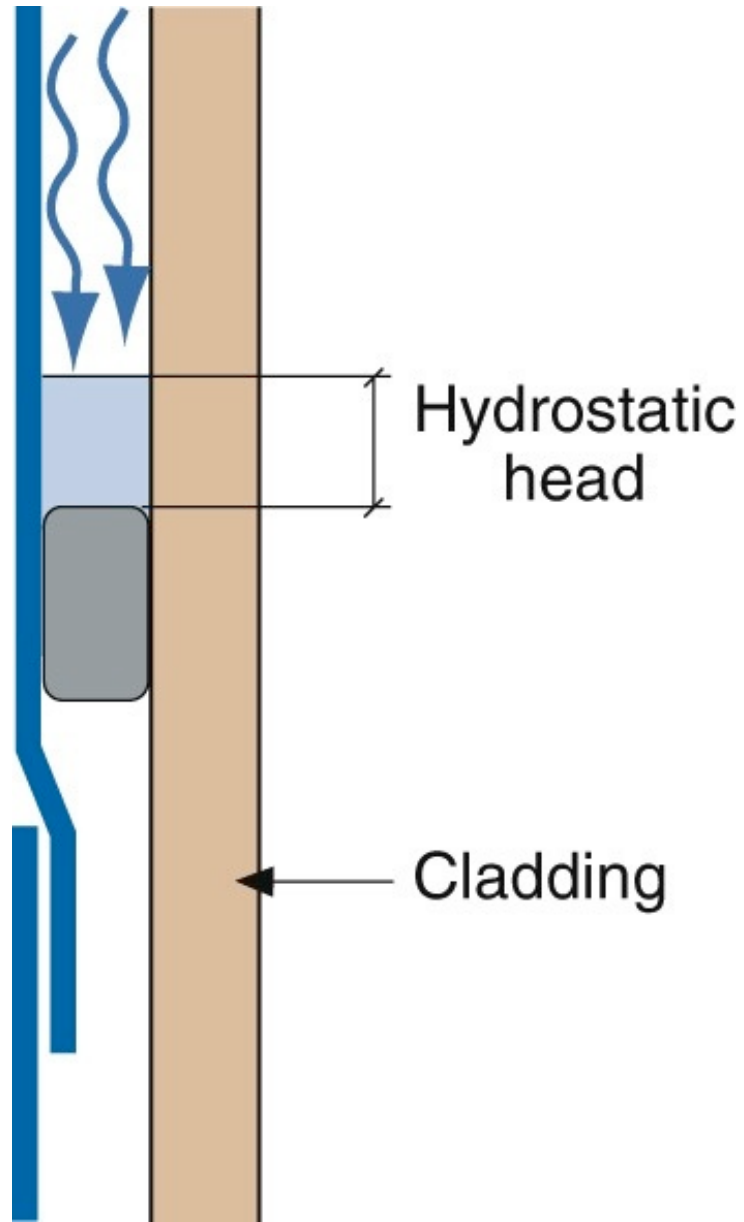


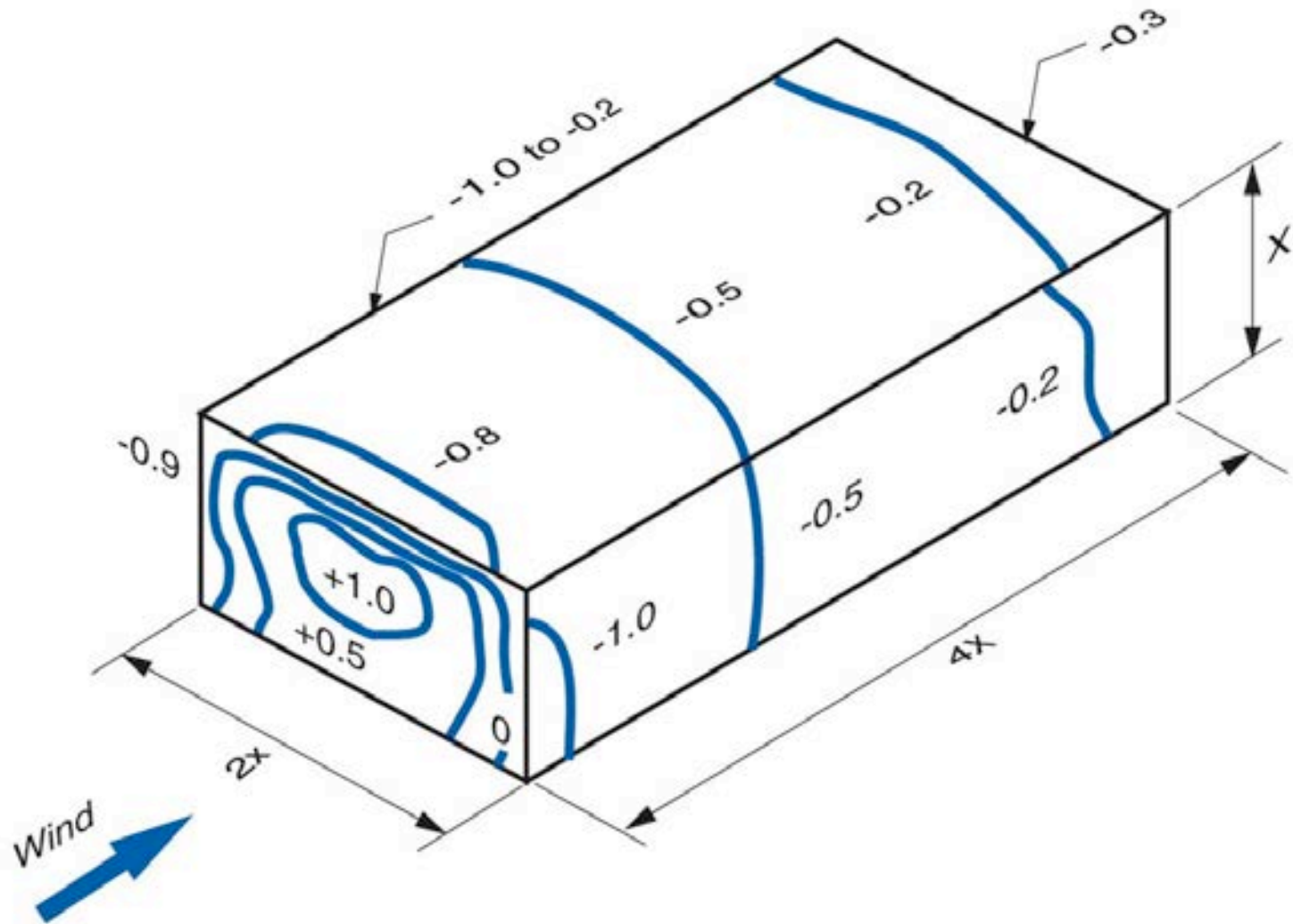






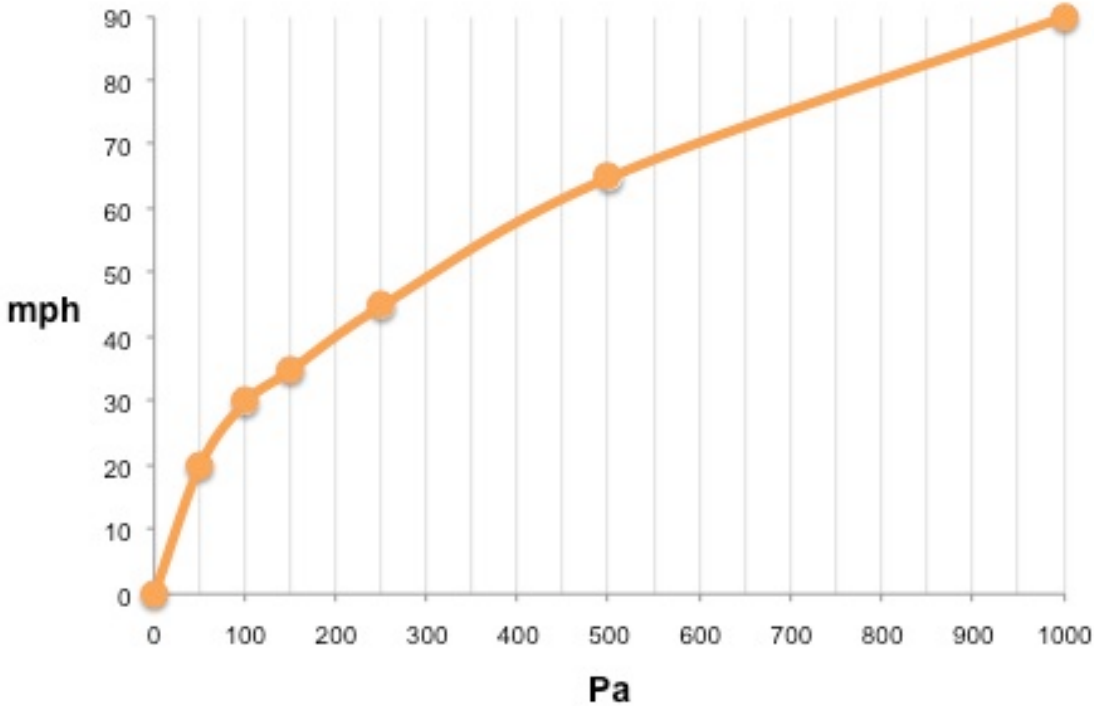




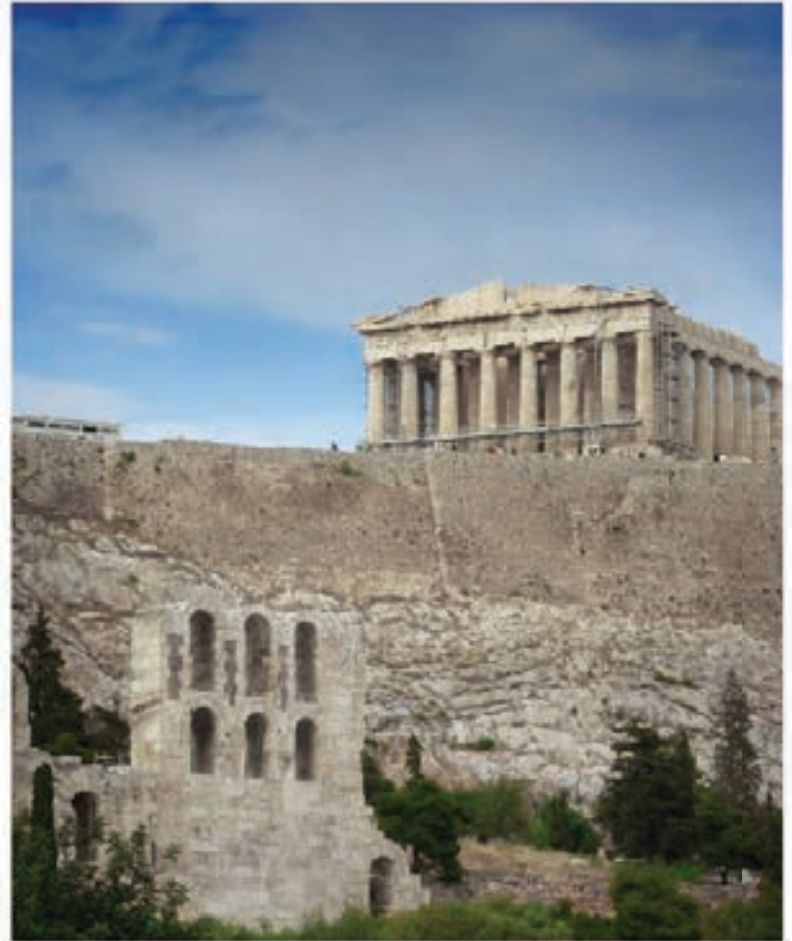


Pascals	mph
50	Pa = 20 mph
100	Pa = 30 mph
150	Pa = 35 mph
250	Pa = 45 mph
500	Pa = 65 mph
1,000	Pa = 90 mph

Wind Speed (mph) vs. Stagnation Pressure (Pa)











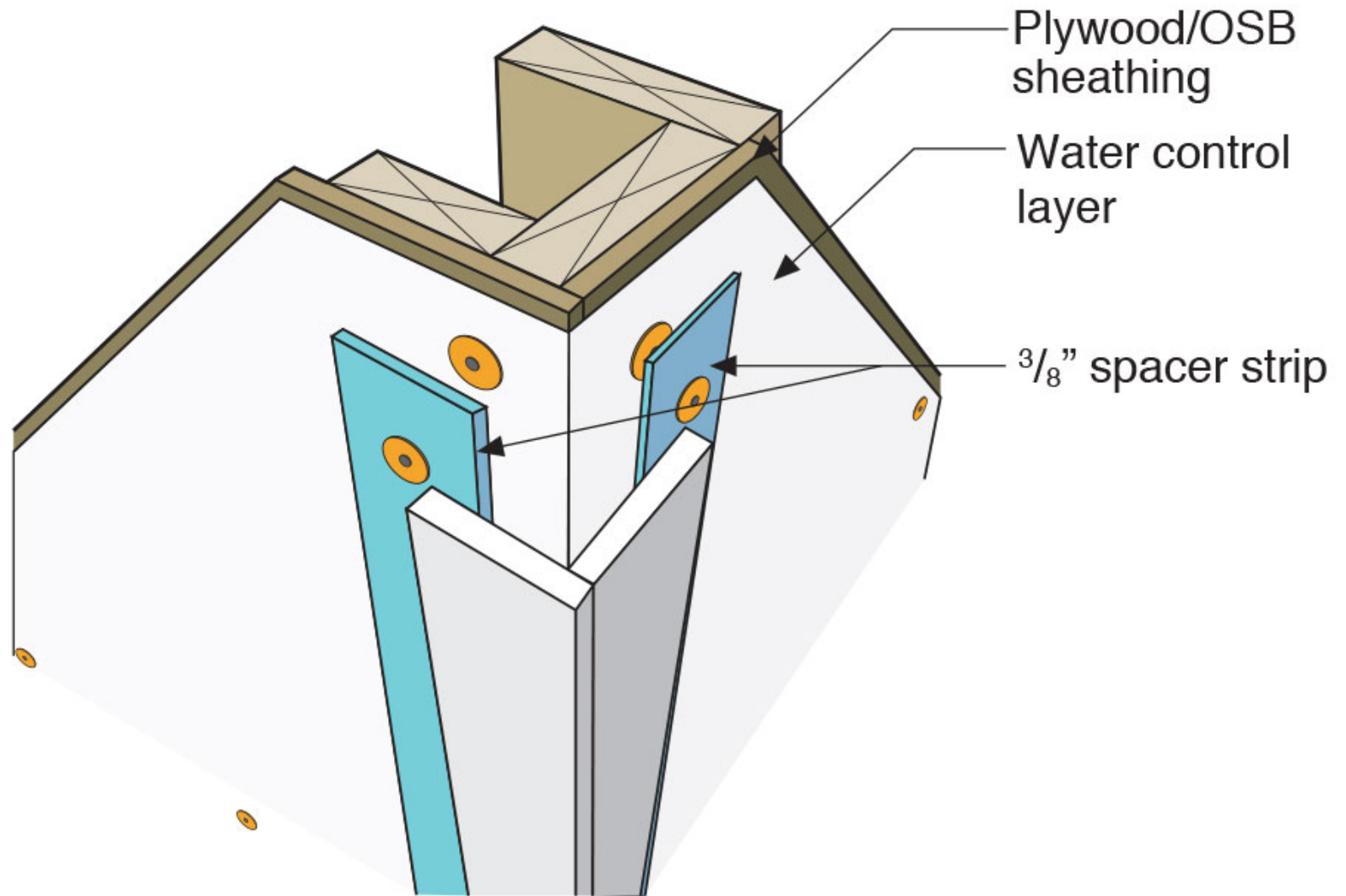






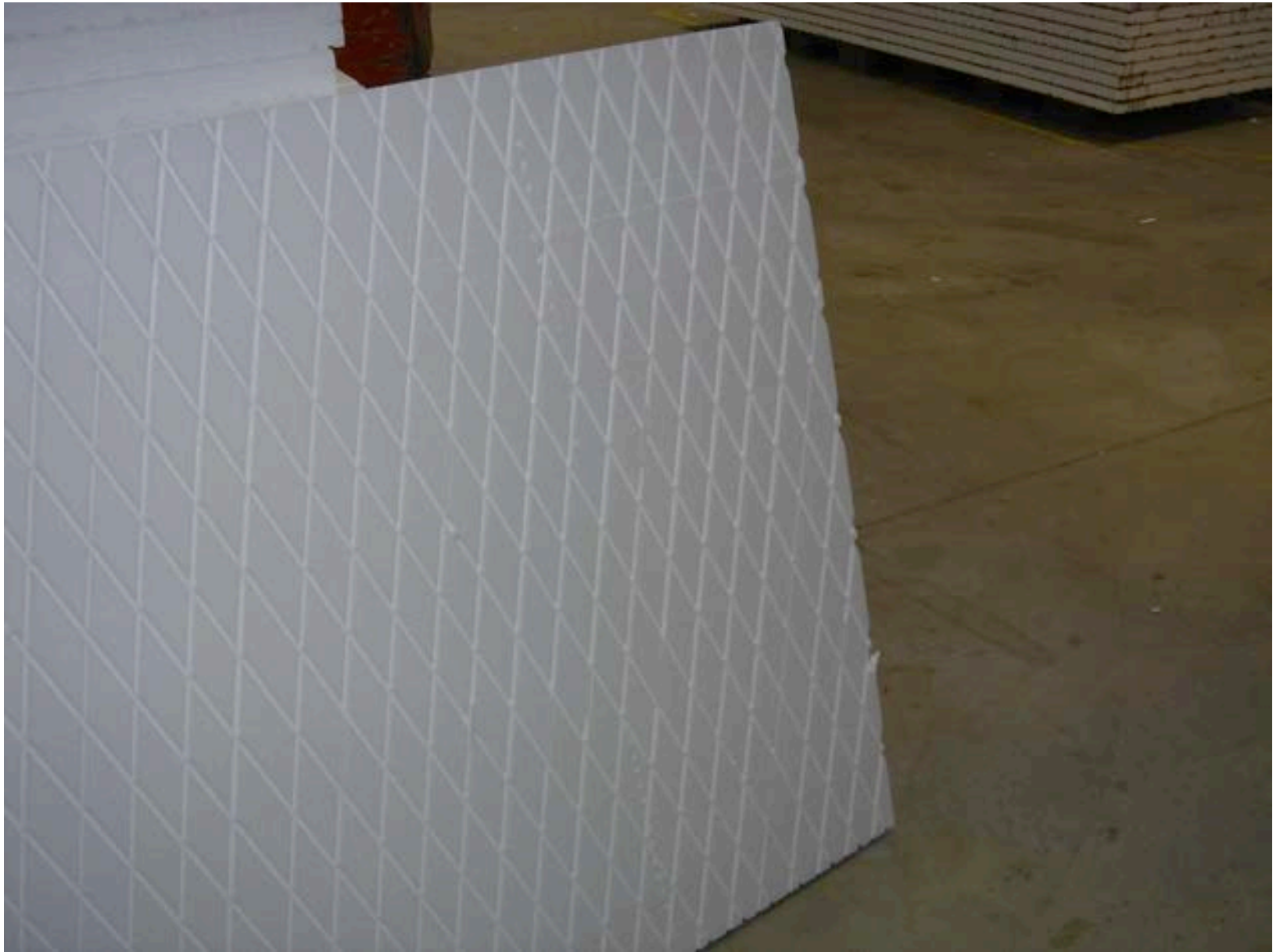




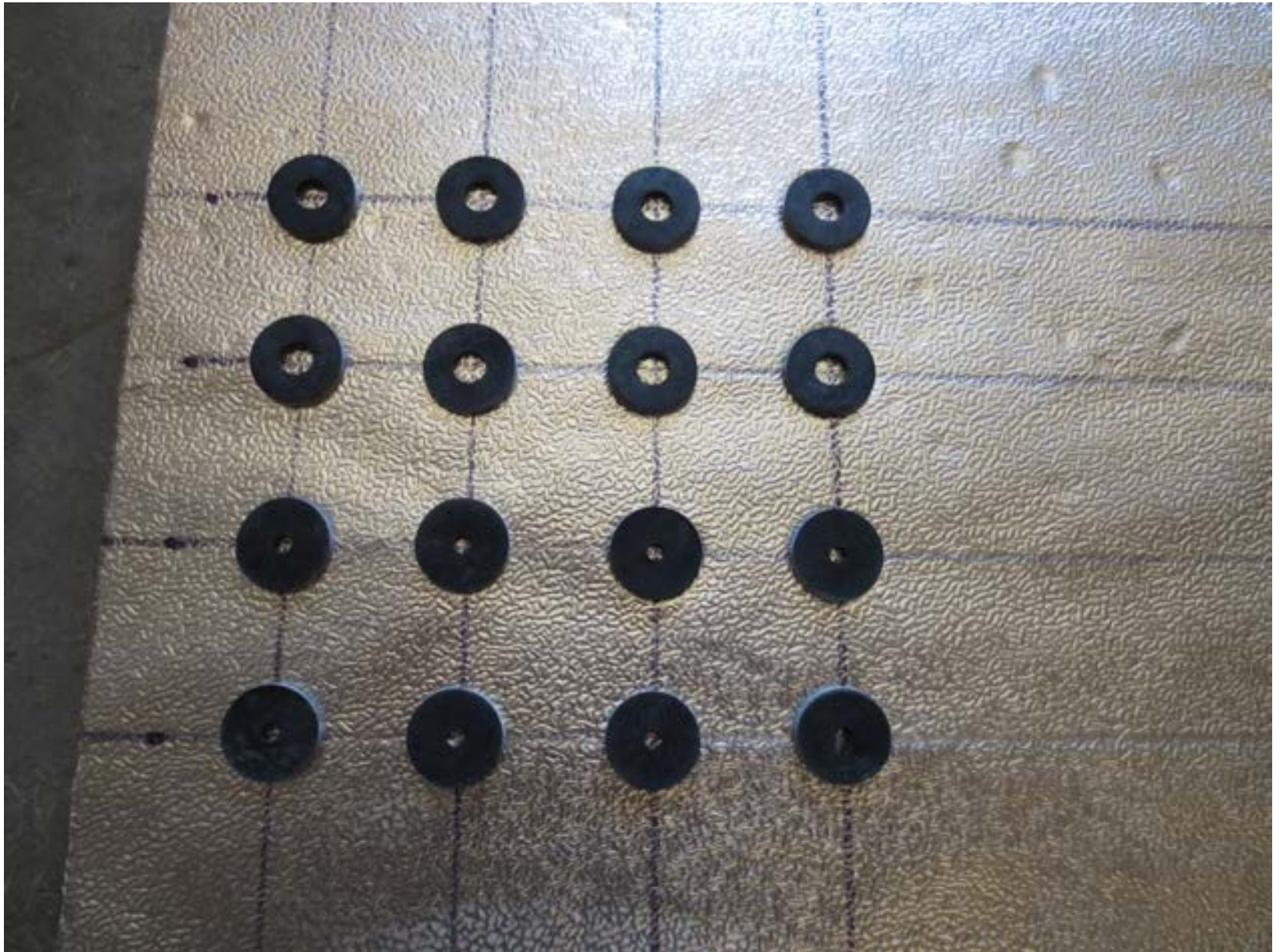




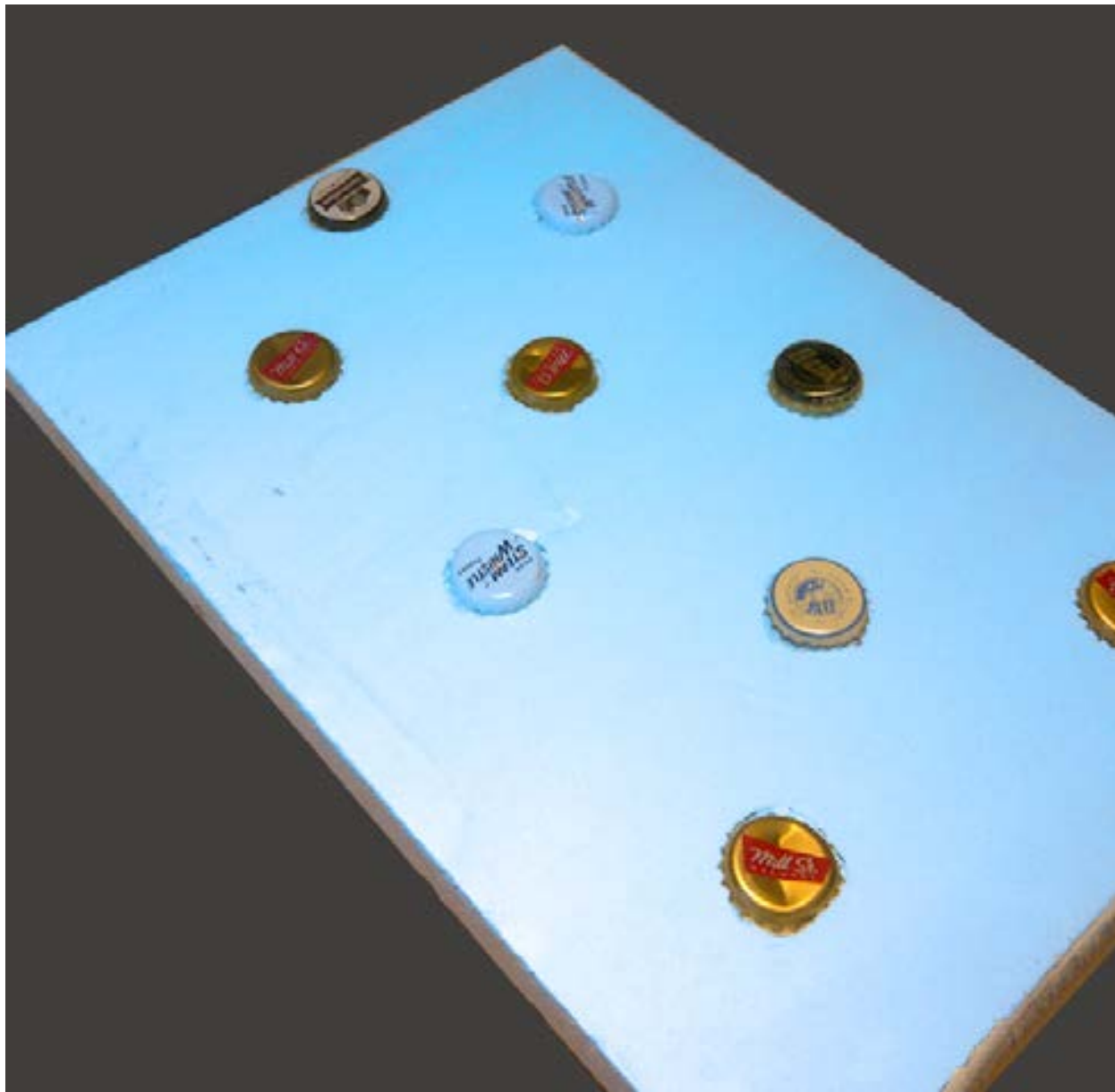




Rain Screen



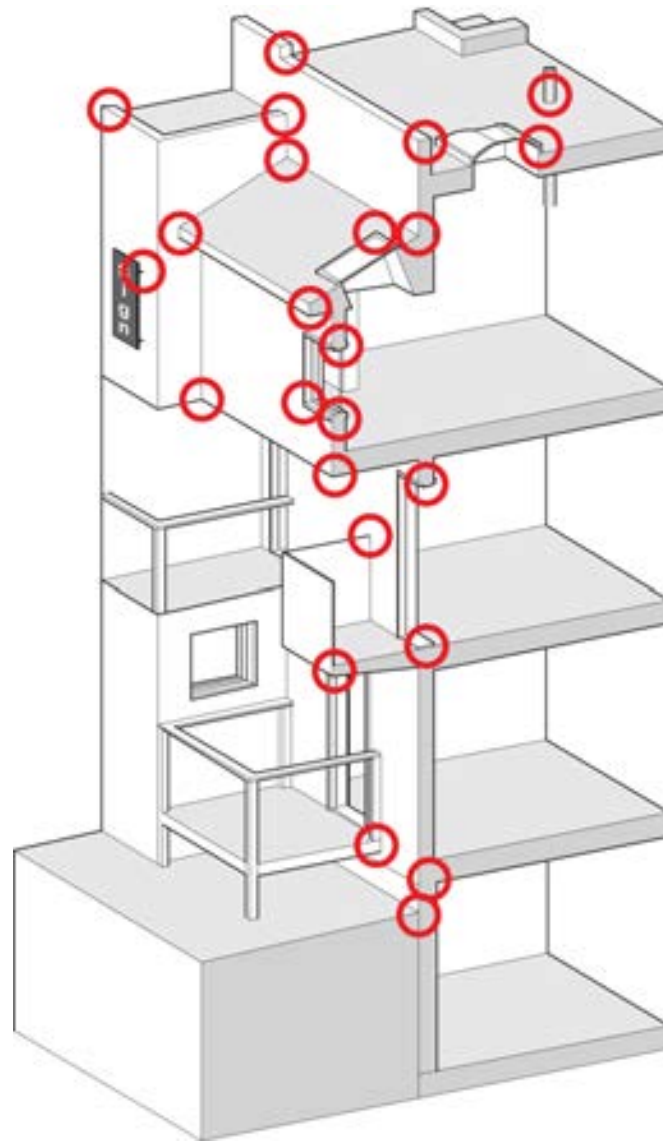
Beer Screen?



Commercial Enclosure: Simple Layers



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



























































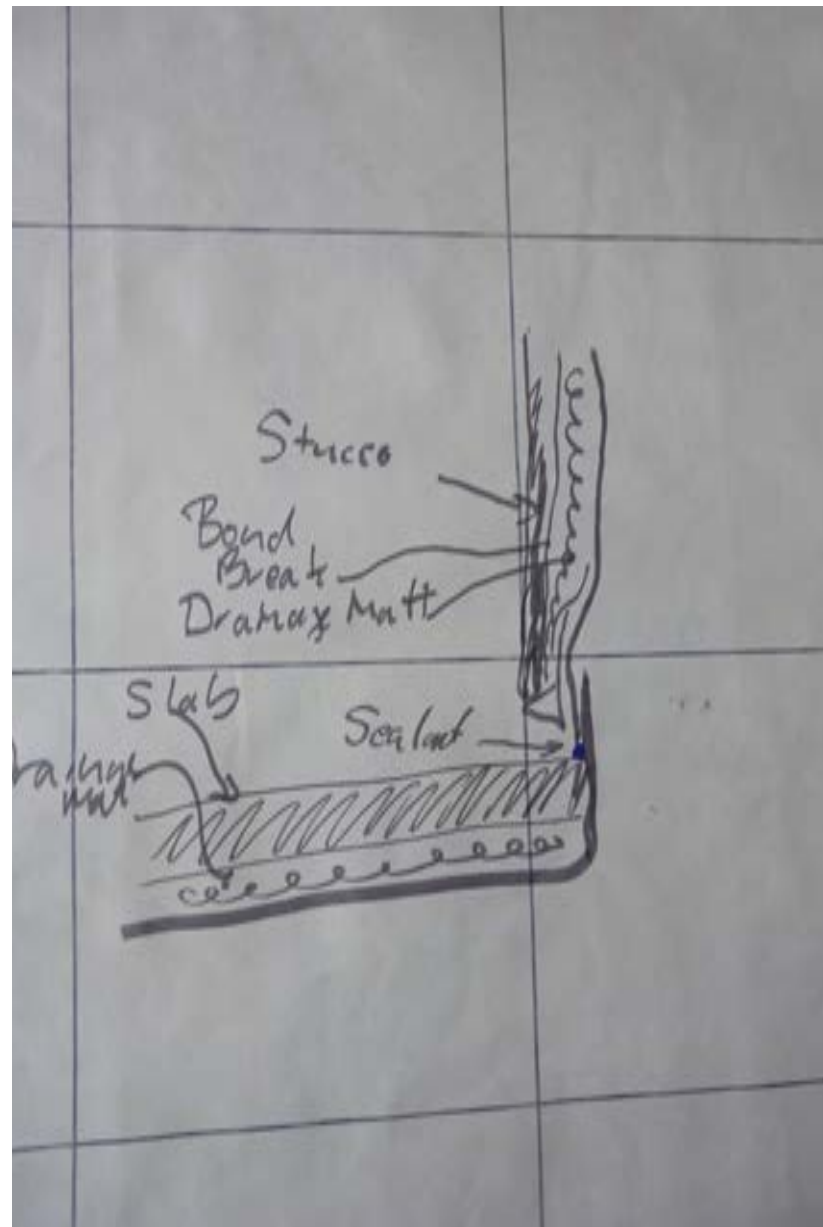
































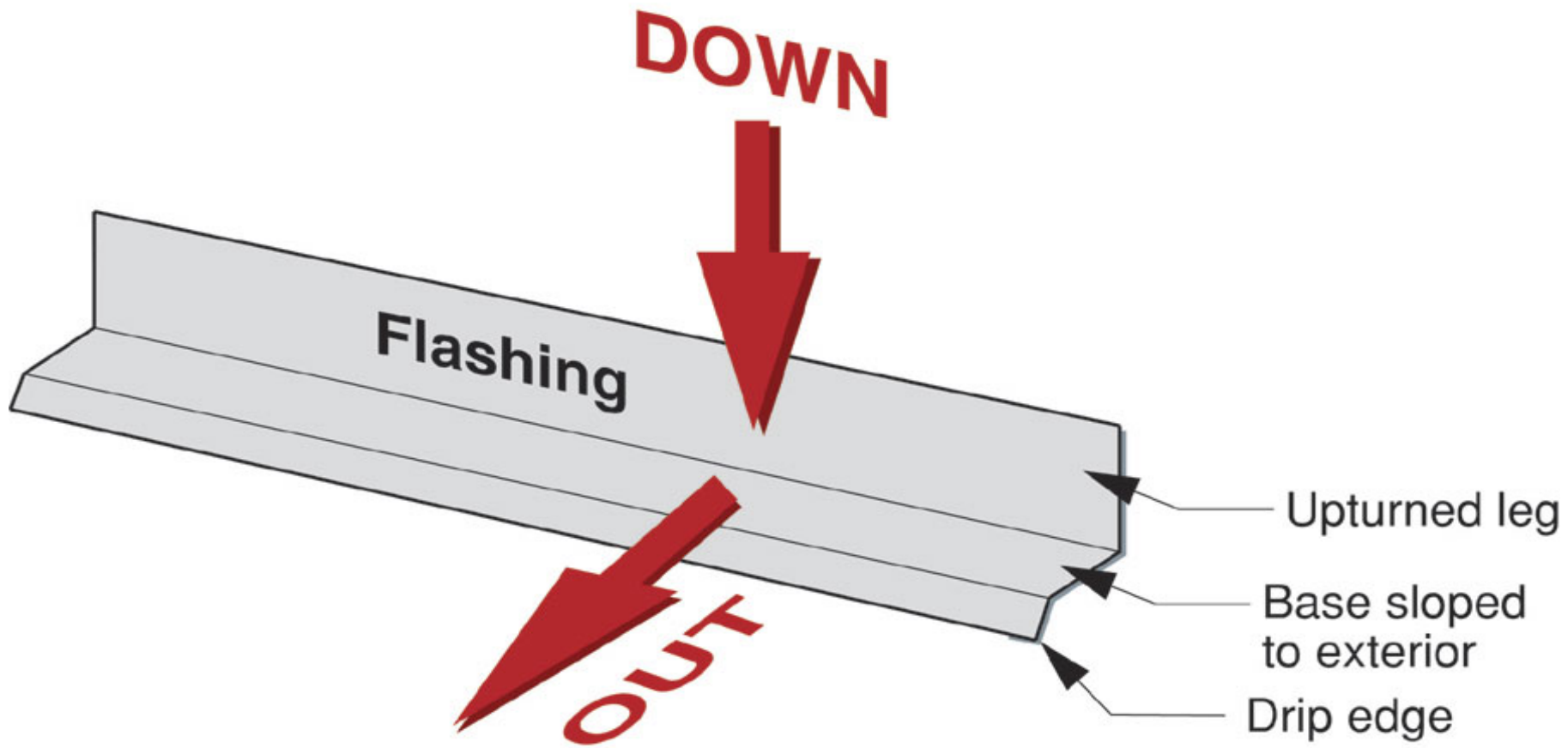


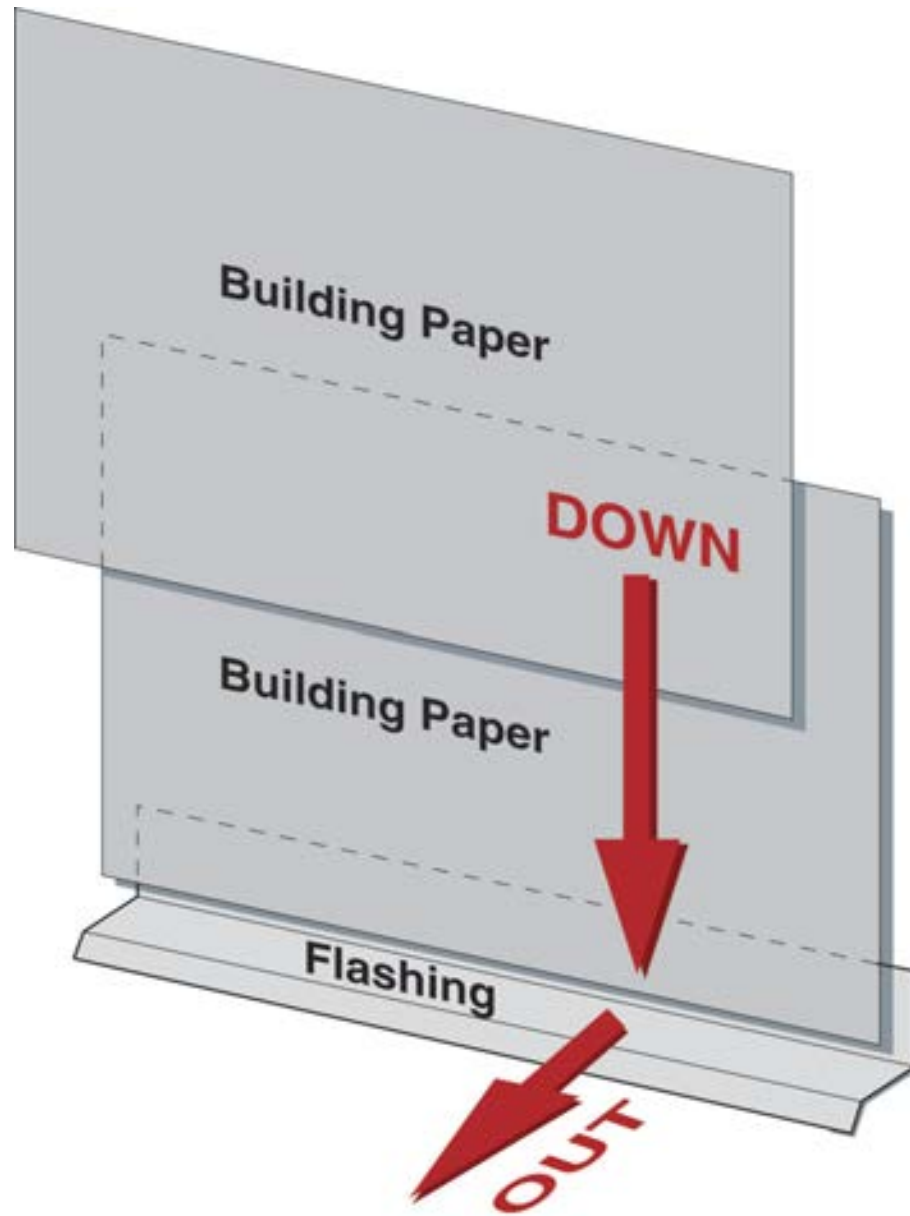


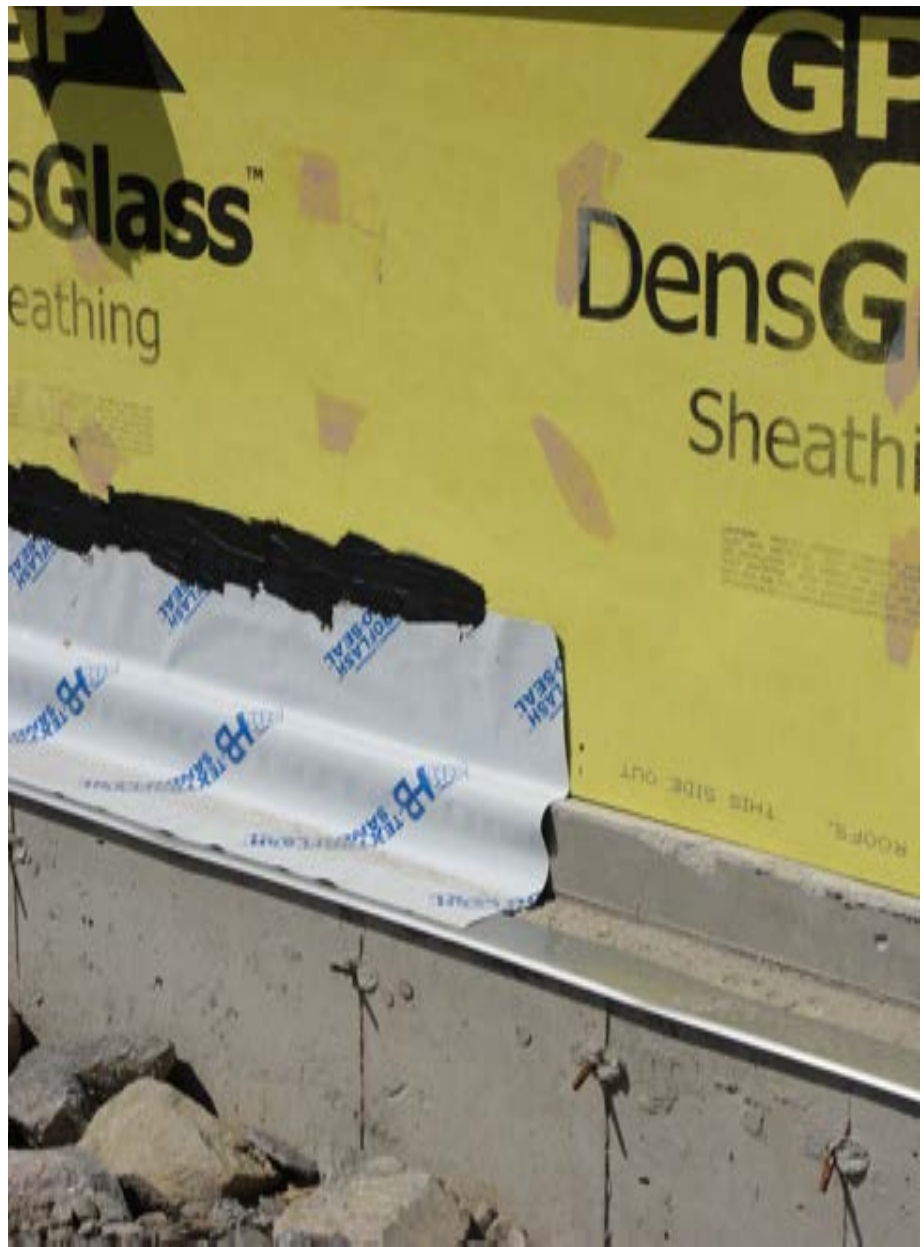






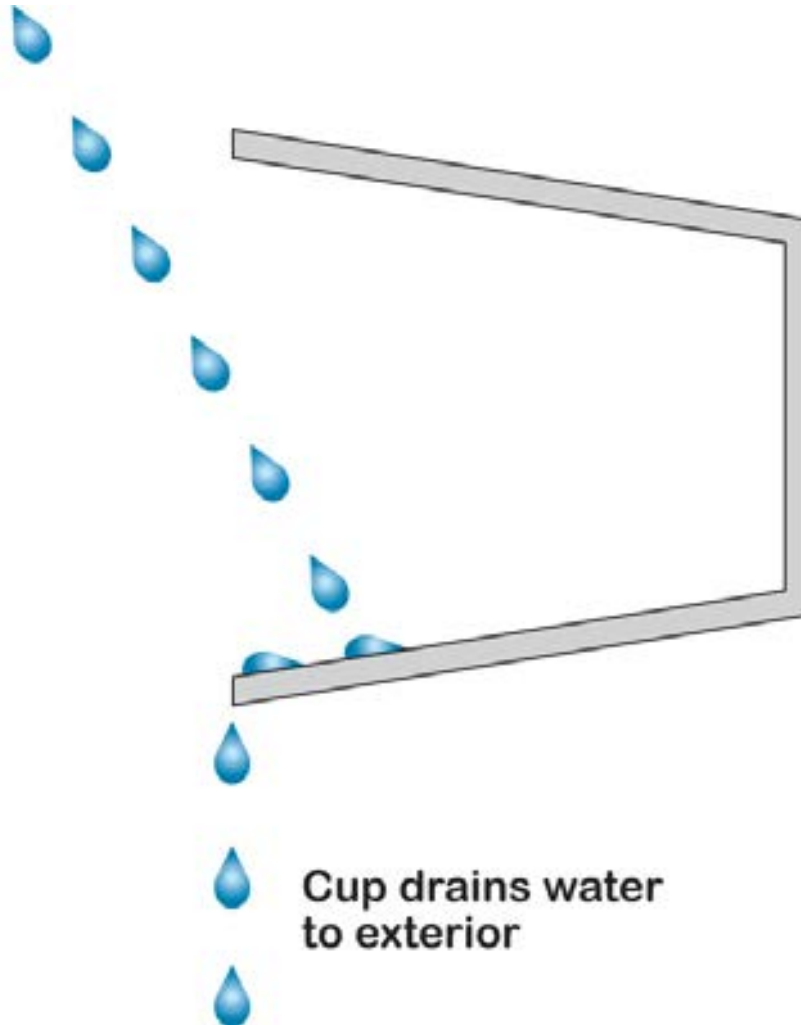








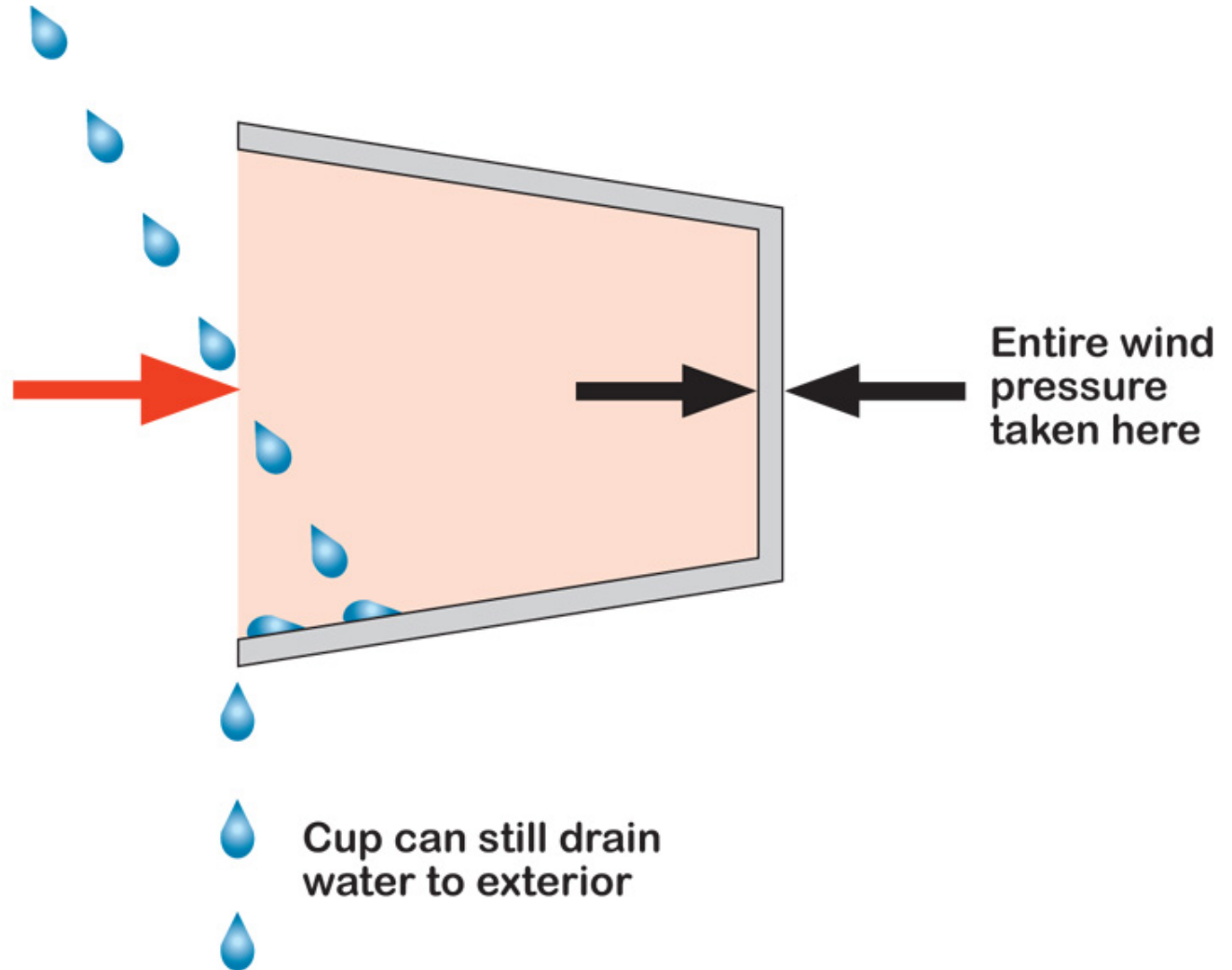
Rain enters cup
due to momentum
("kinetic energy")

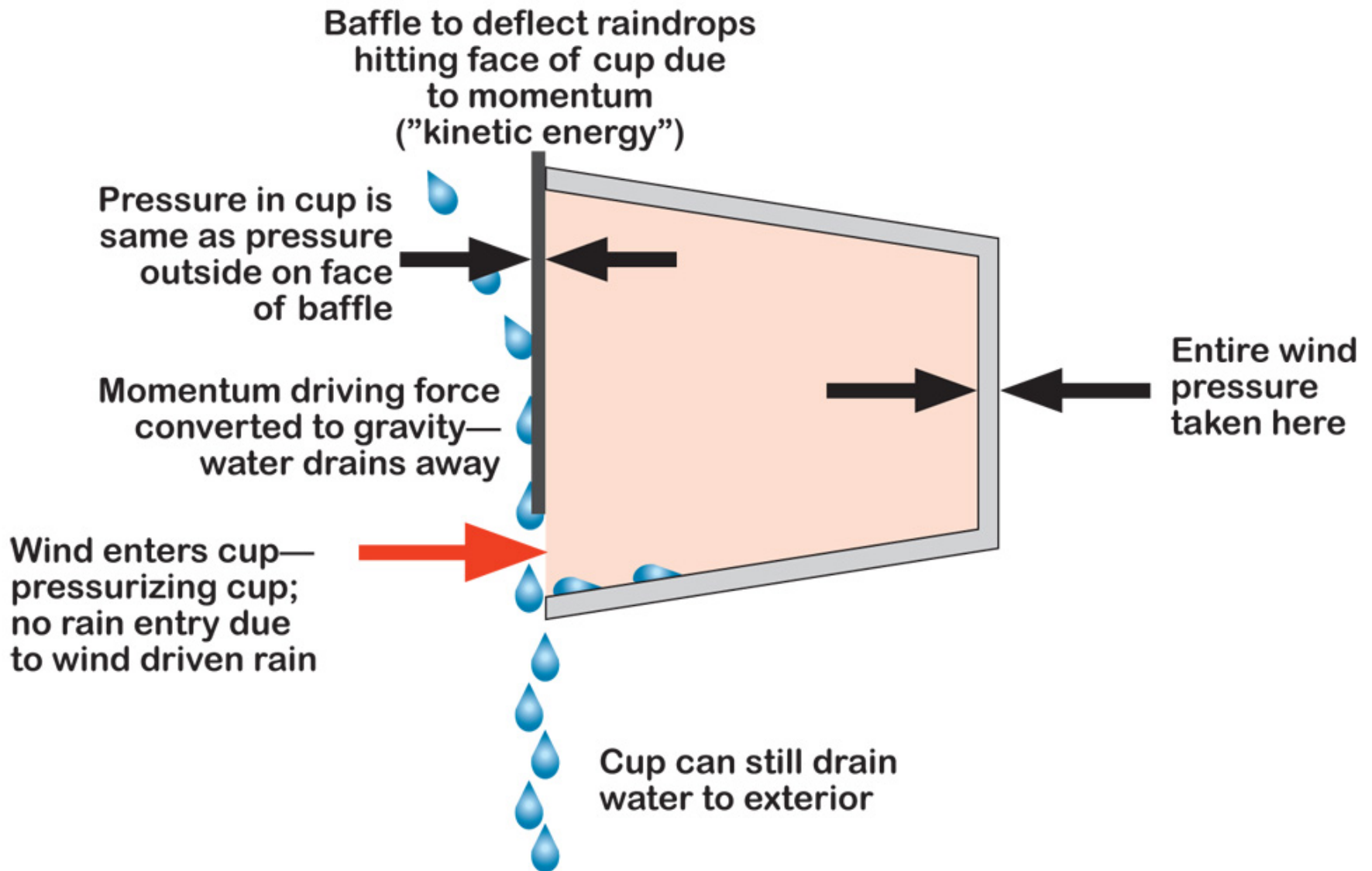


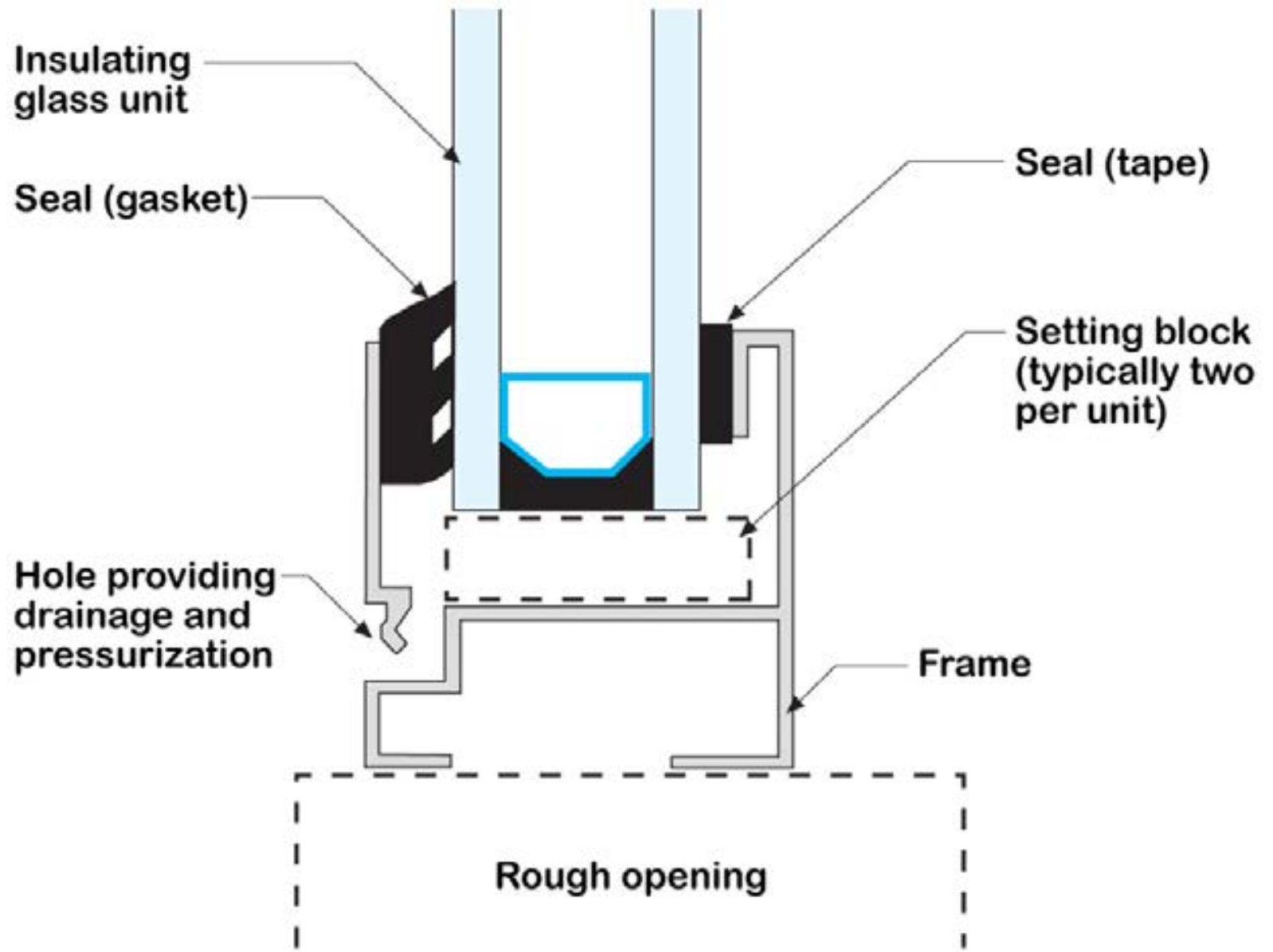
Cup drains water
to exterior

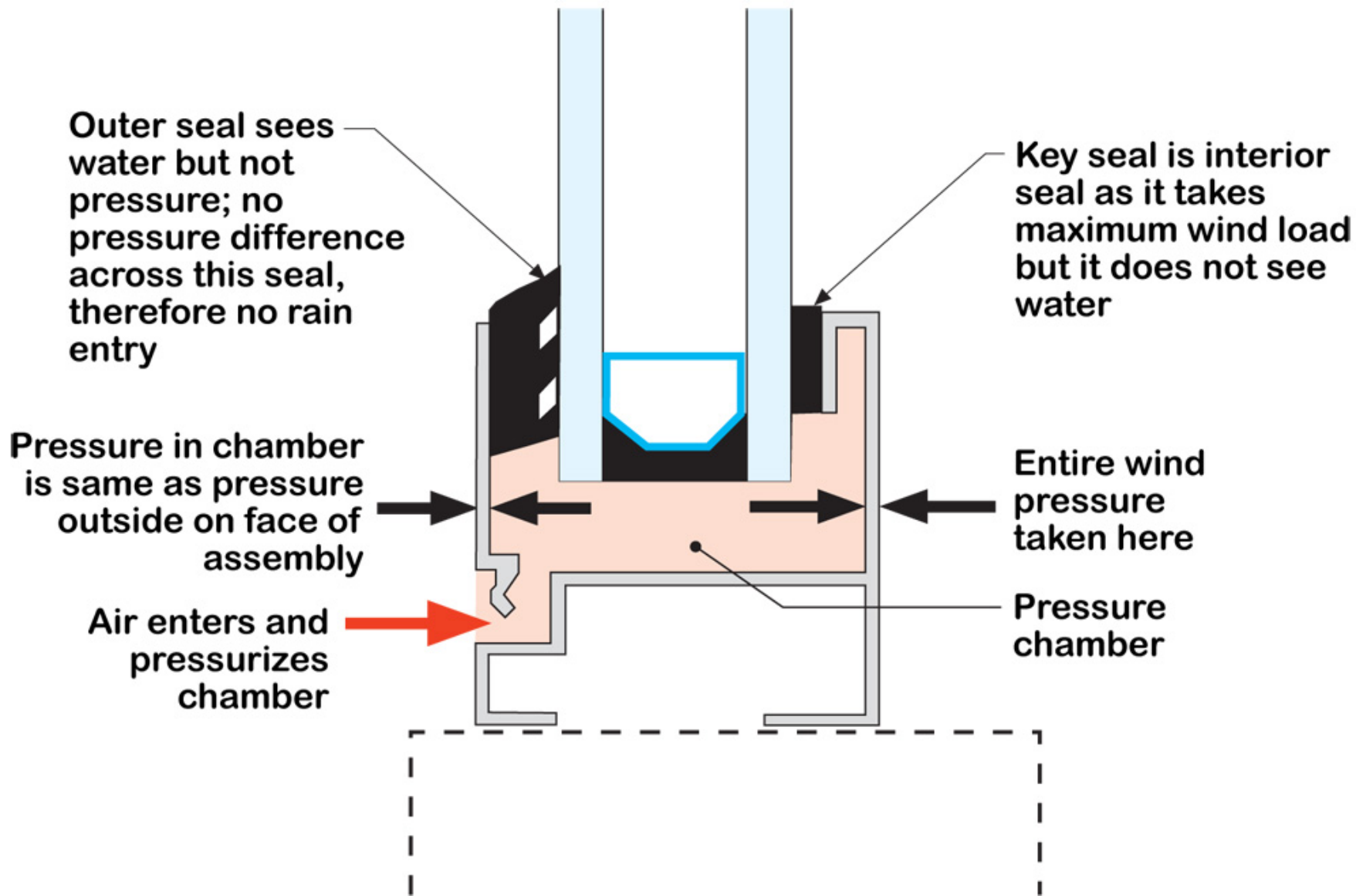
Rain enters cup due to momentum ("kinetic energy")

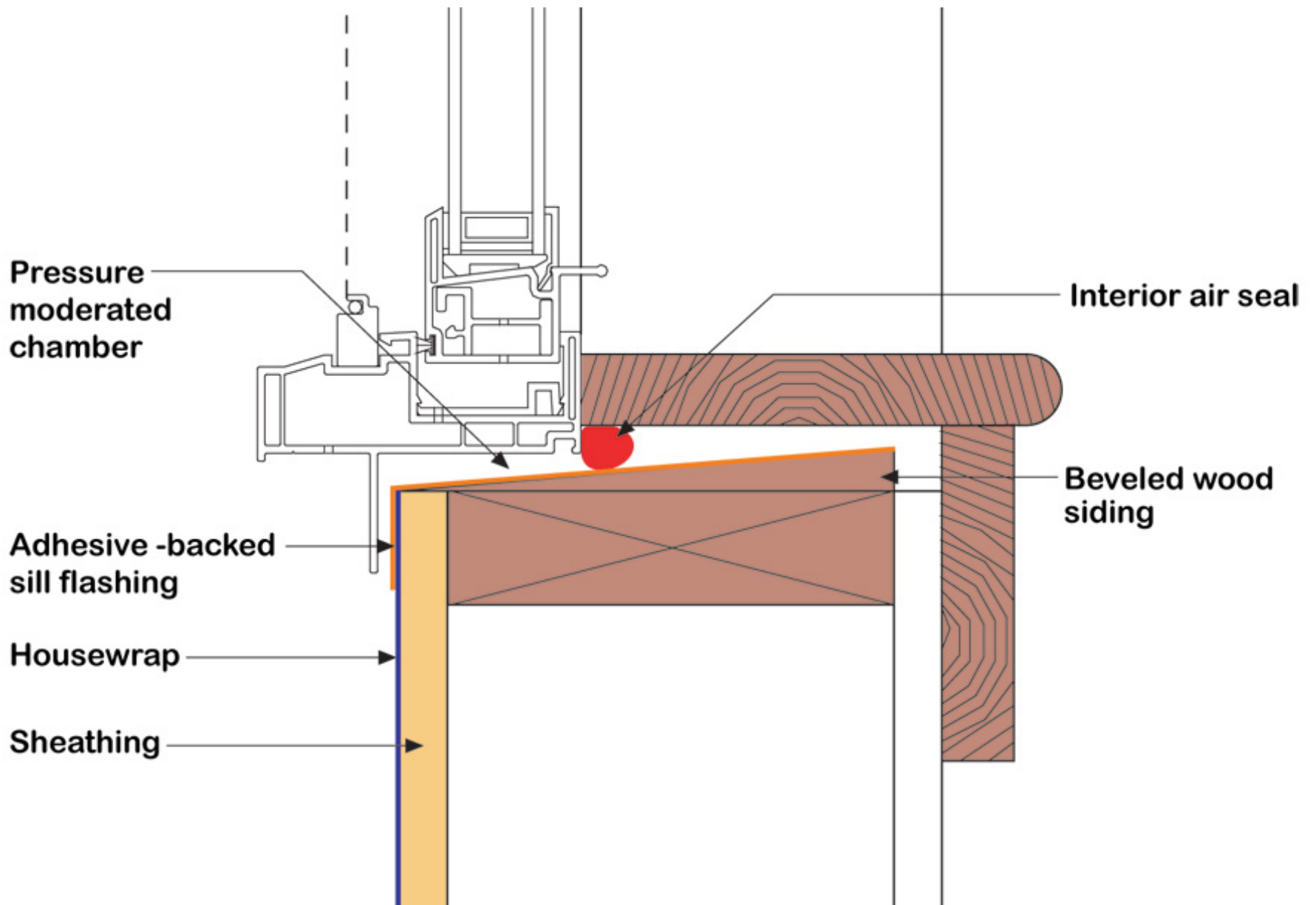
Wind enters cup—pressurizing cup; no rain entry due to wind driven rain











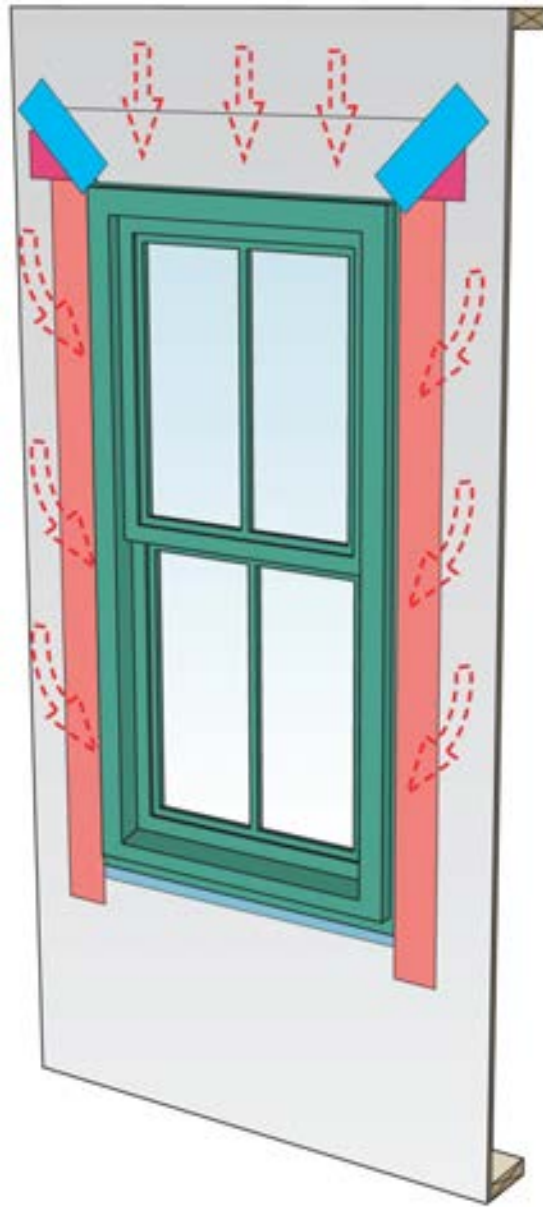


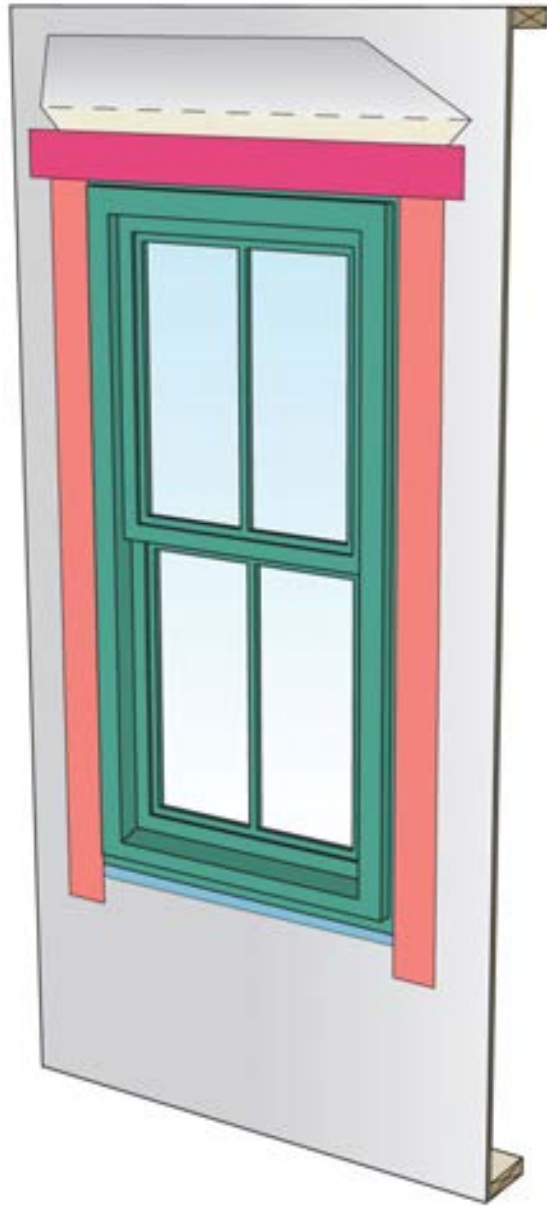




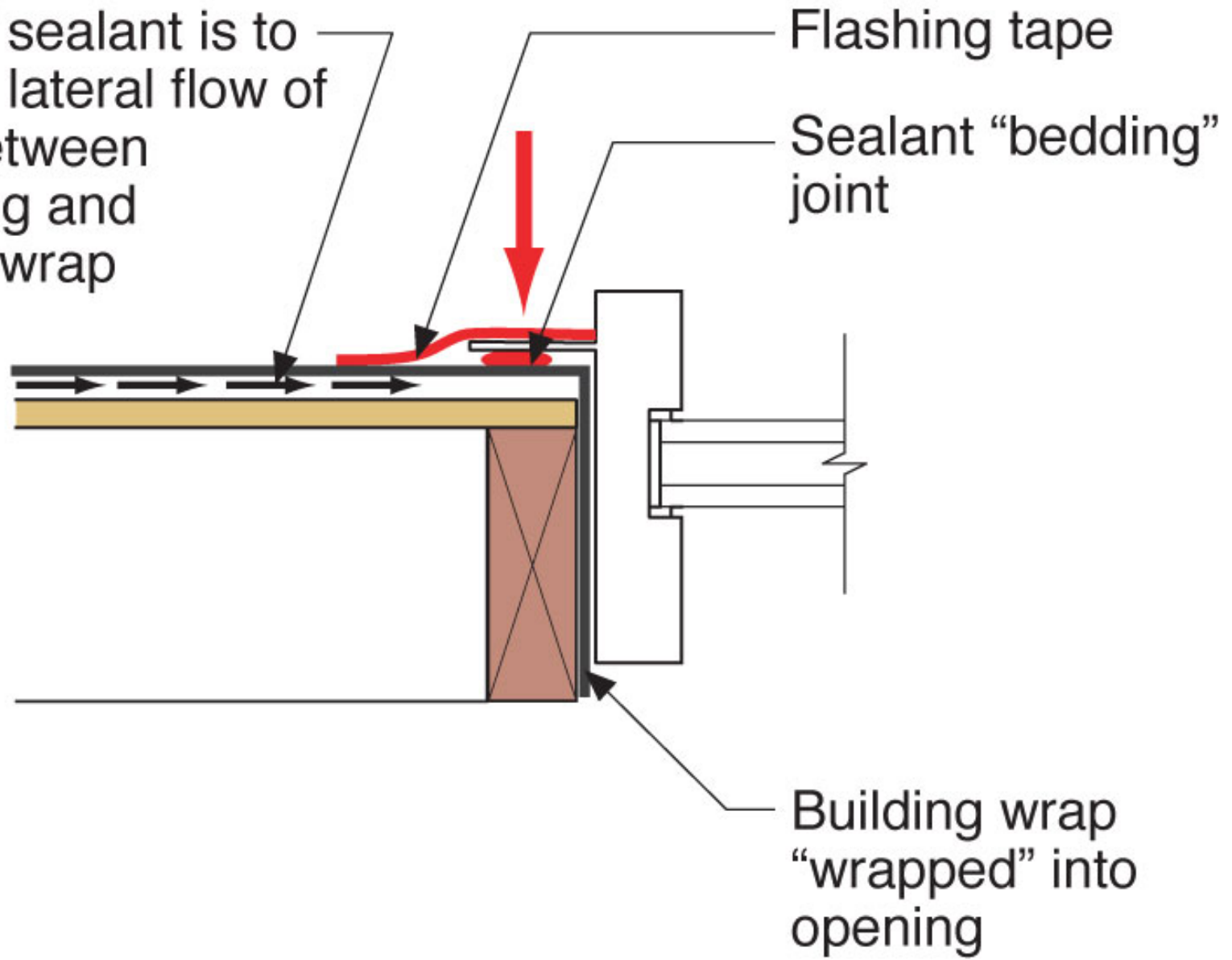


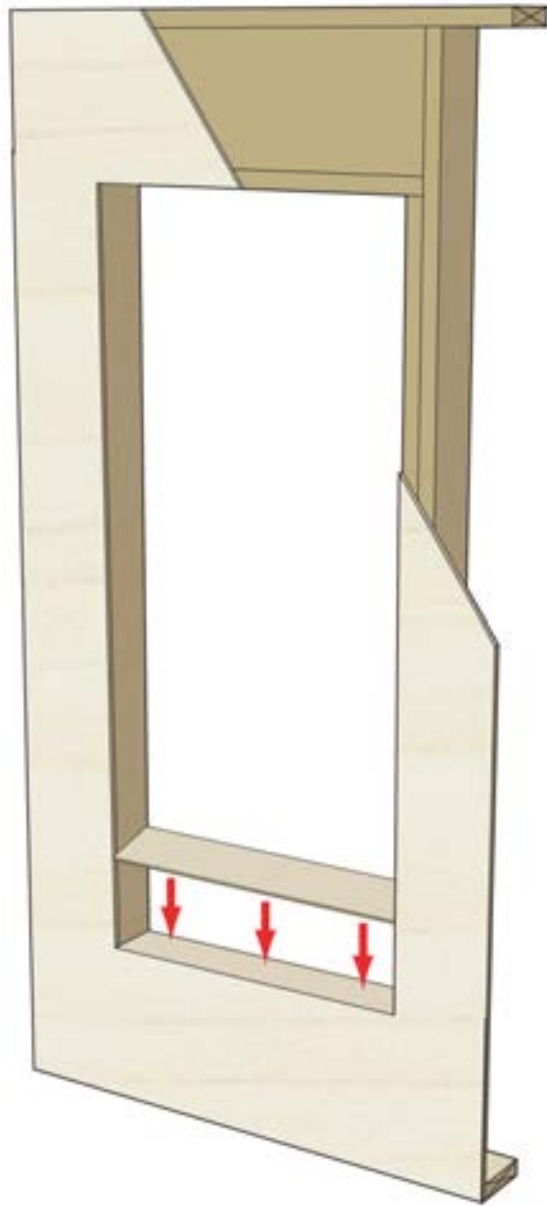


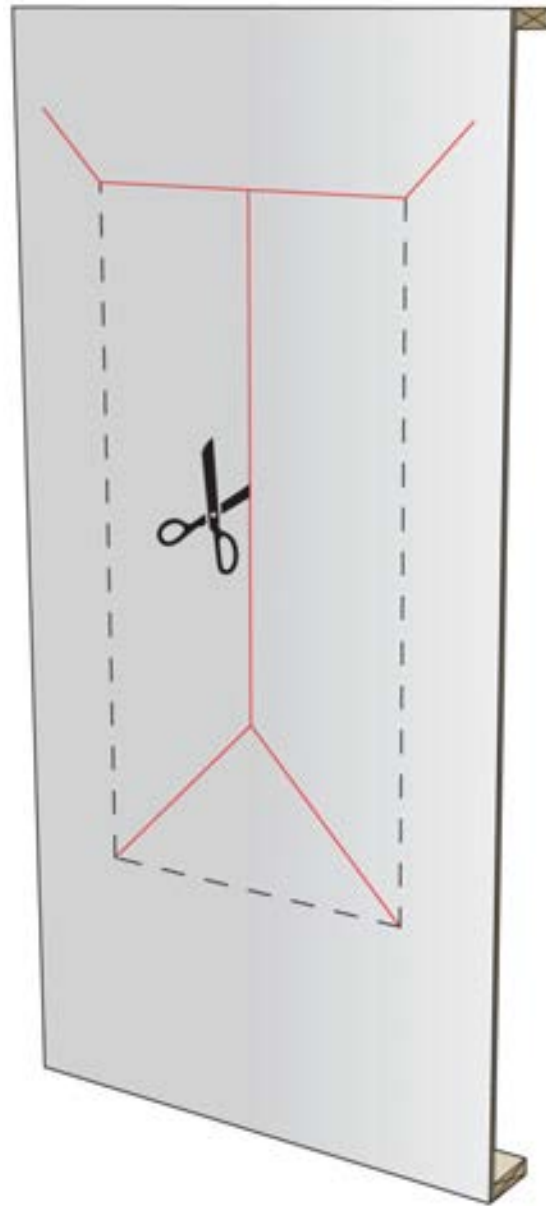


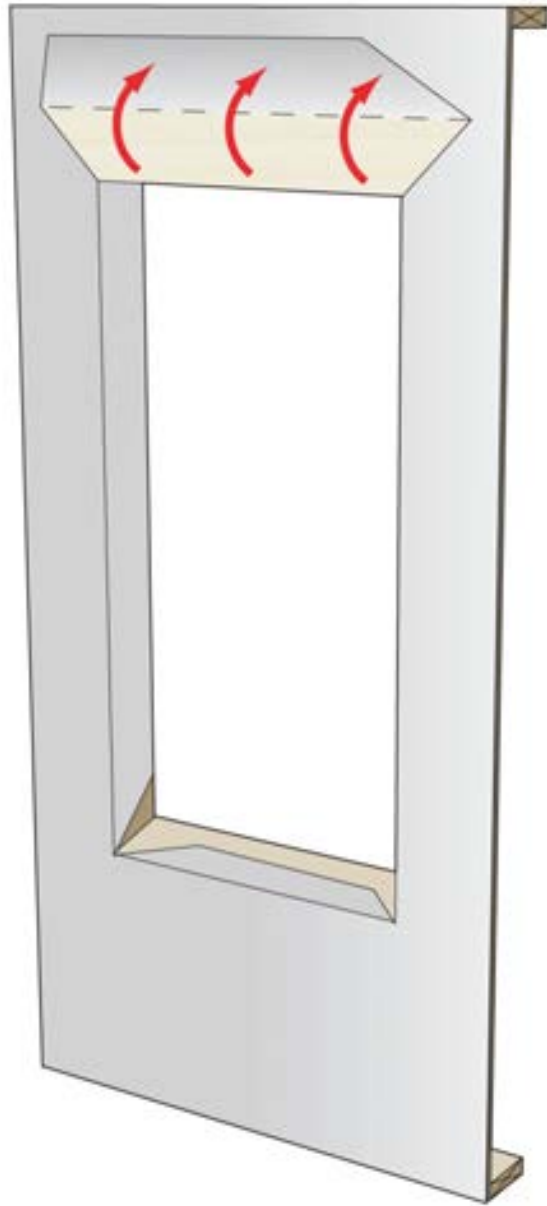


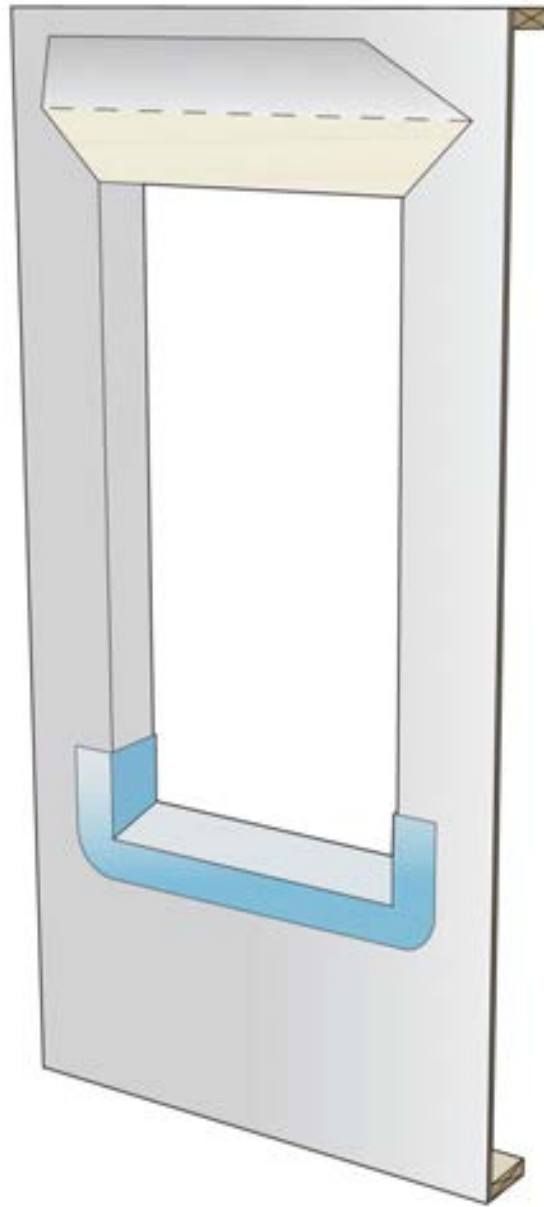
Intent of sealant is to limit this lateral flow of water between sheathing and building wrap

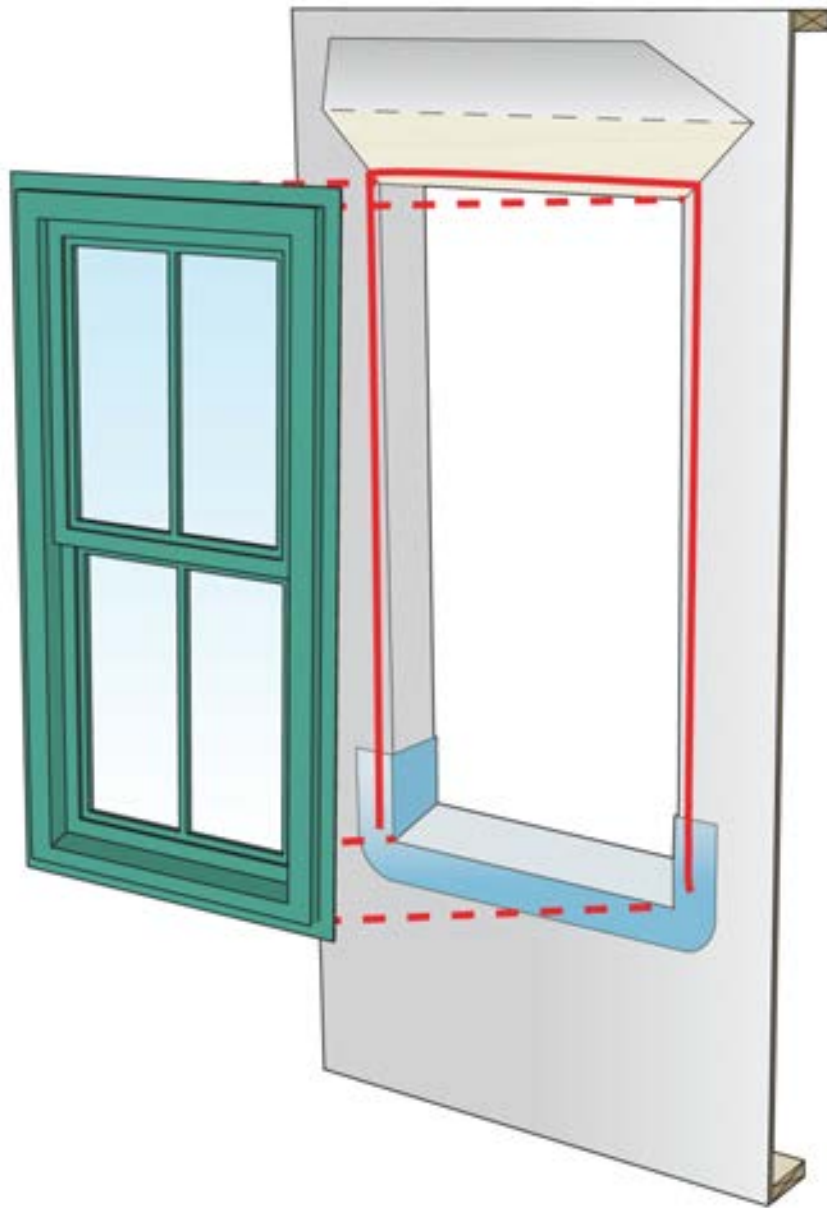


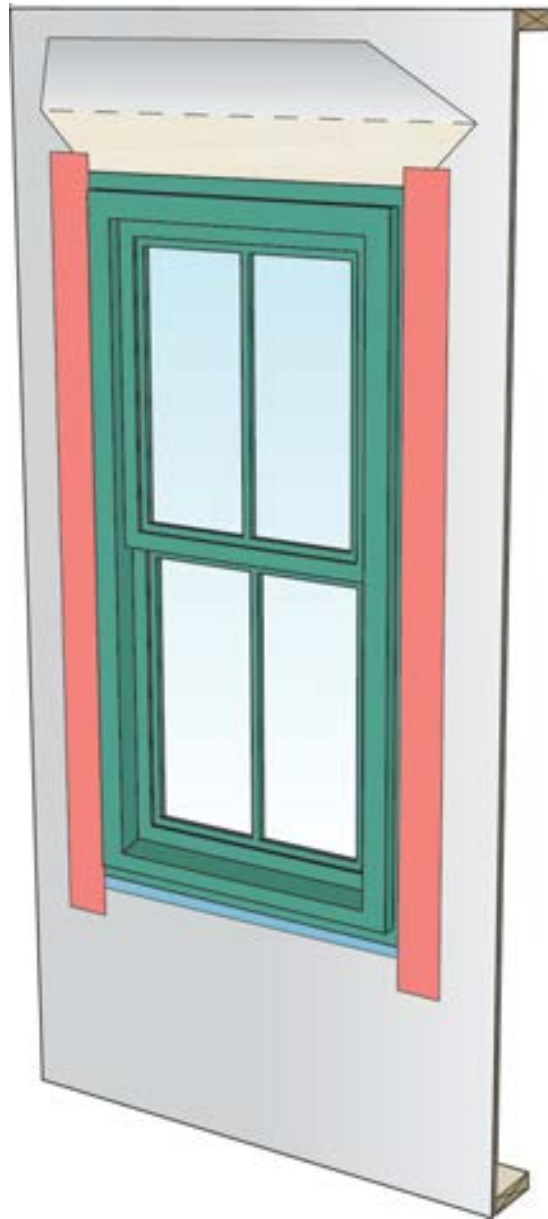


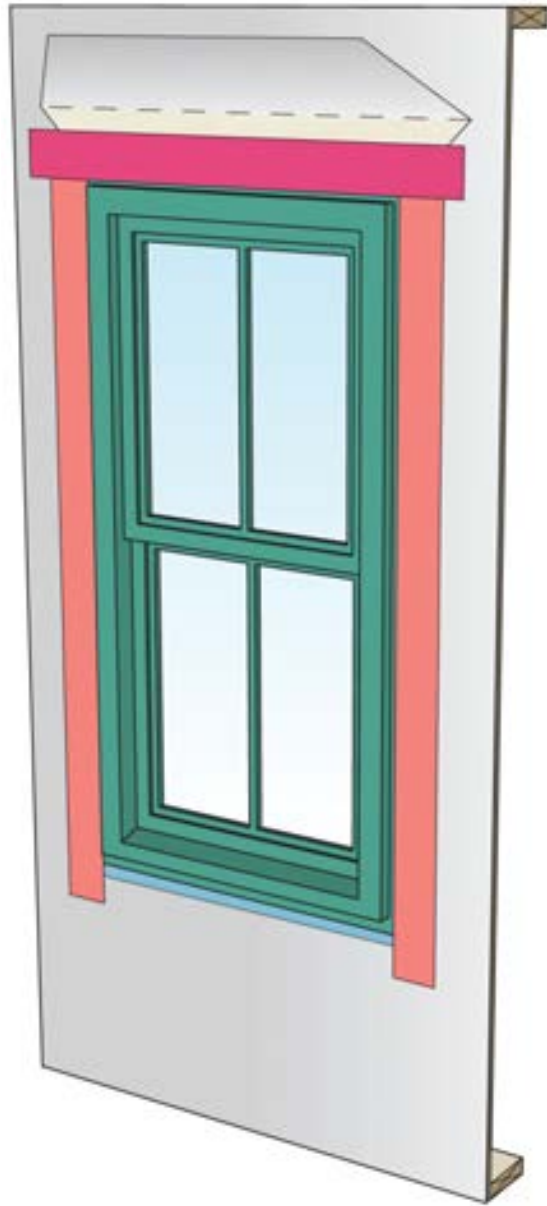


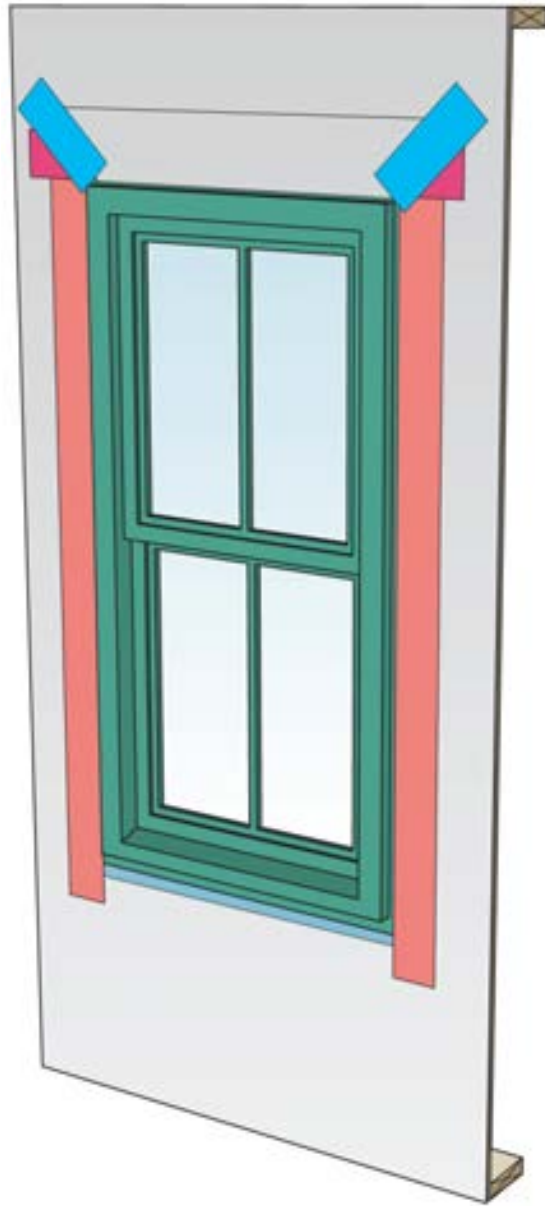


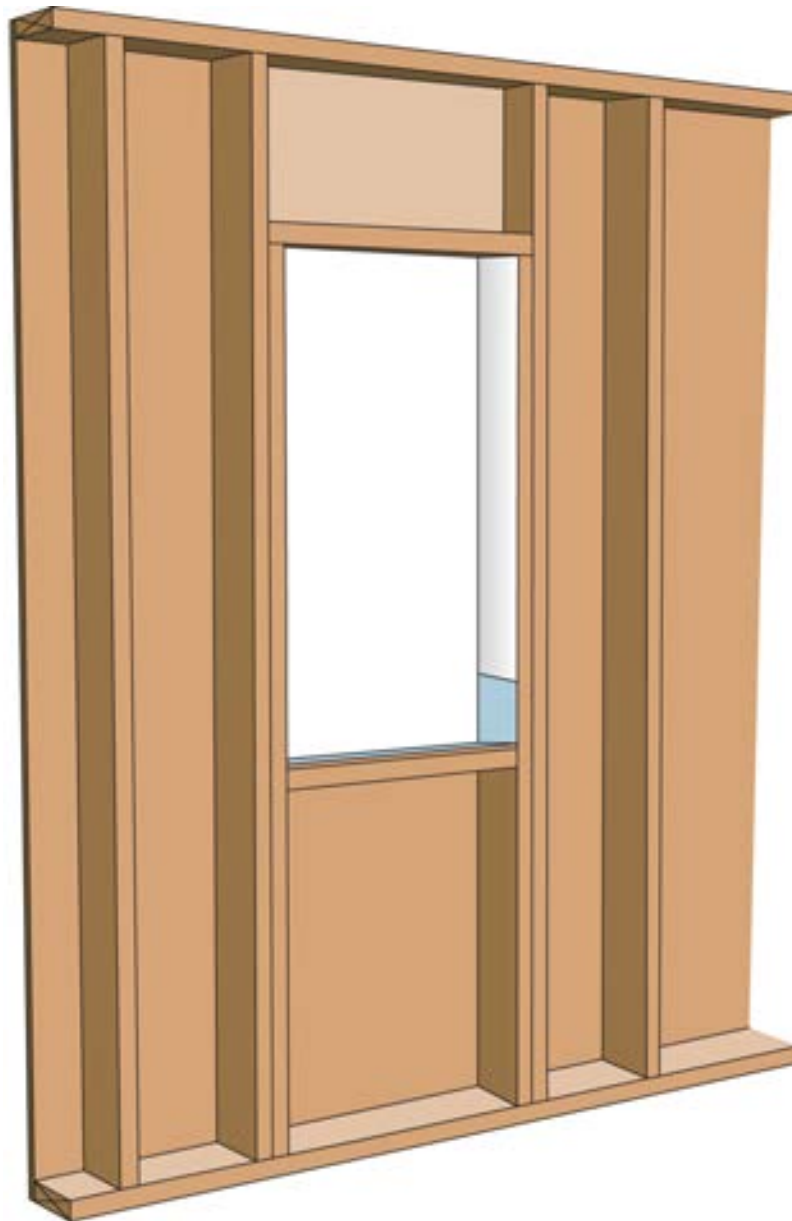








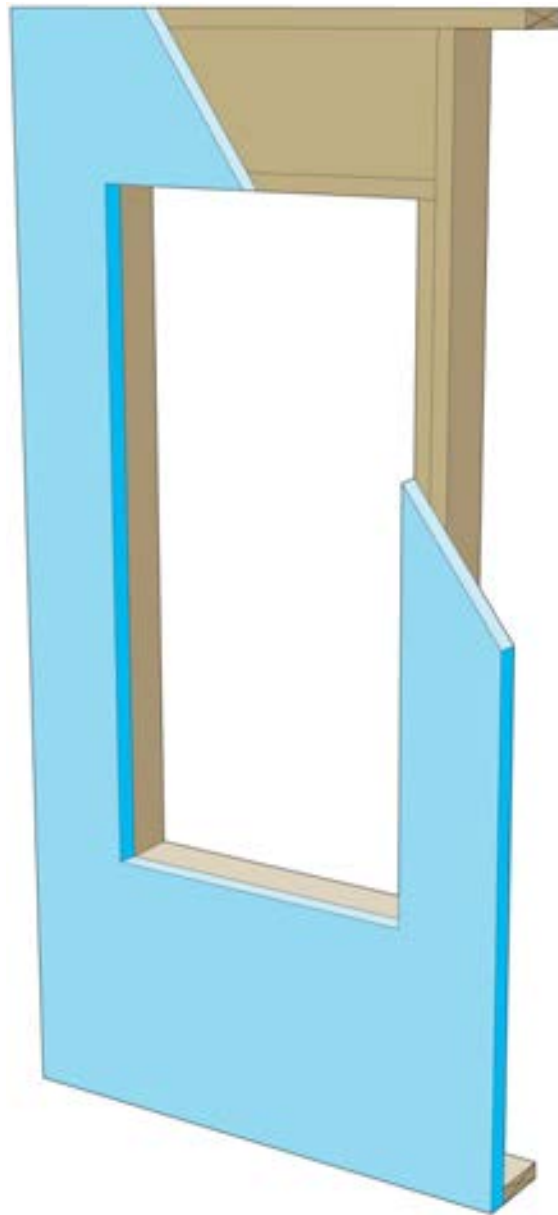


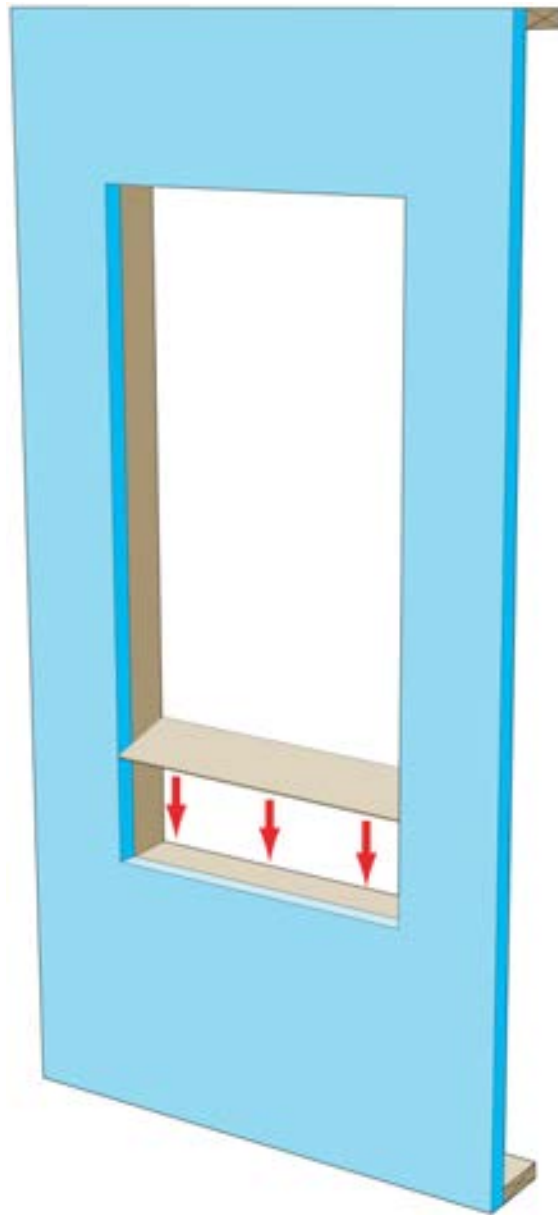


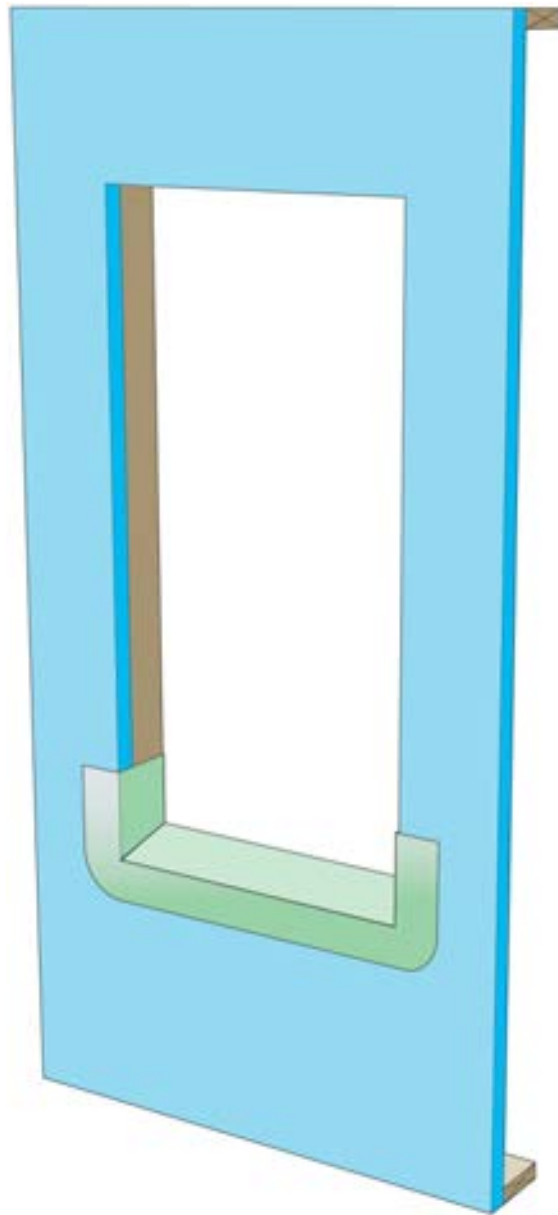


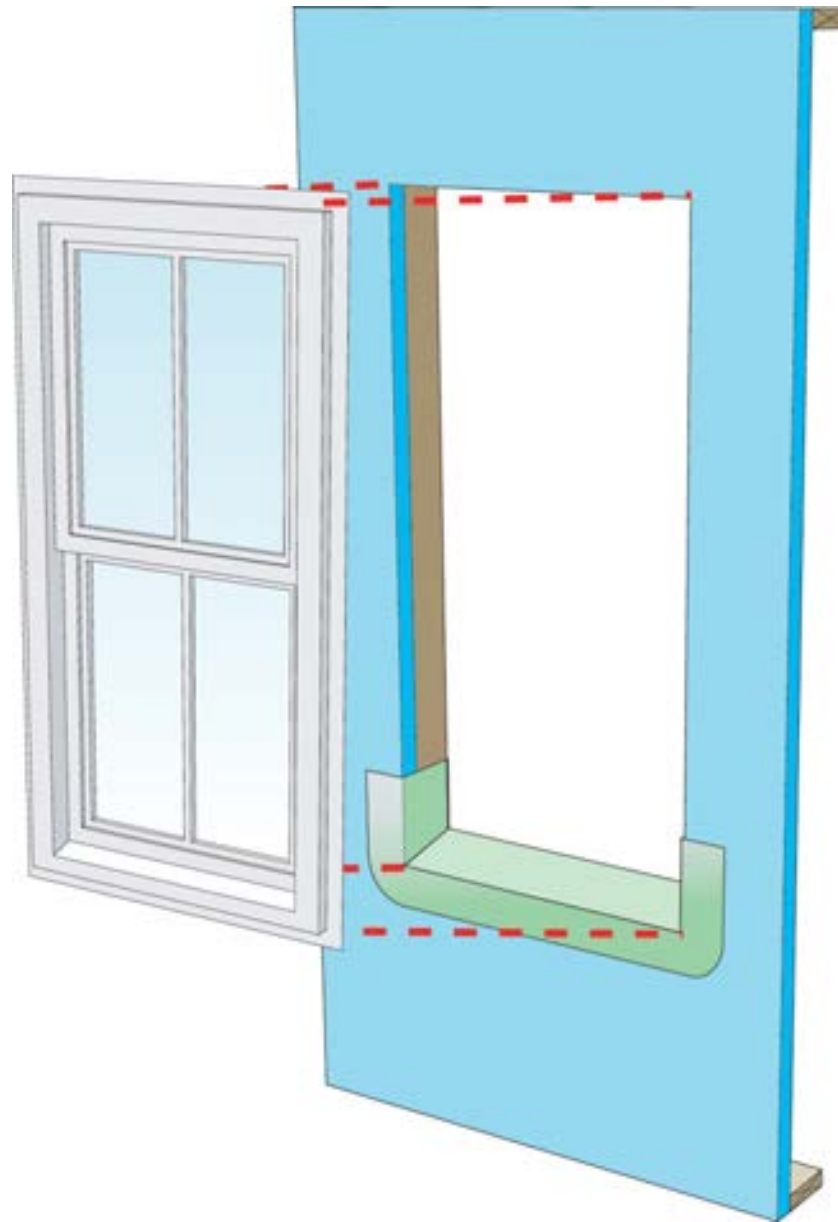








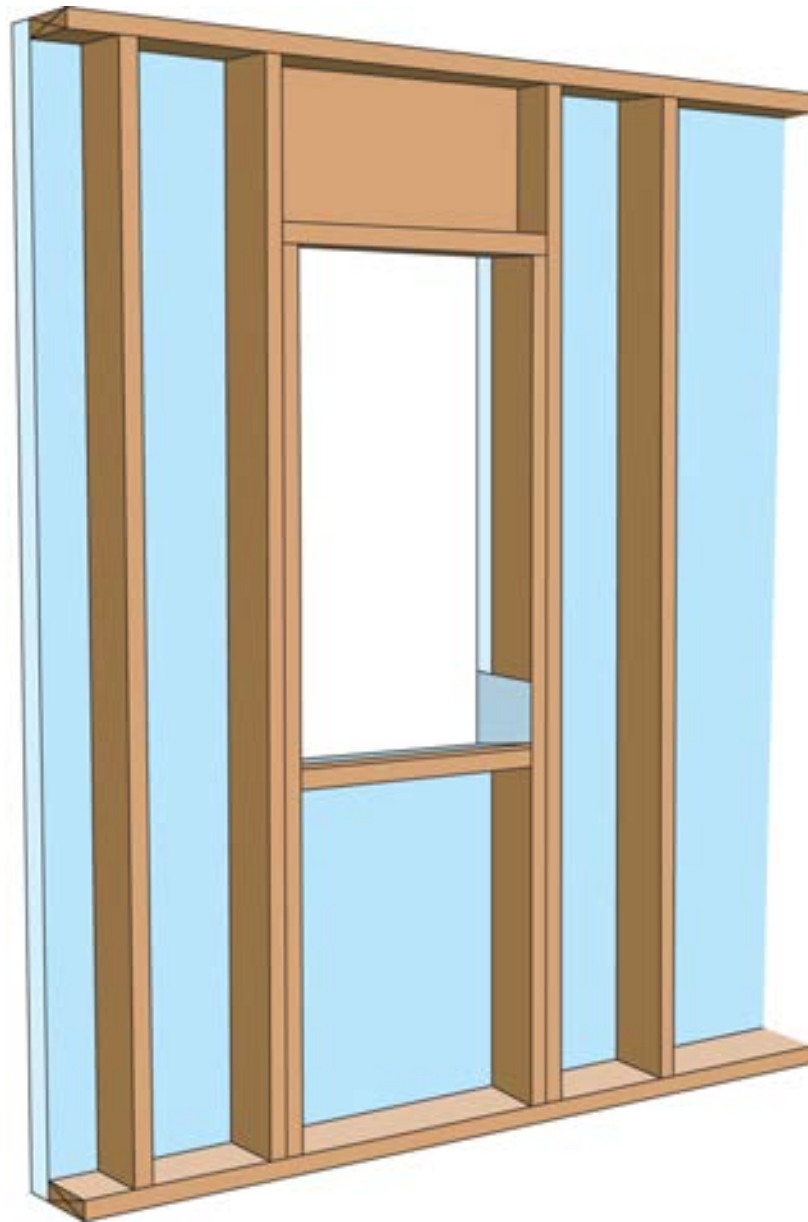


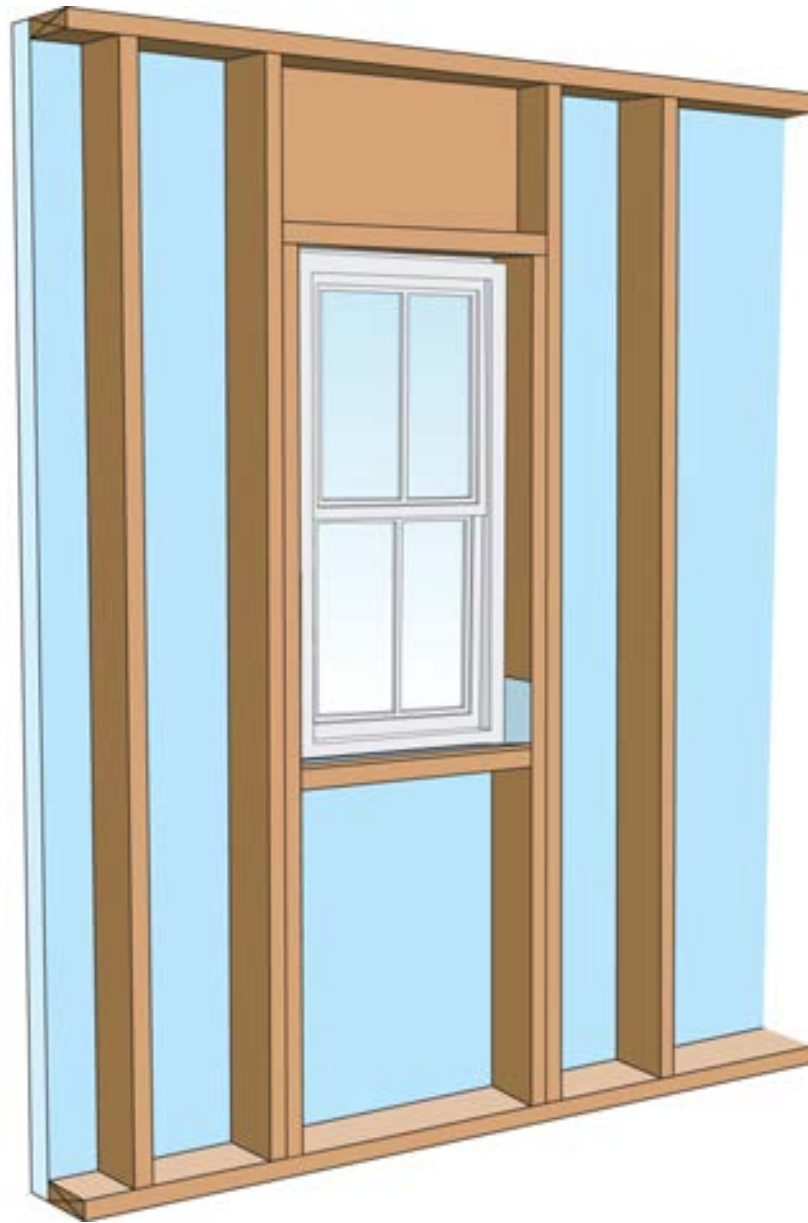


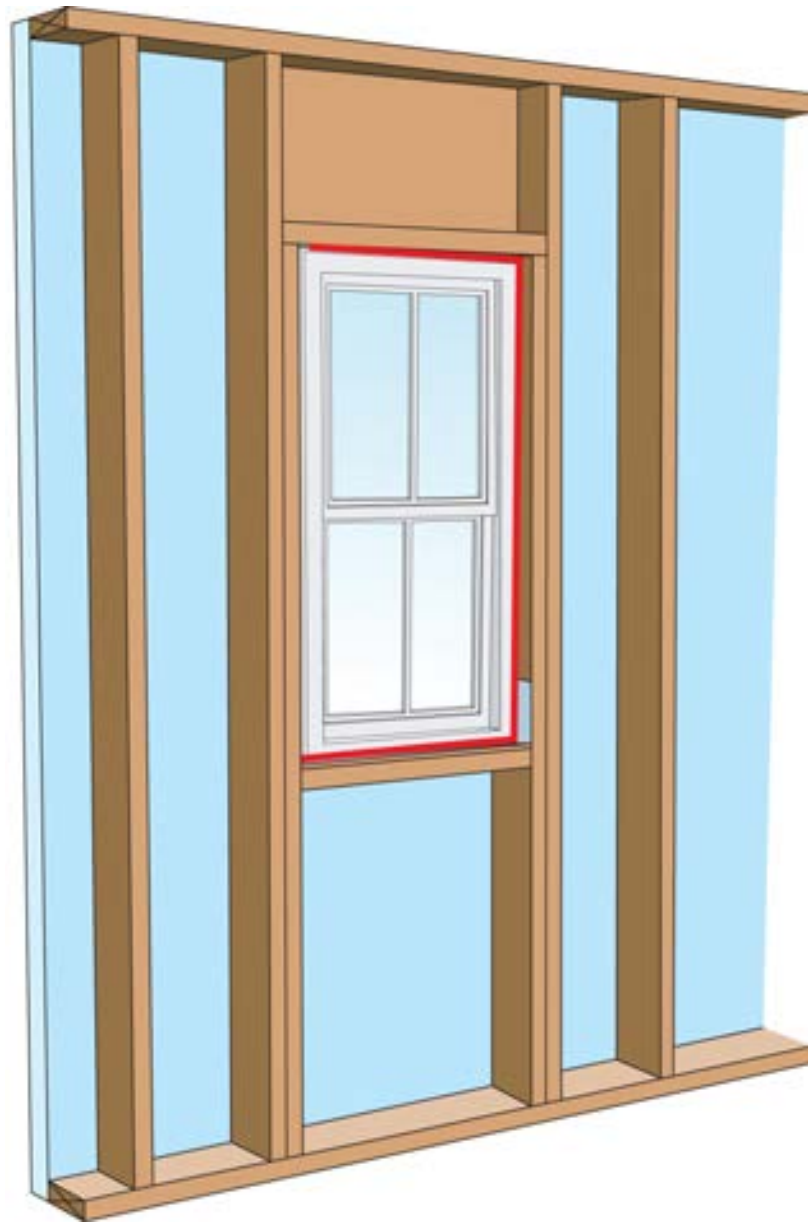






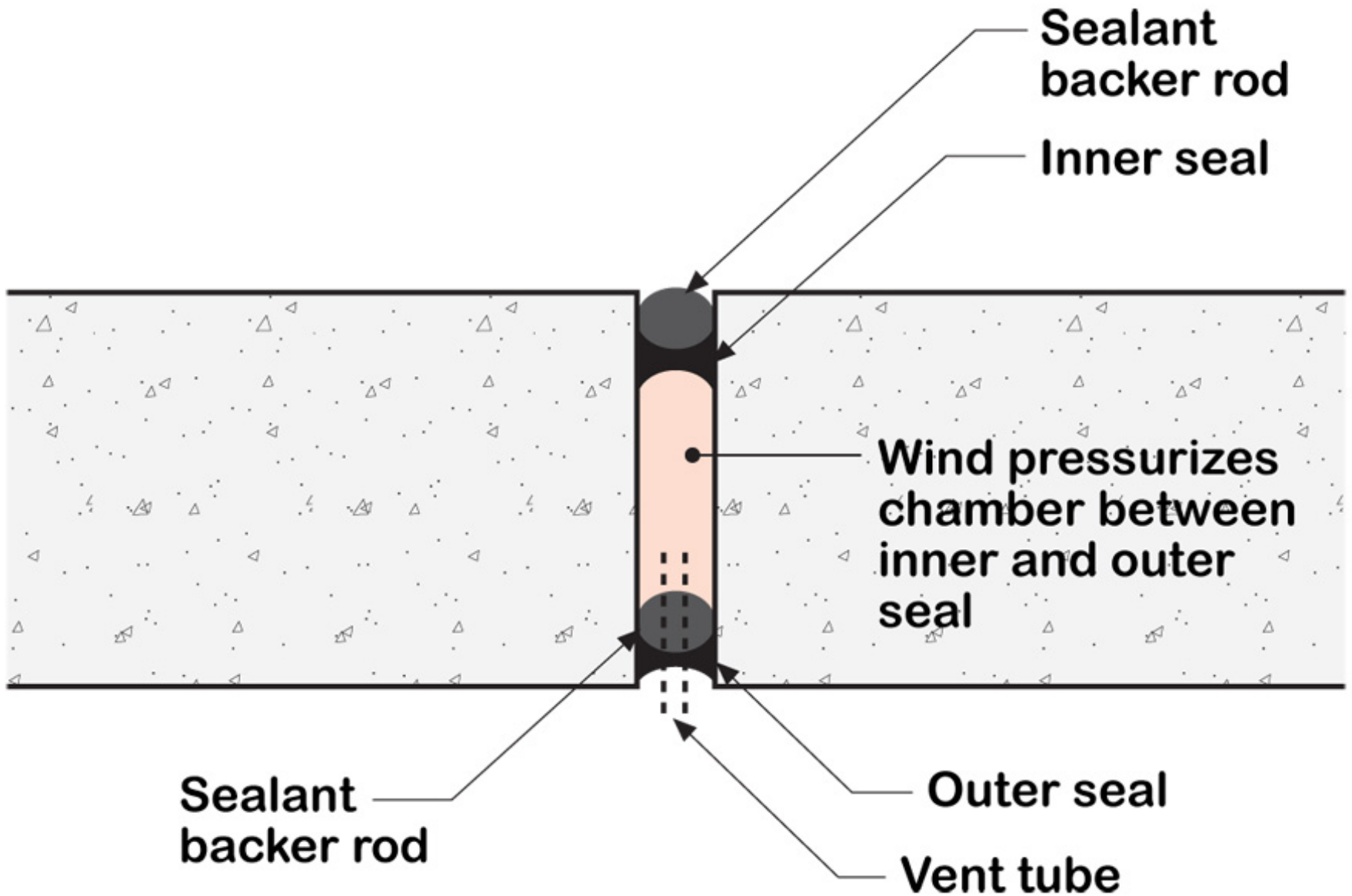


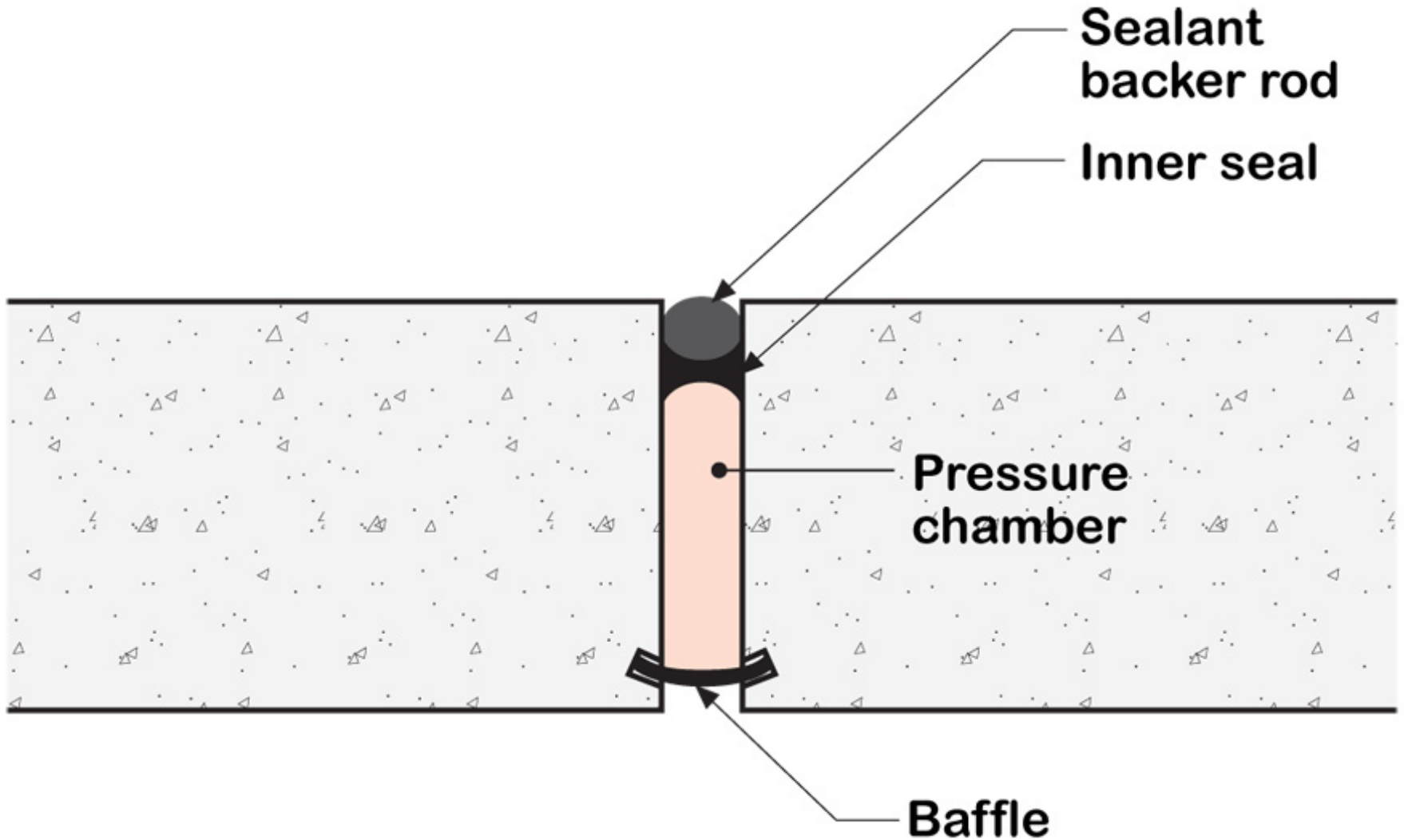


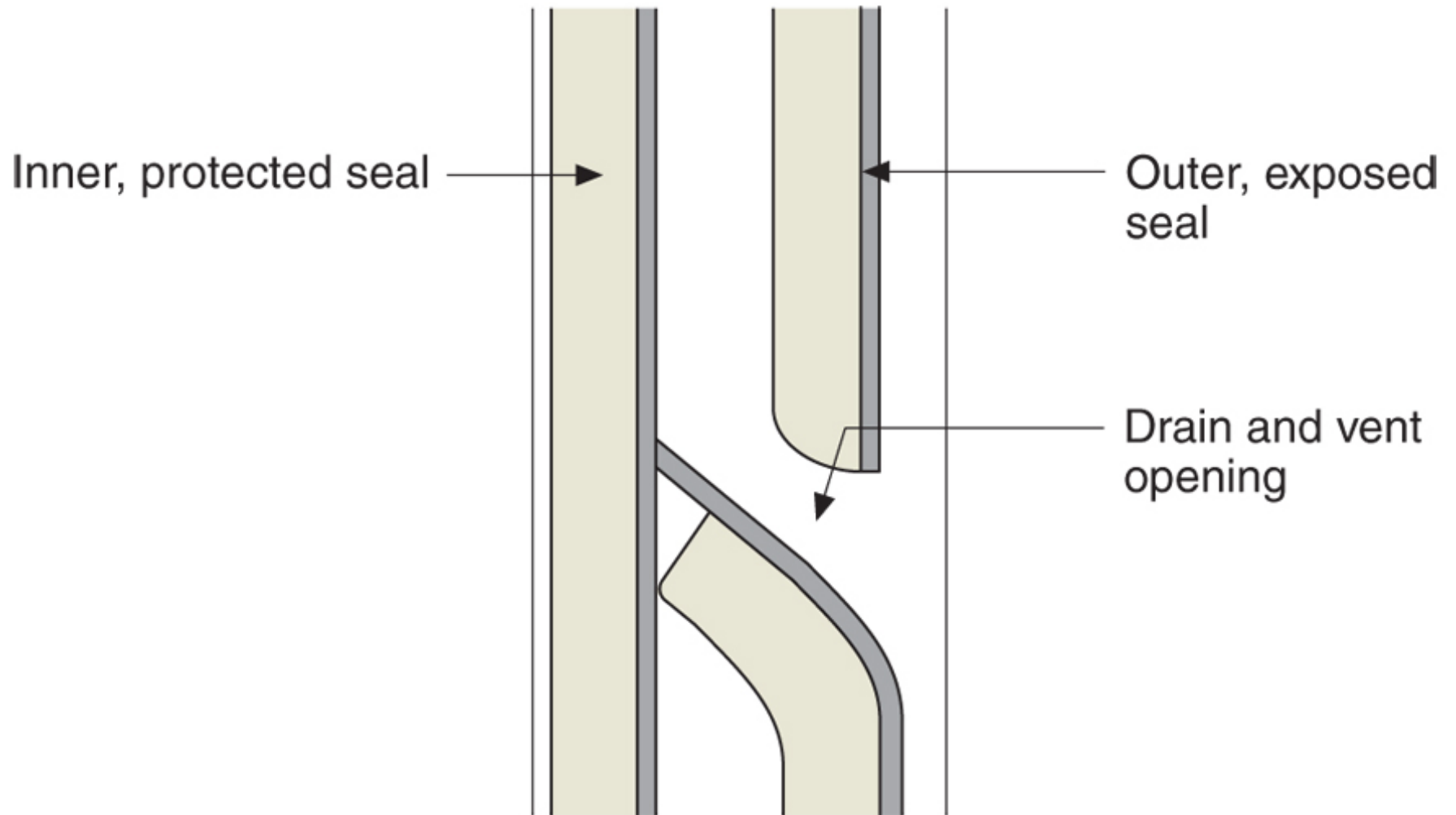


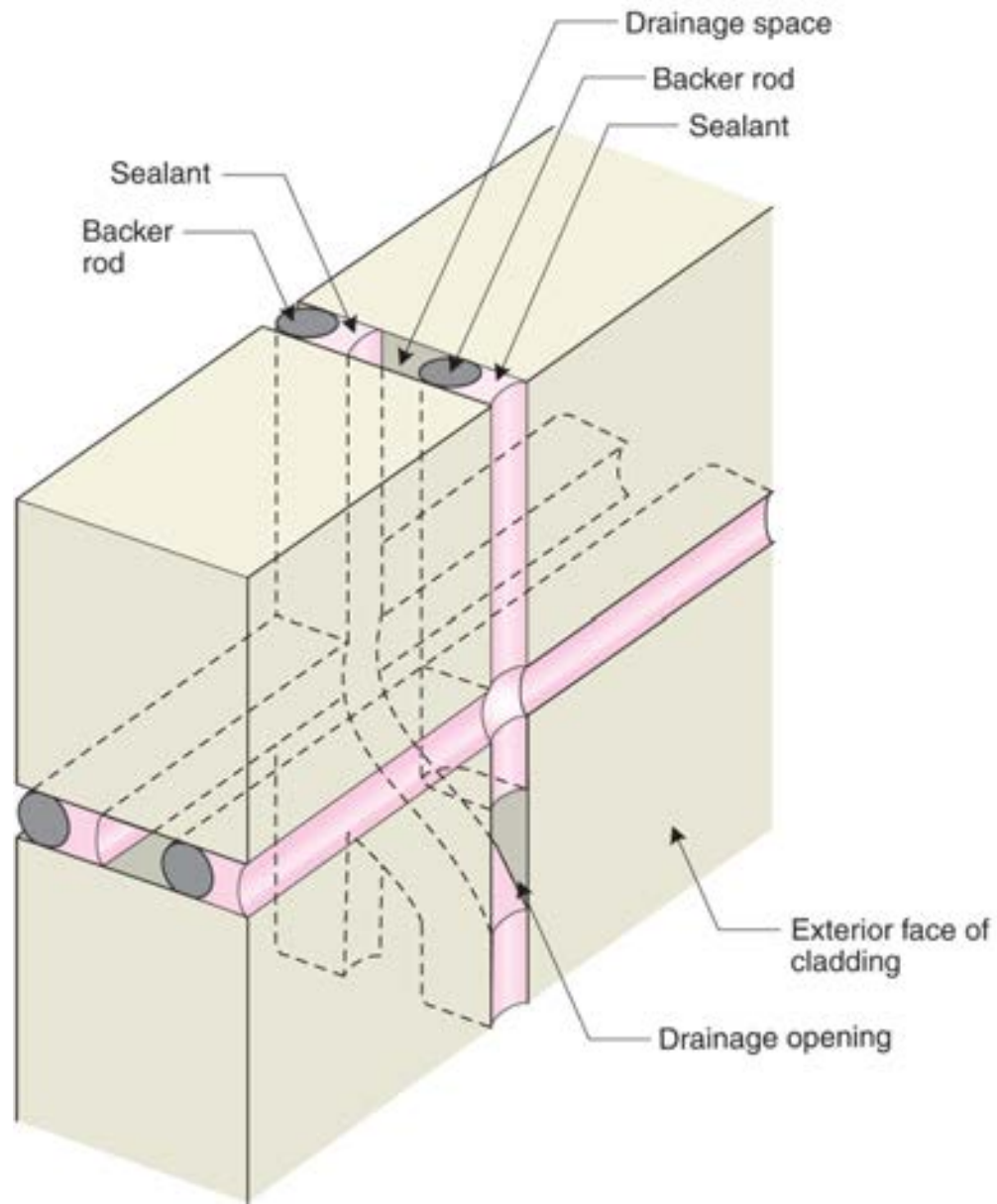
















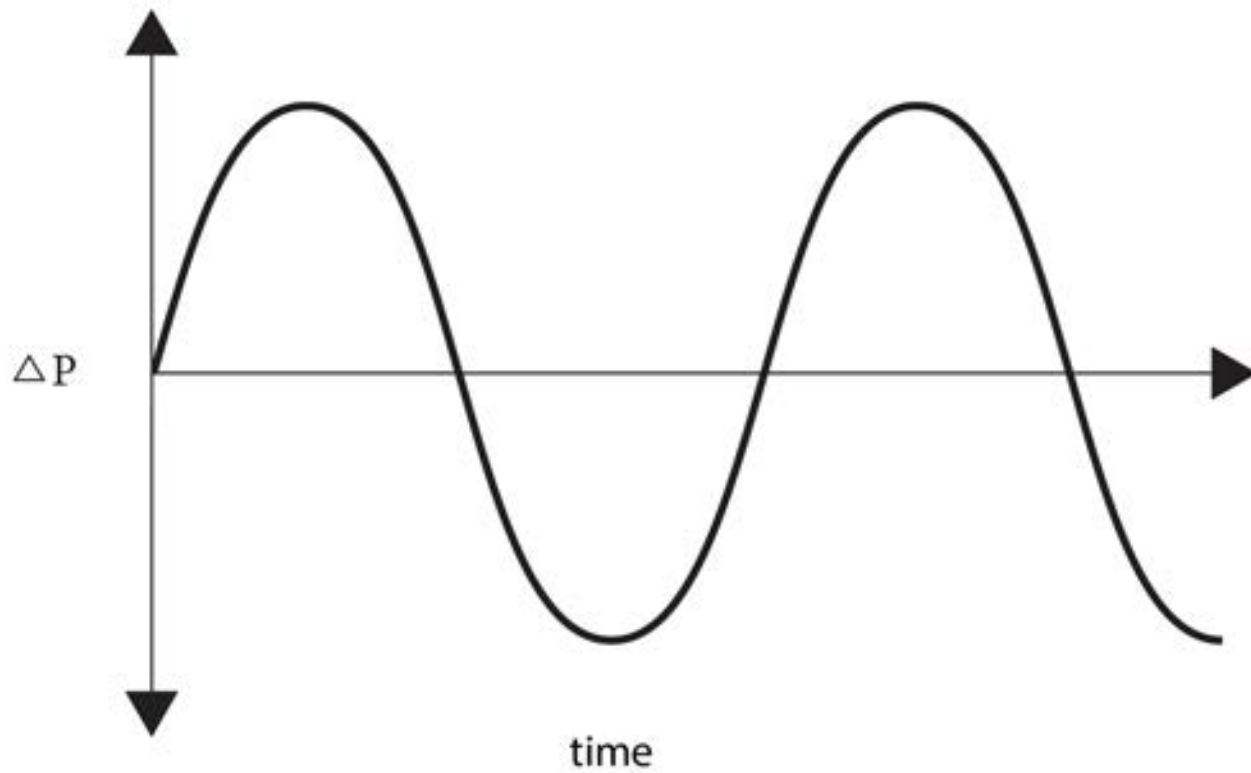


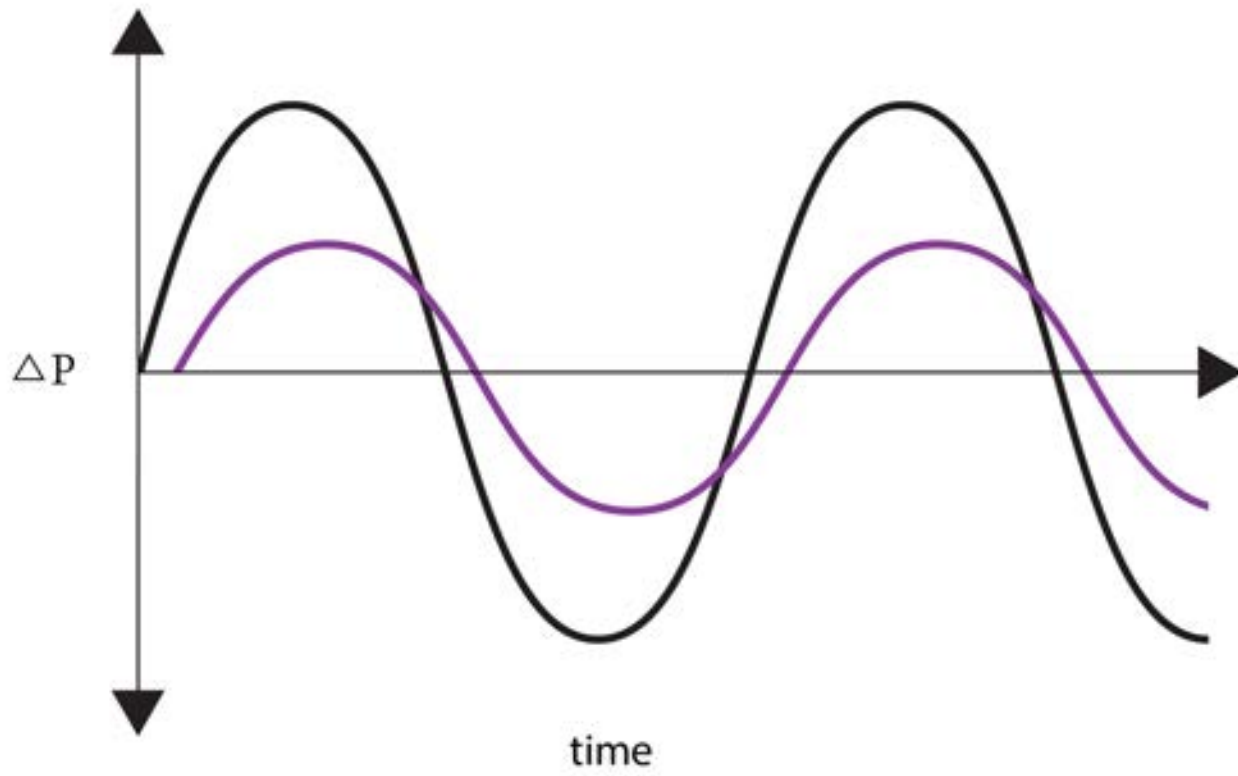


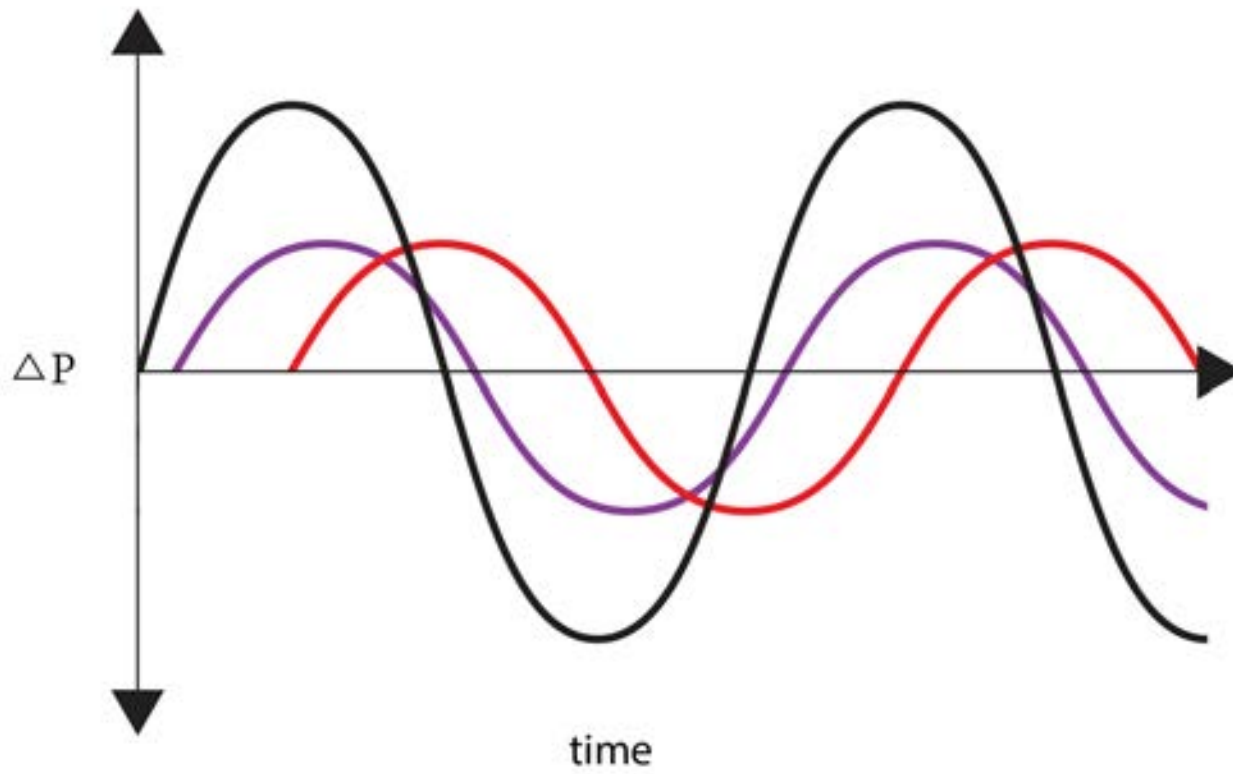
Open Joints vs Closed Joints

Open Joints vs Closed Joints

Limits of Pressure Equalization







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

