

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

Building Science

Roofs

presented by www.buildingscience.com

Arrhenius Equation

For Every 10 Degree K Rise
Activation Energy Doubles

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

Damage Functions

Water

Heat

Ultra-violet Radiation

2nd Law of Thermodynamics

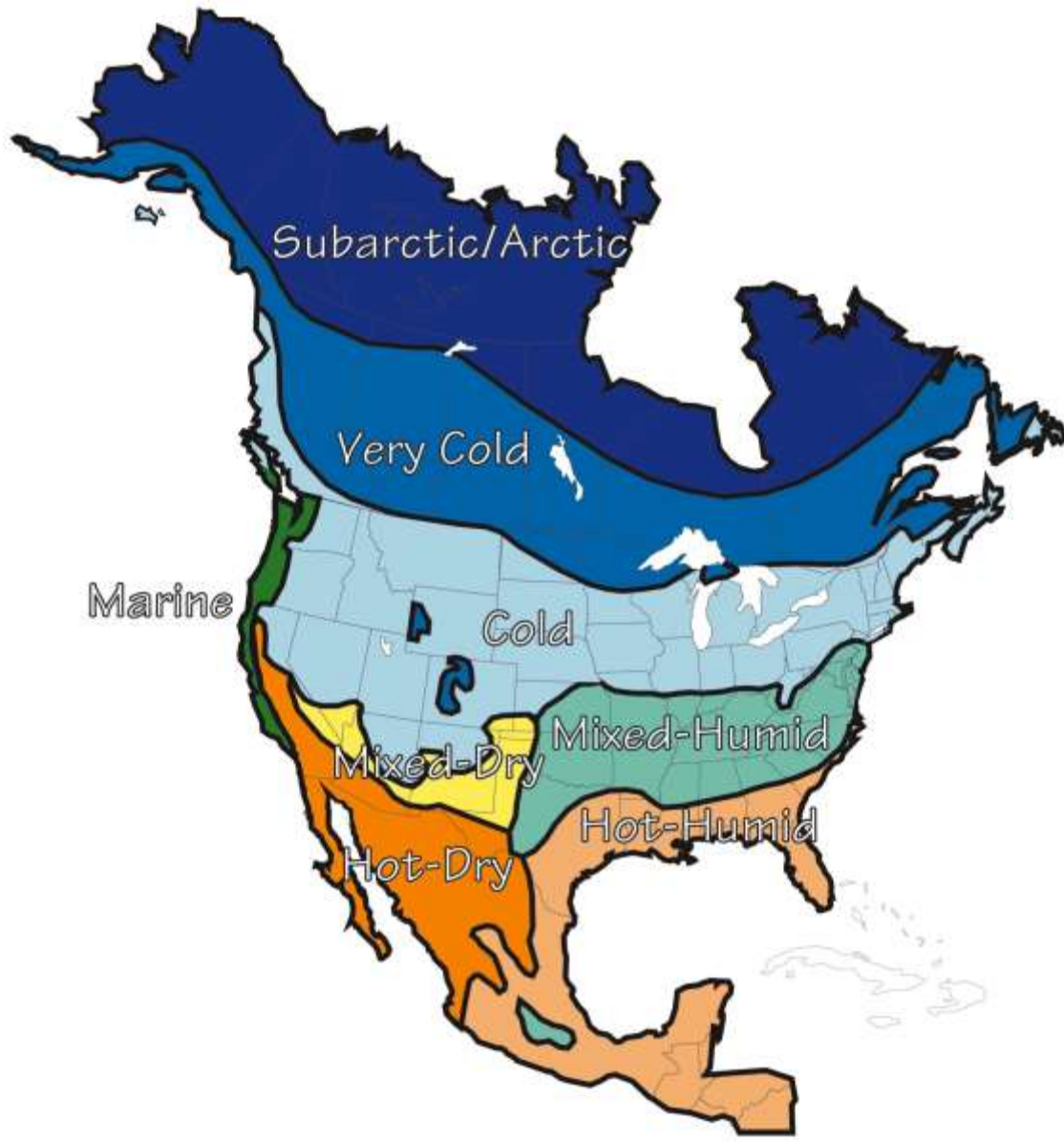
Heat Flow Is From Warm To Cold

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





Exposure

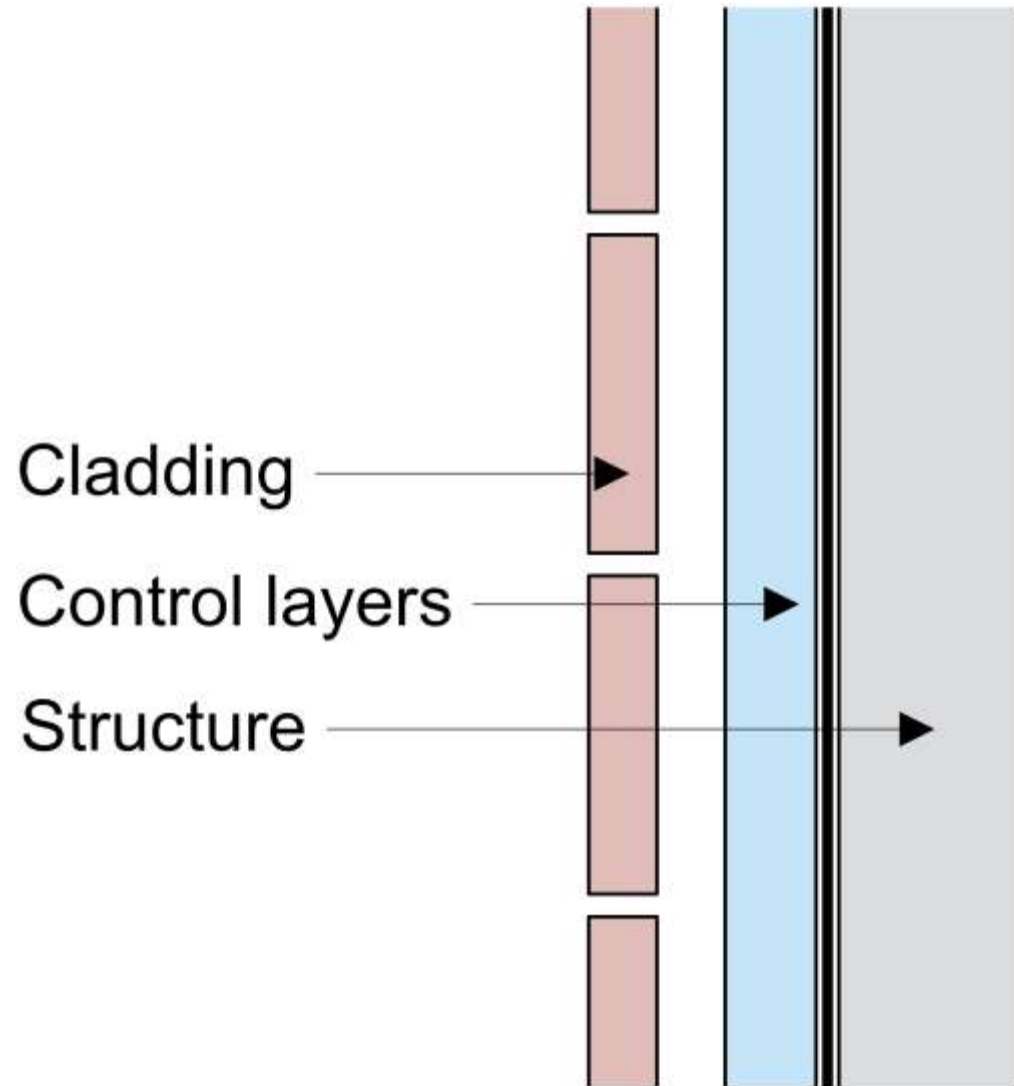
Extreme		Over 60"
High		40" - 60"
Moderate		20" - 40"
Low		Under 20"

Water Control Layer

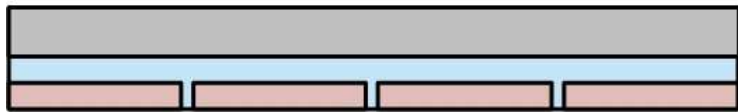
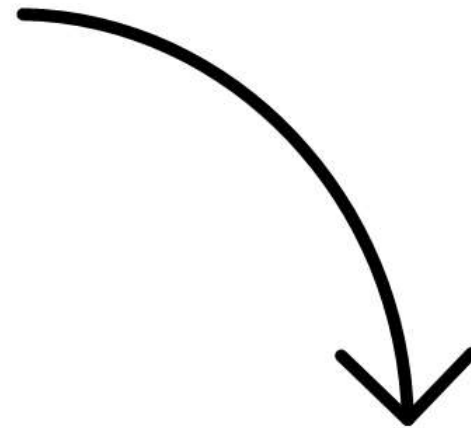
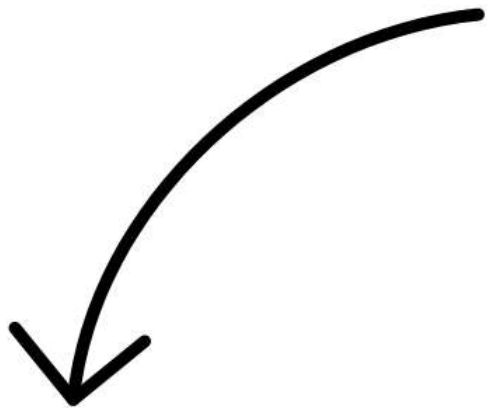
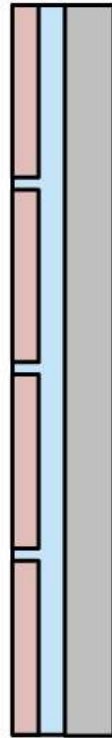
Air Control Layer

Vapor Control Layer

Thermal Control Layer



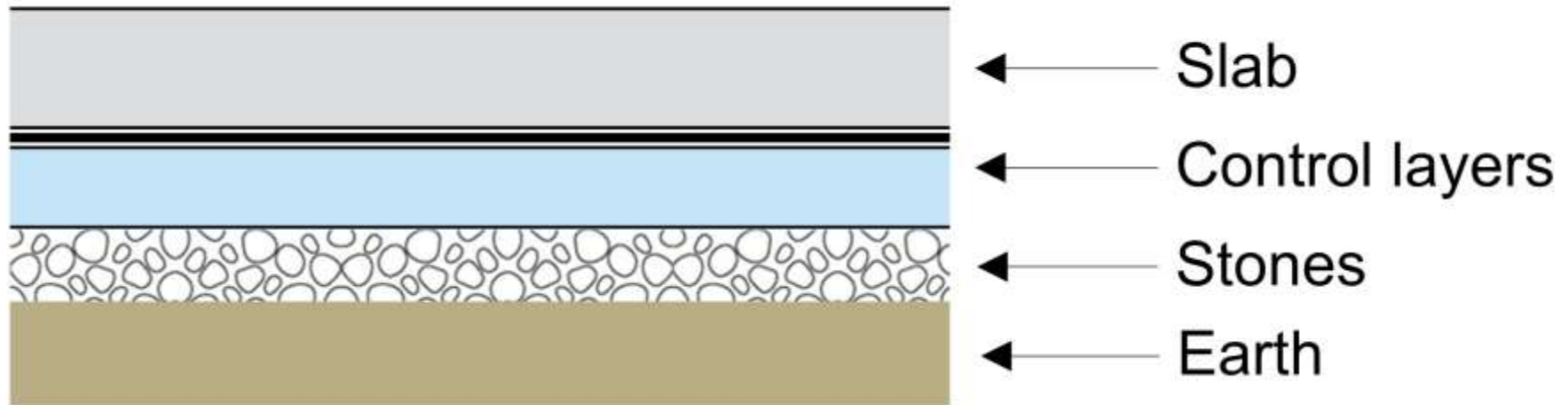
Wall

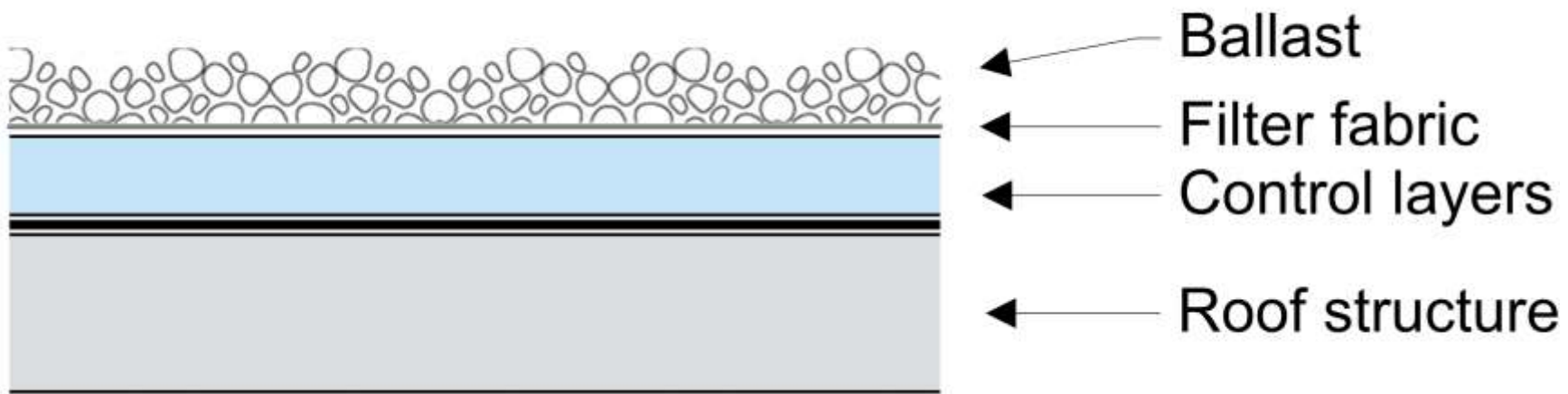


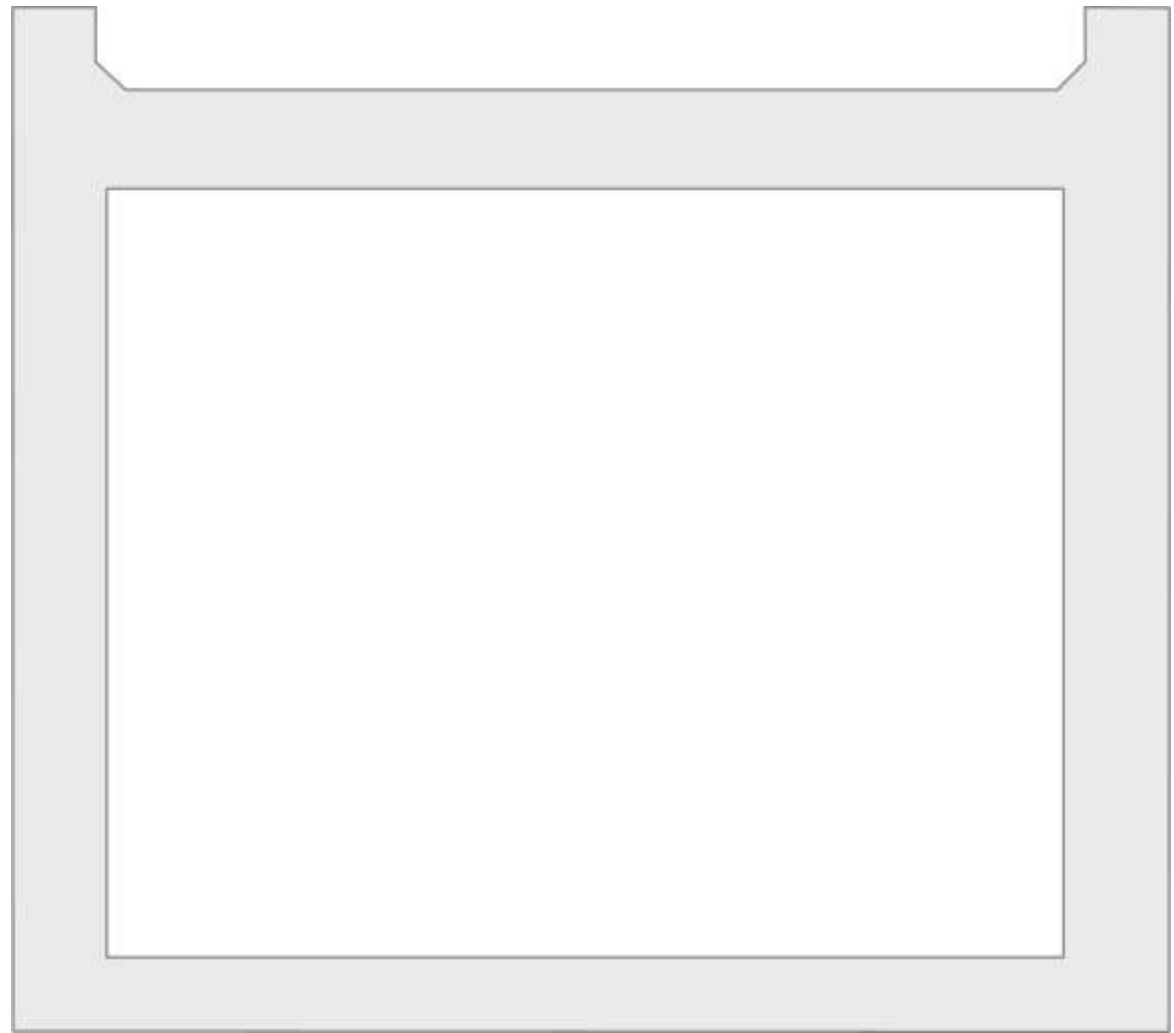
Slab



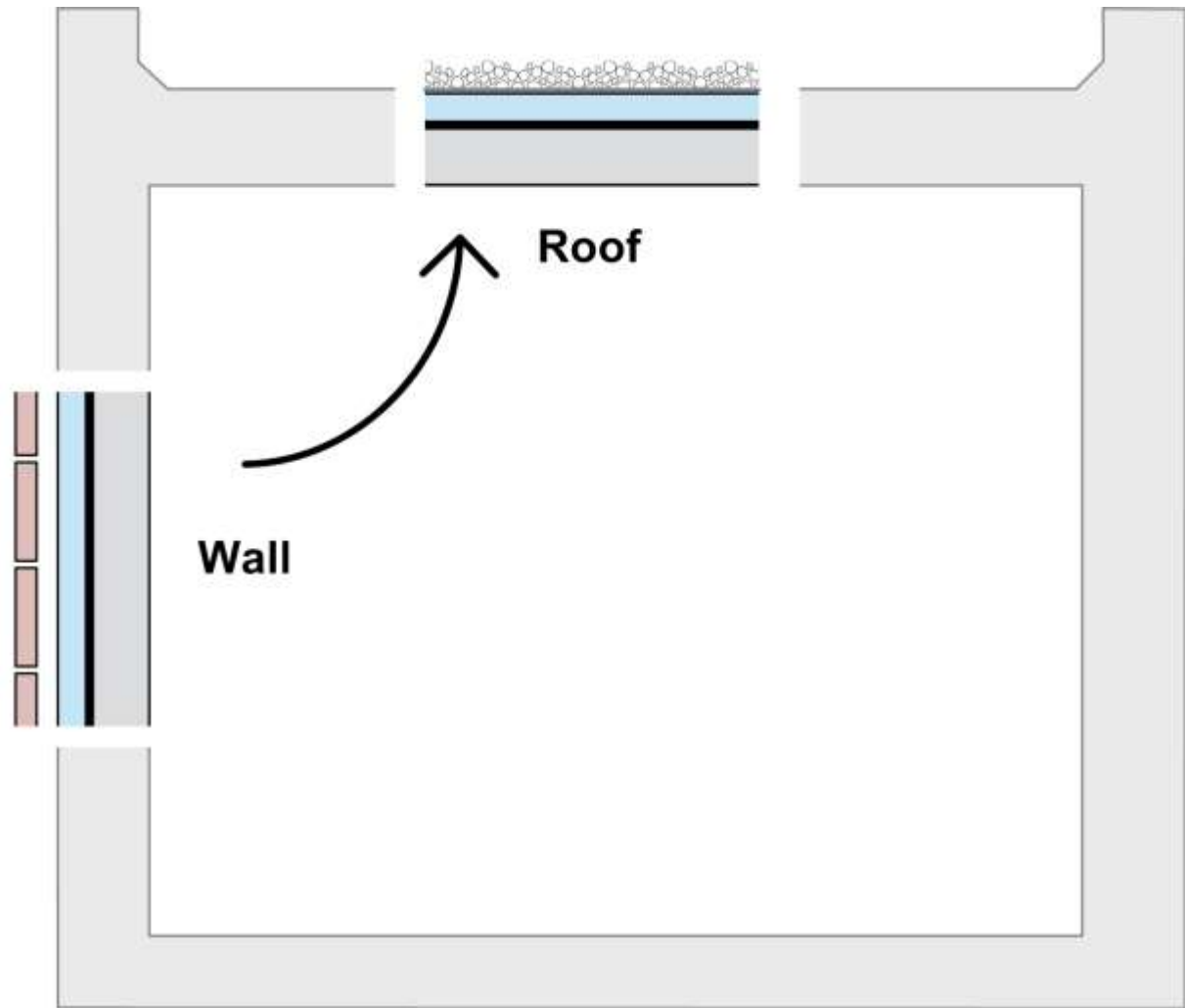
Roof

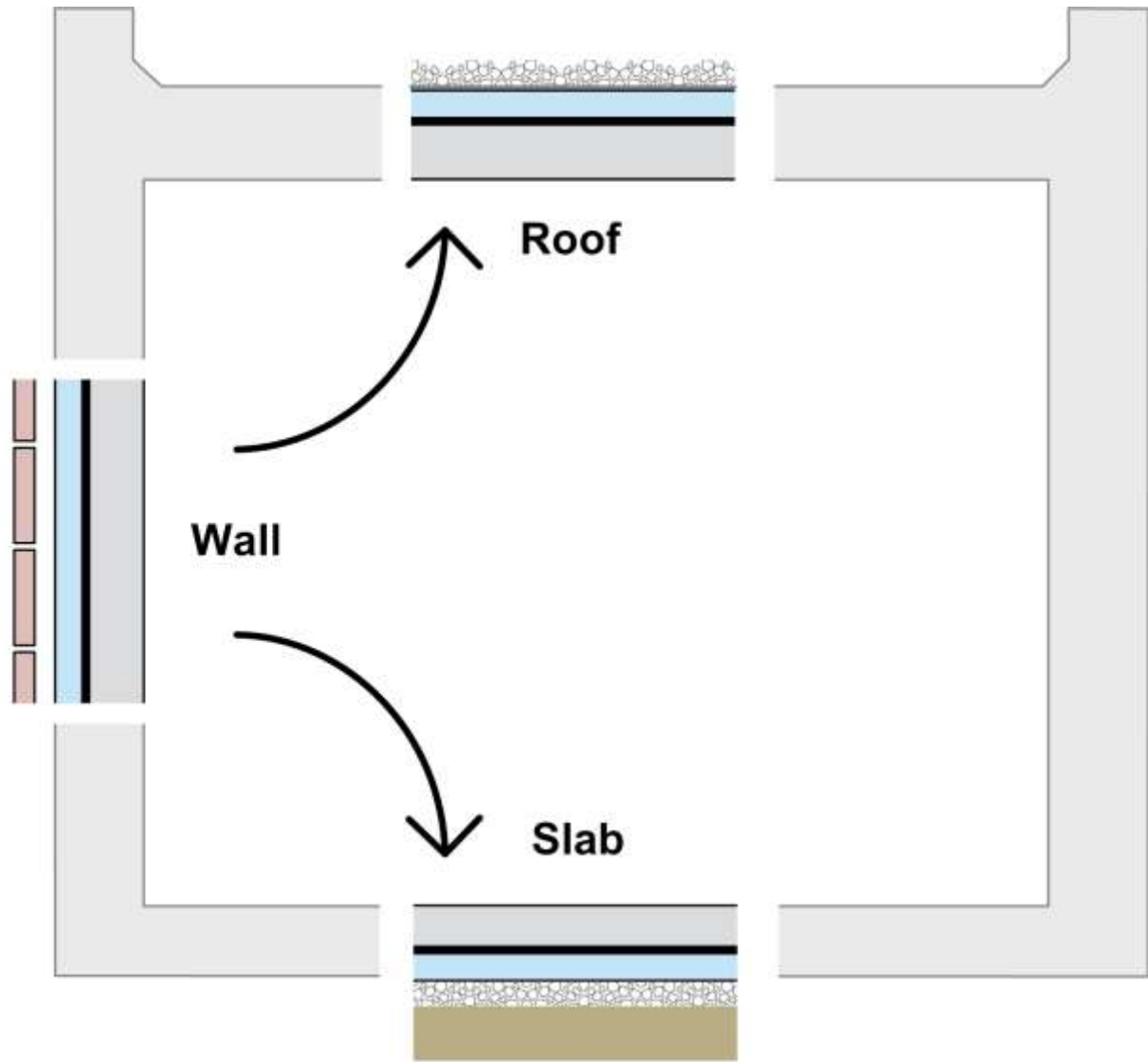


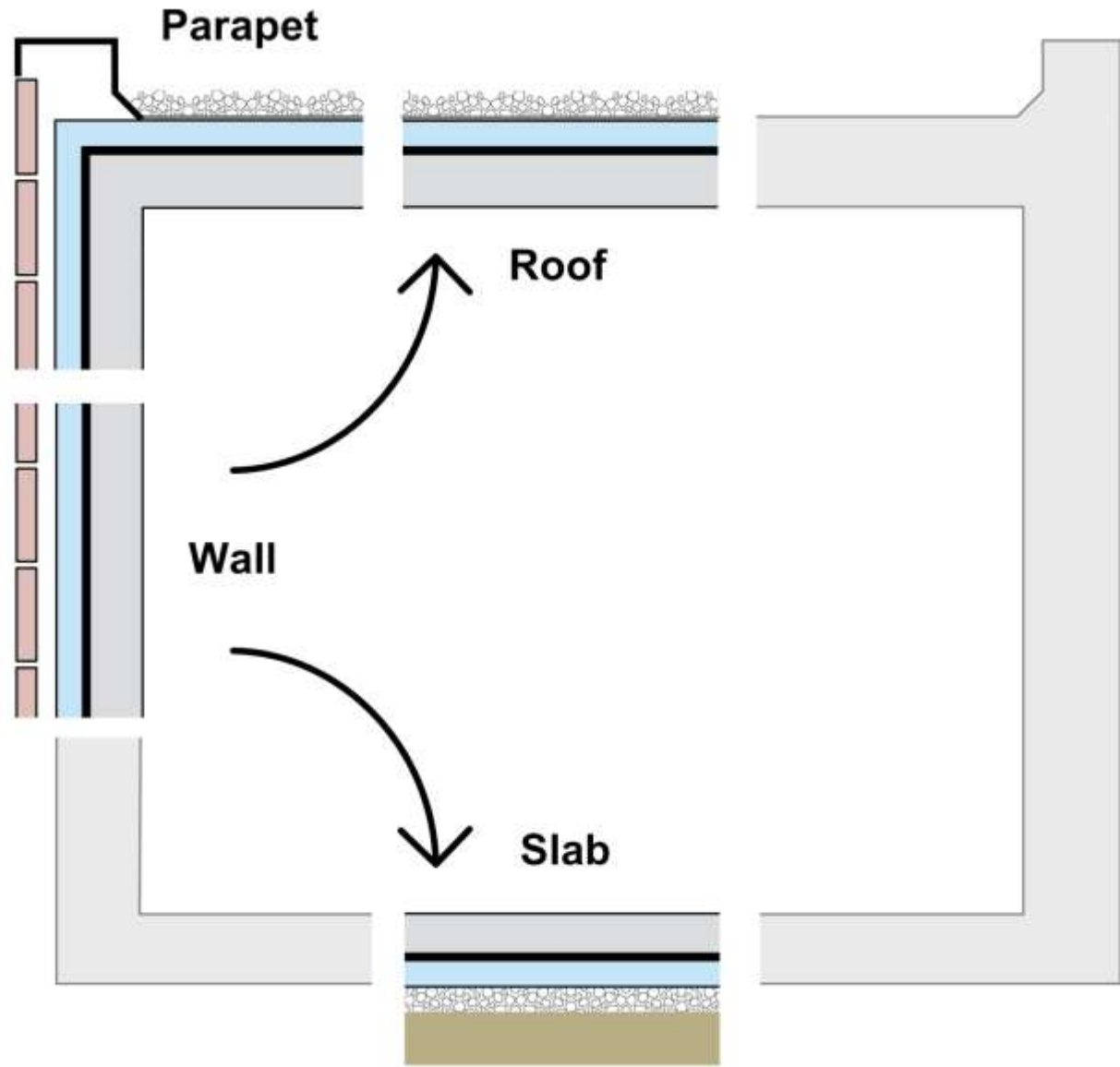


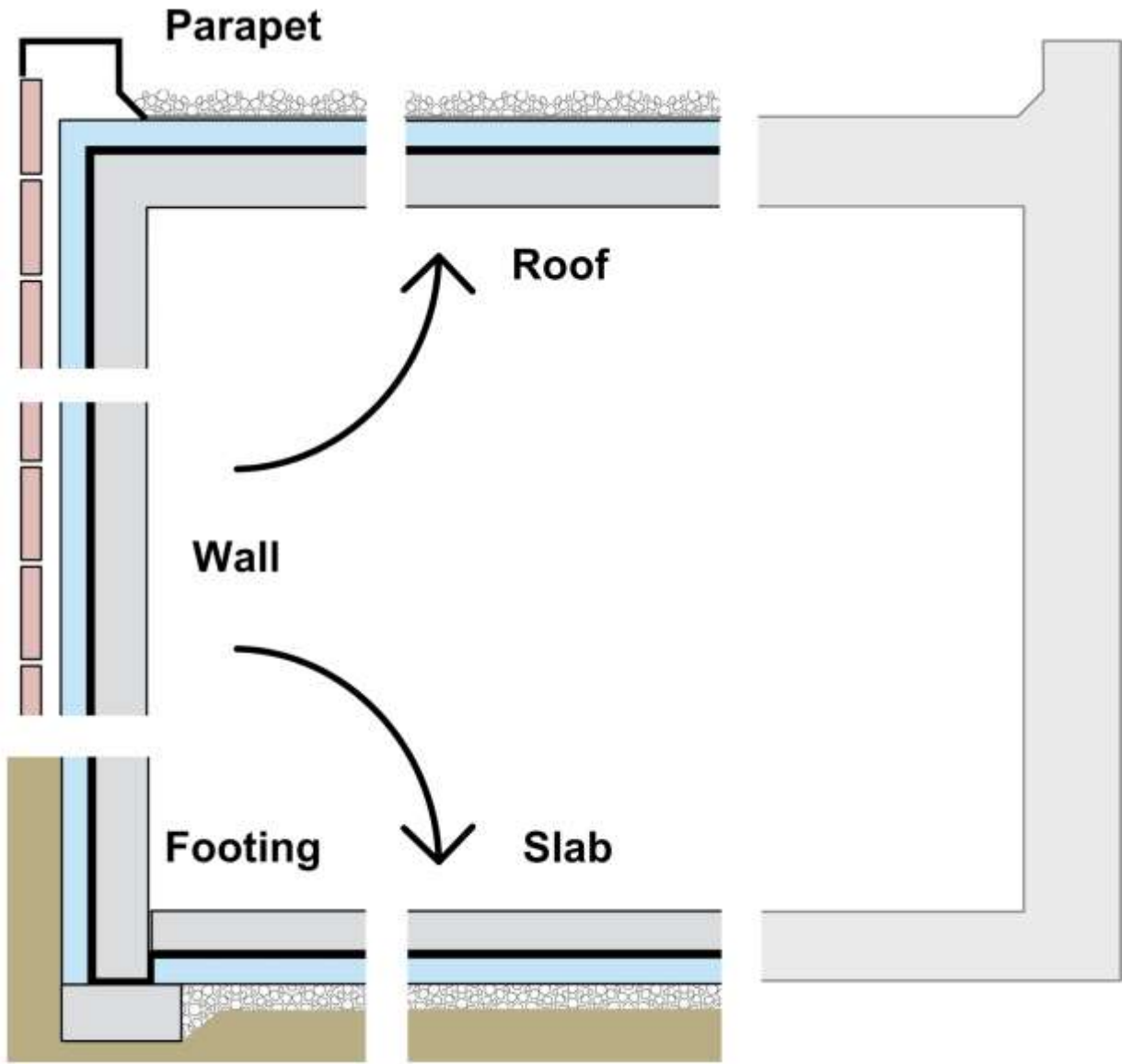




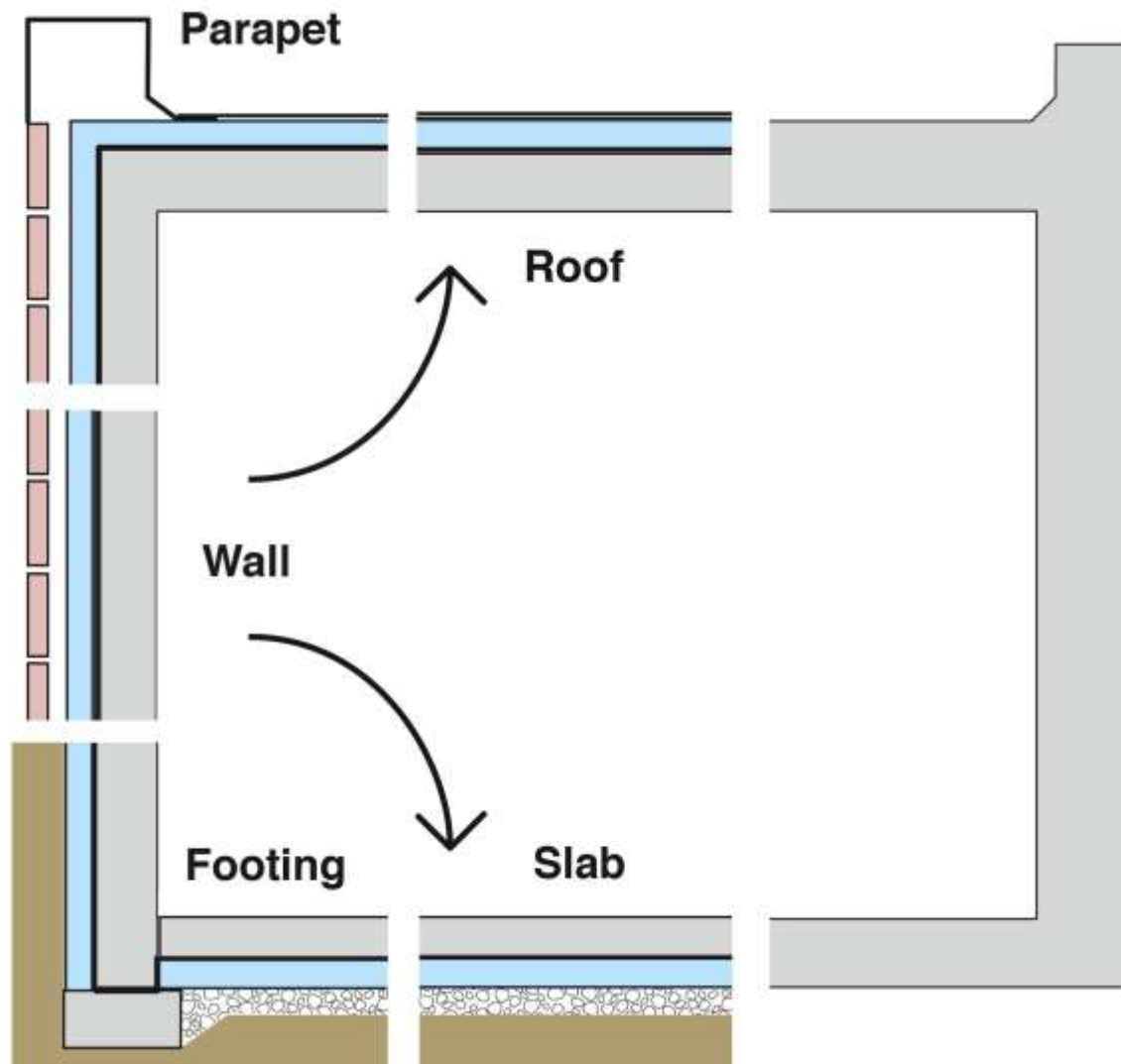


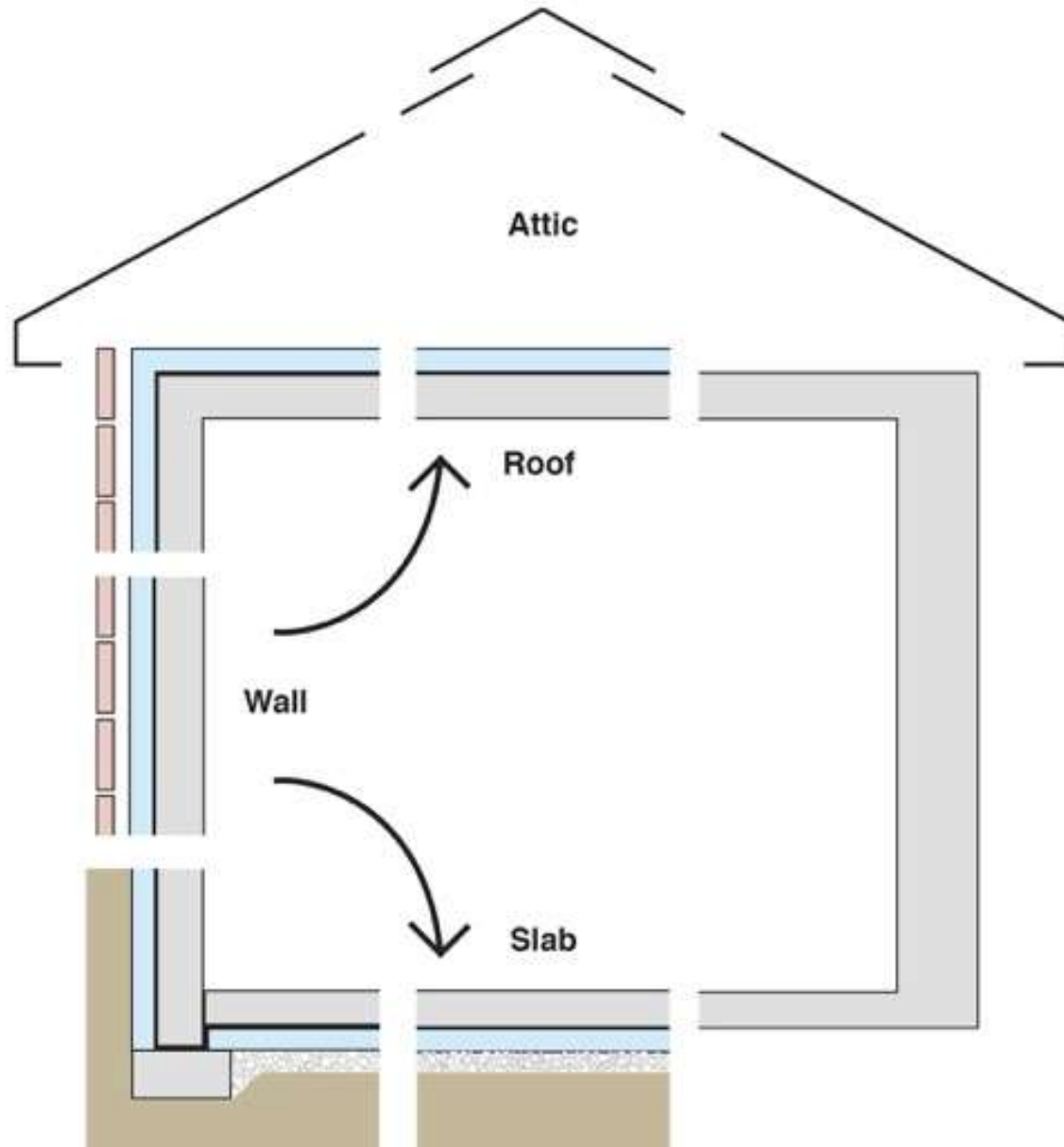


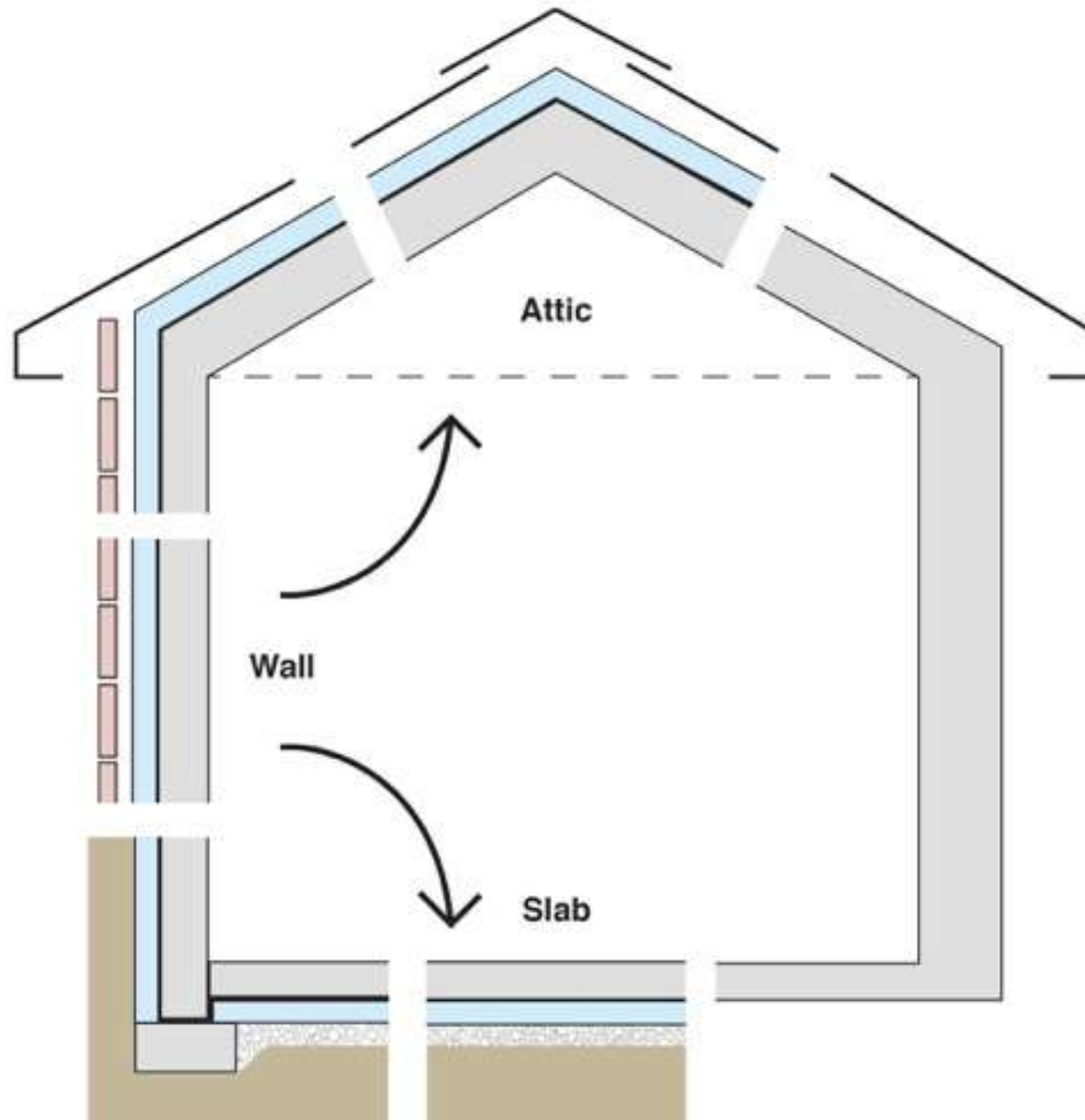


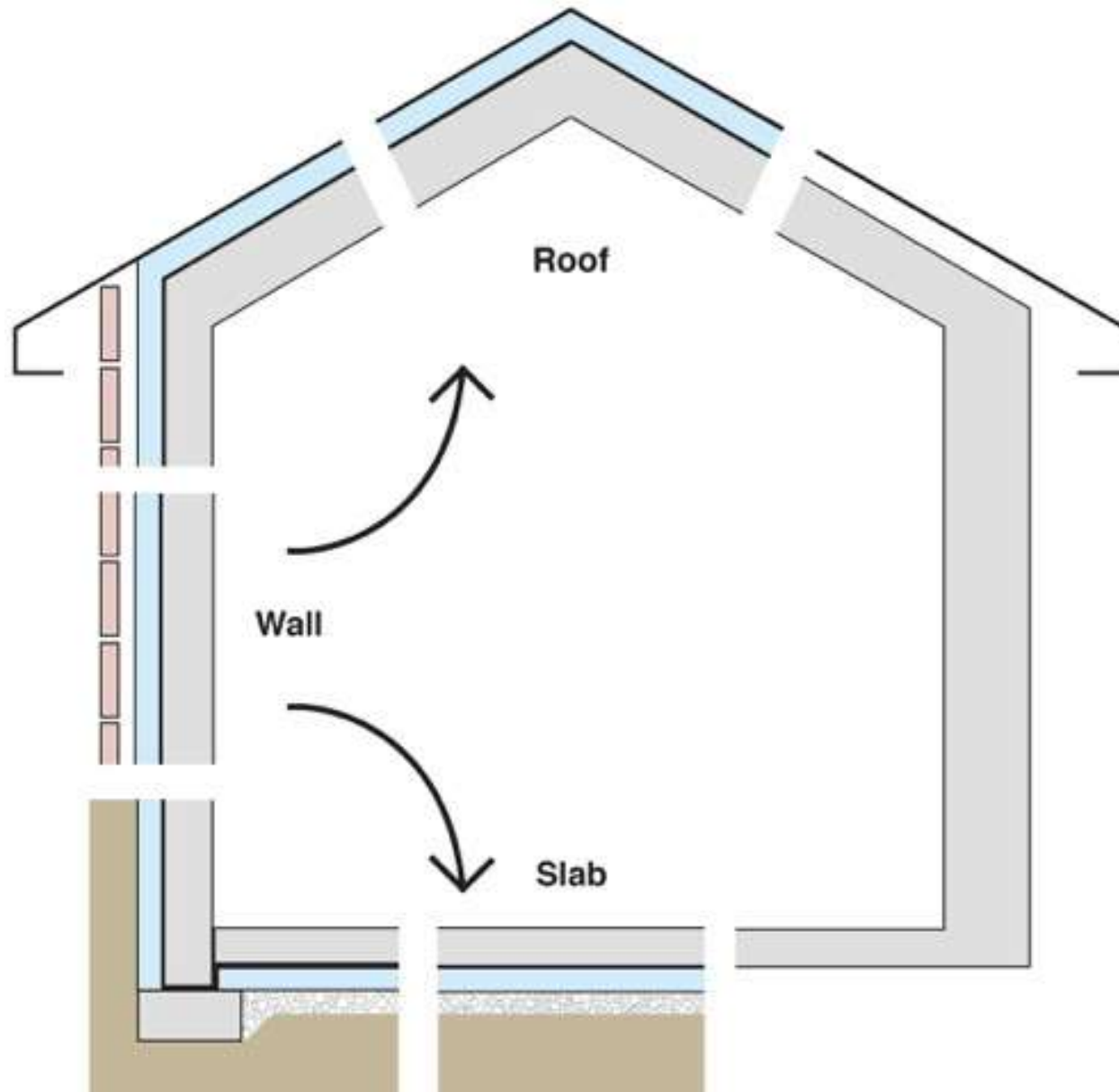


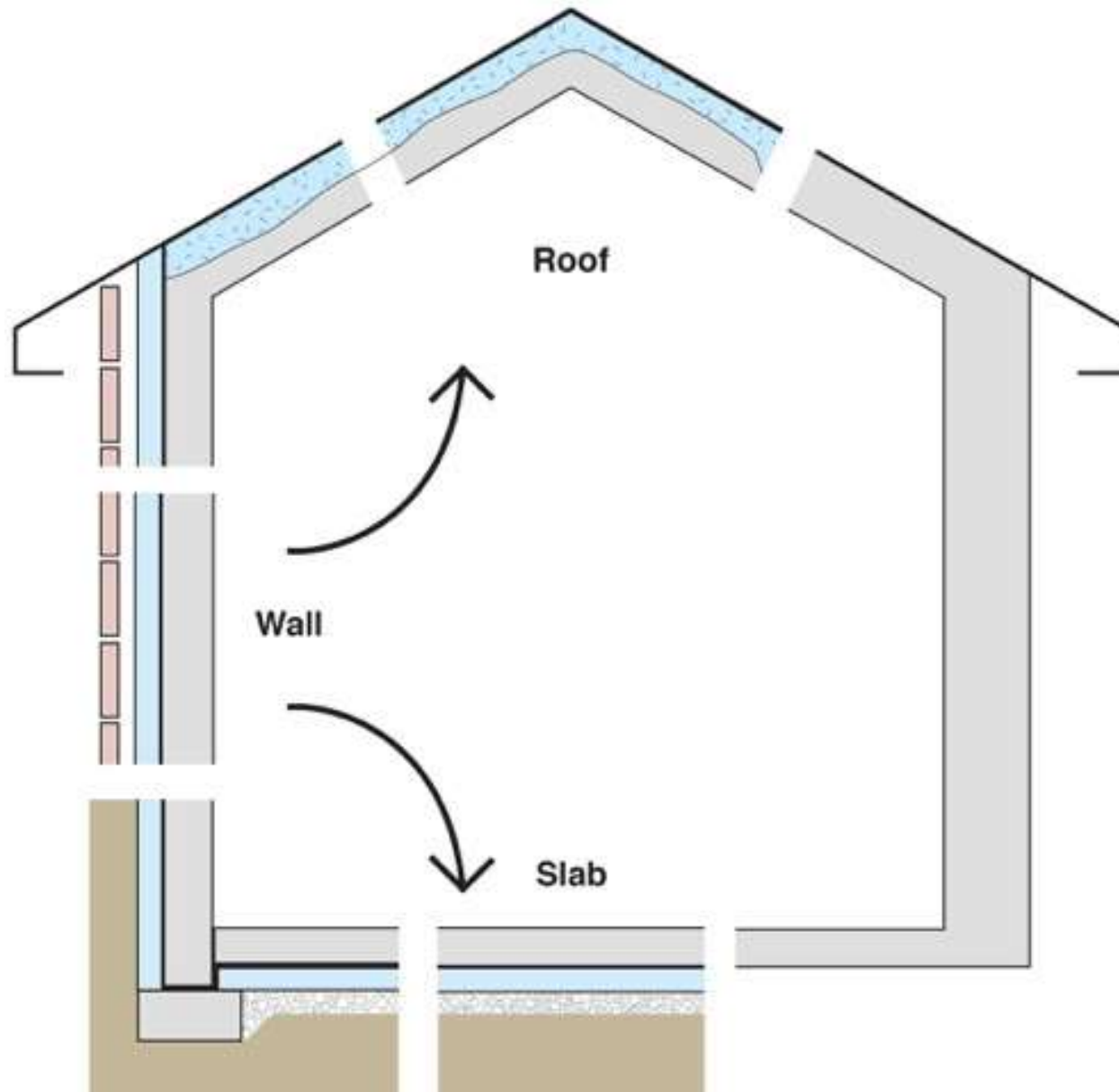


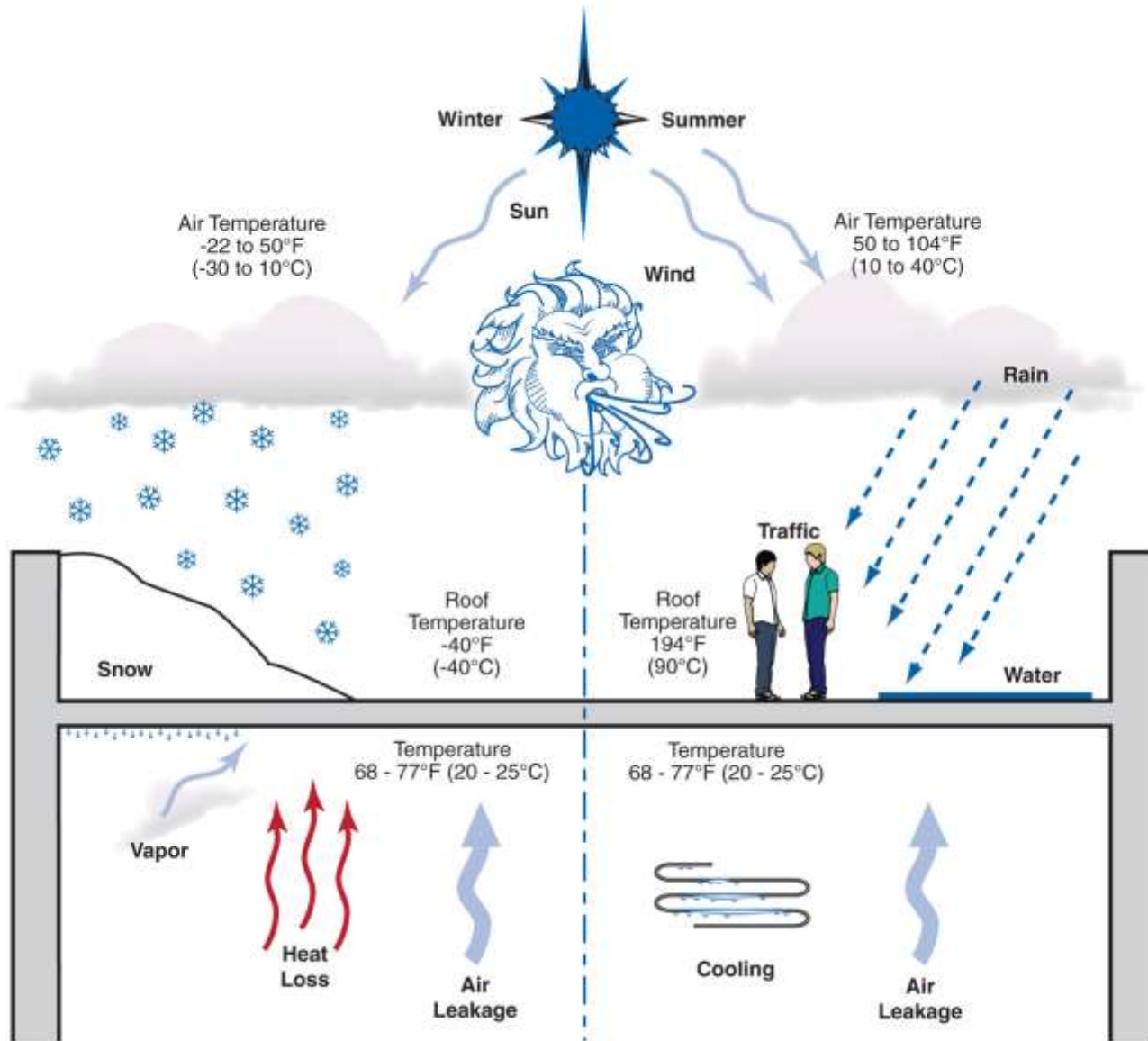




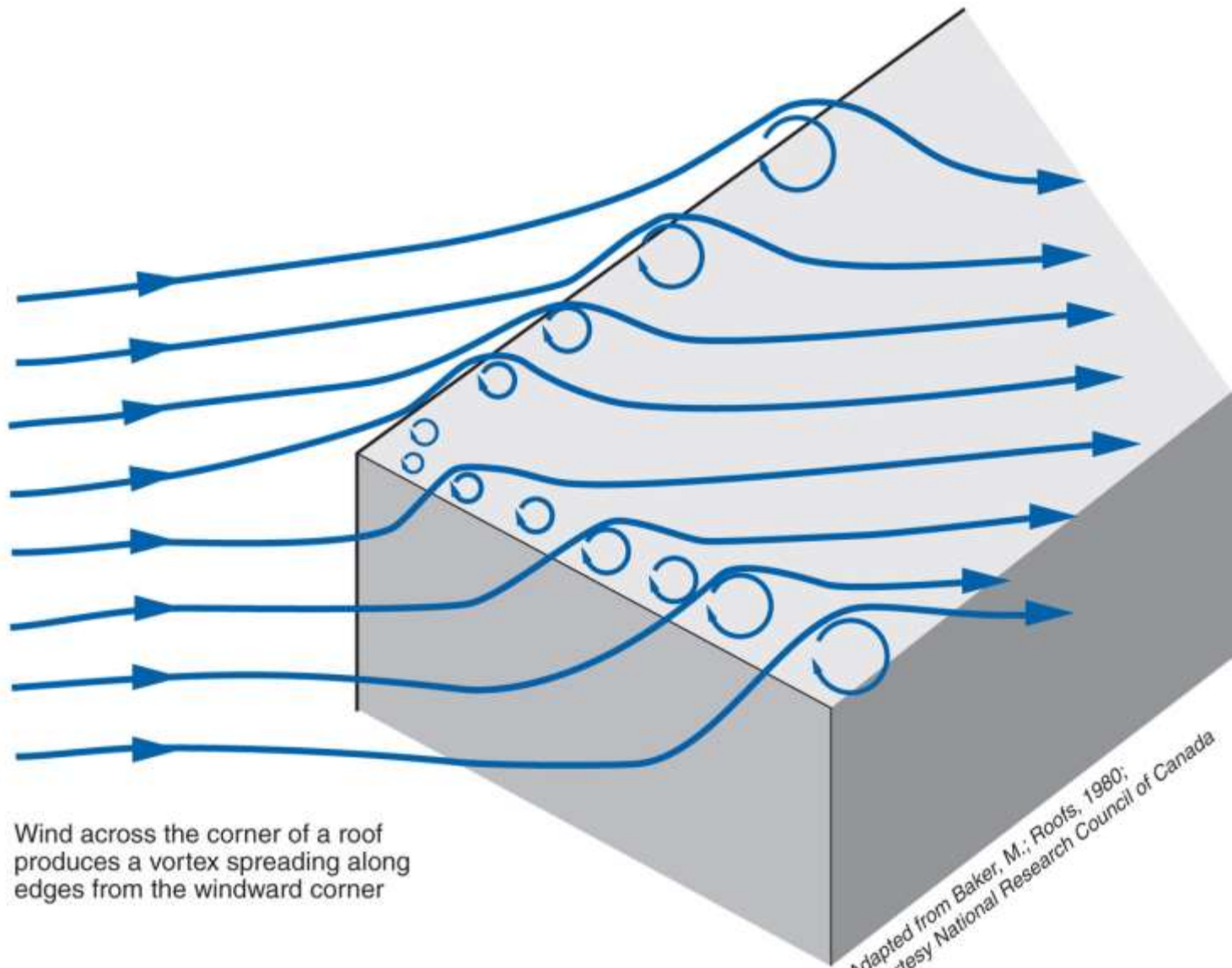






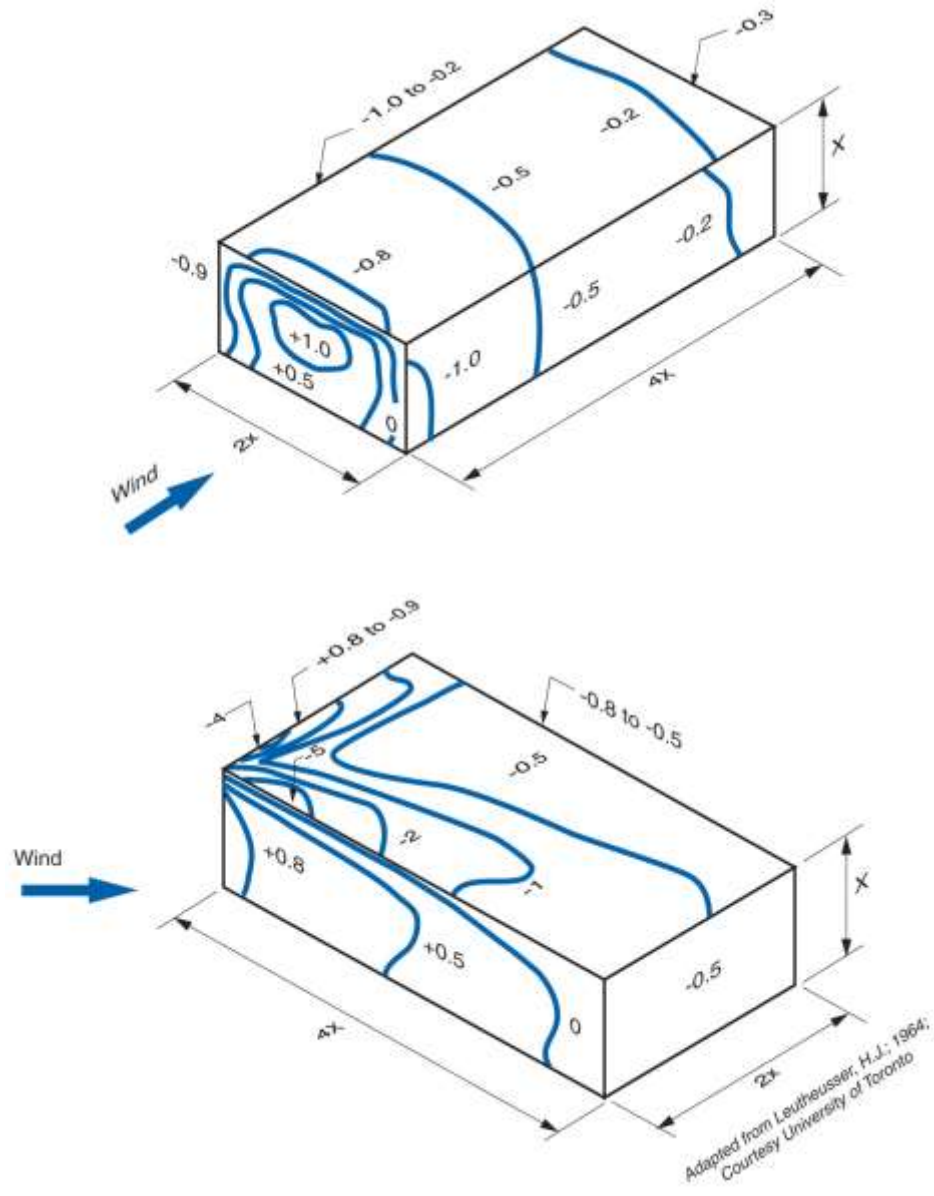


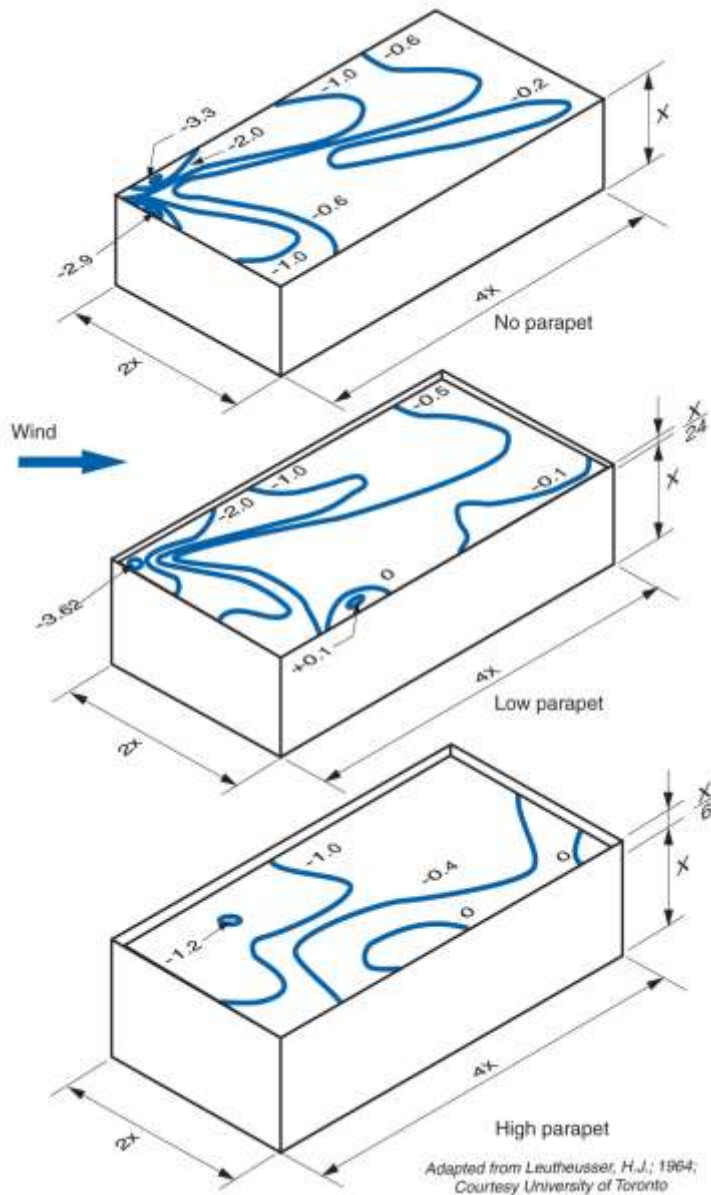
Adapted from Baker, M.; *Roofs*, 1980;
 Courtesy National Research Council of Canada

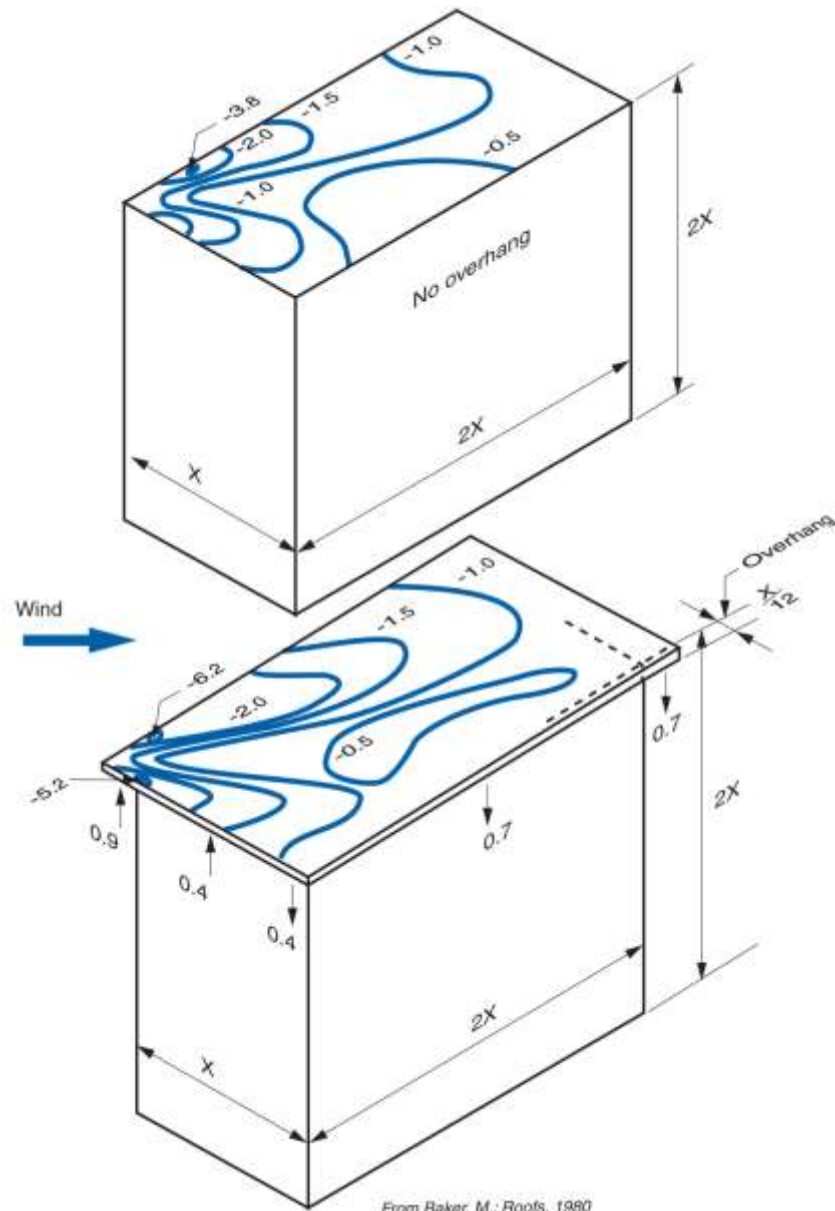


Wind across the corner of a roof produces a vortex spreading along edges from the windward corner

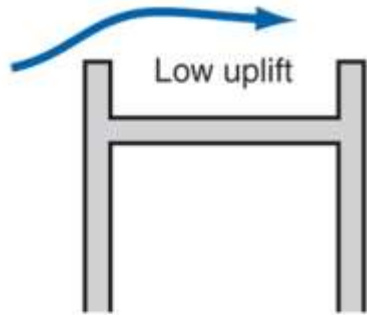
Adapted from Baker, M.; Roofs, 1980;
Courtesy National Research Council of Canada



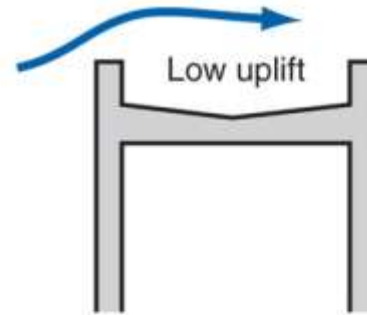




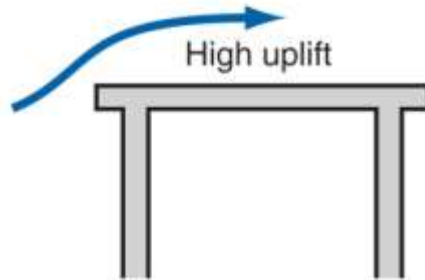
From Baker, M.; *Roofs*, 1980



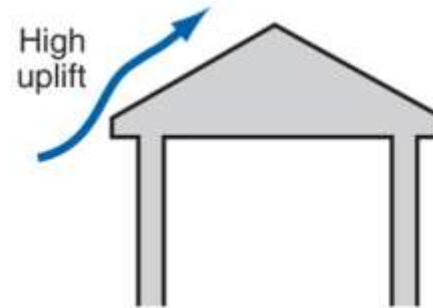
Flat roof with parapets
blow-off hazard: low
slippage hazard: low



Sloped roof with parapets
blow-off hazard: low
slippage hazard: medium

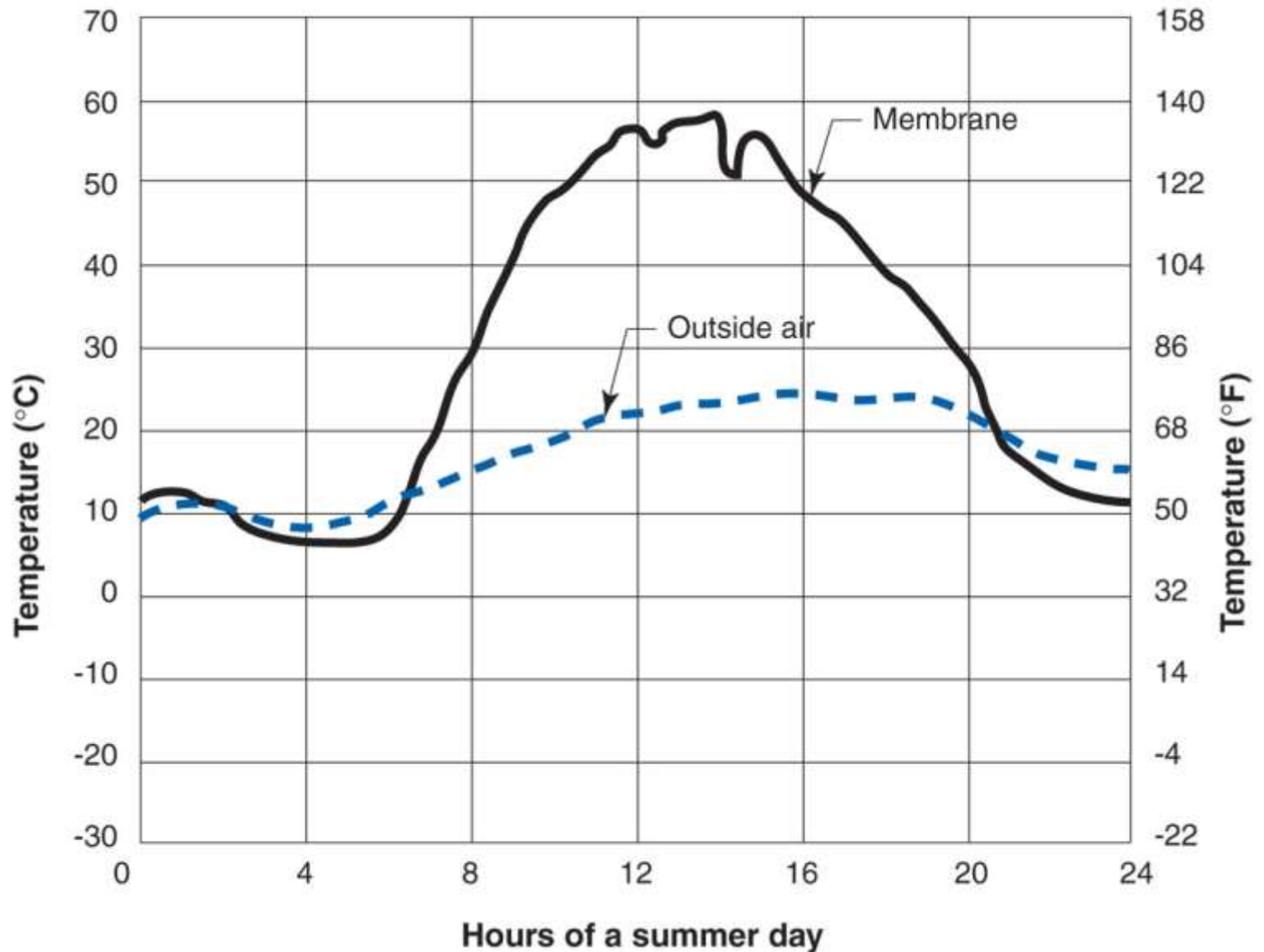


Flat roof or overhang
blow off hazard: high
slippage hazard: low



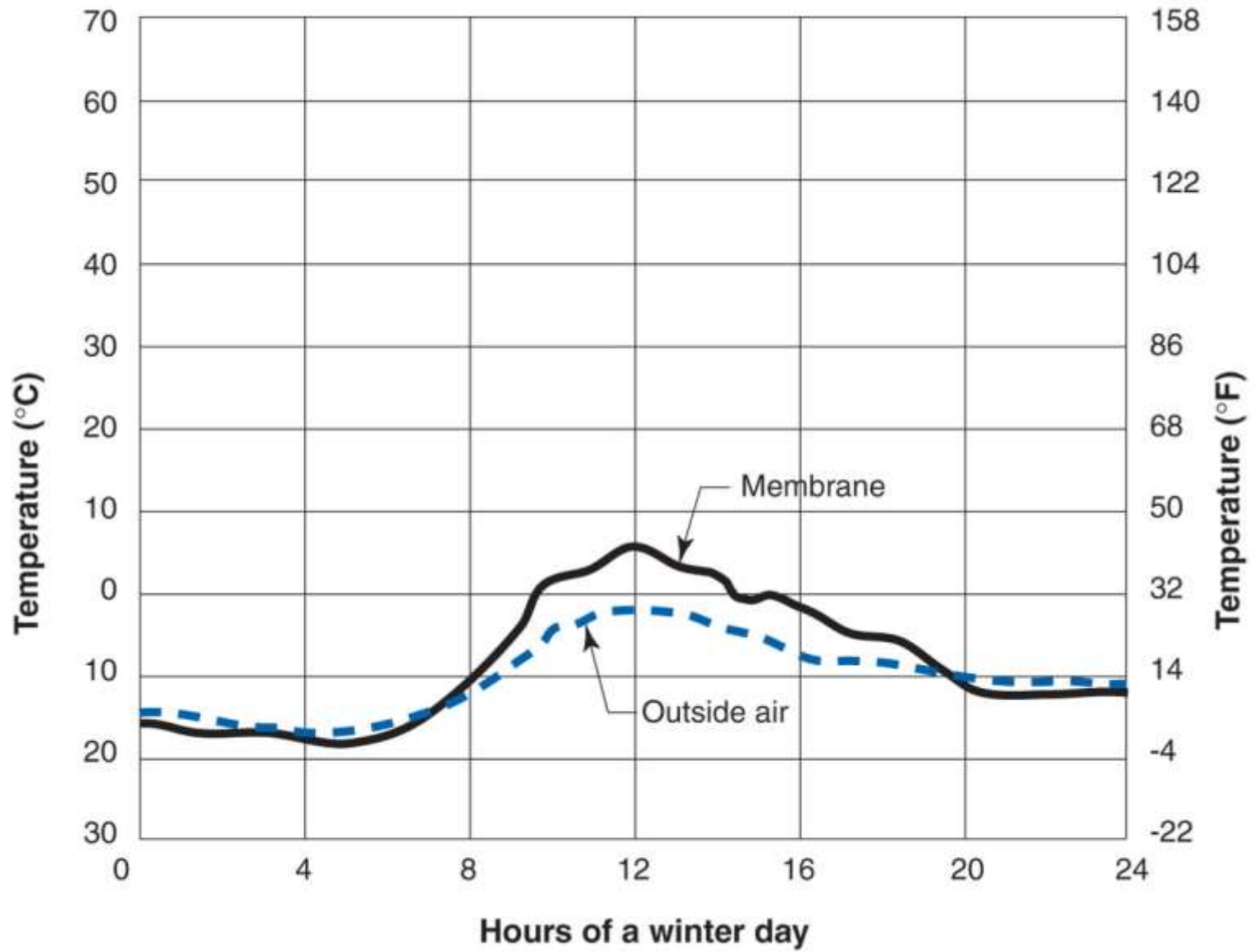
Outward sloping roof
blow-off hazard: high
slippage hazard: high

From Baker, M.; Roofs, 1980



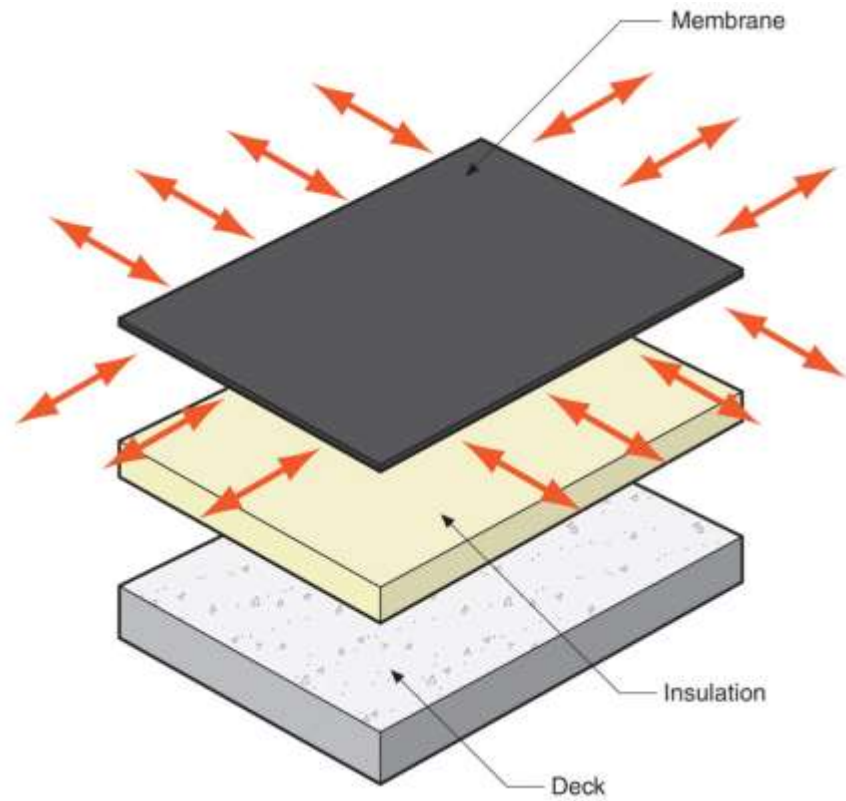
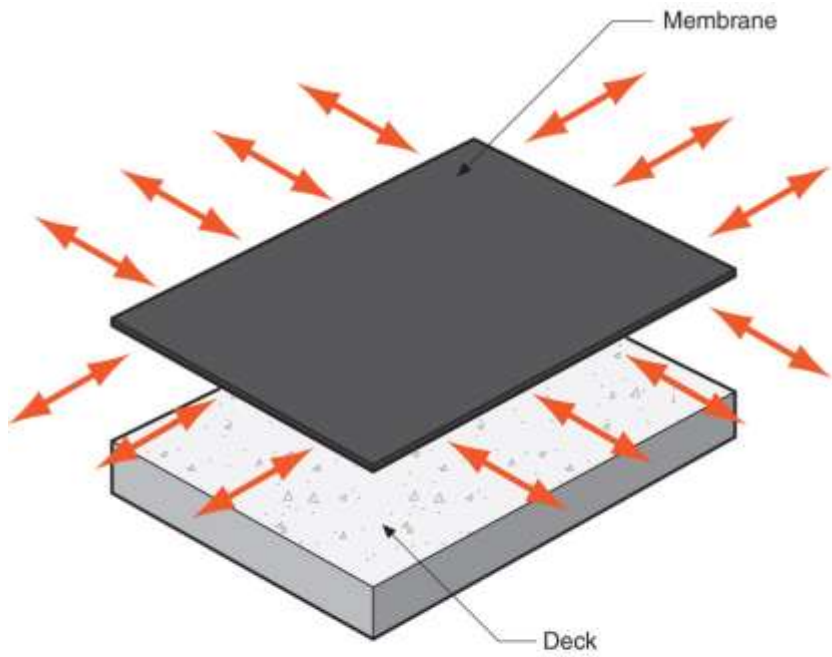
Hours of a summer day

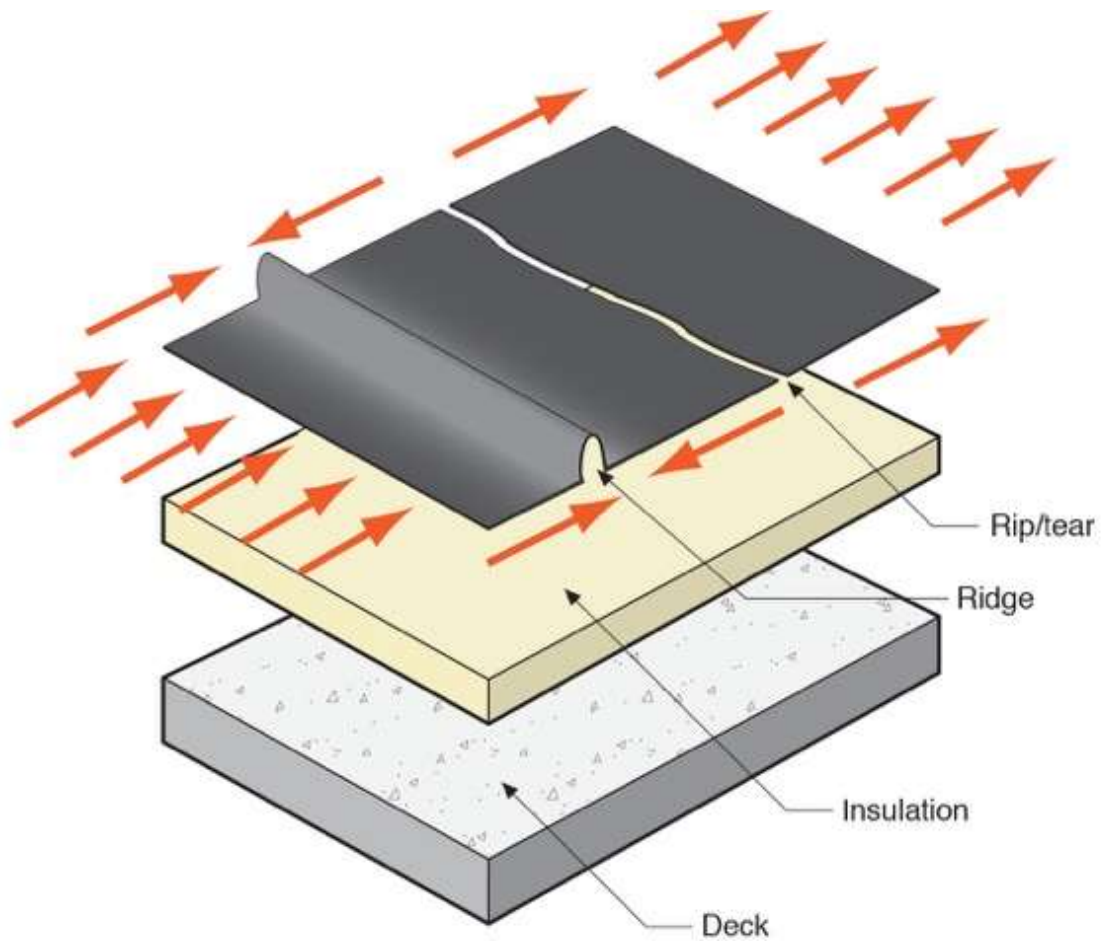
From Baker, M.; Roofs, 1980



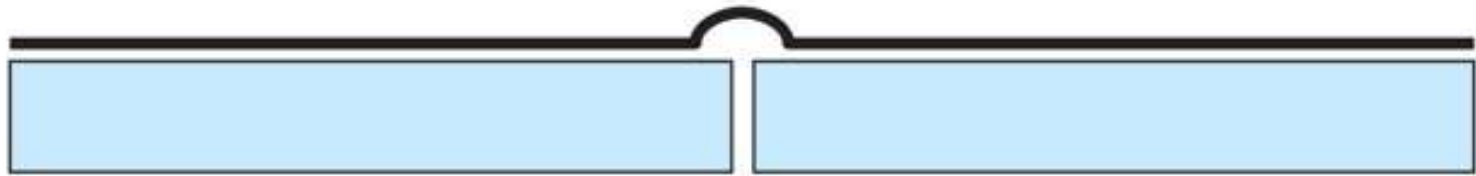
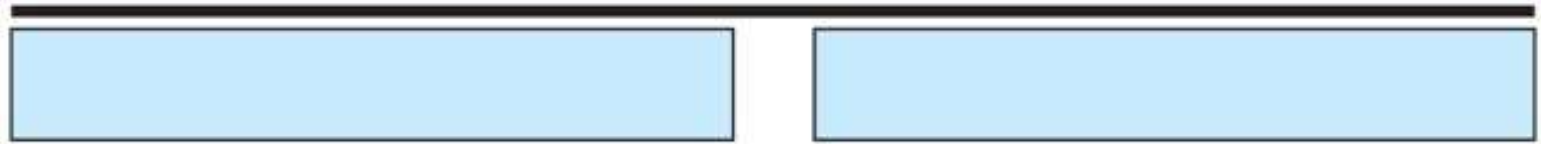
Hours of a winter day

From Baker, M.; *Roofs*, 1980

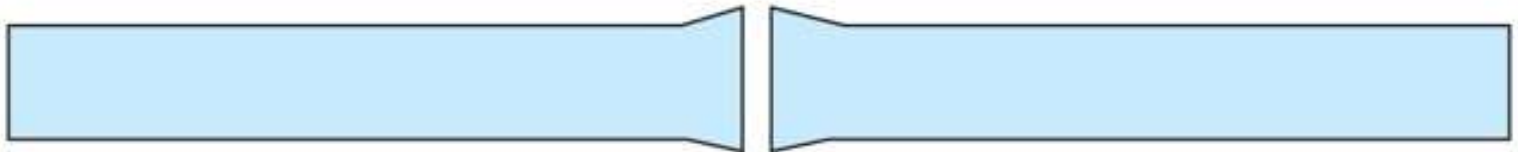
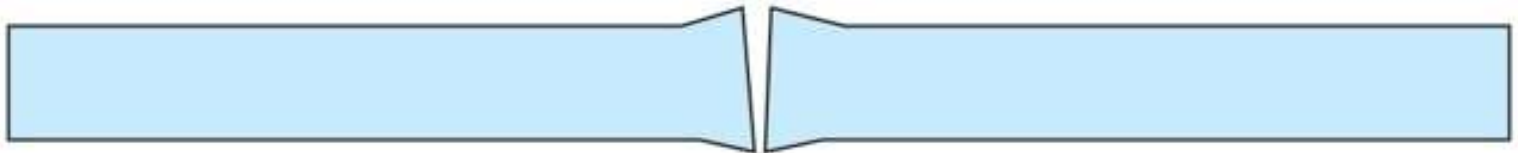
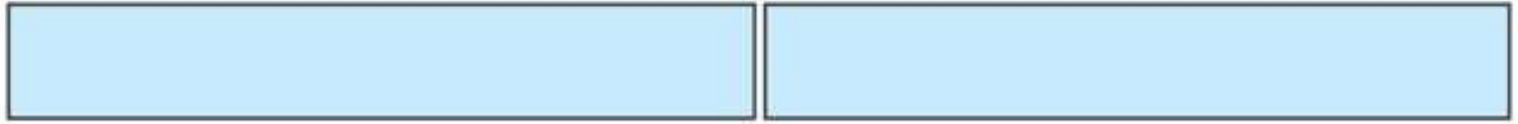


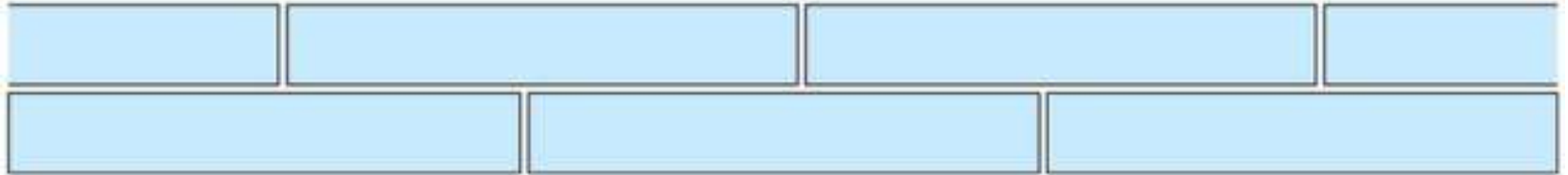








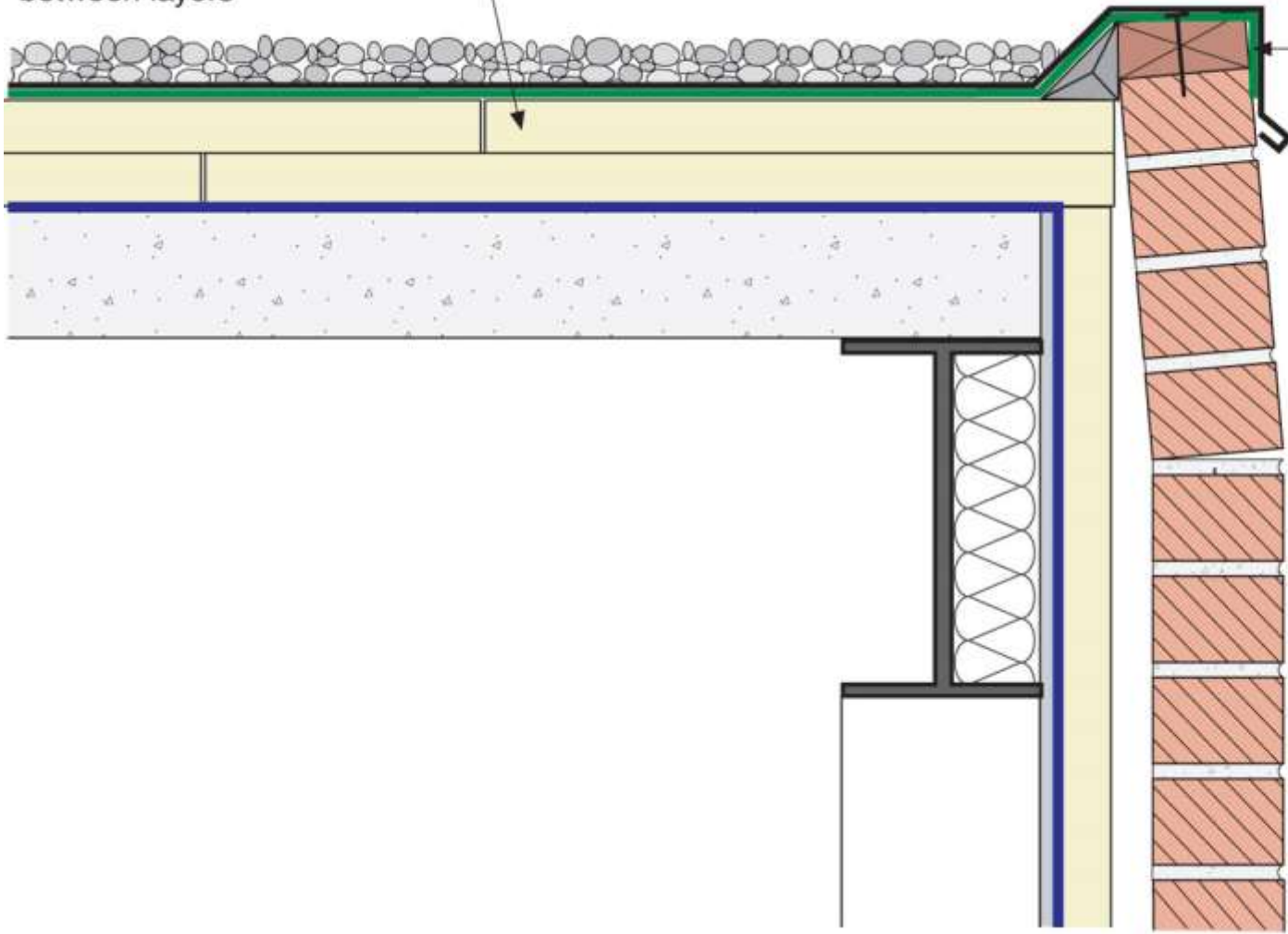






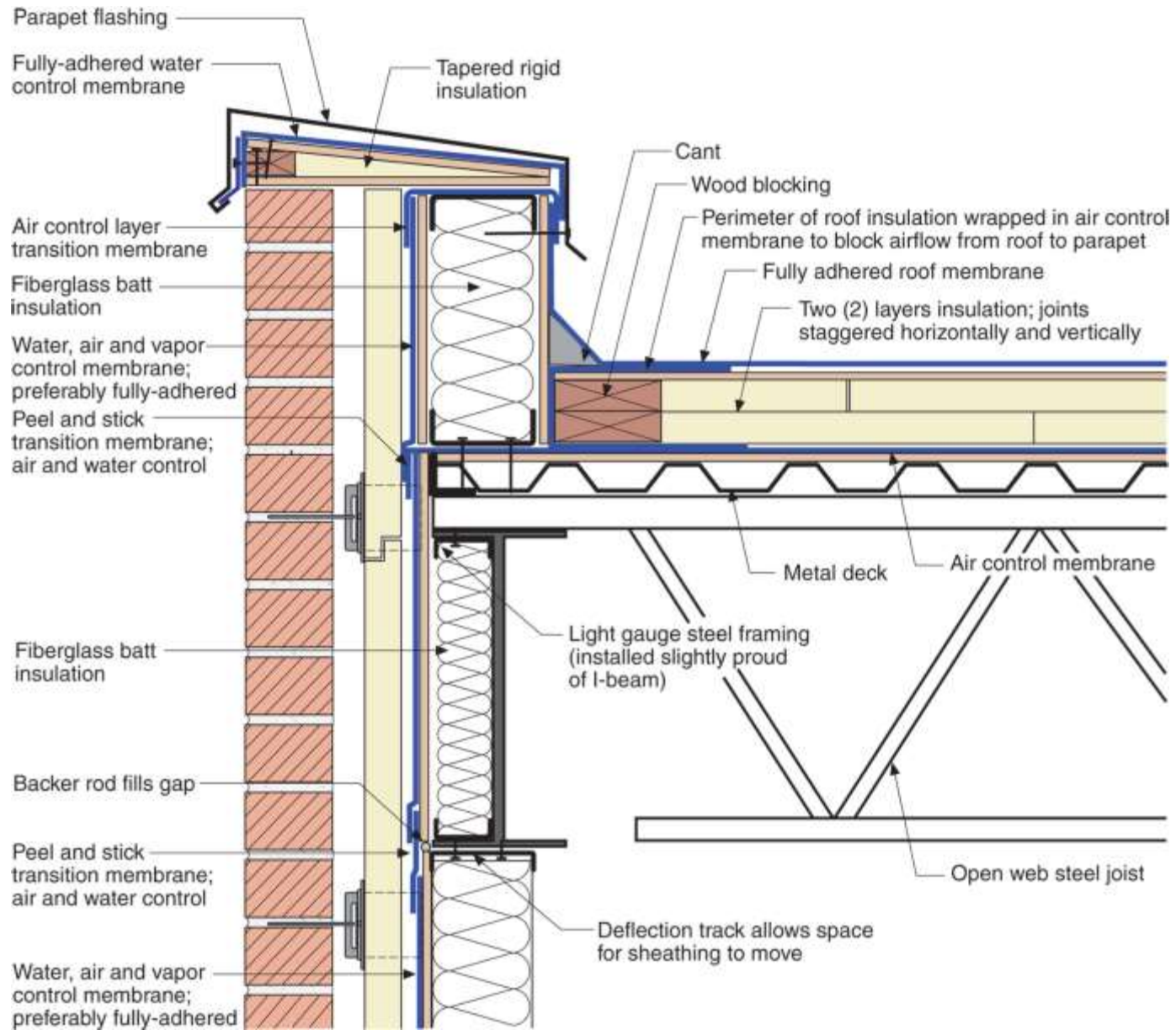


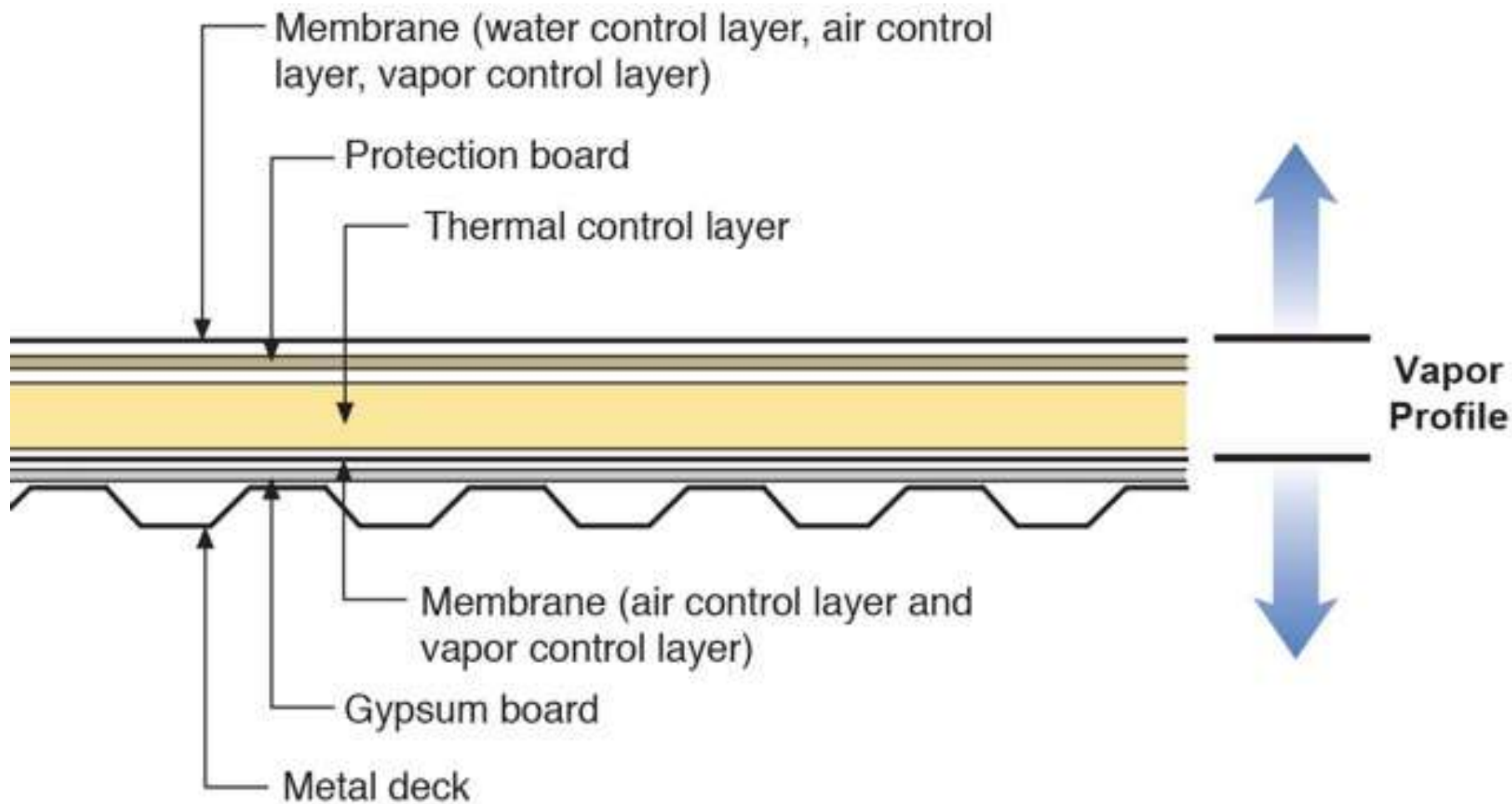
Insulation moved because of poor adhesion to deck and between layers

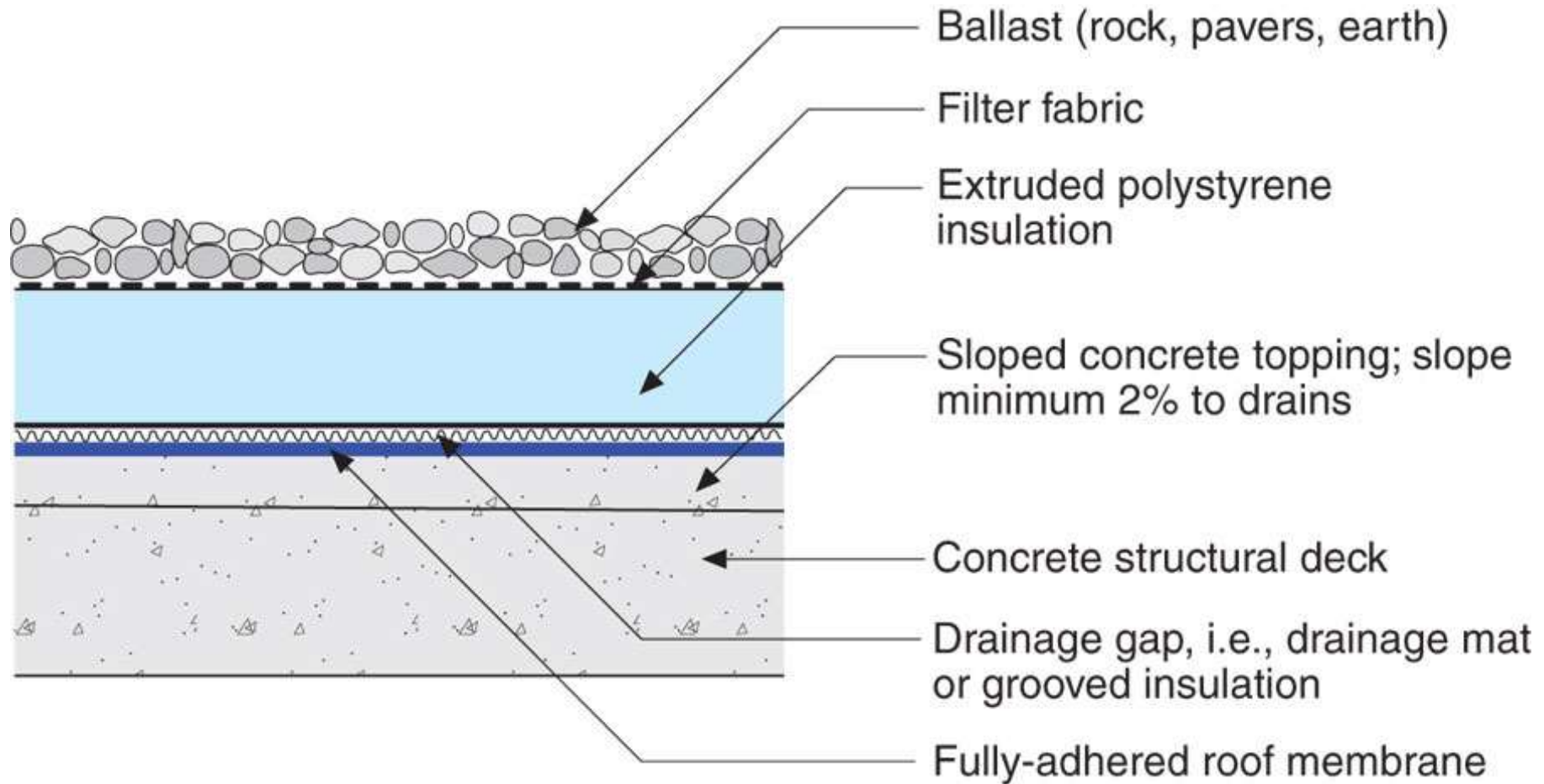


Top four courses of brick and wood blocking pulled inward by contracting membrane

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



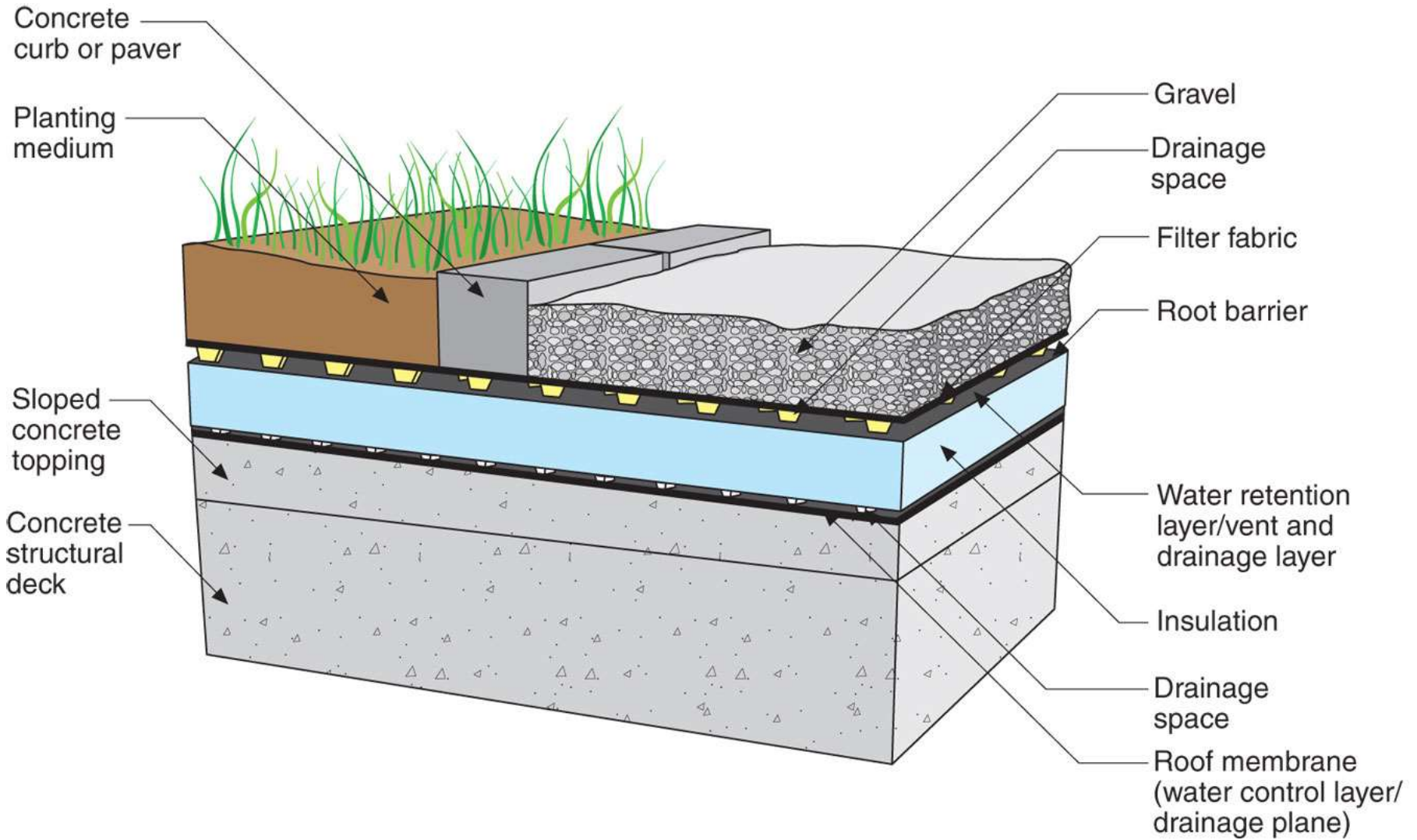






**Really Heavy
Pink Stuff**

**Liquid Waterproofing
over Concrete Deck**



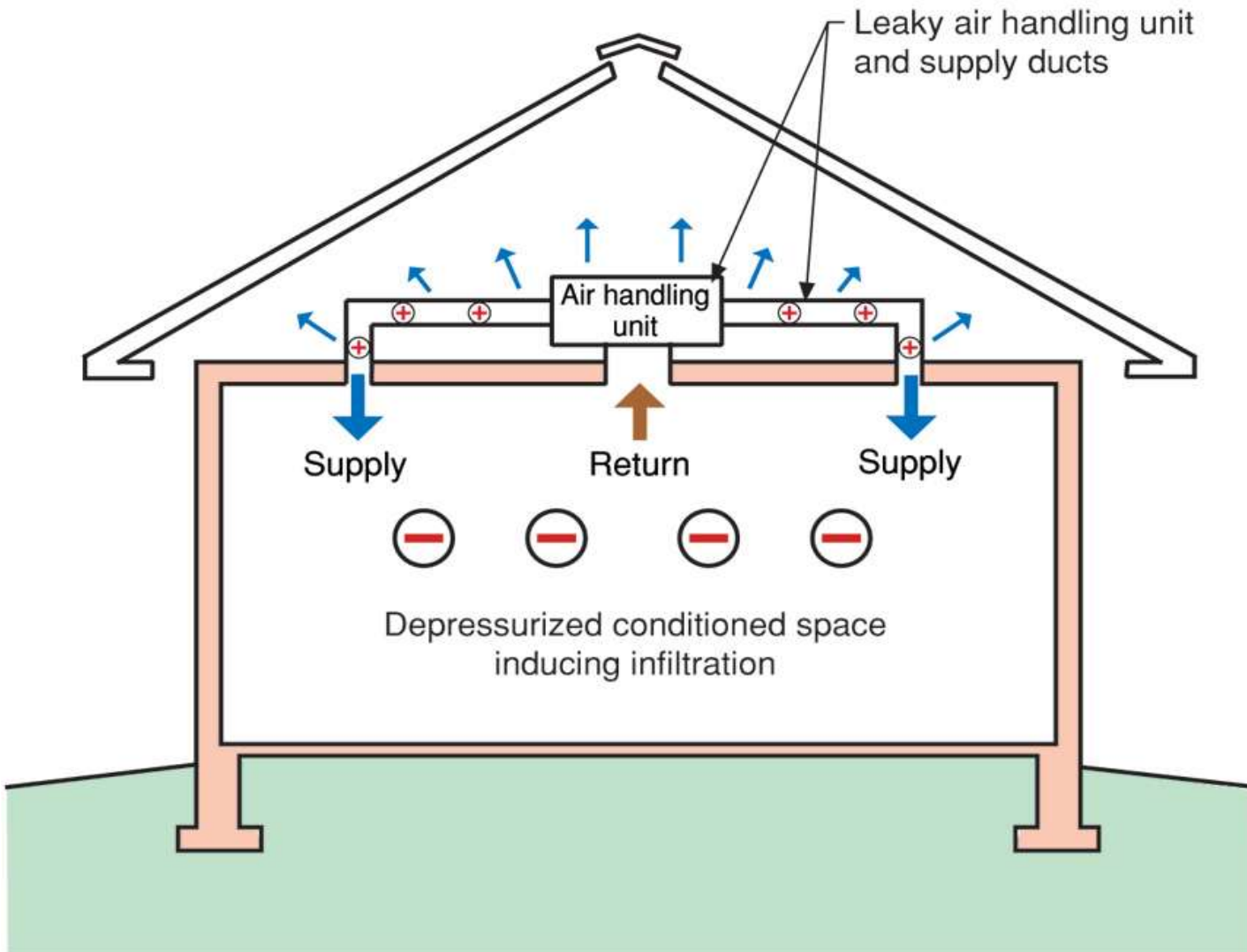












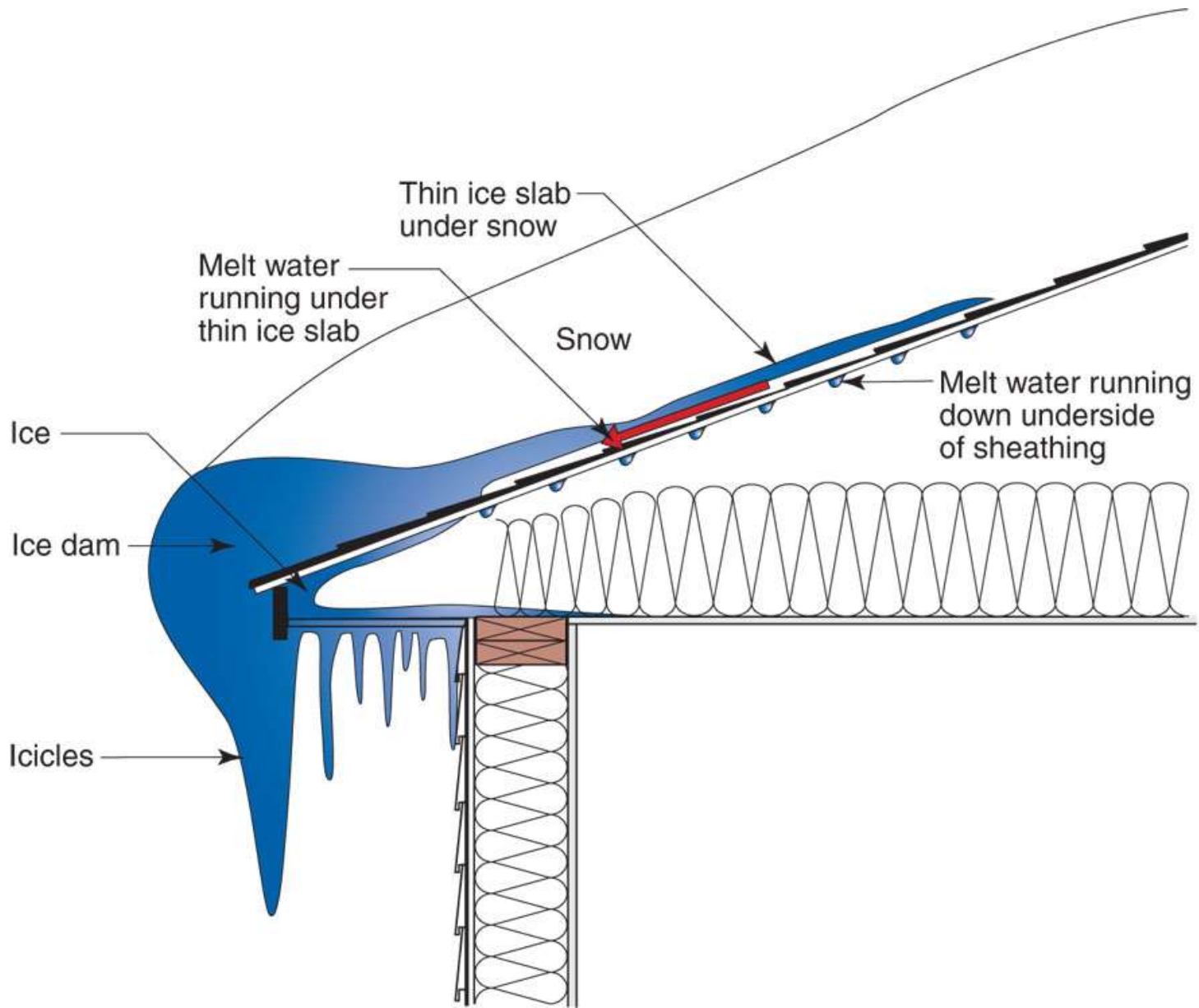
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

















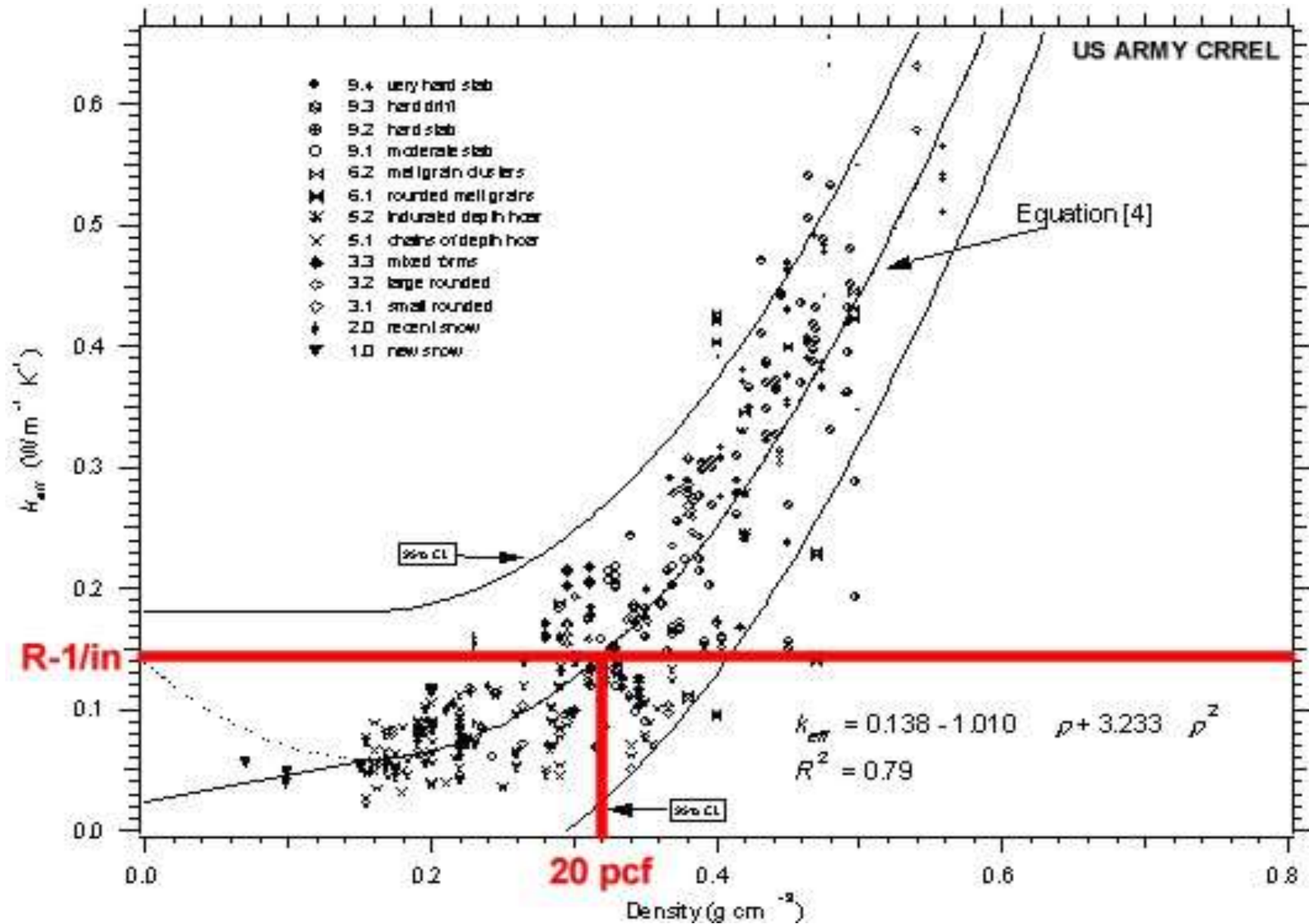






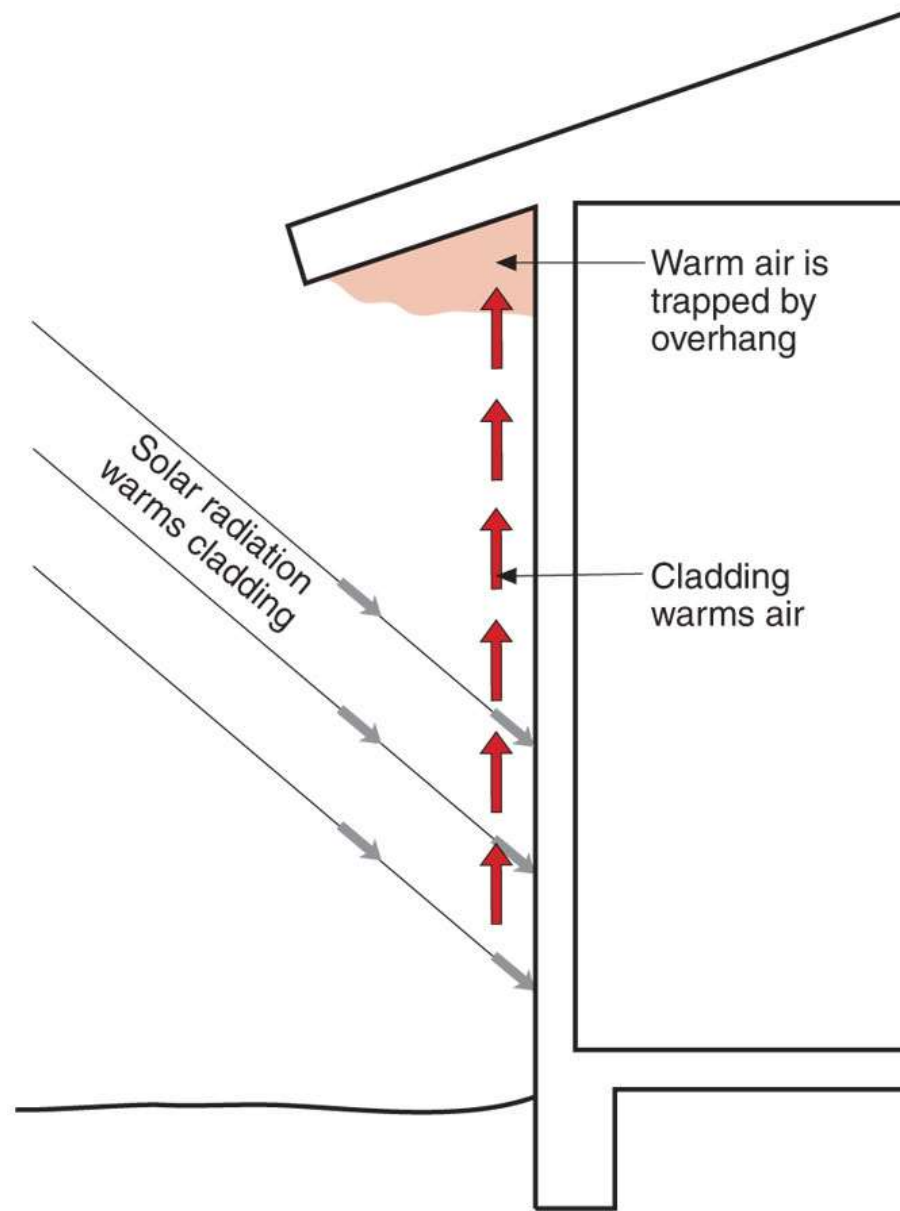










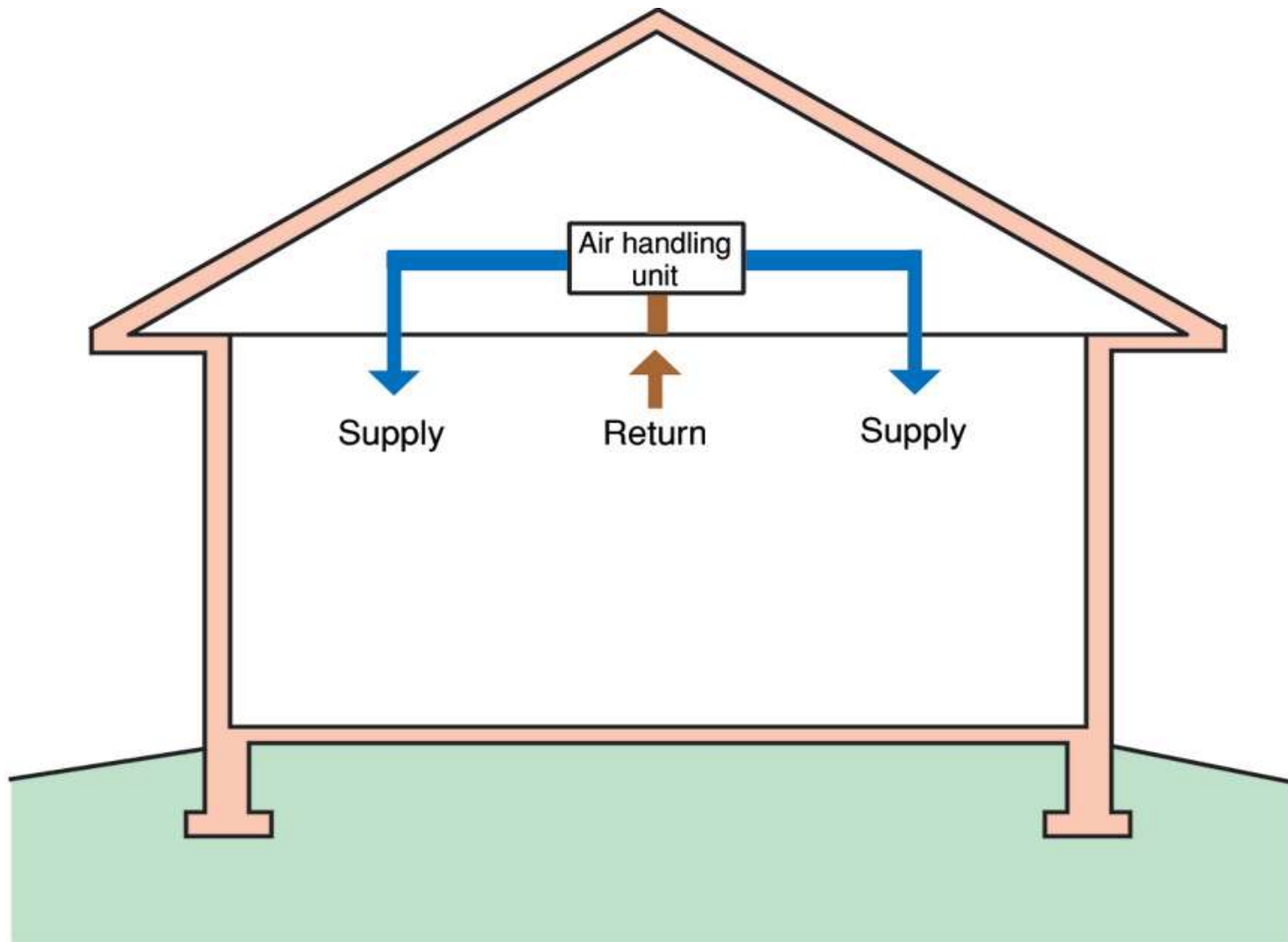




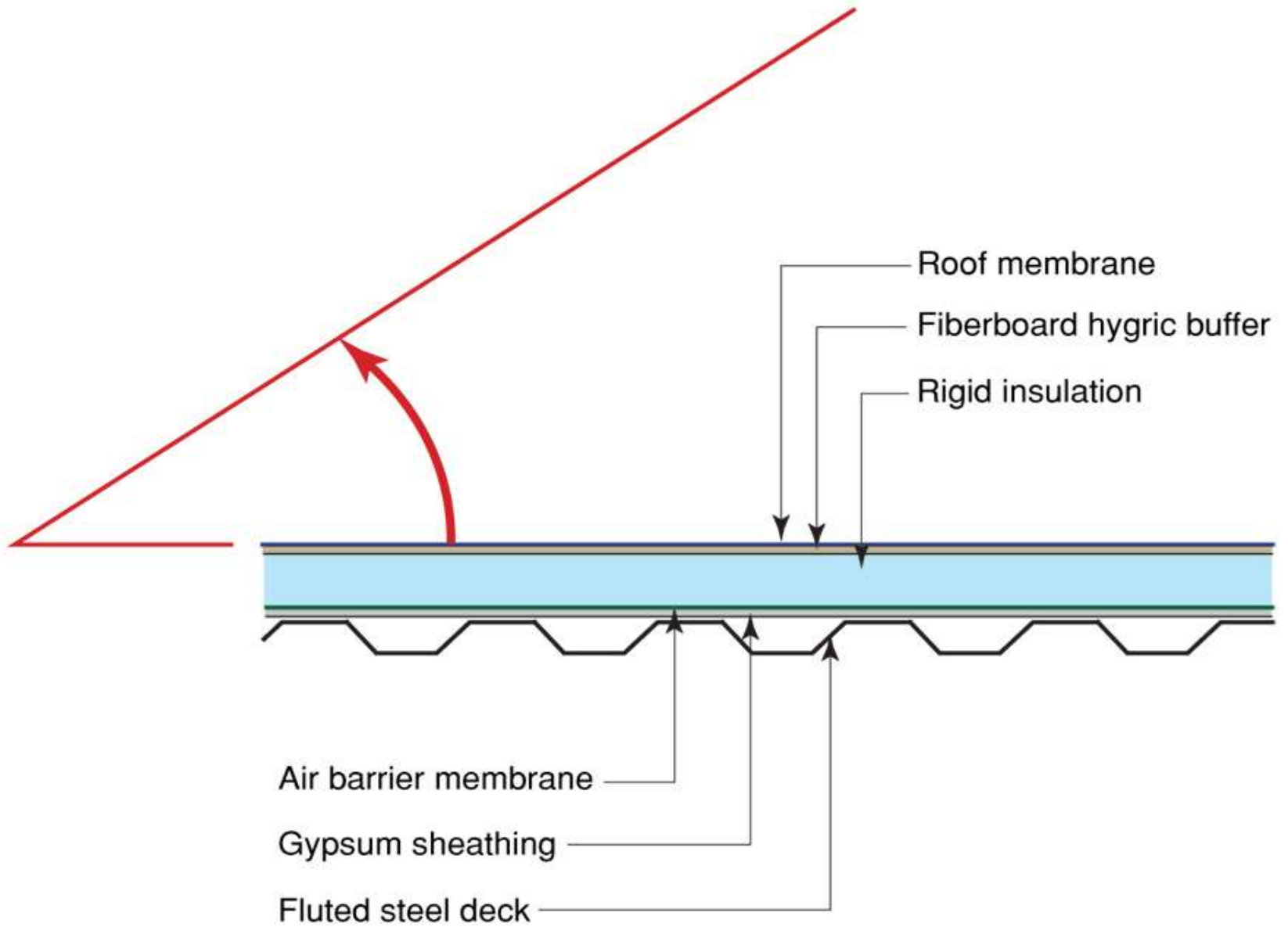


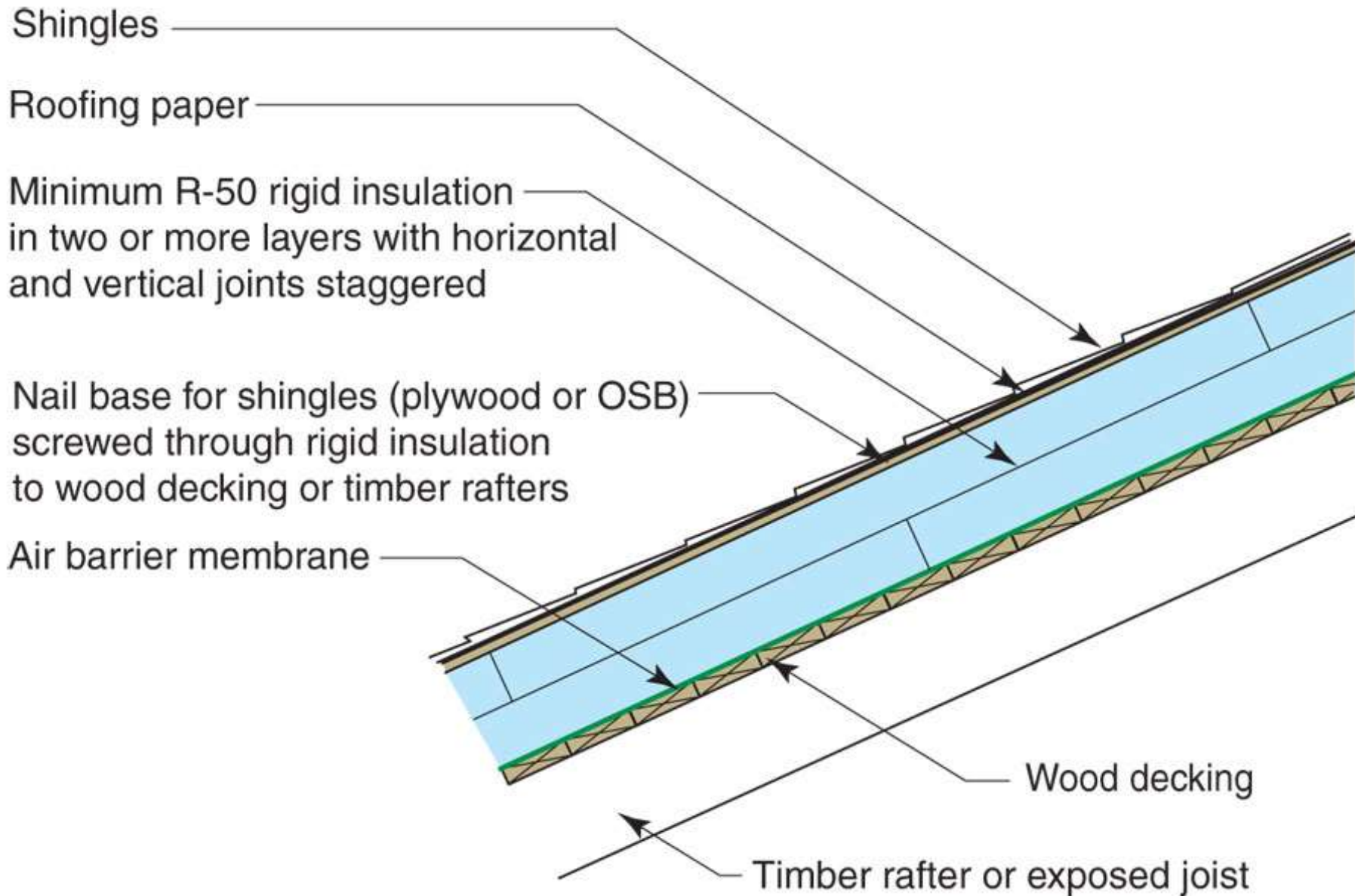


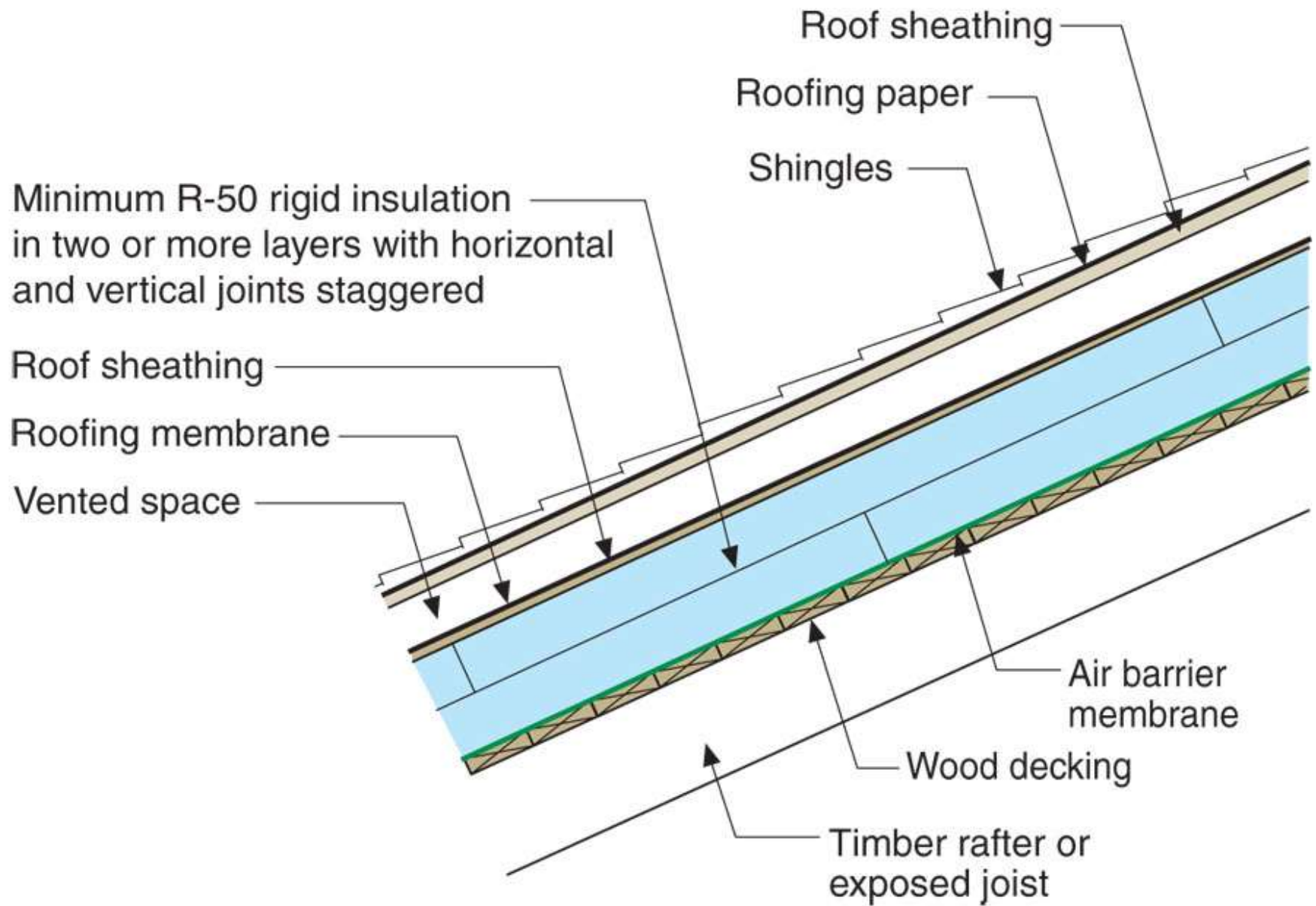


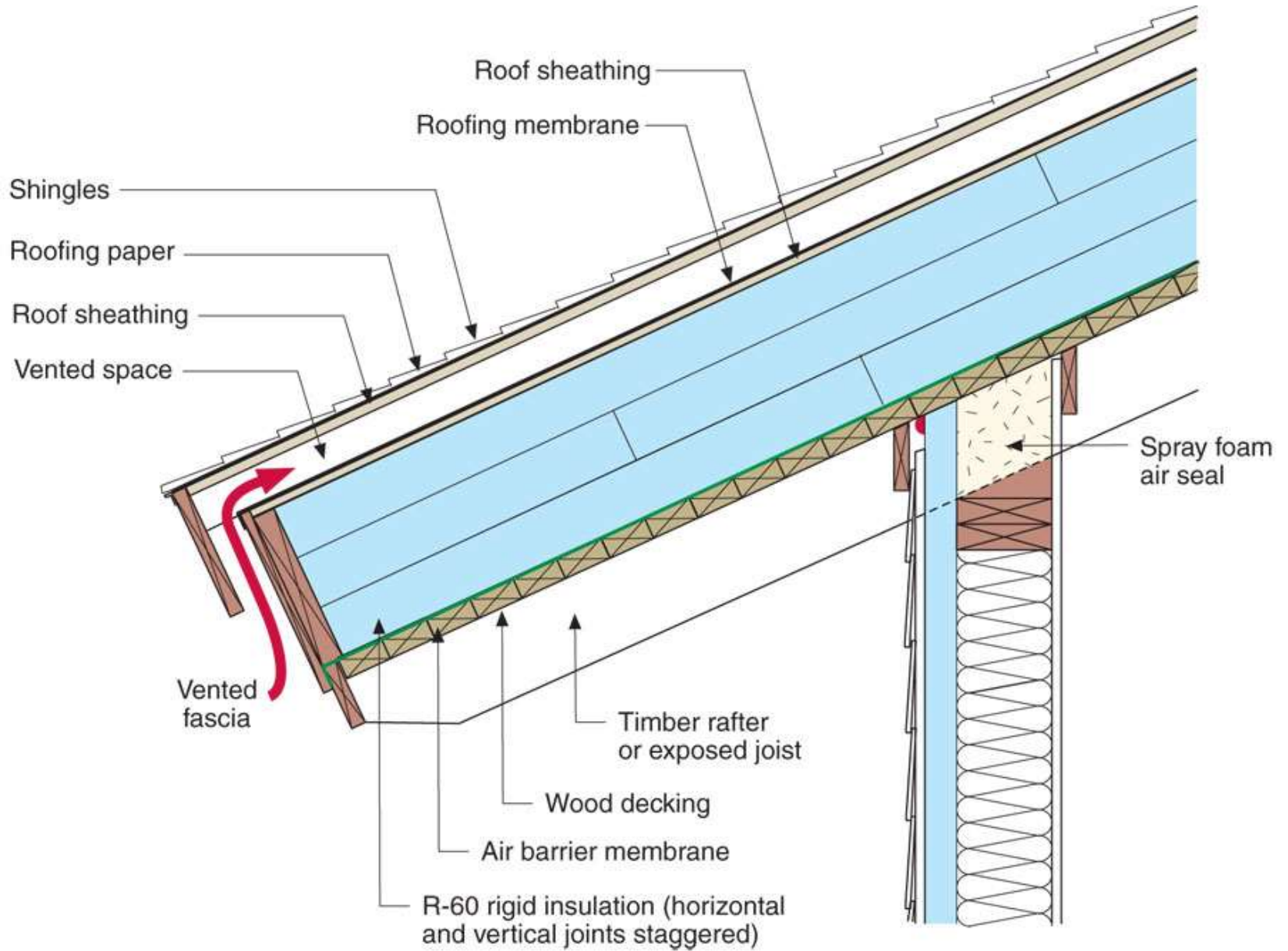


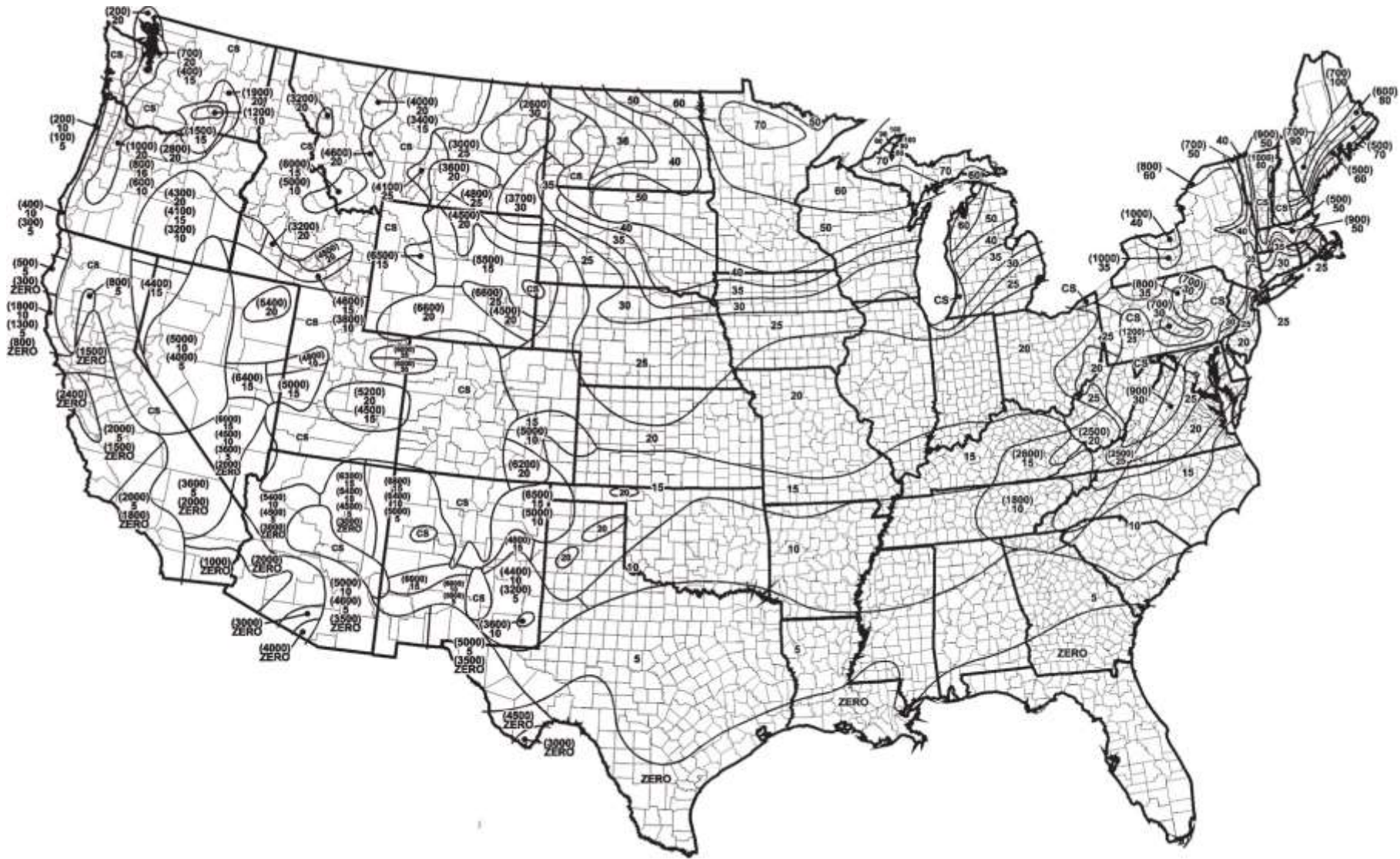
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.













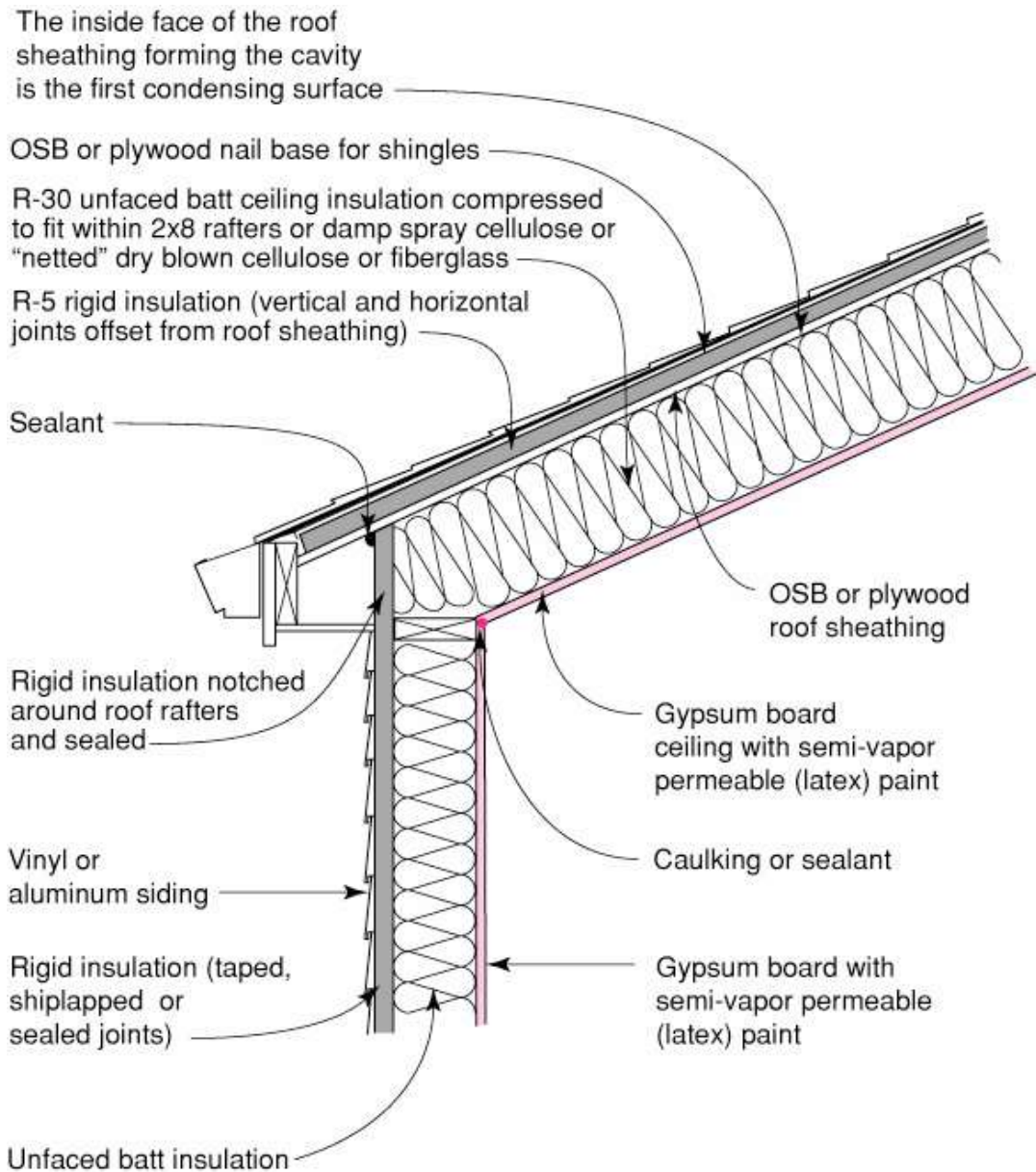


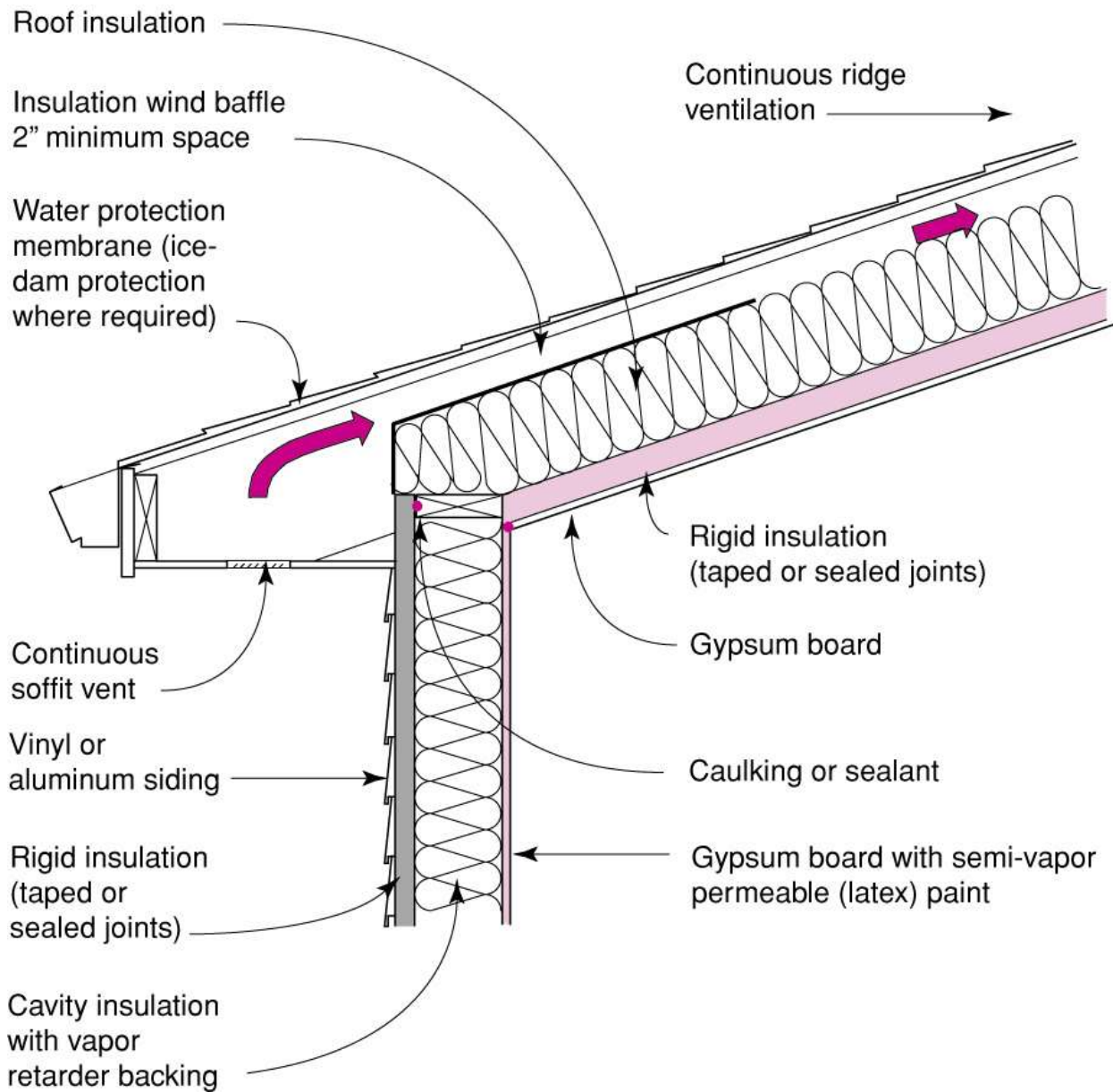


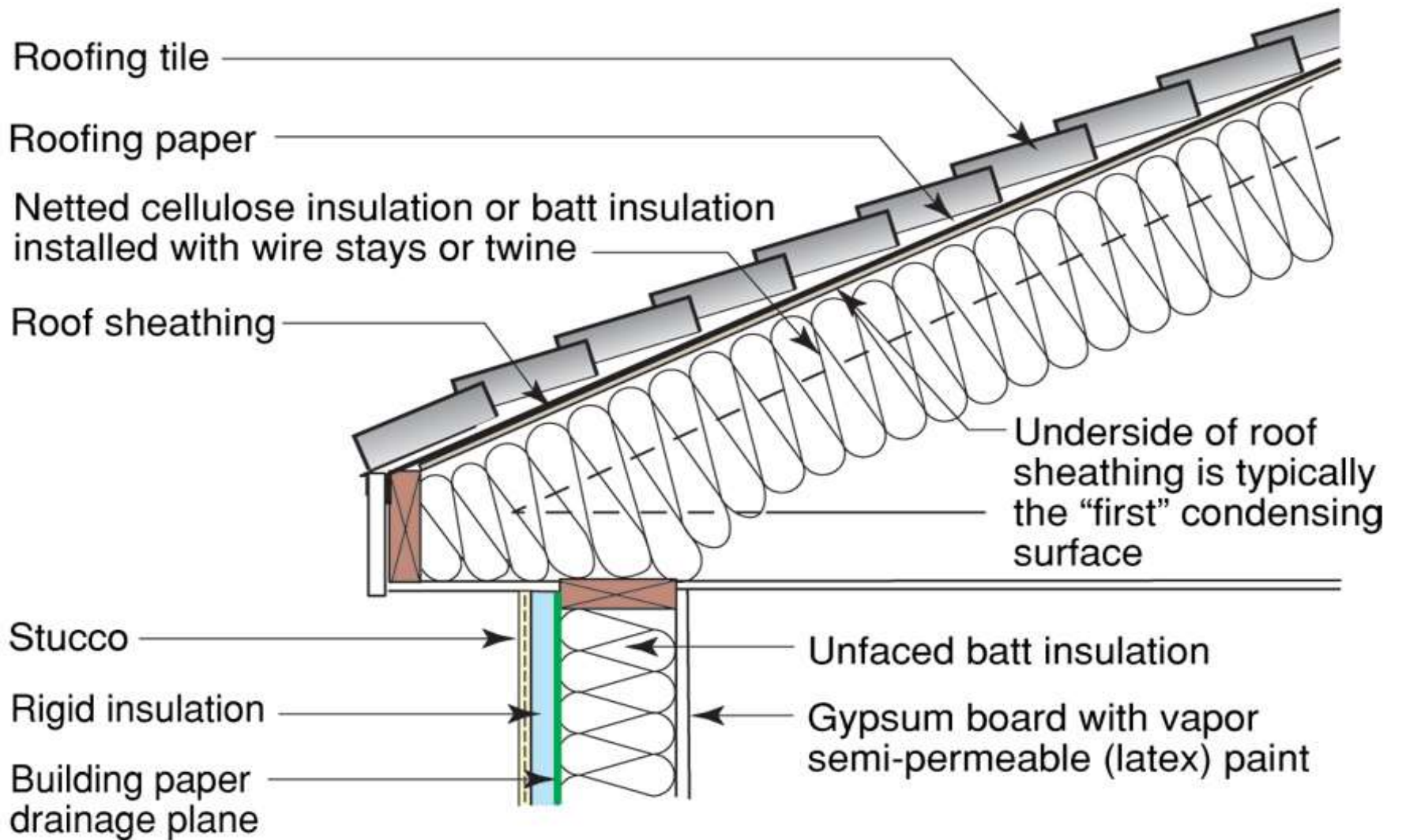








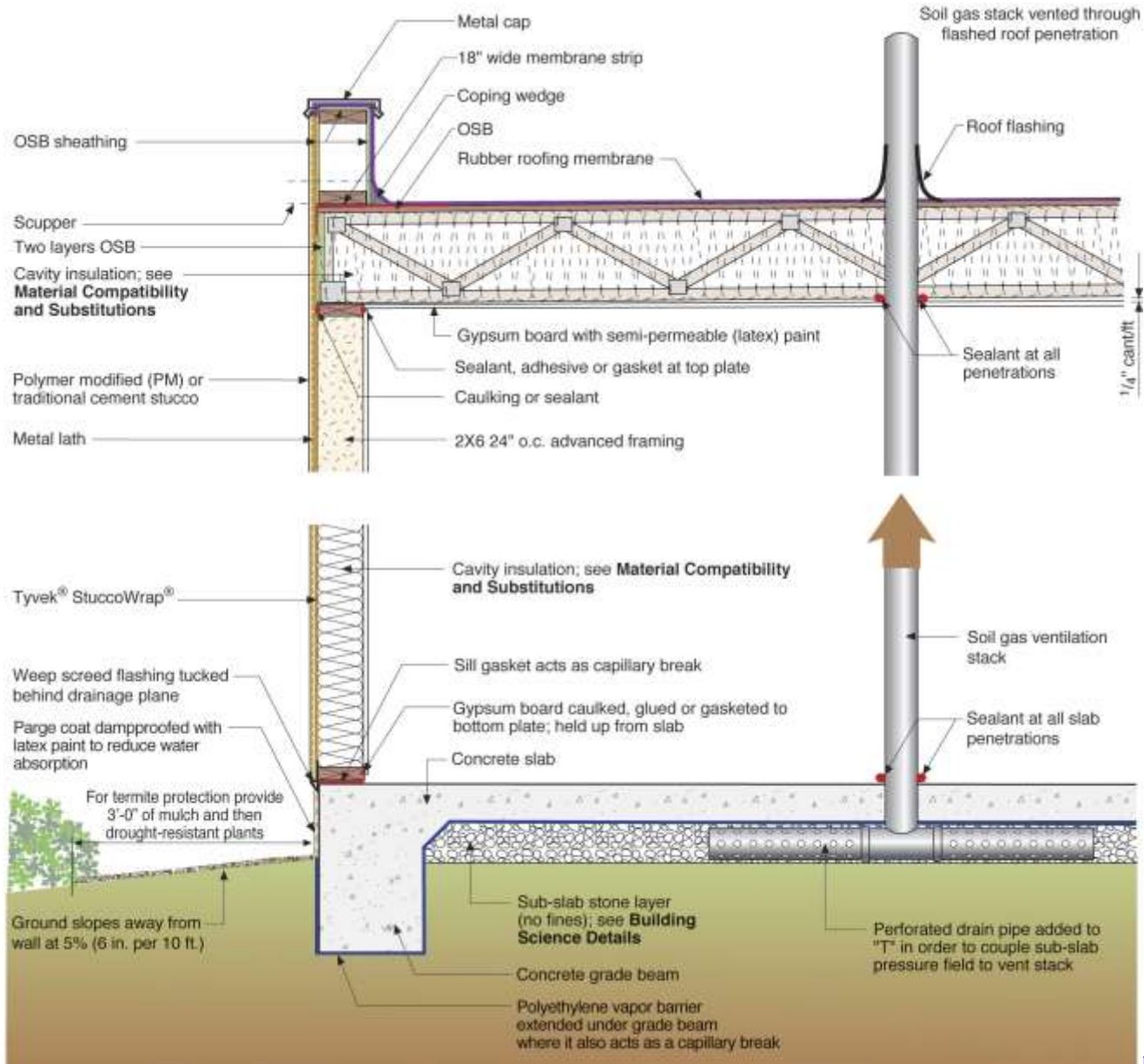


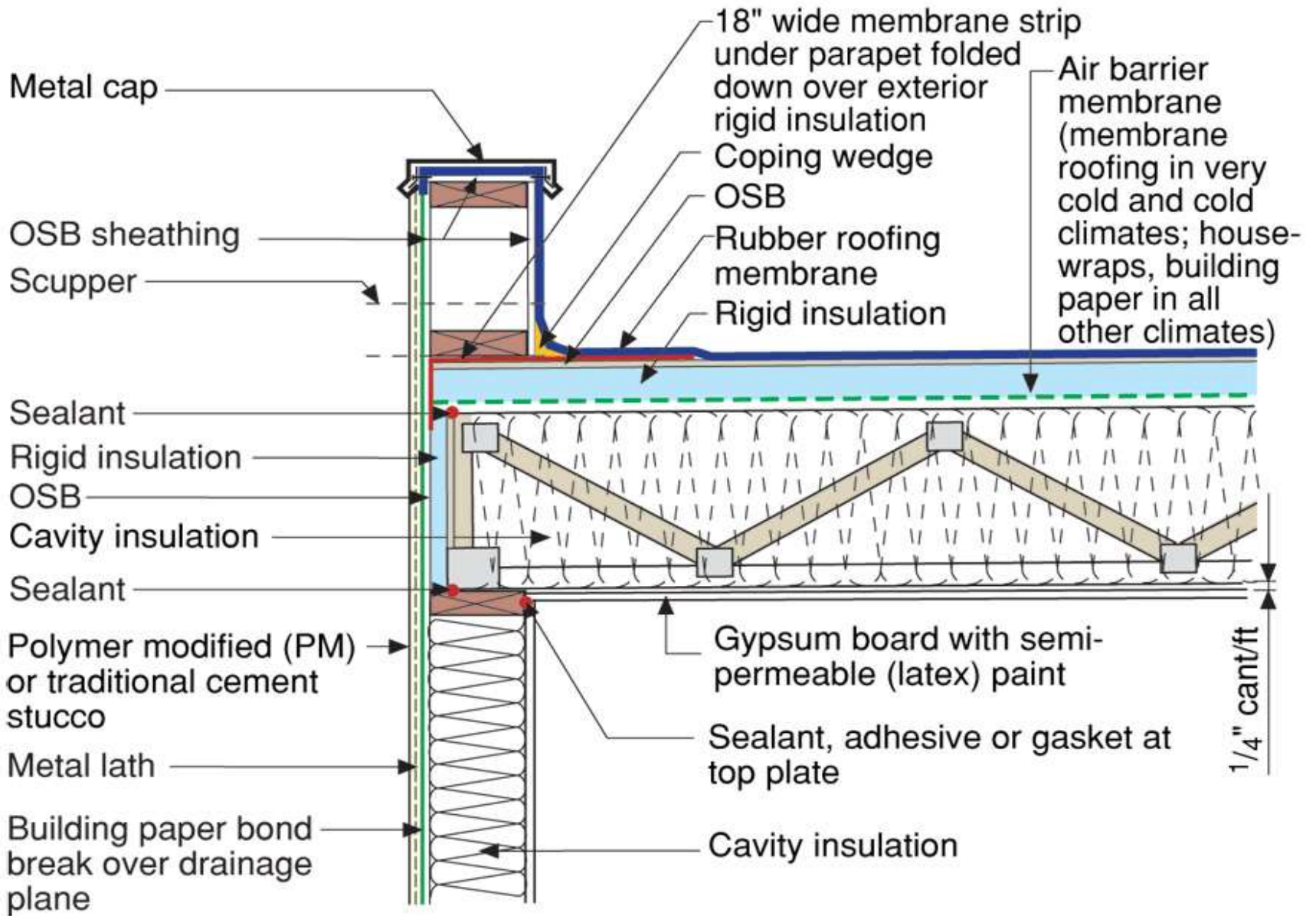


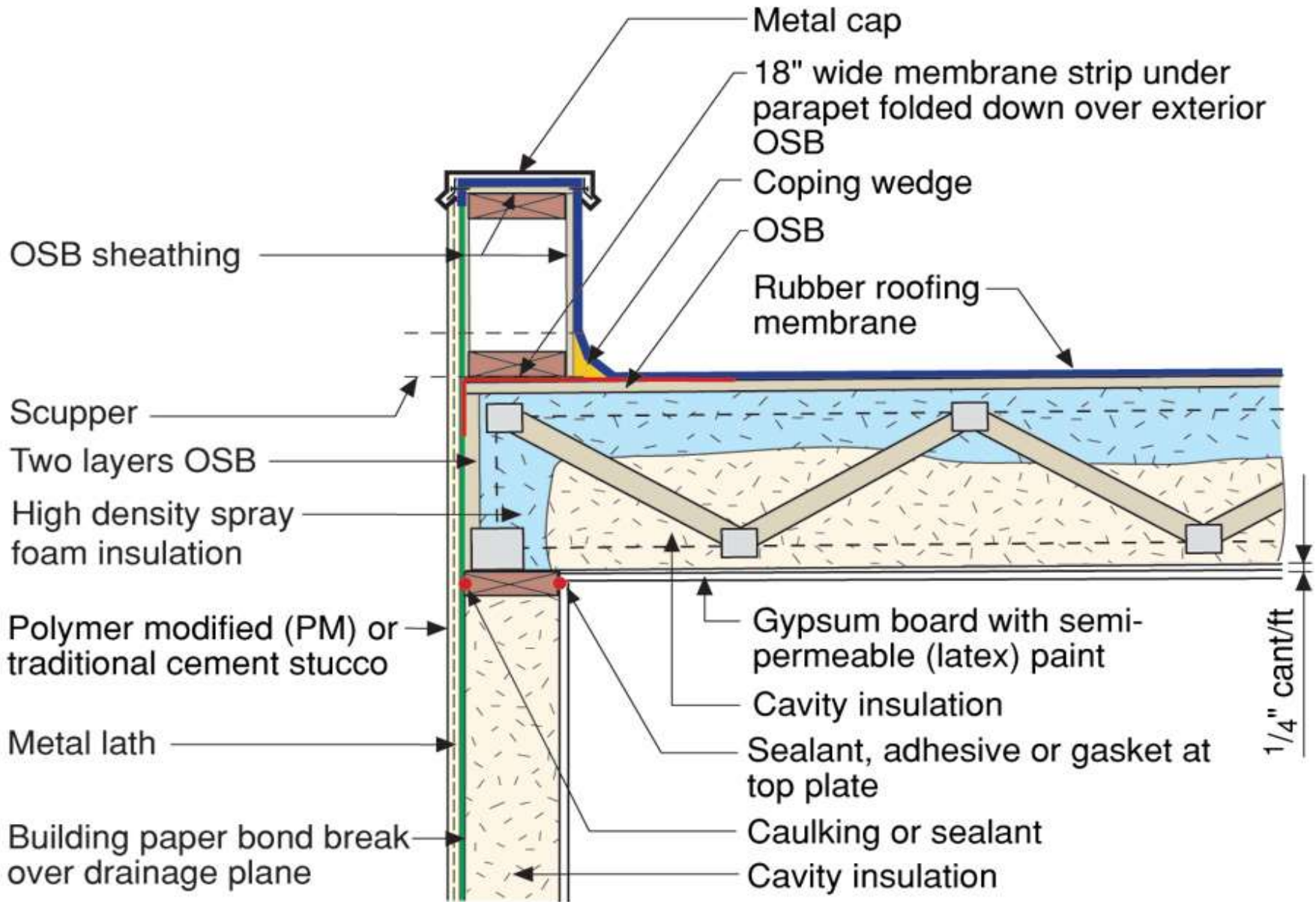




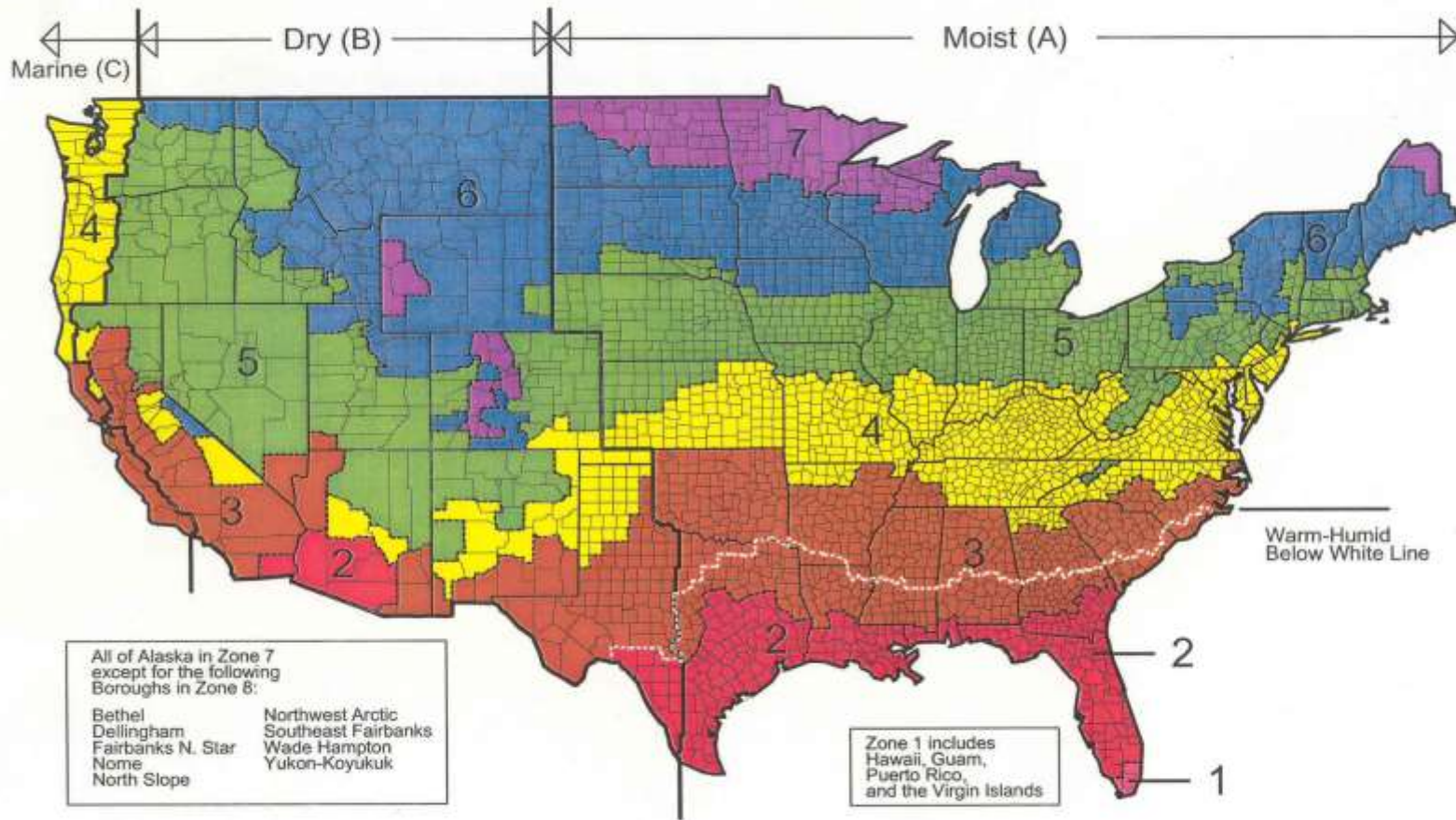








Map of DOE's Proposed Climate Zones



March 24, 2003

