

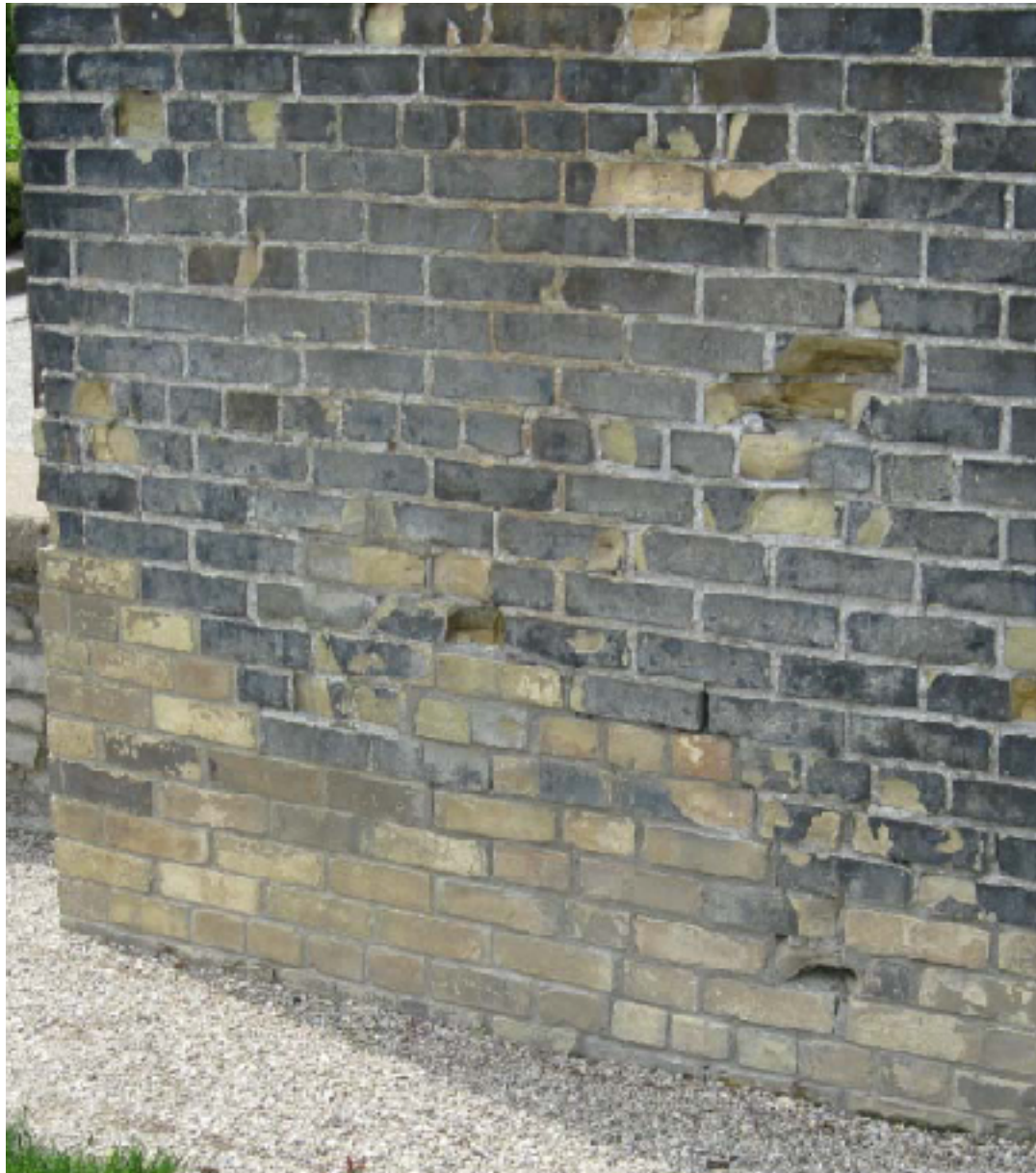
Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

# Building Science

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Adventures In Building Science

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# Freeze-Thaw Damage

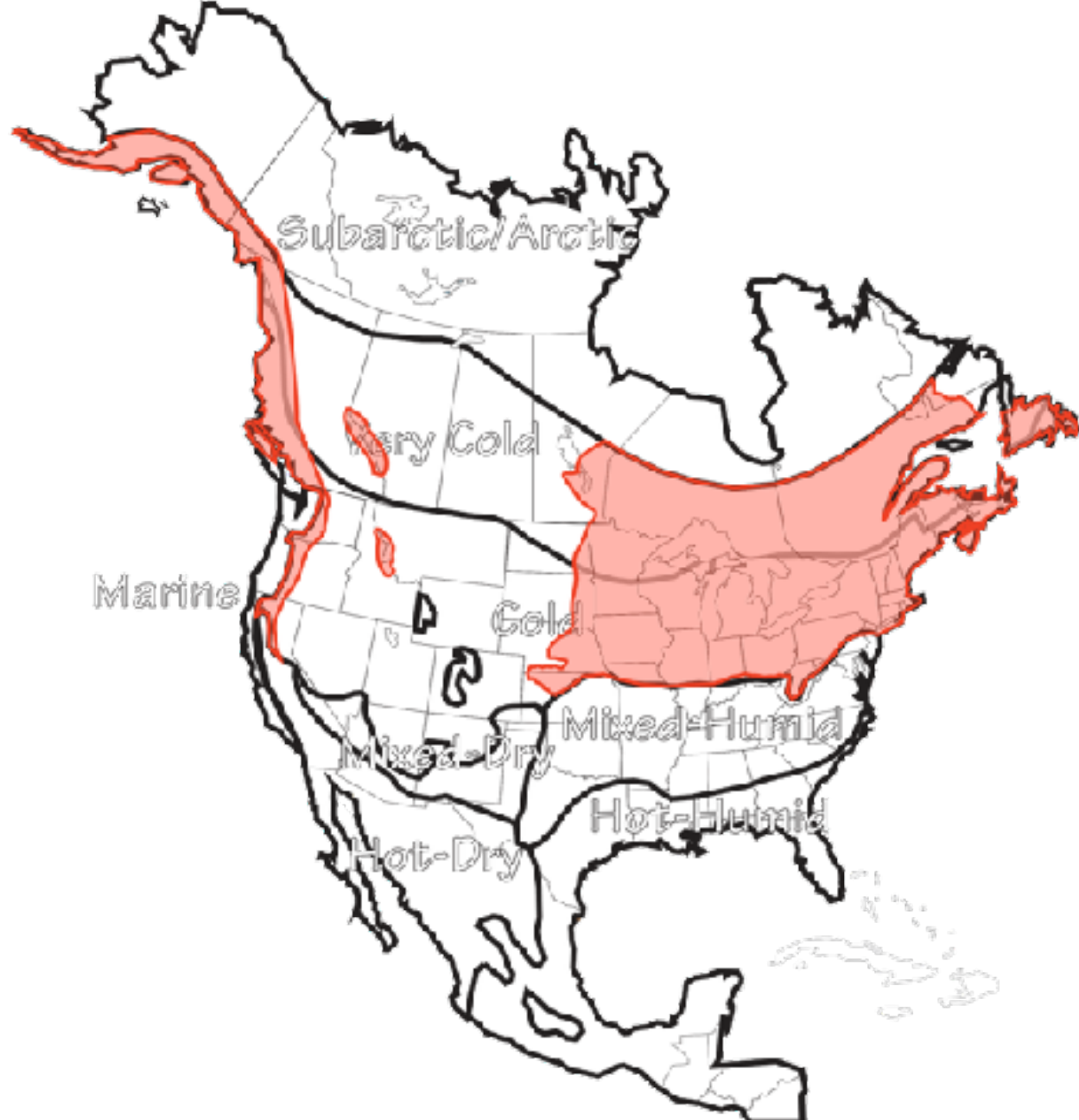
Freeze-Thaw Damage  
Freezing Temperatures  
Water  
Susceptible Brick

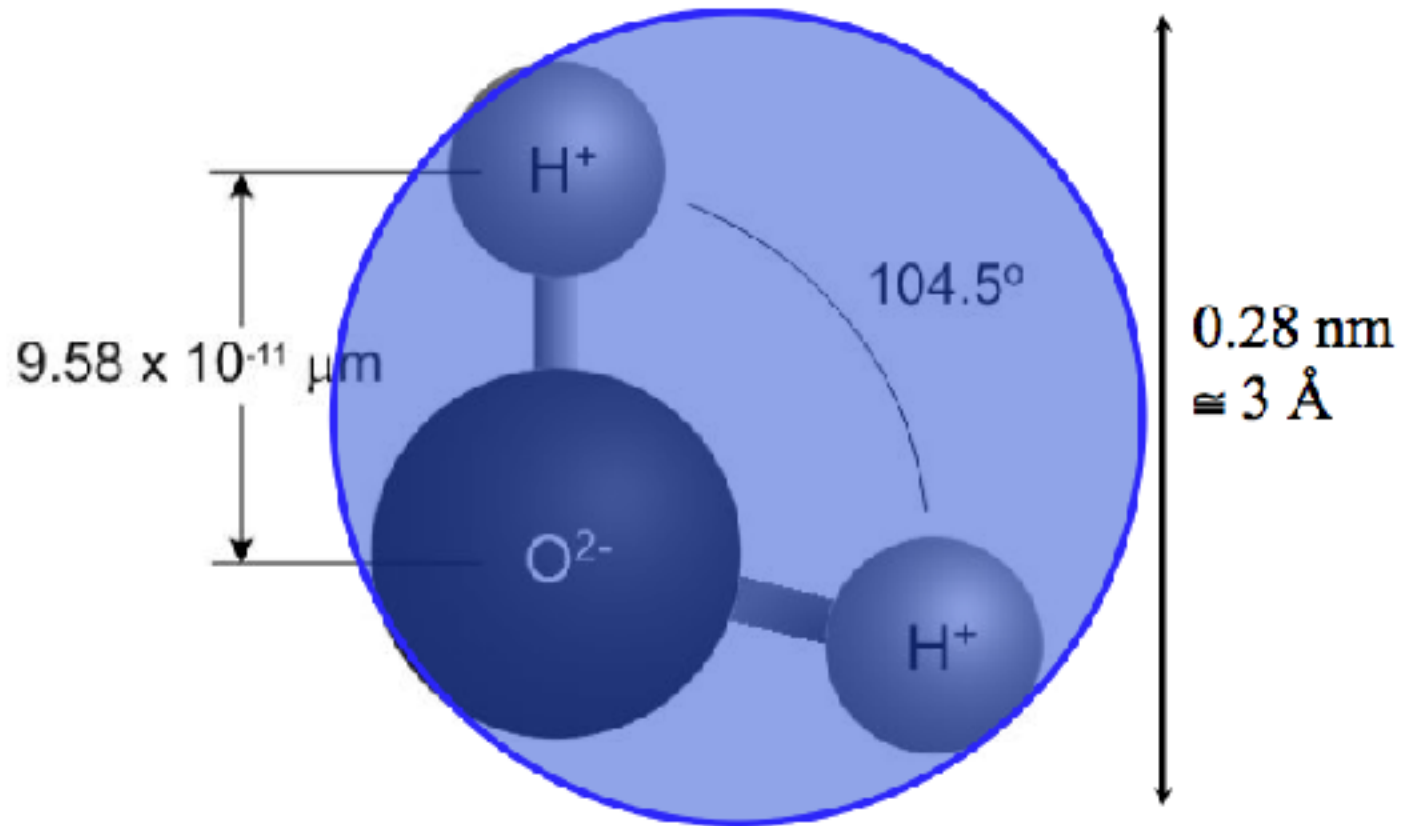




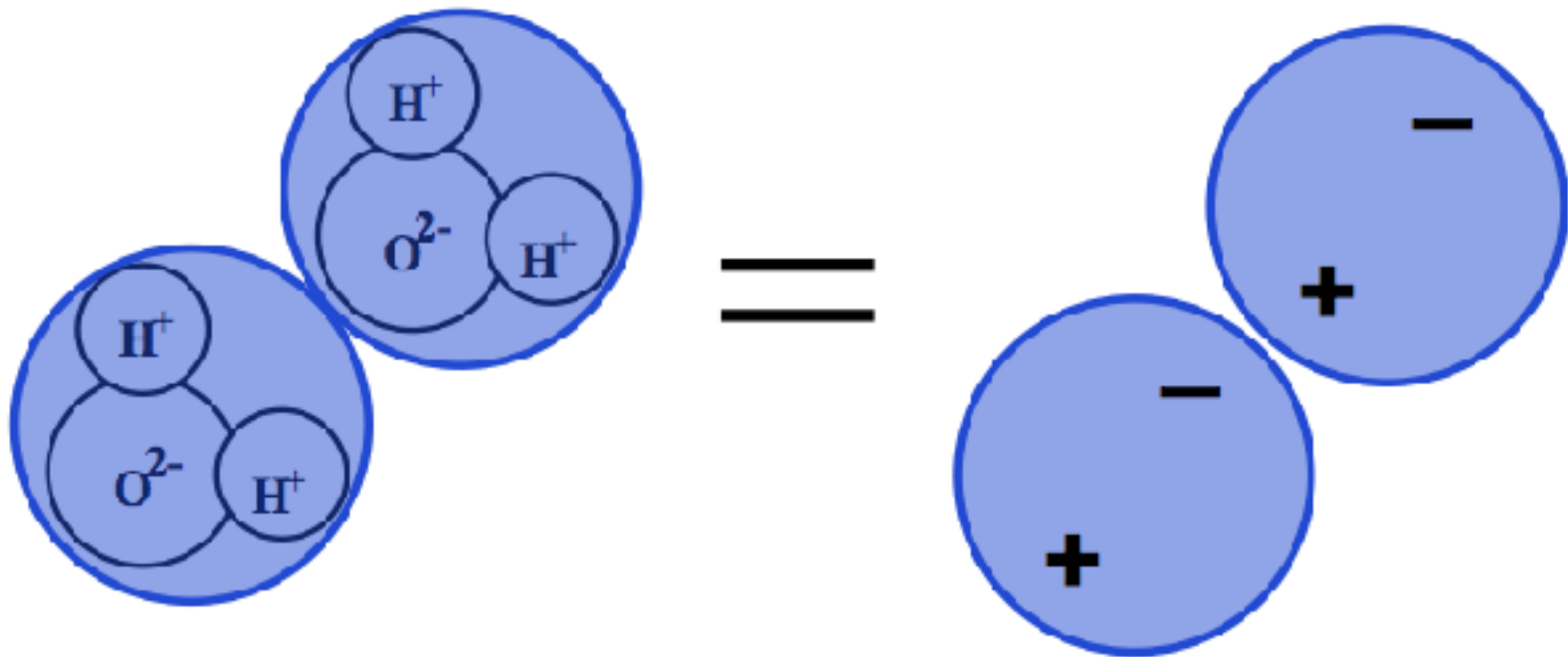
Exposure

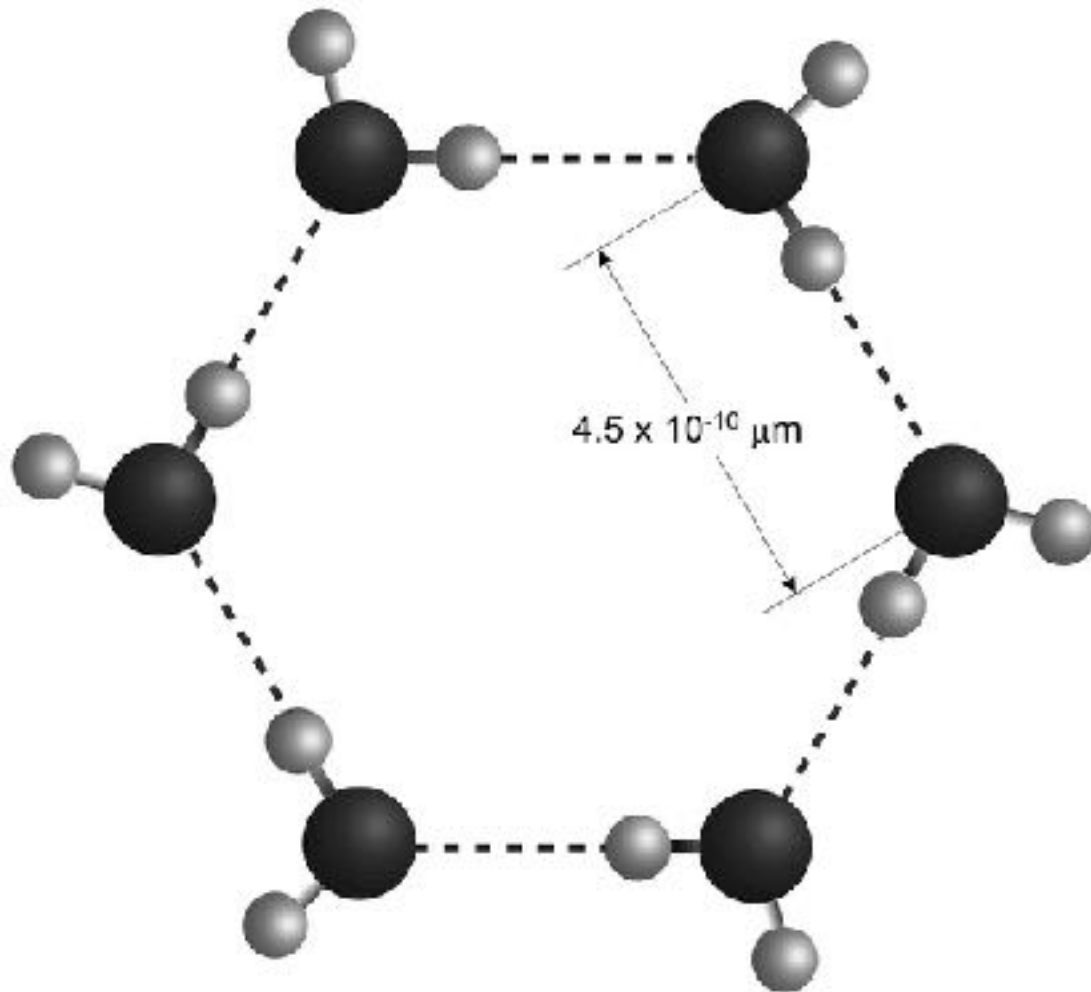
Extreme	Over 60"
High	40" - 60"
Moderate	20" - 40"
Low	Under 20"



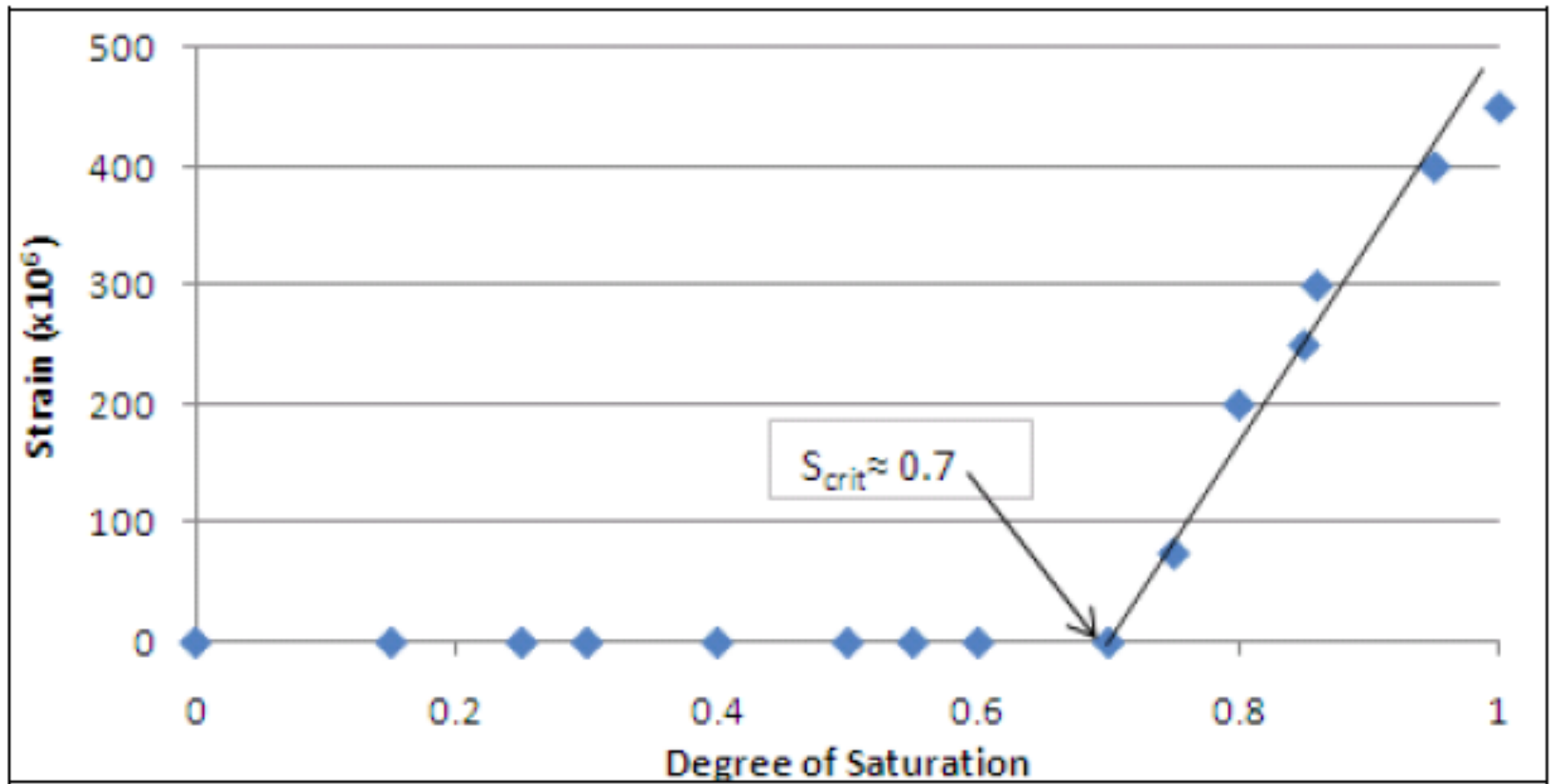






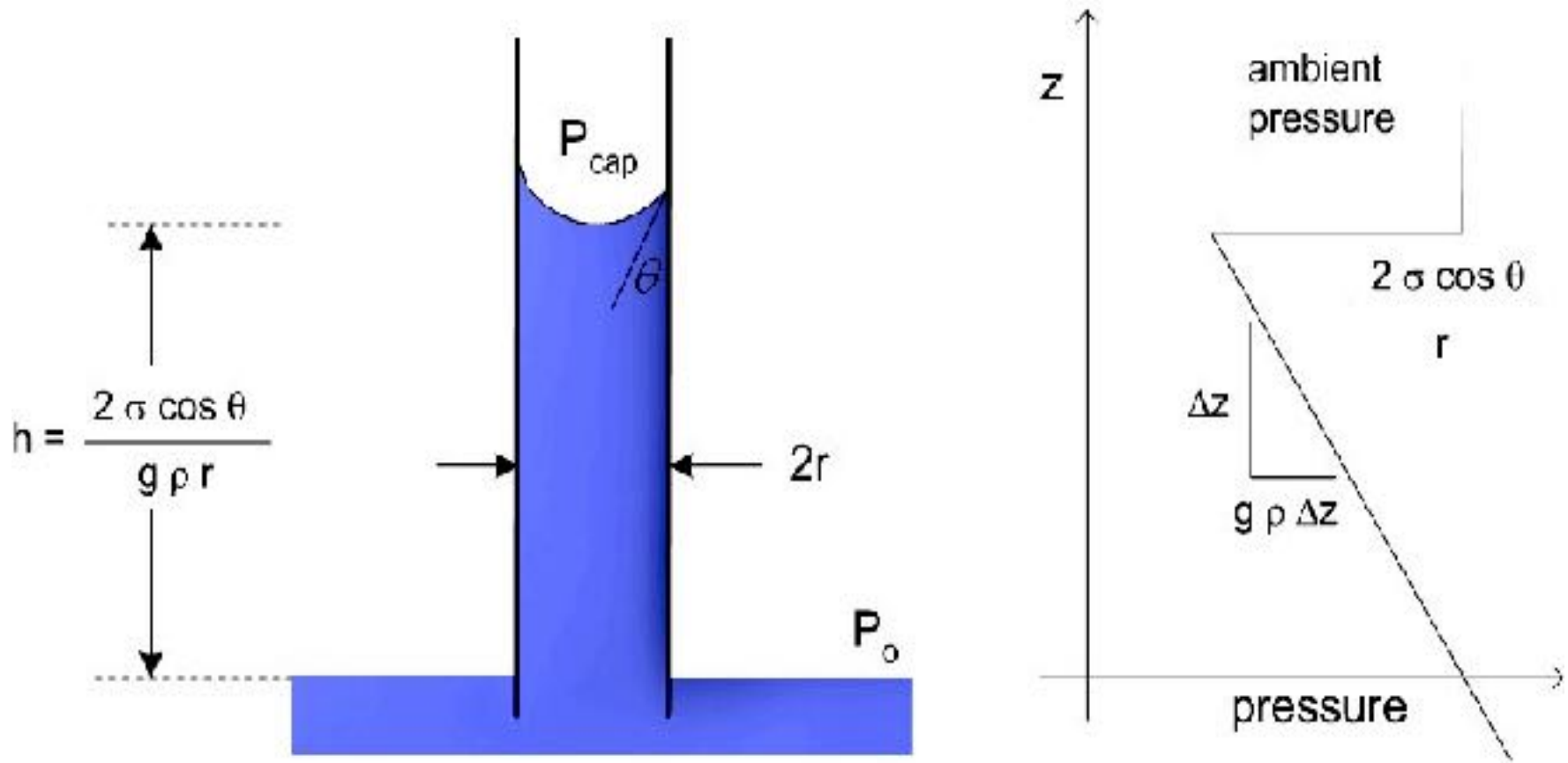


# Susceptible Brick Firing Temperature Vitrification

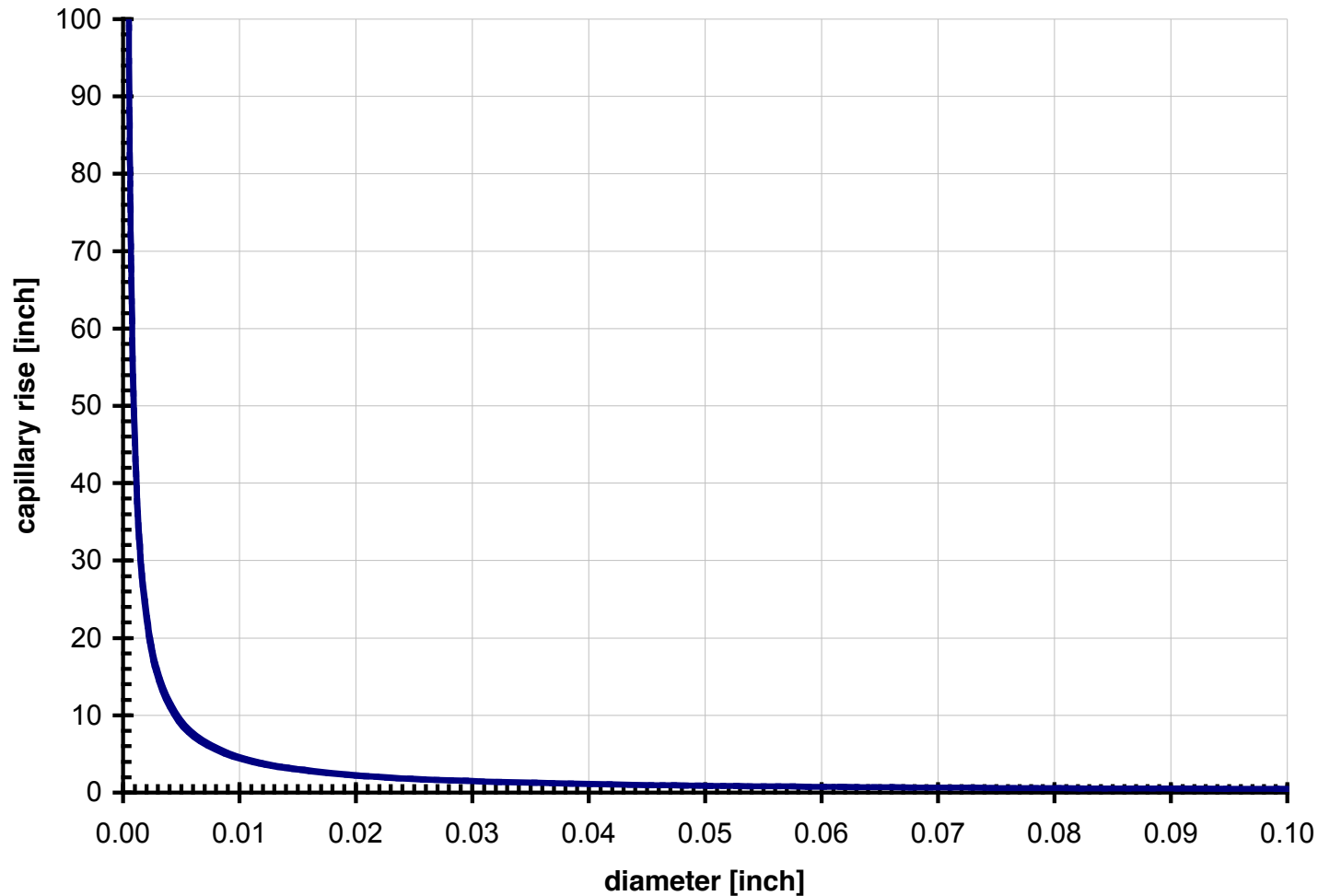


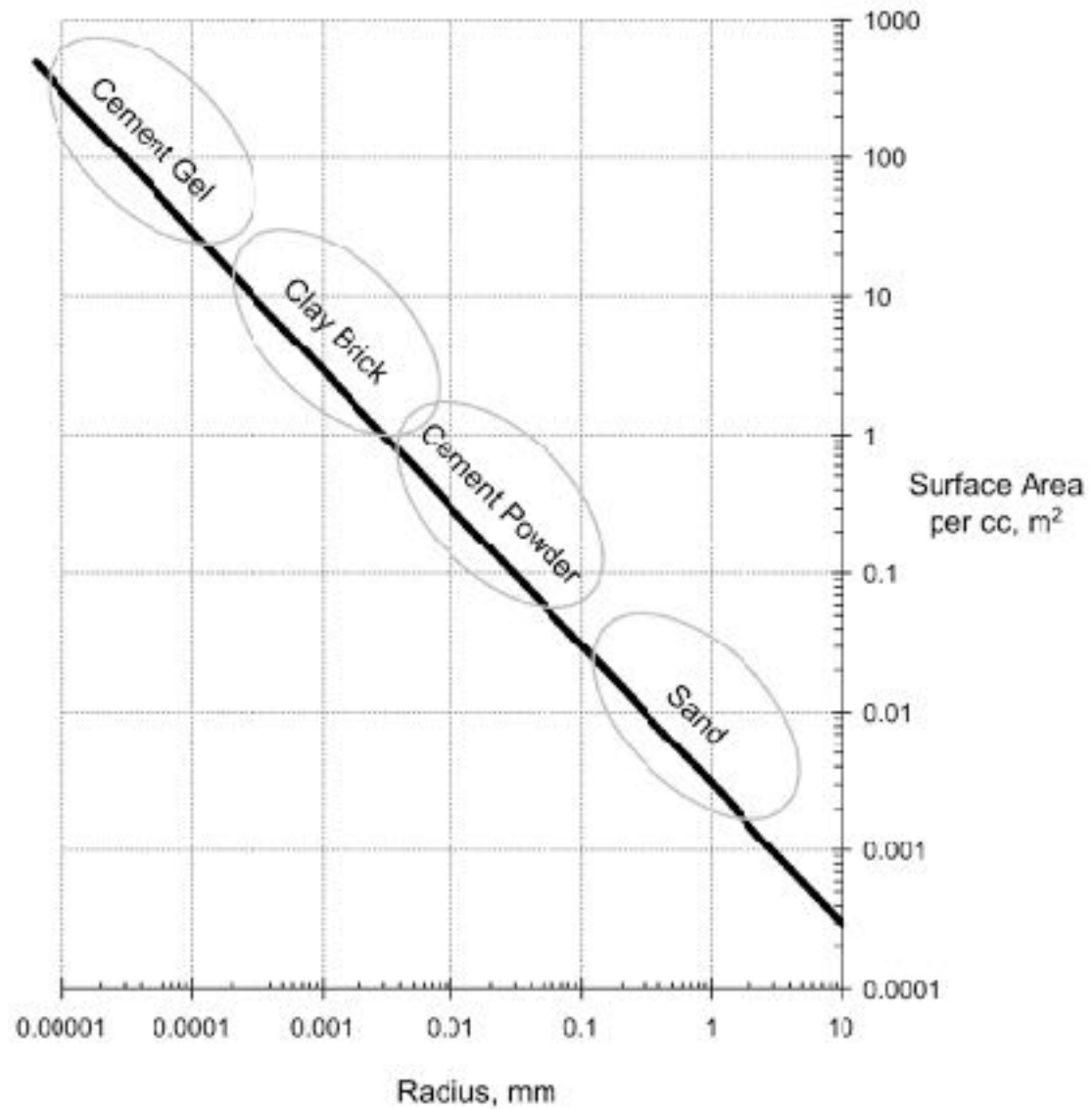


# Calculating capillary rise



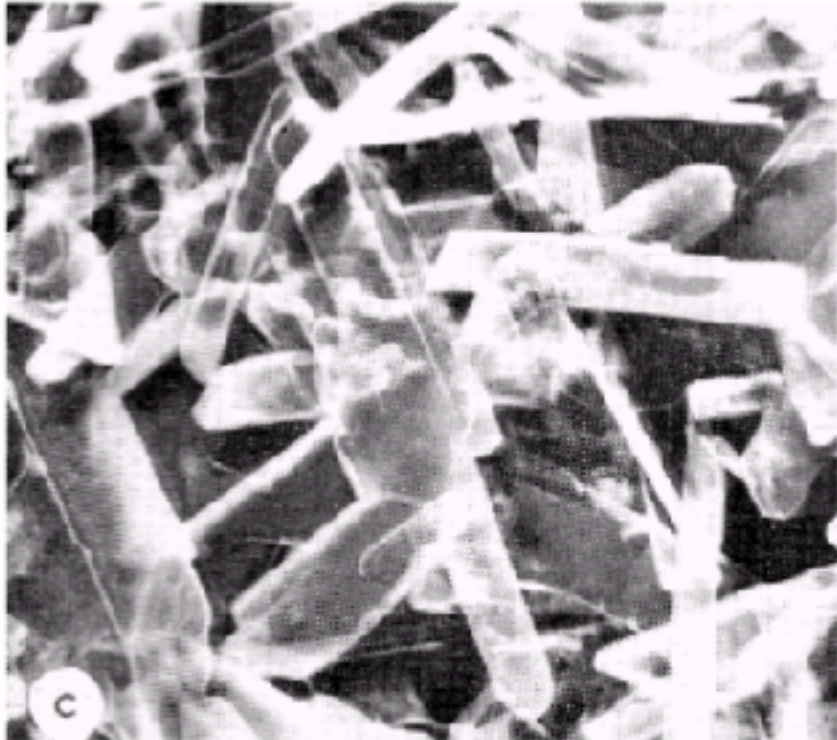
# Capillary rise versus diameter



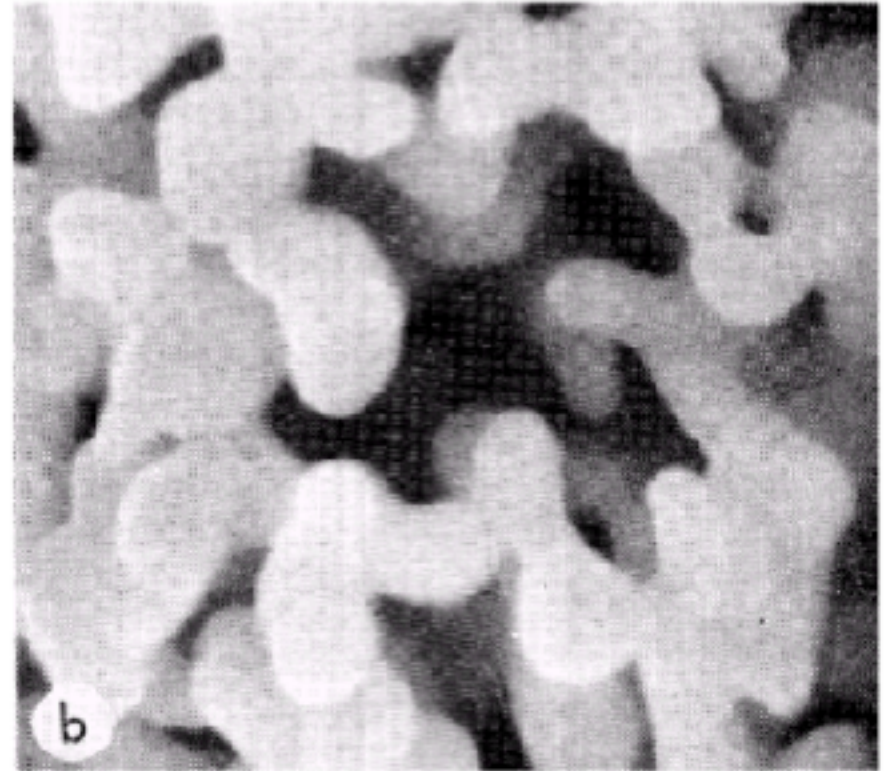


Surface area vs. particle size  
From Straube & Burnett, 2005

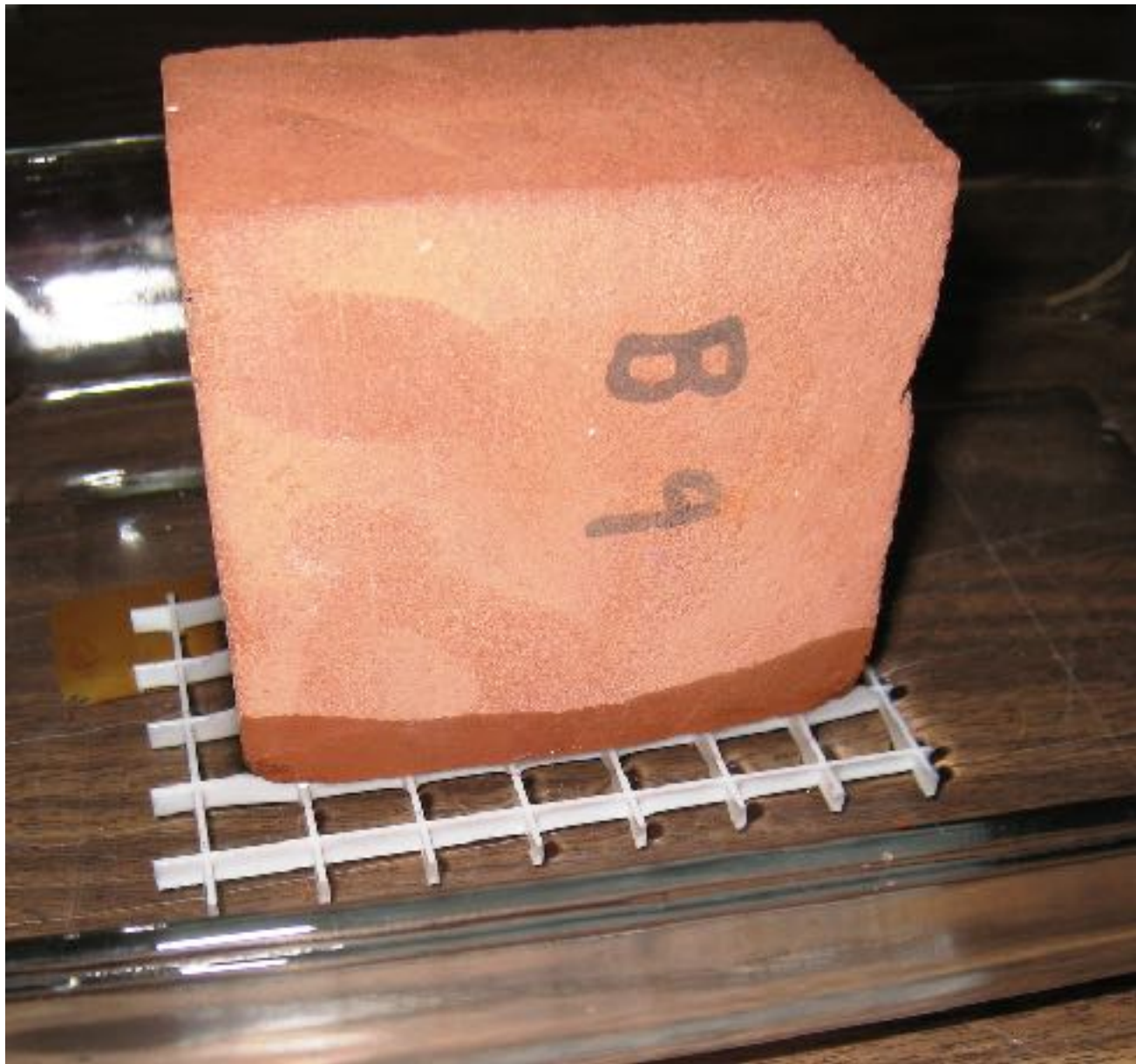


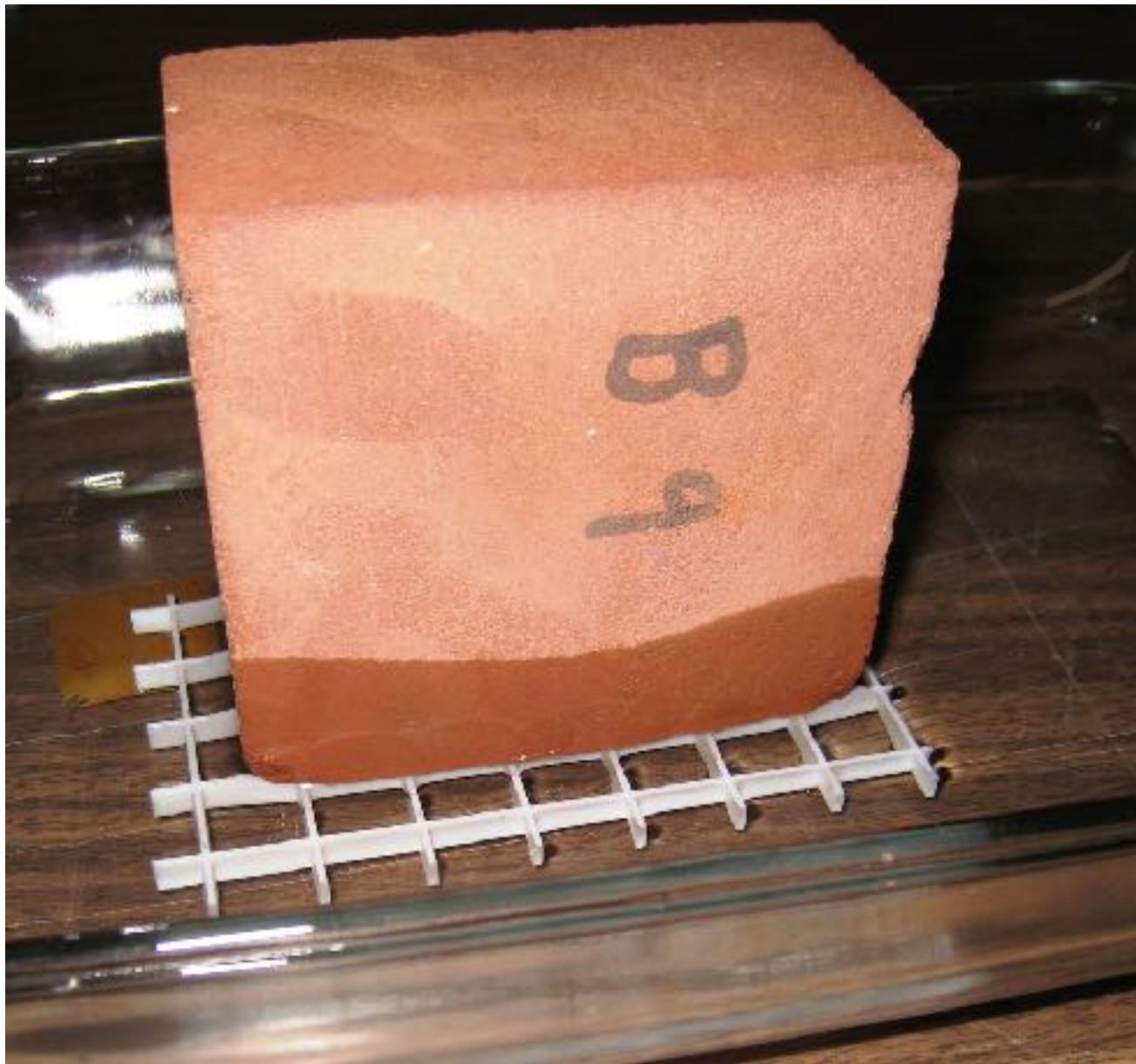


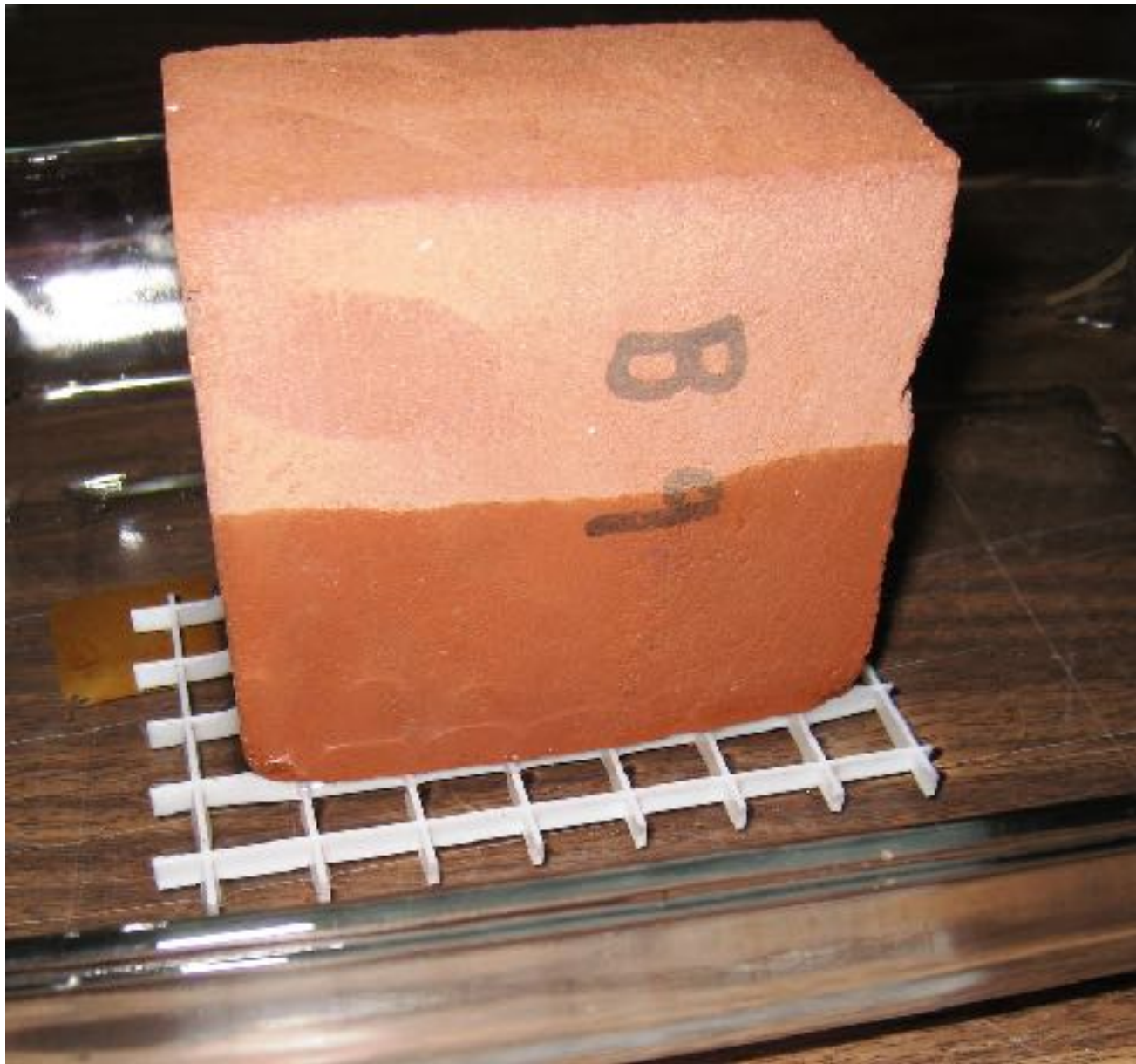
*Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.*

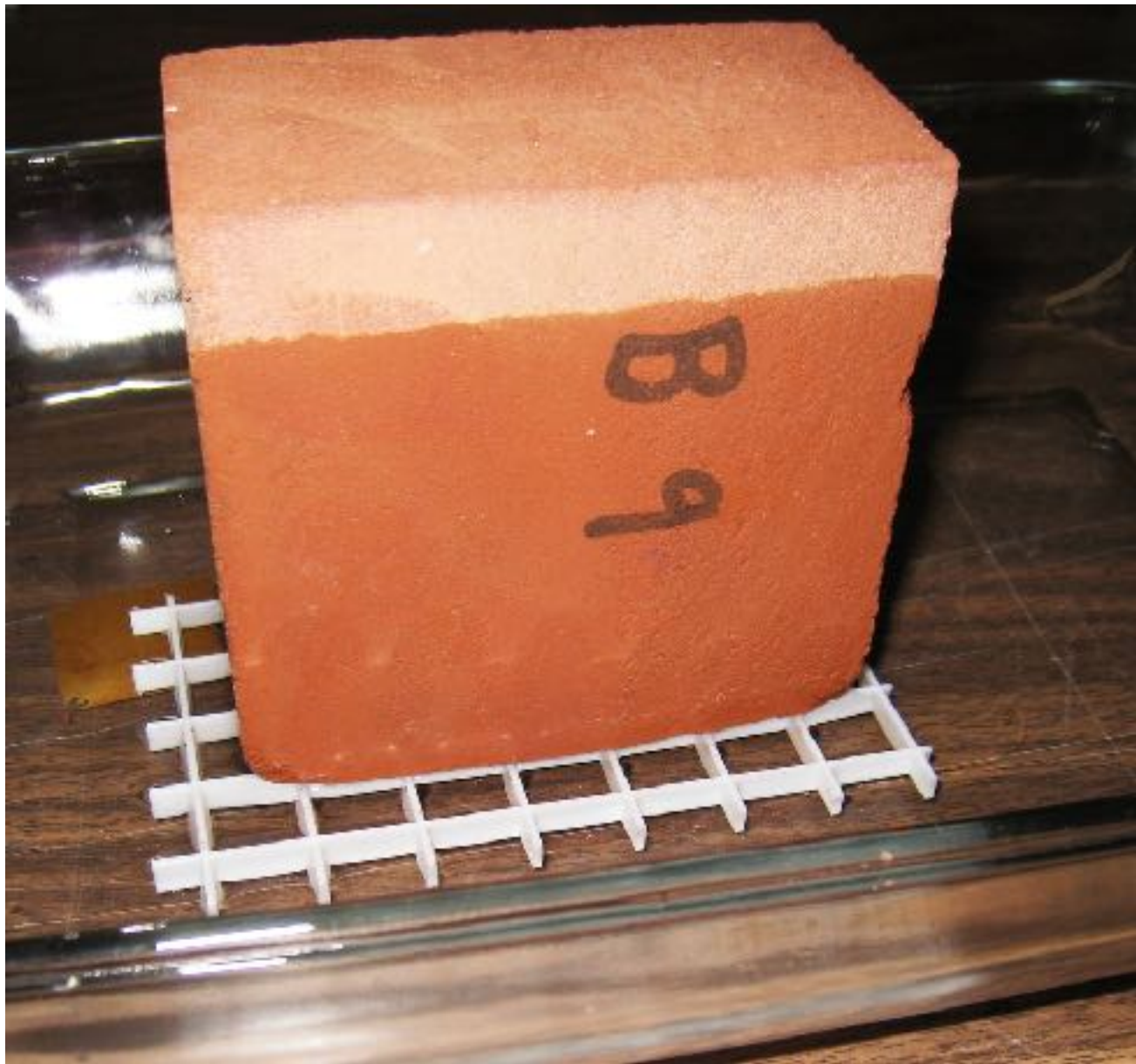


*Figure 1b. Brick, sintered clay, porosity 40 per cent.*

























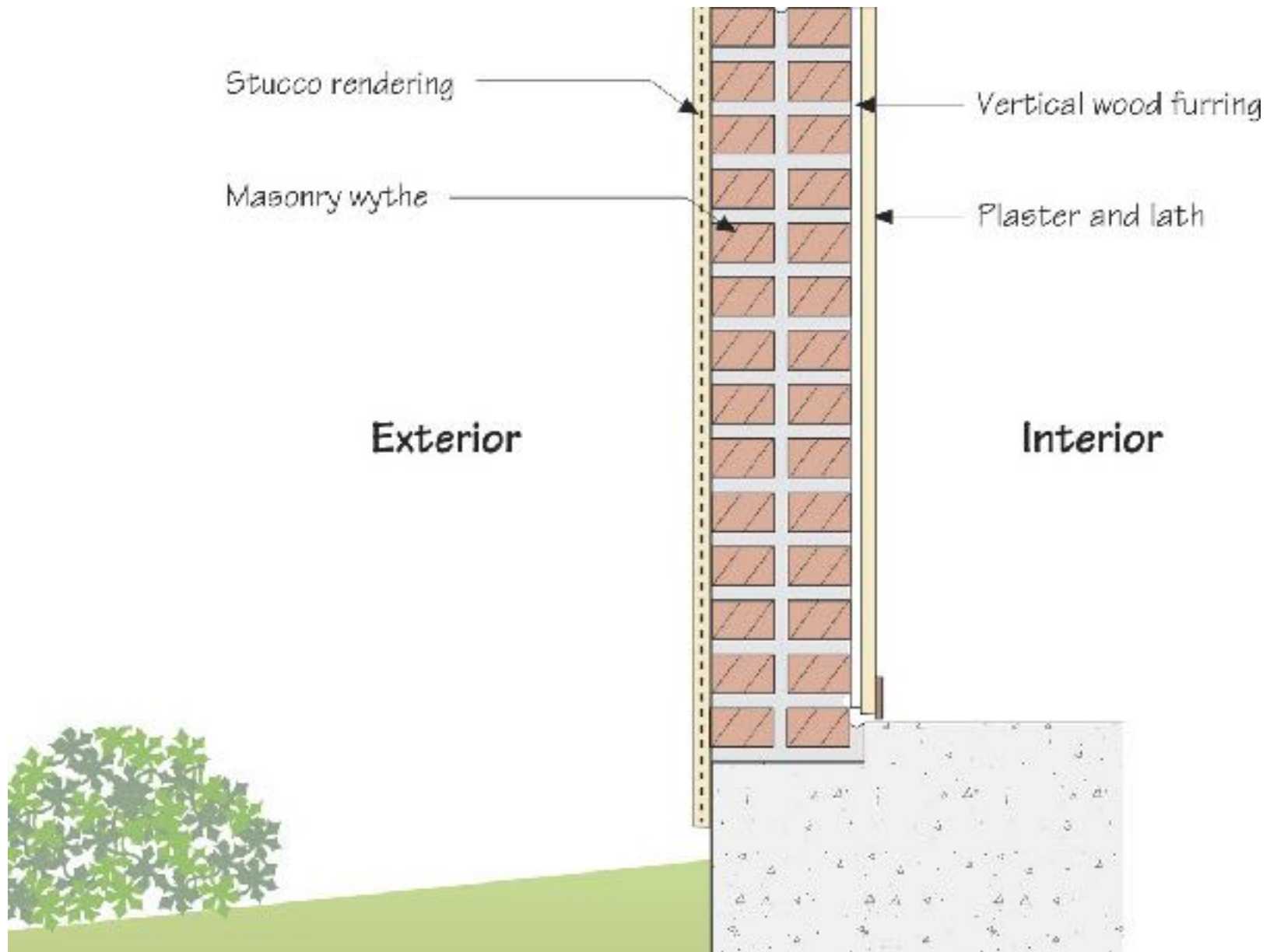












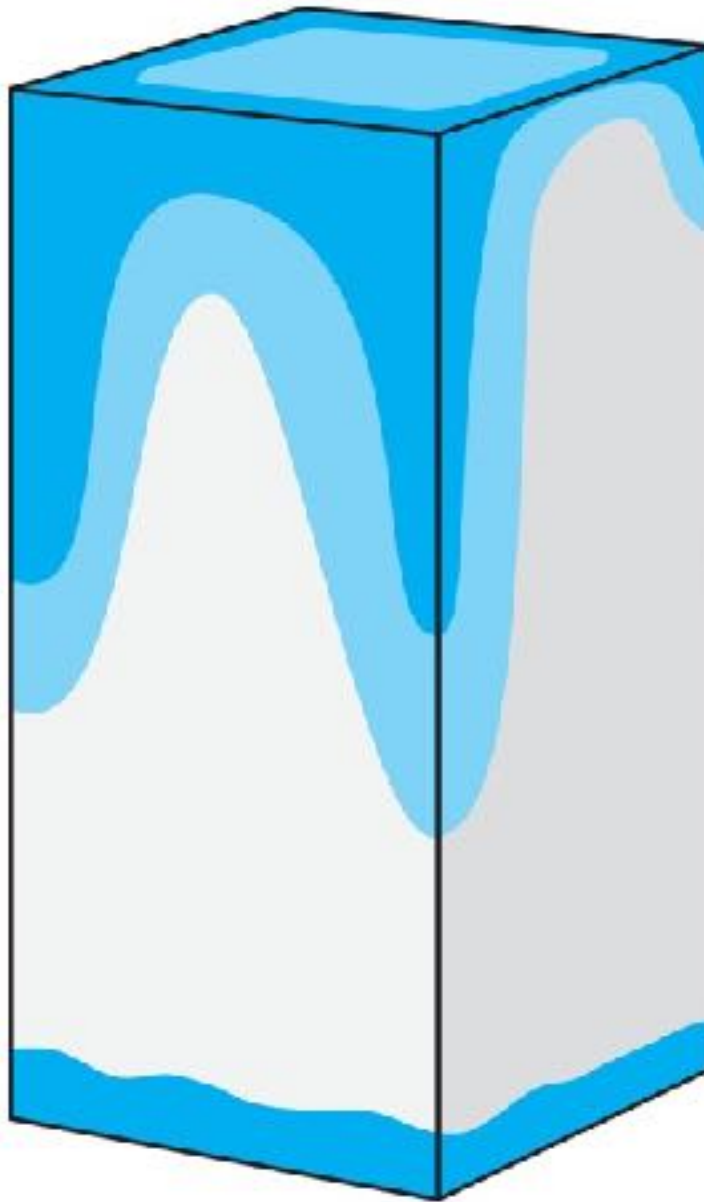


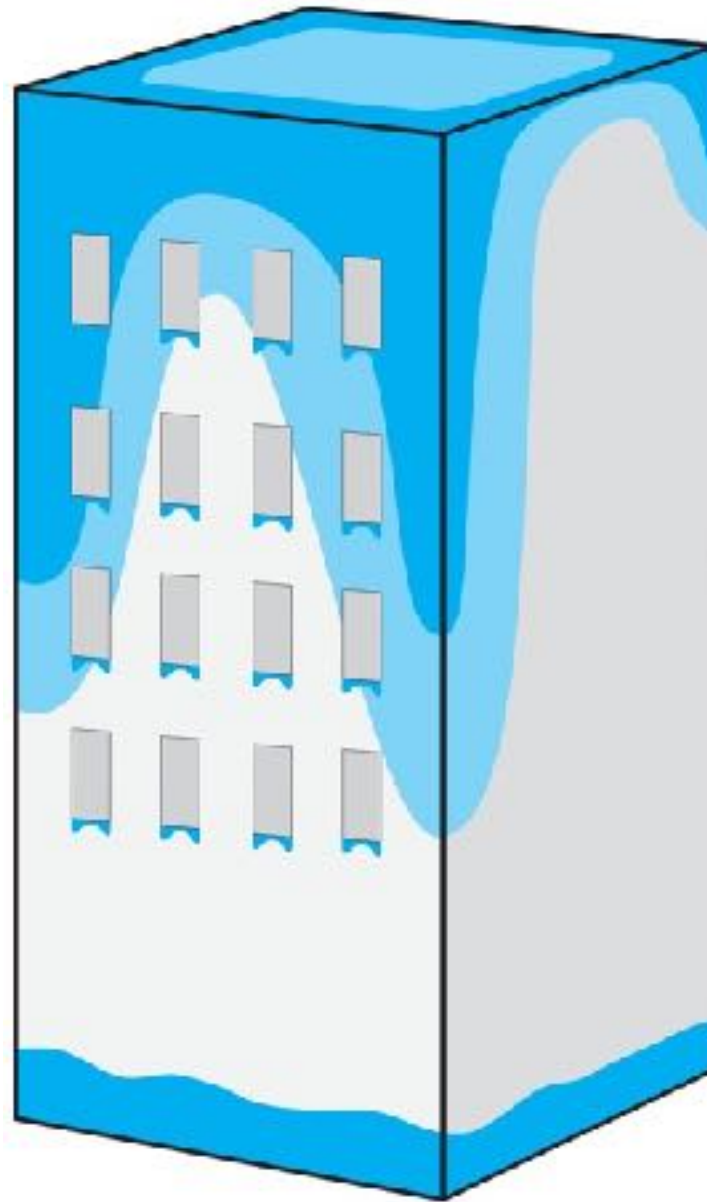












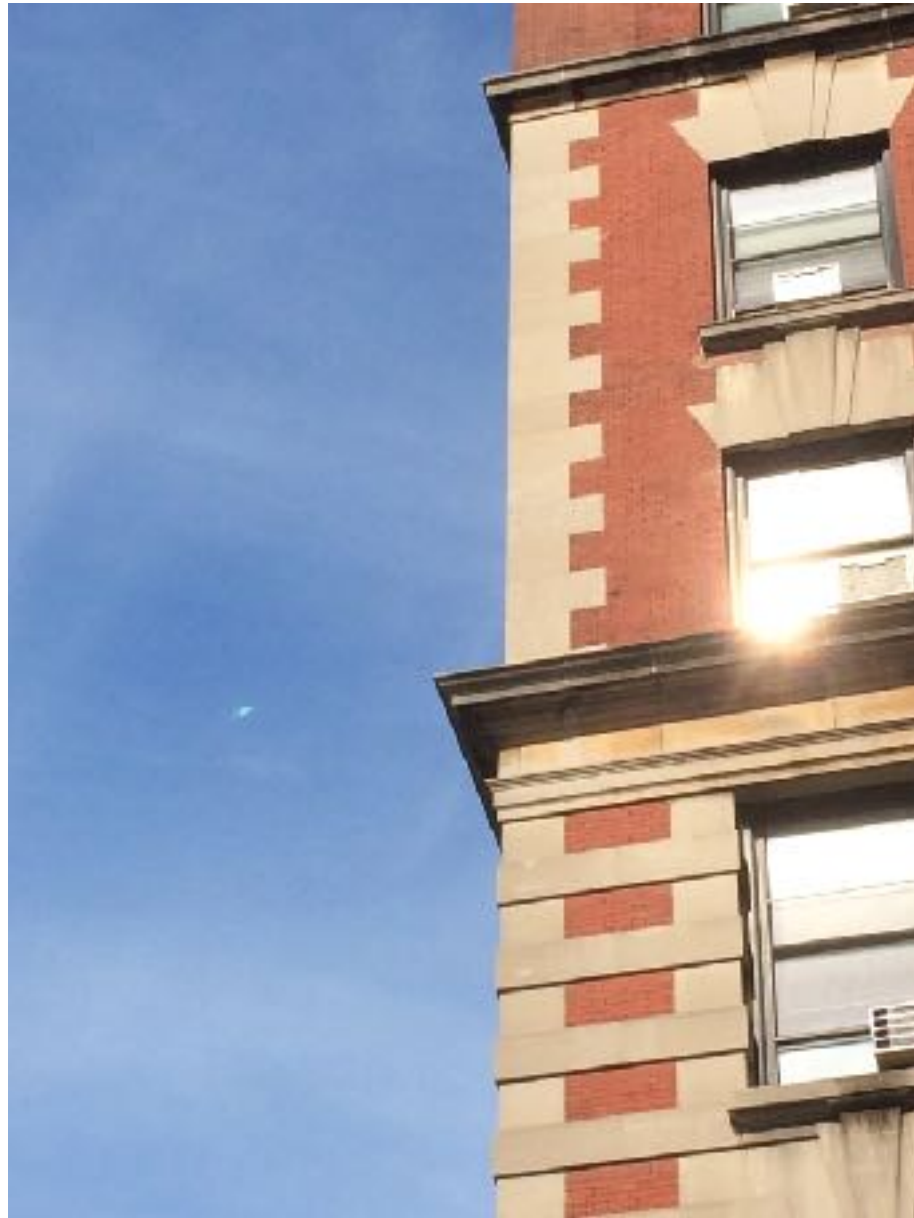
























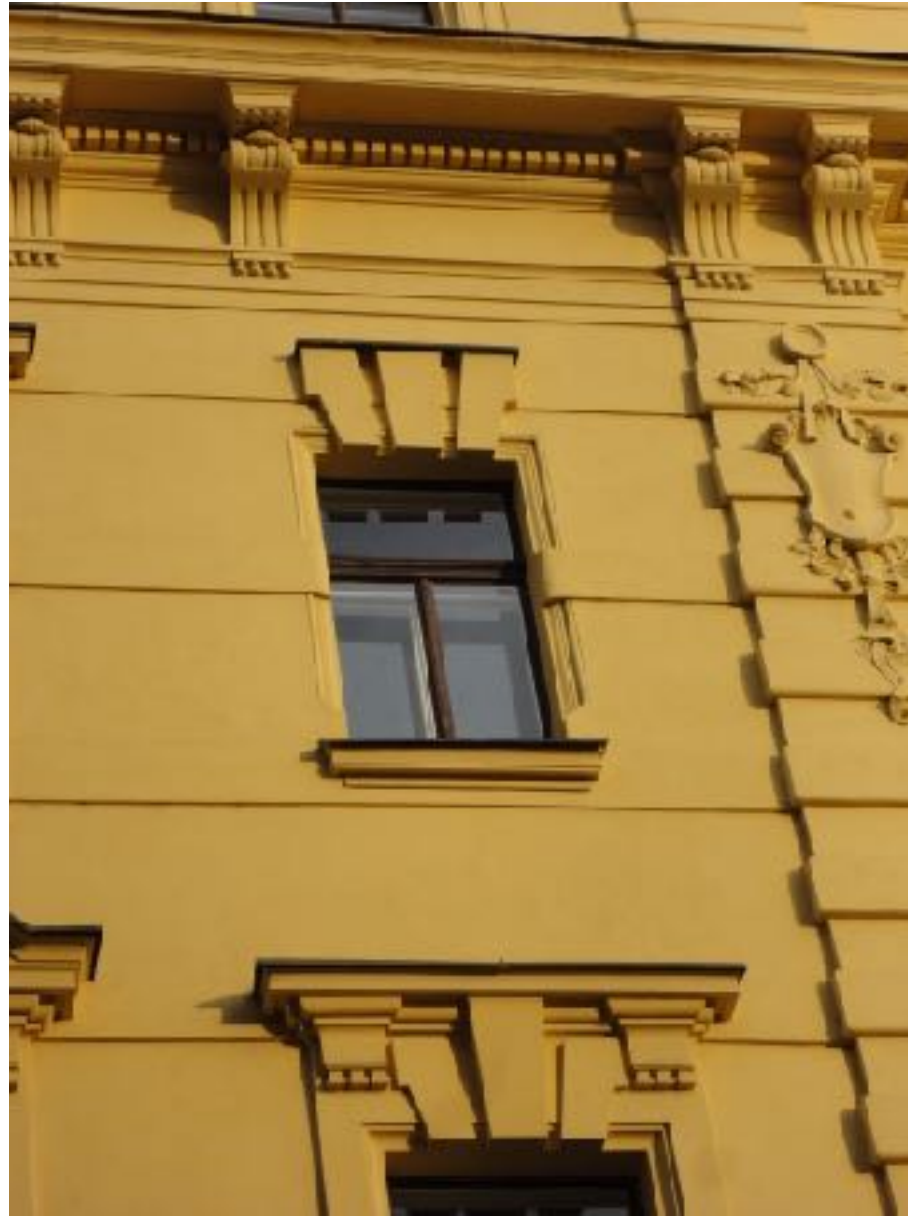














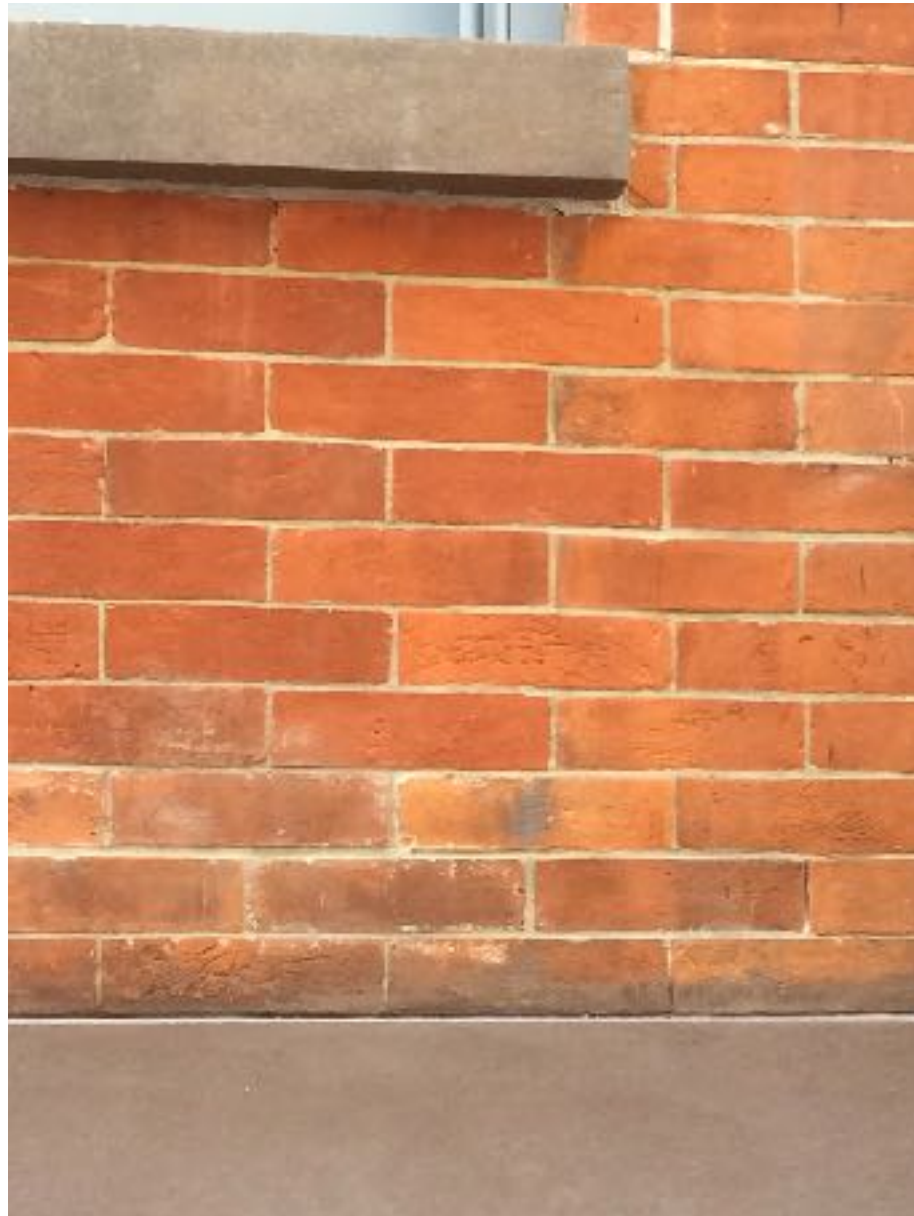






















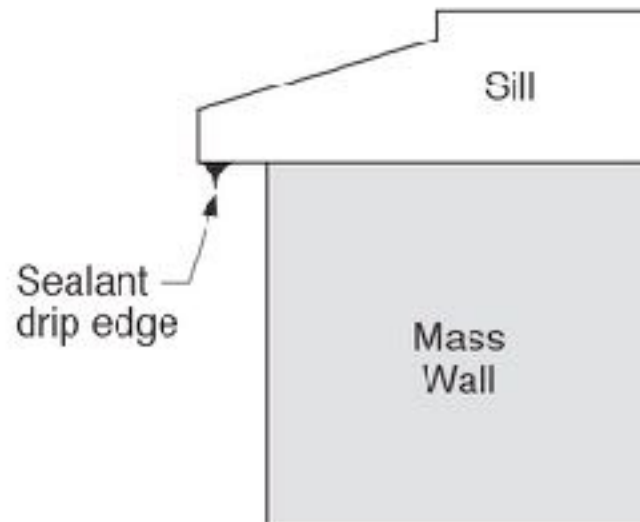
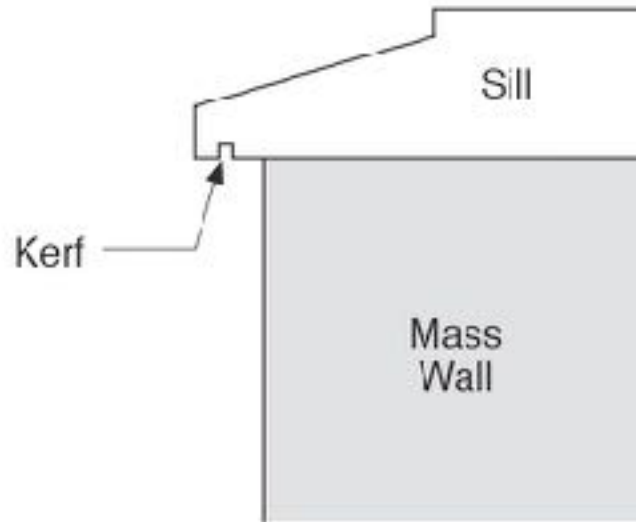


































































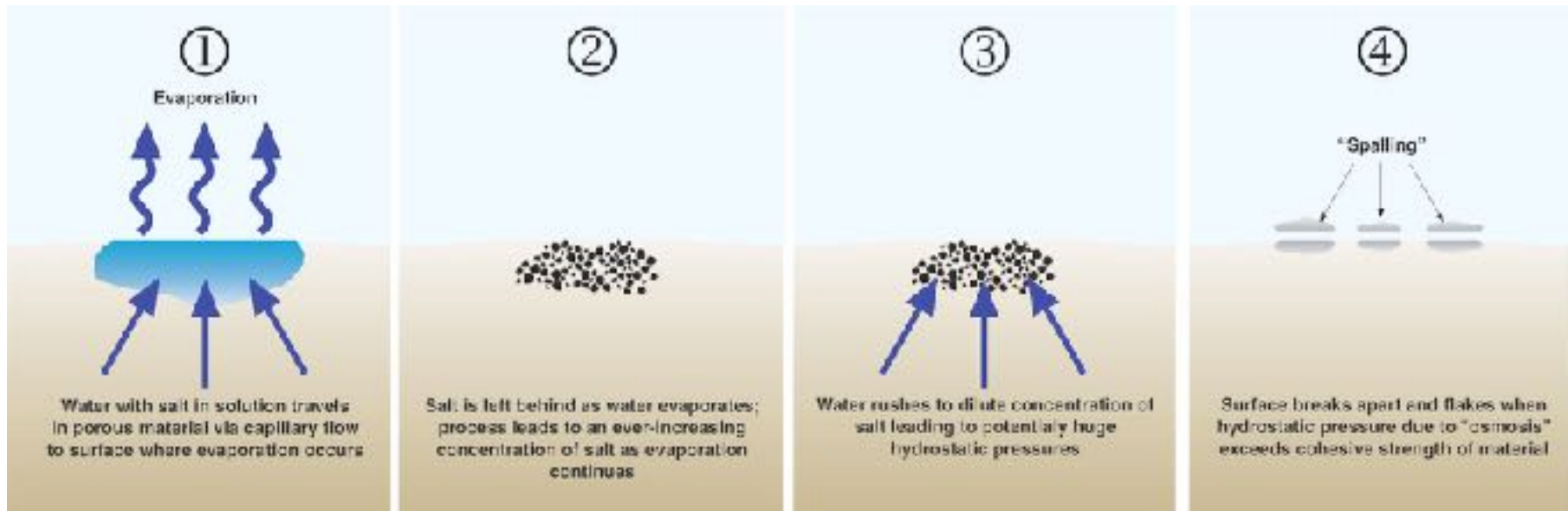












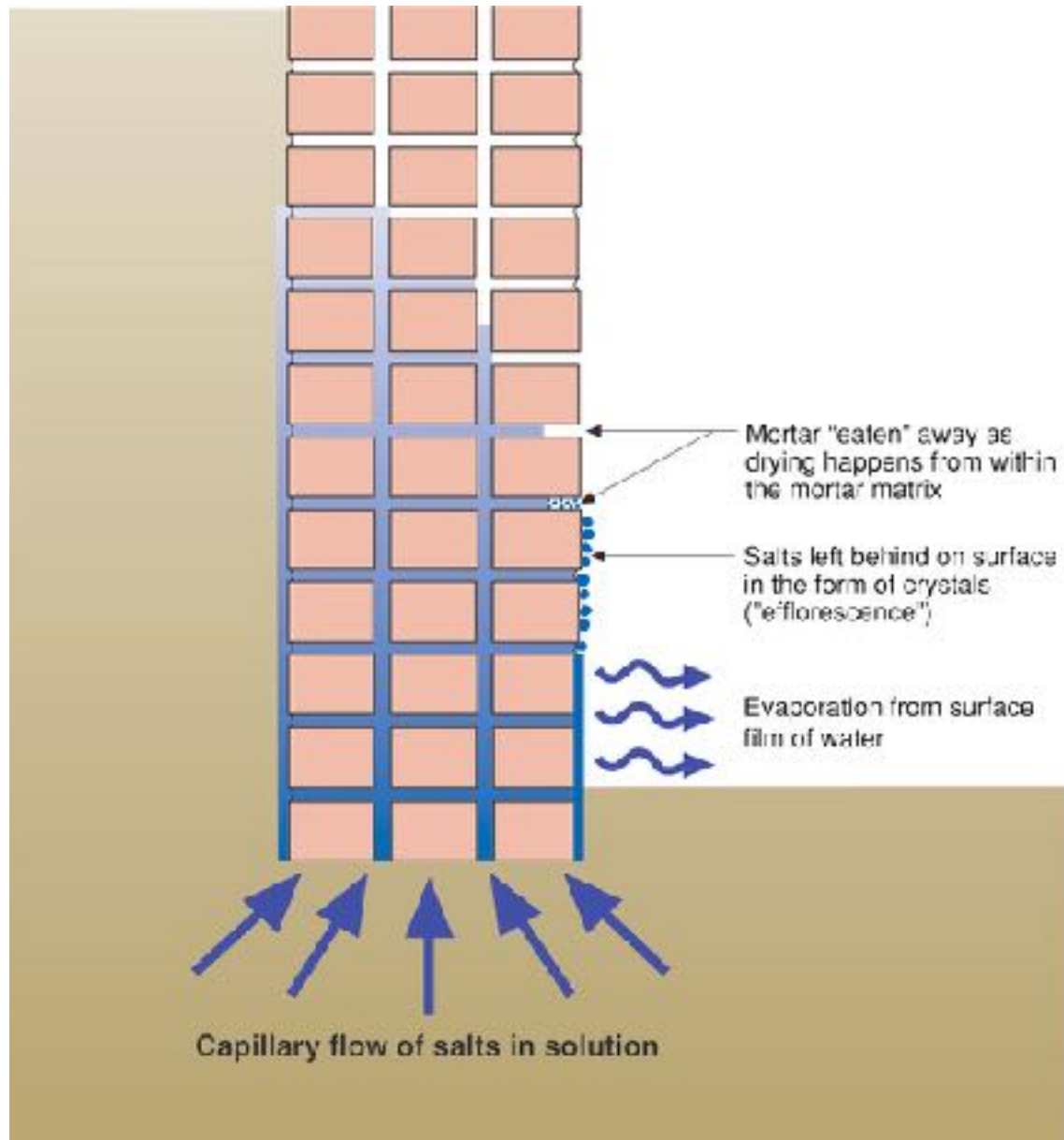
# Diffusion + Capillarity + Osmosis = Problem

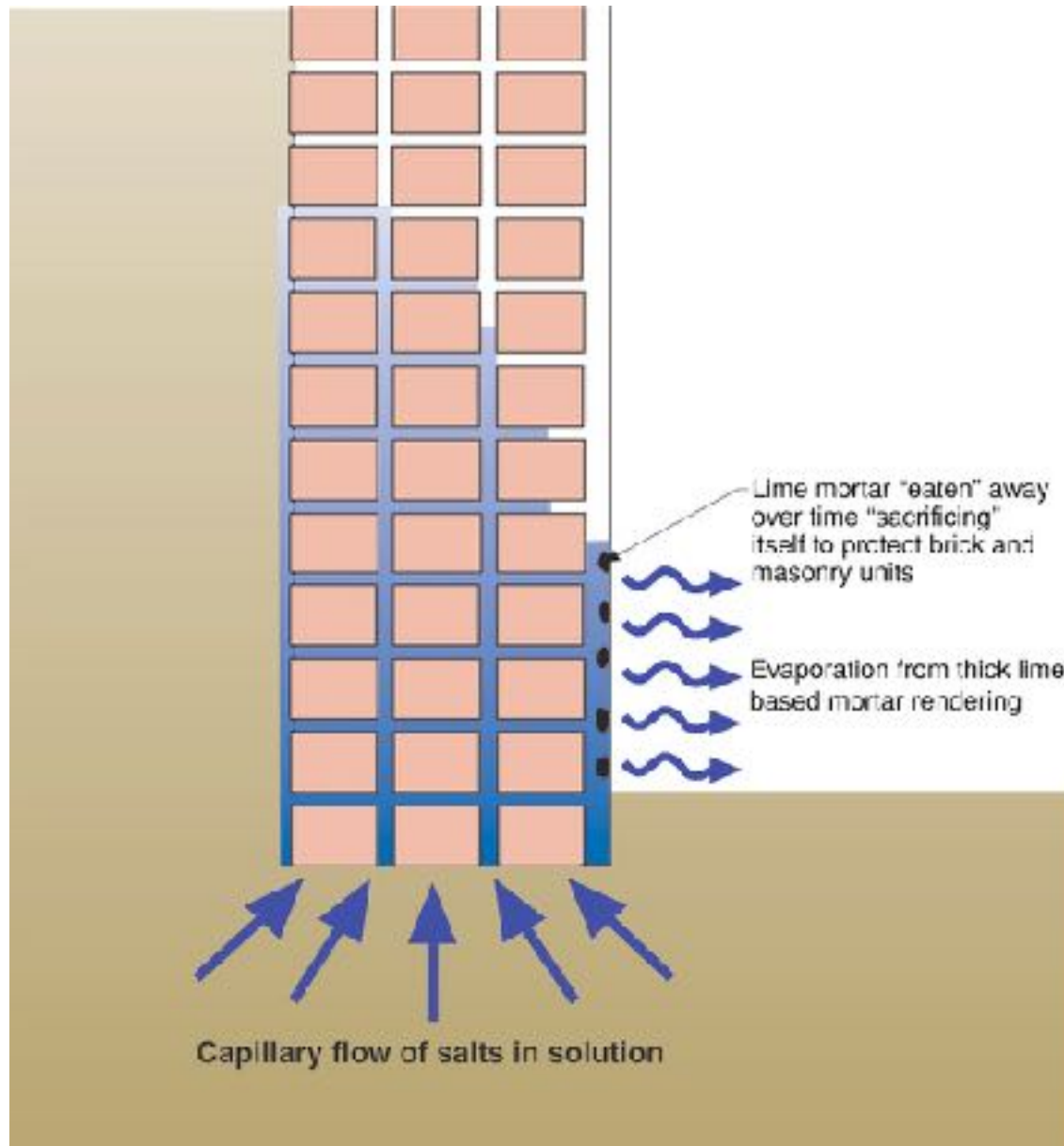
- Diffusion Vapor Pressure 3 to 5 psi
- Capillary Pressure 300 to 500 psi
- Osmosis Pressure 3,000 to 5,000 psi















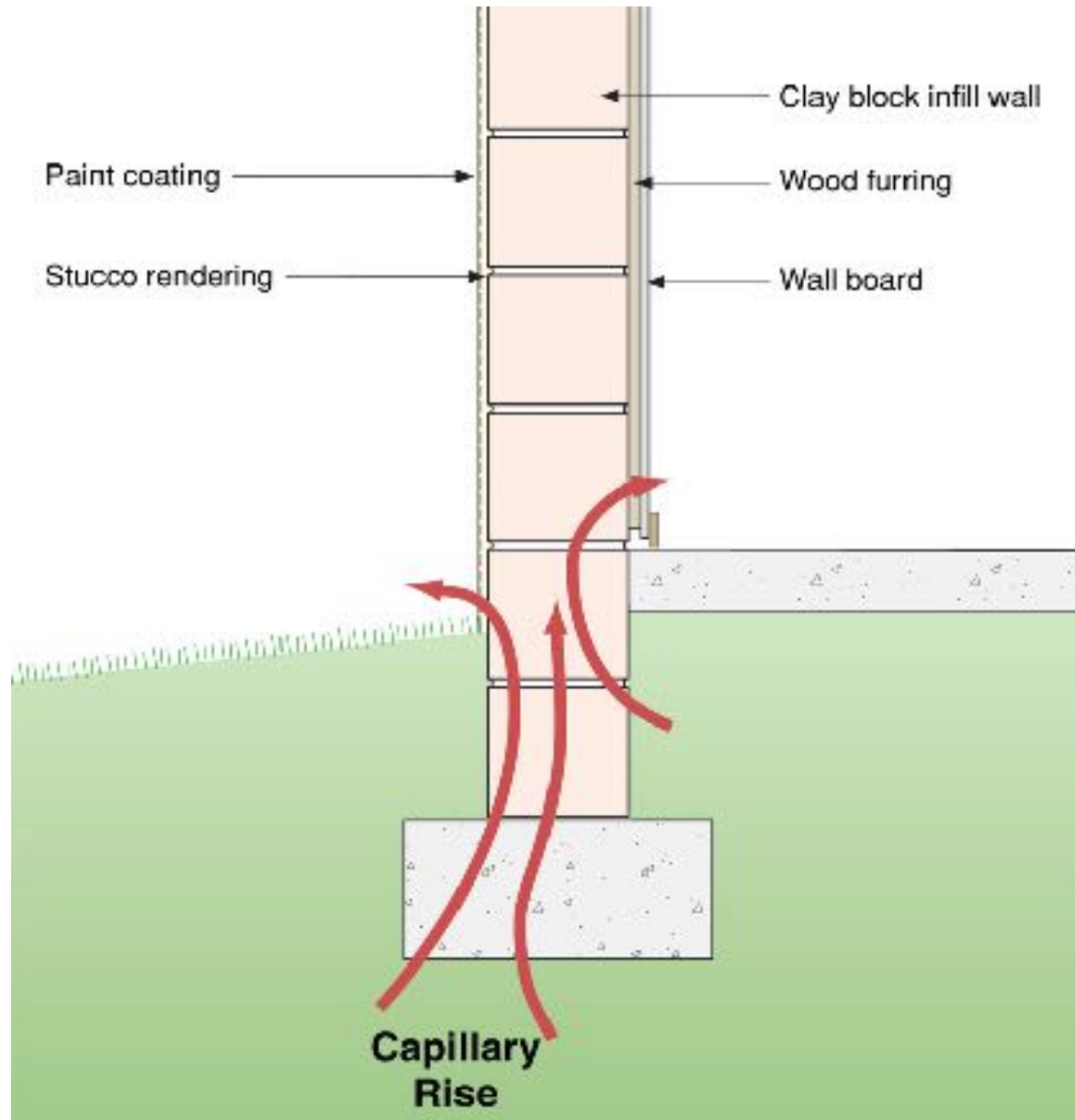


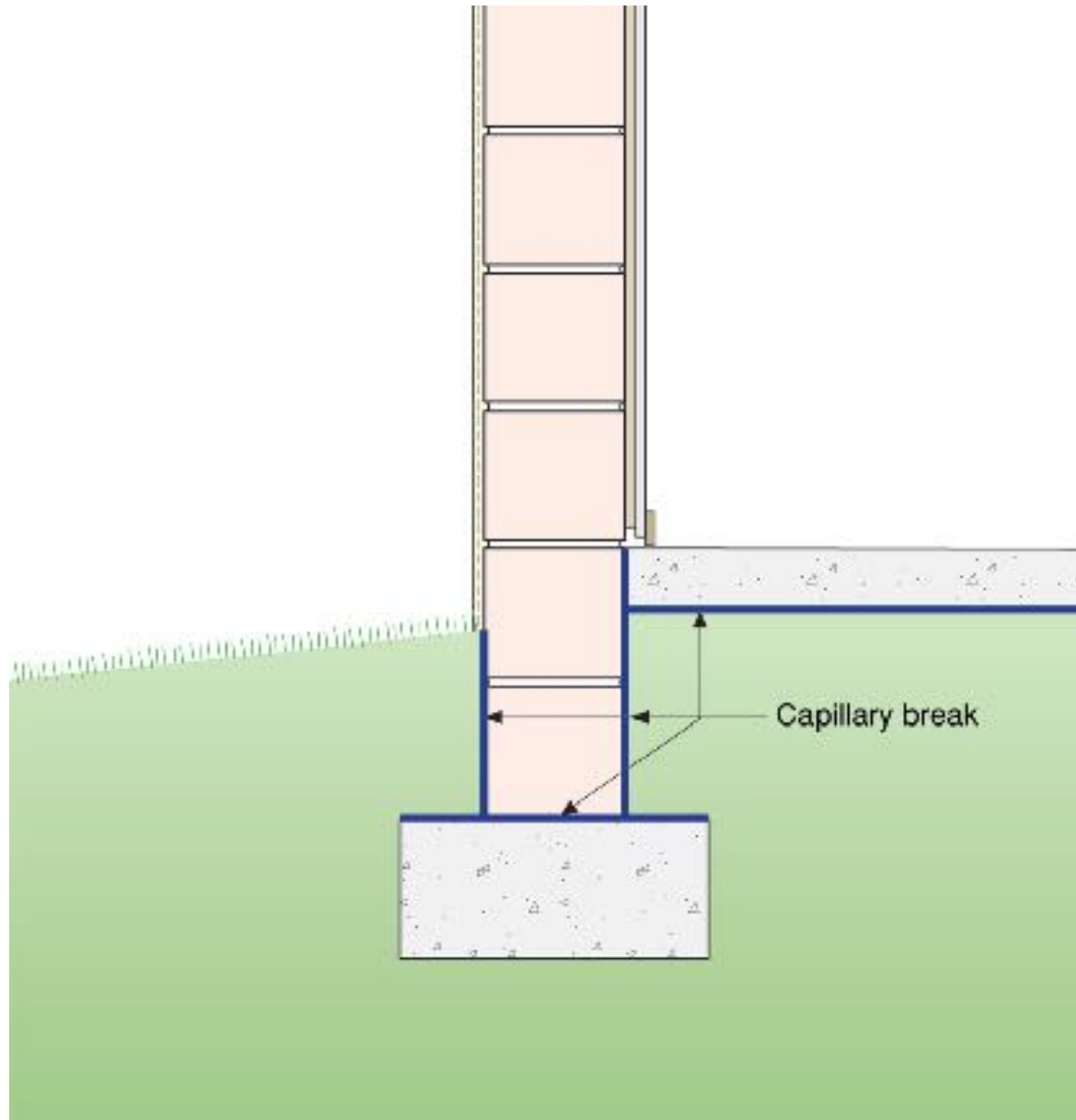




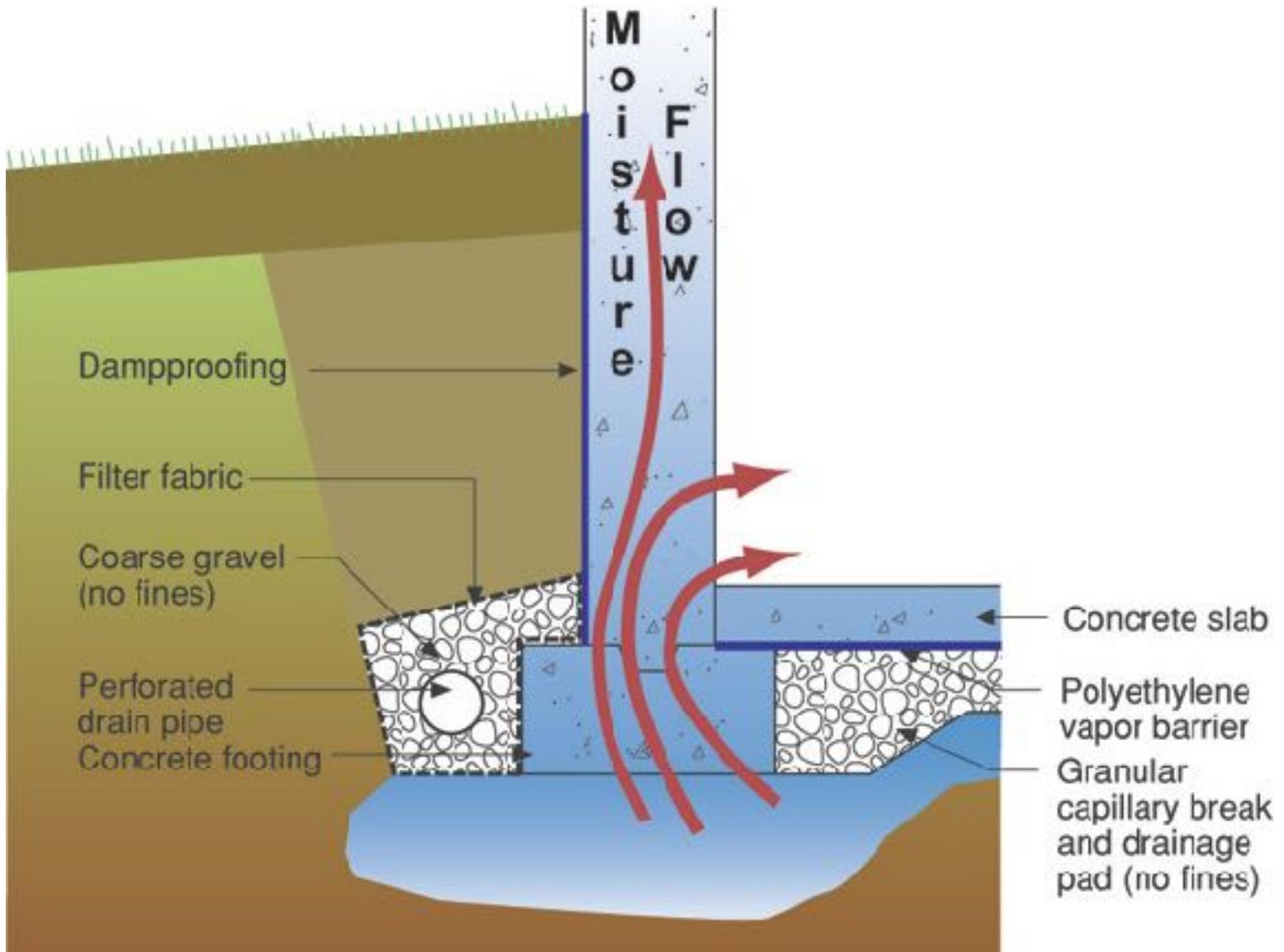


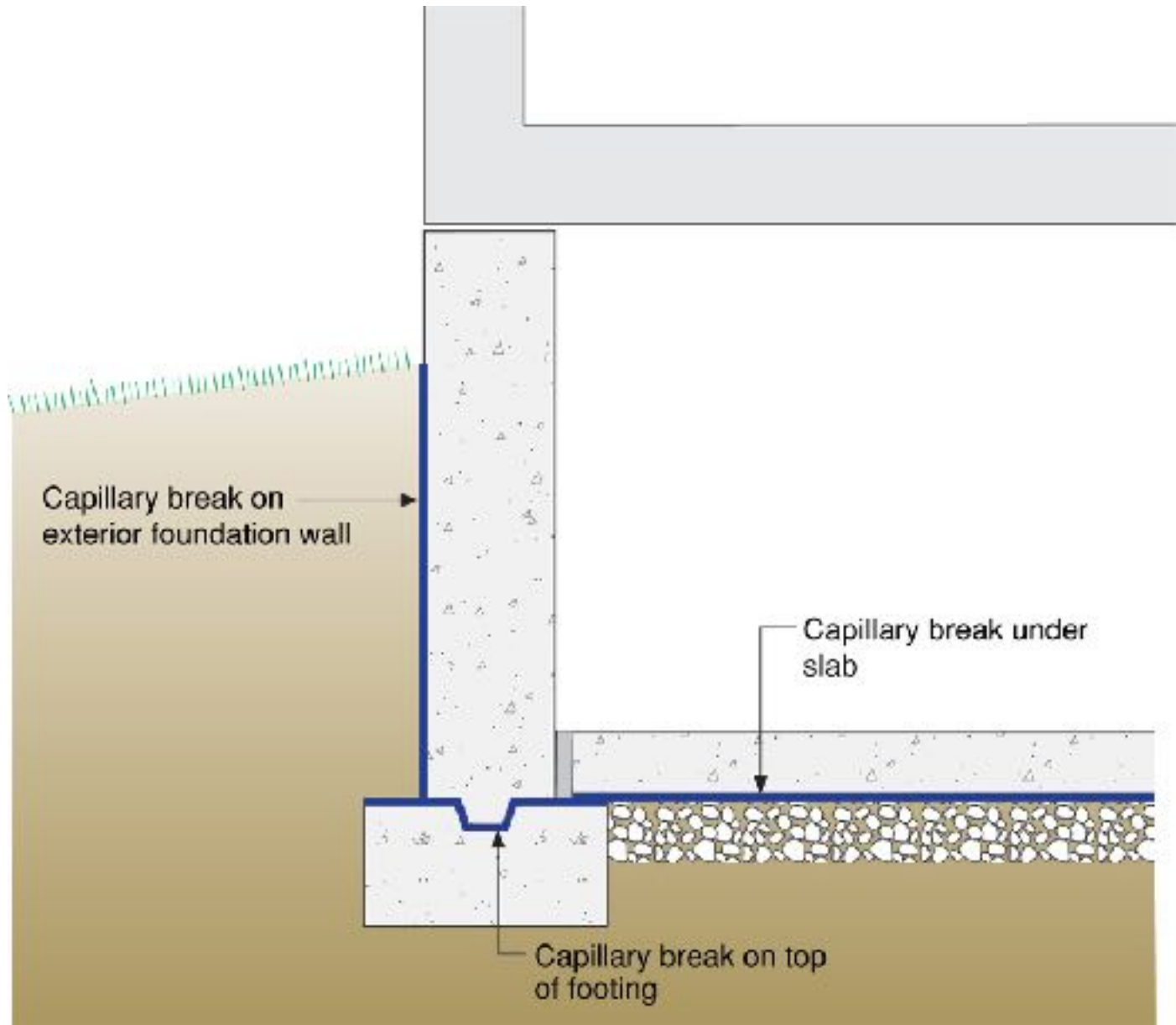














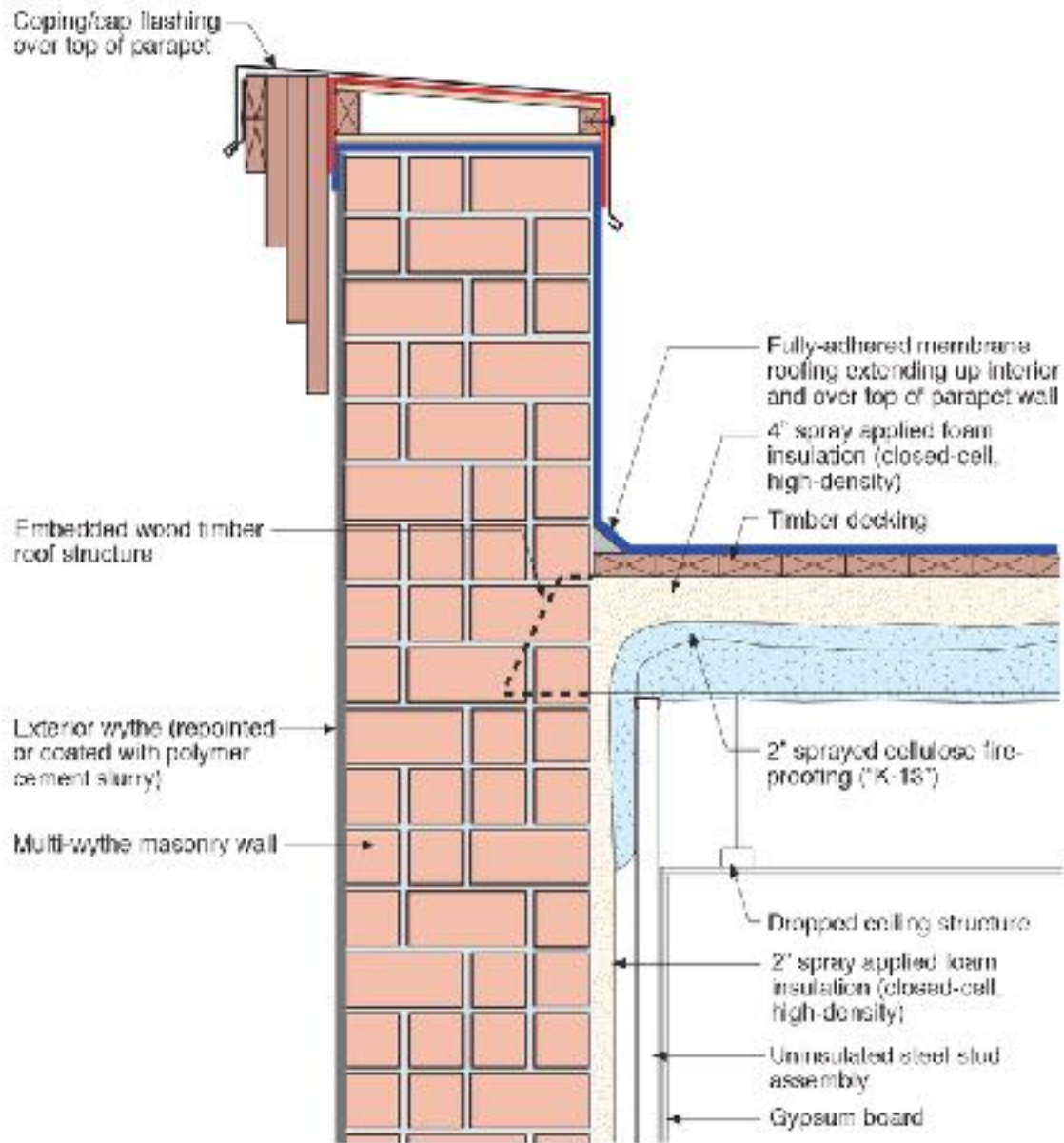






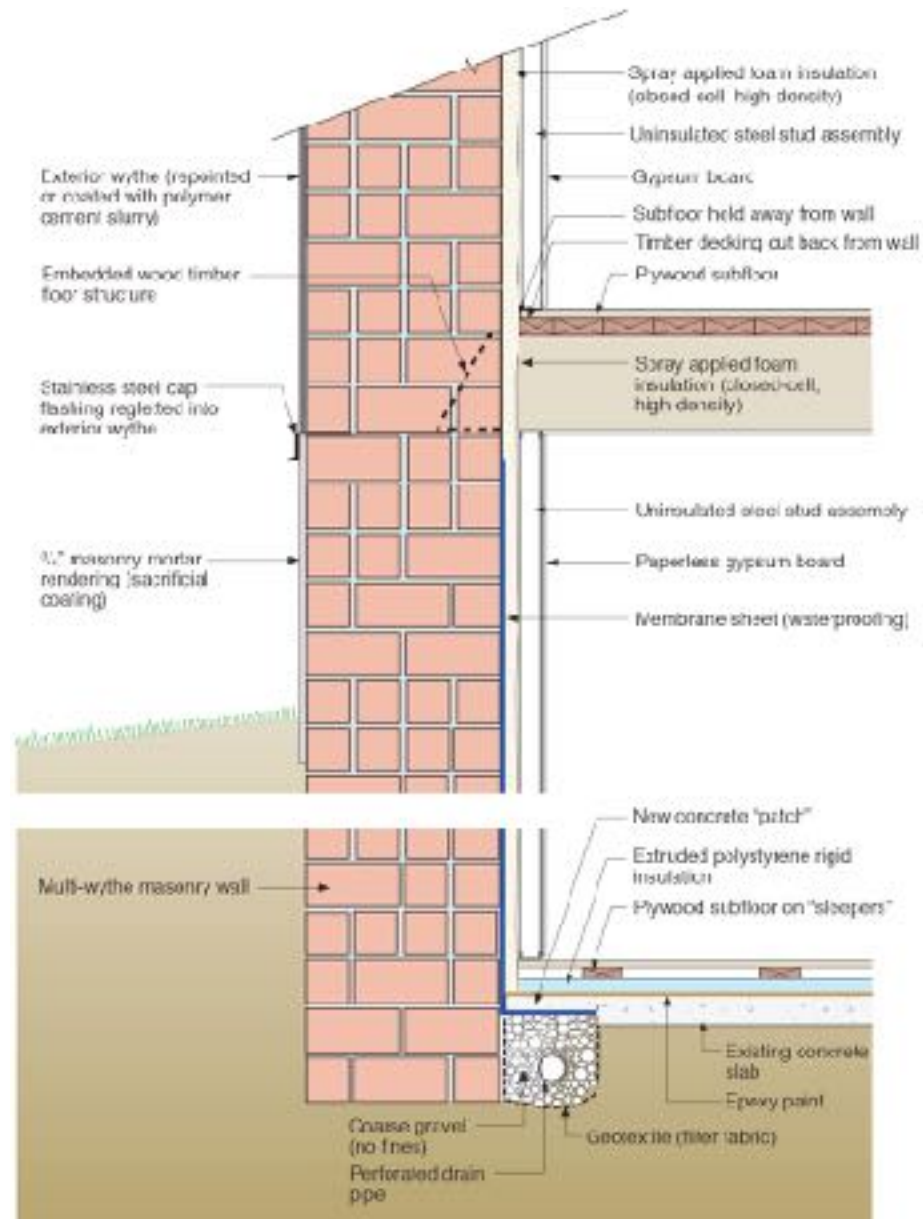


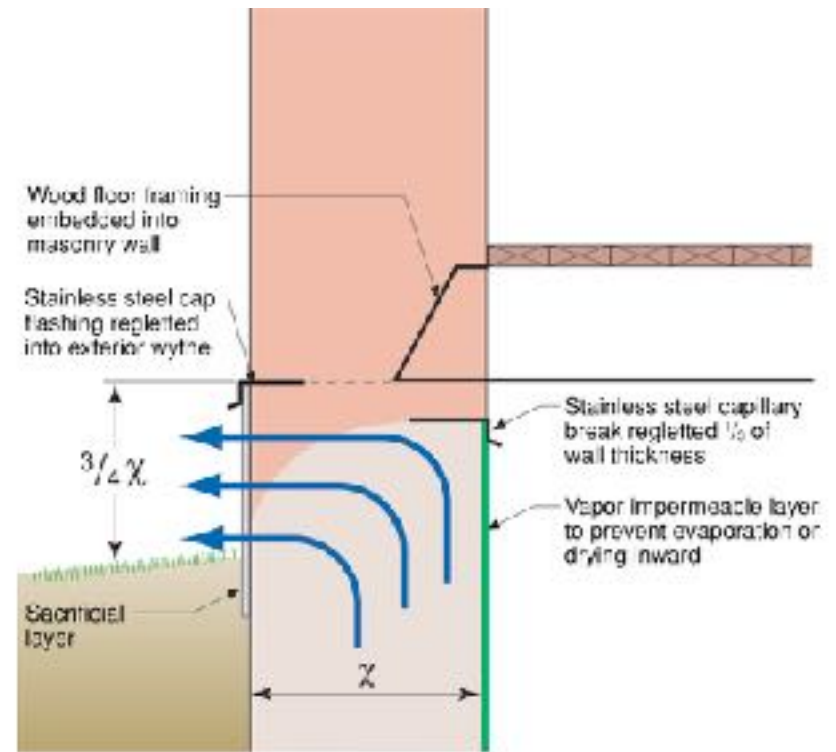
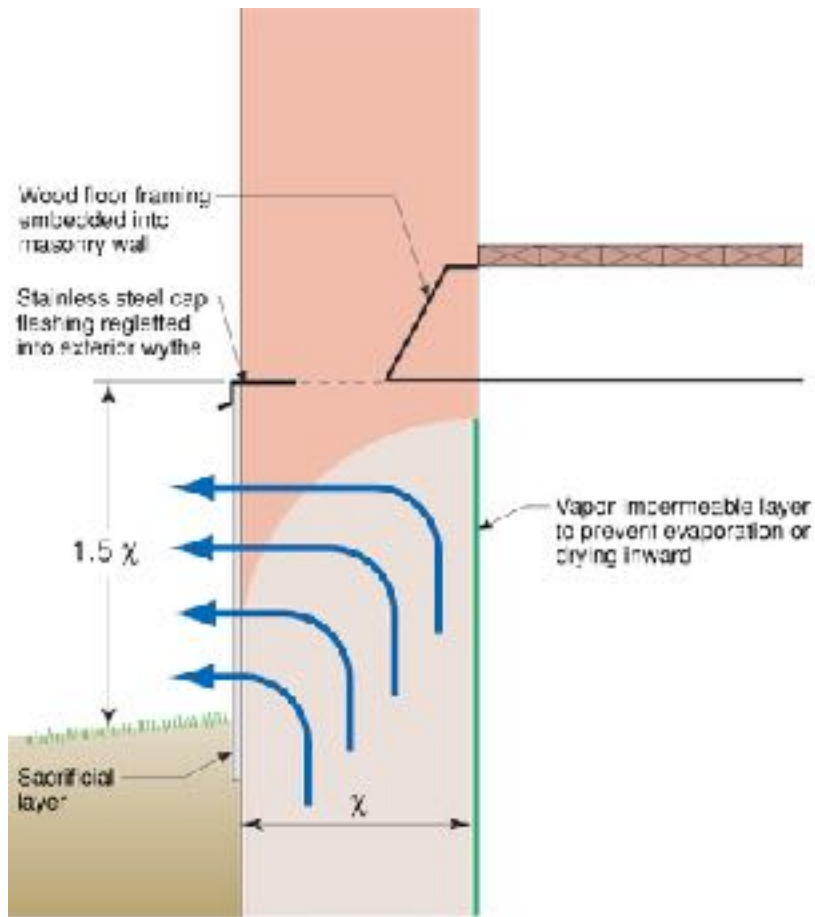


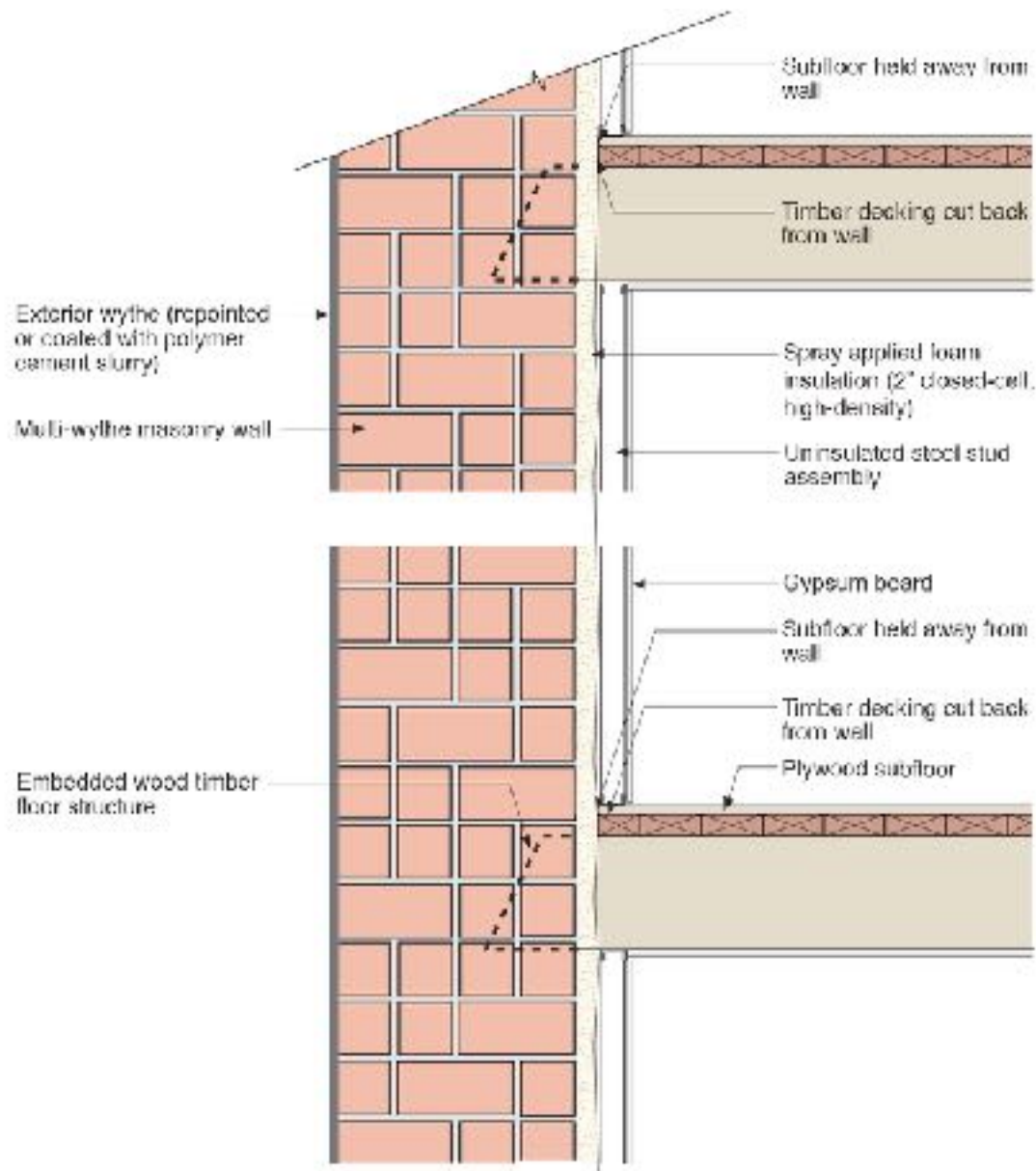






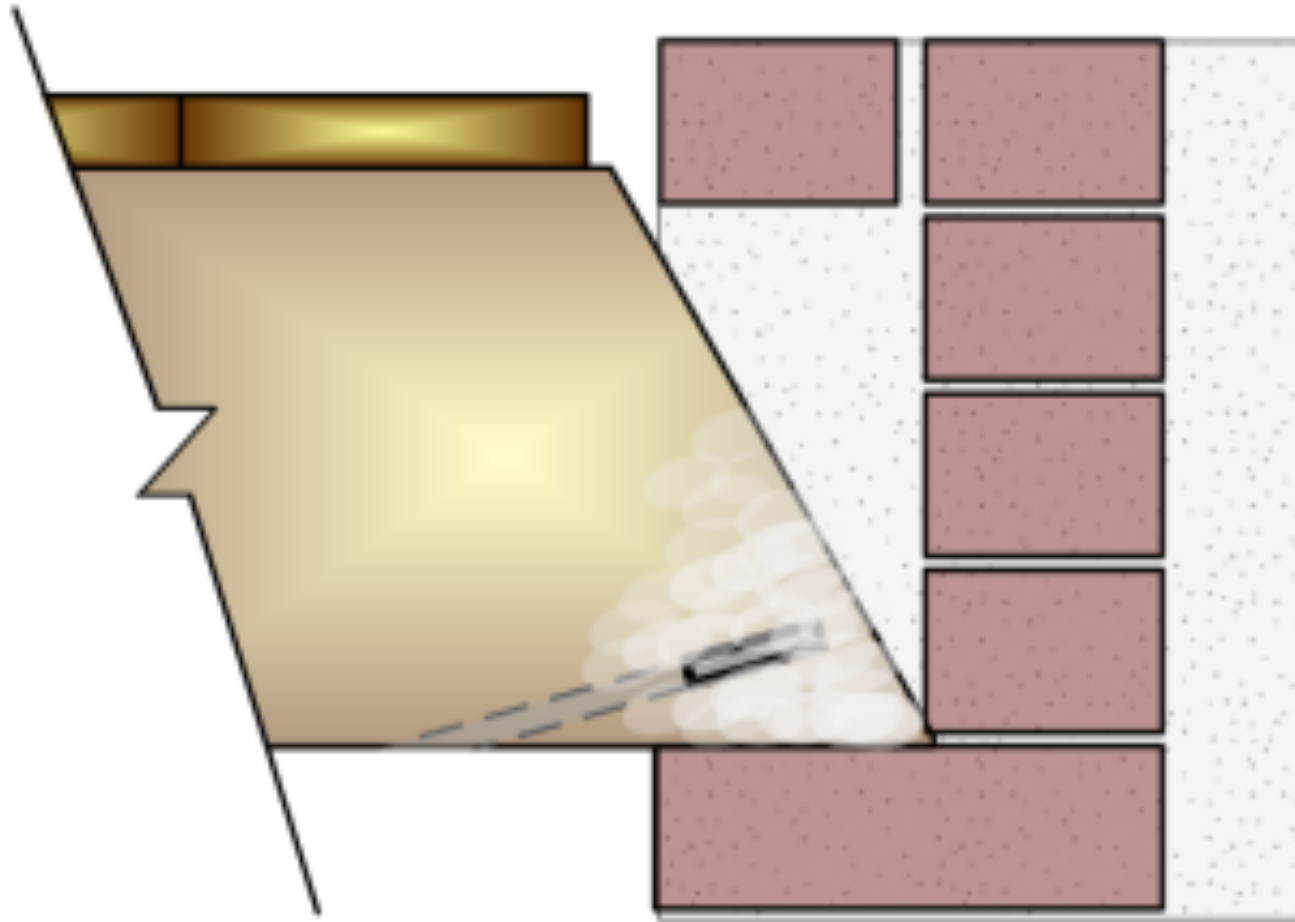


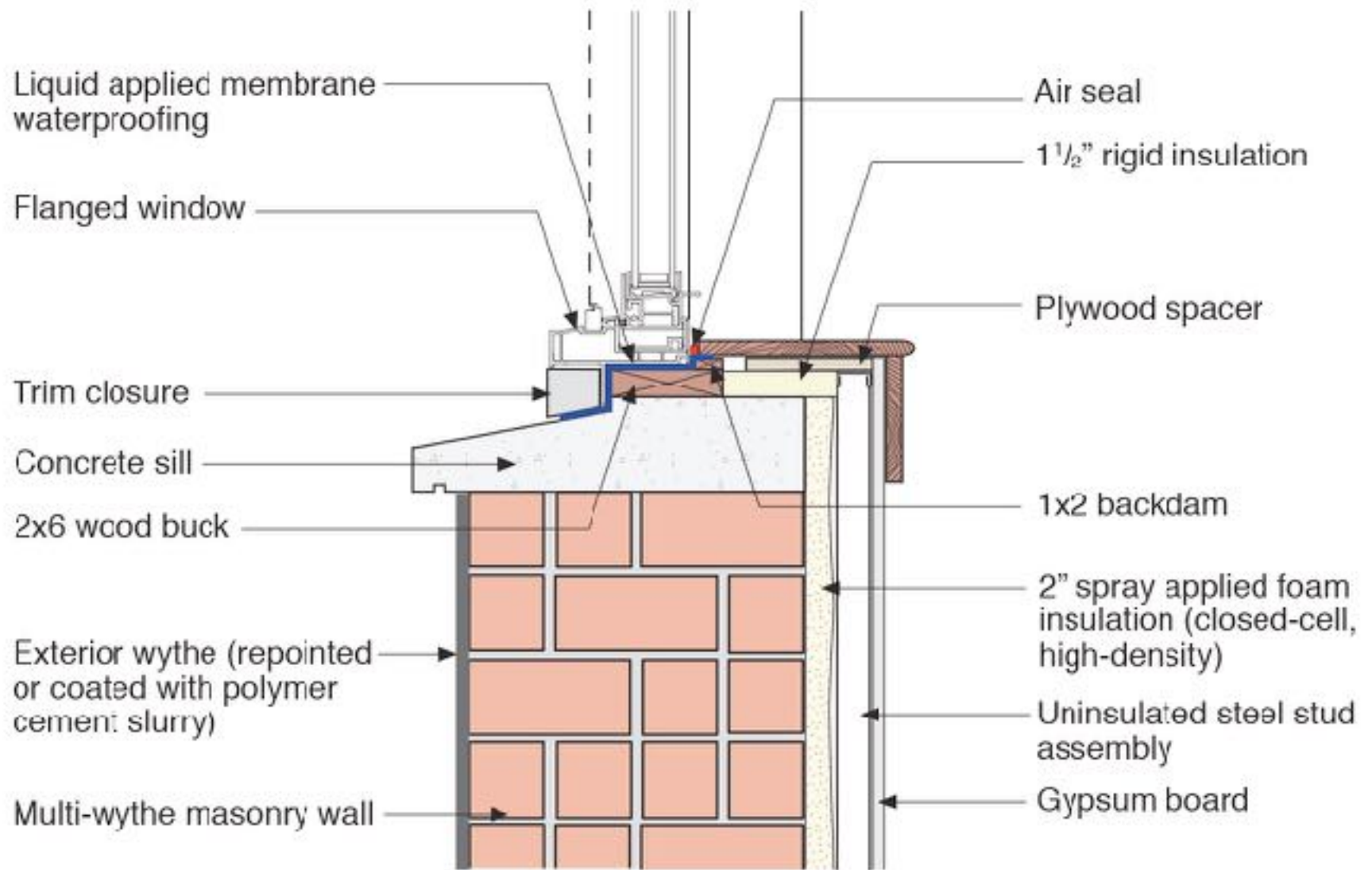










































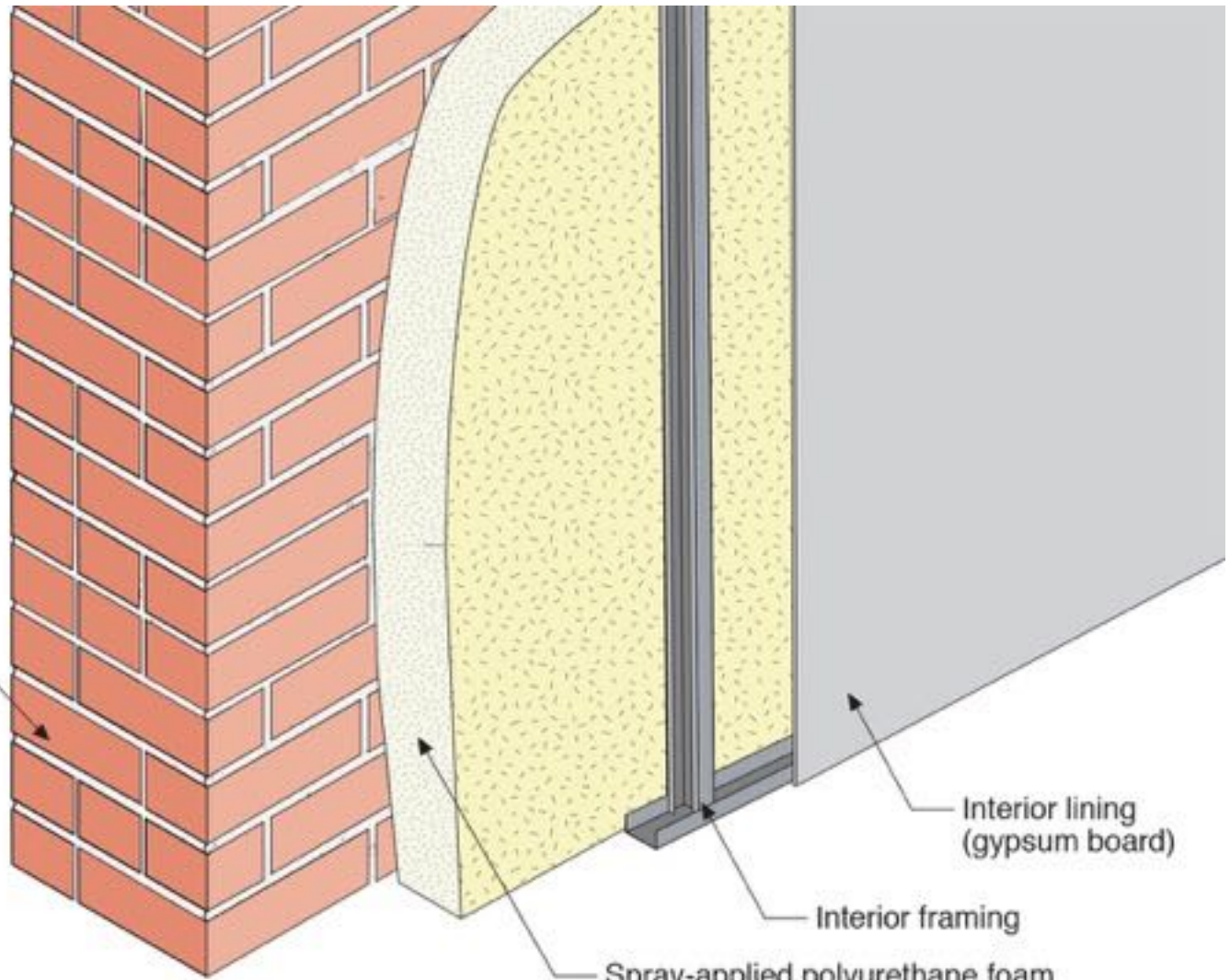








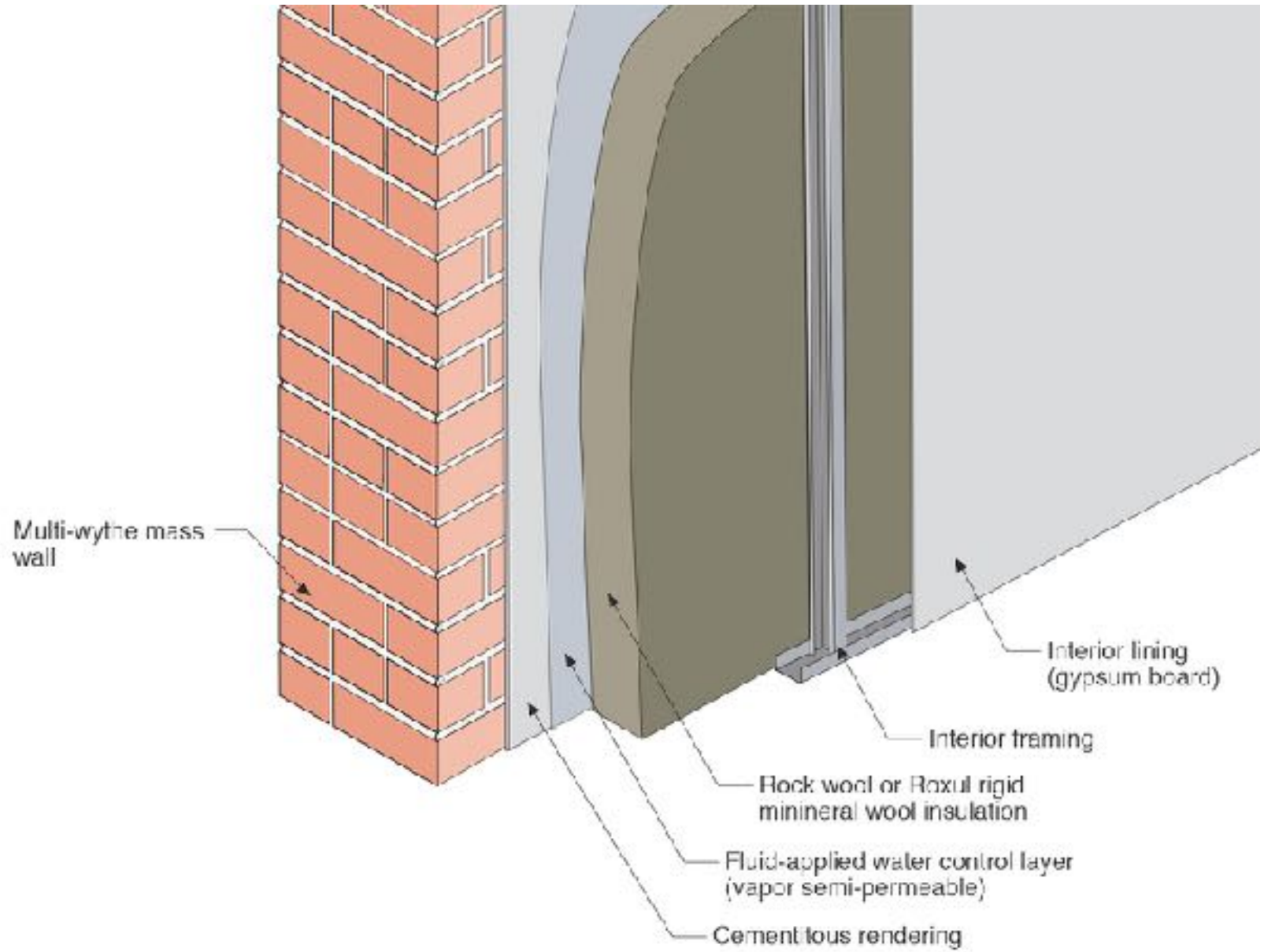
Multi-wythe mass wall

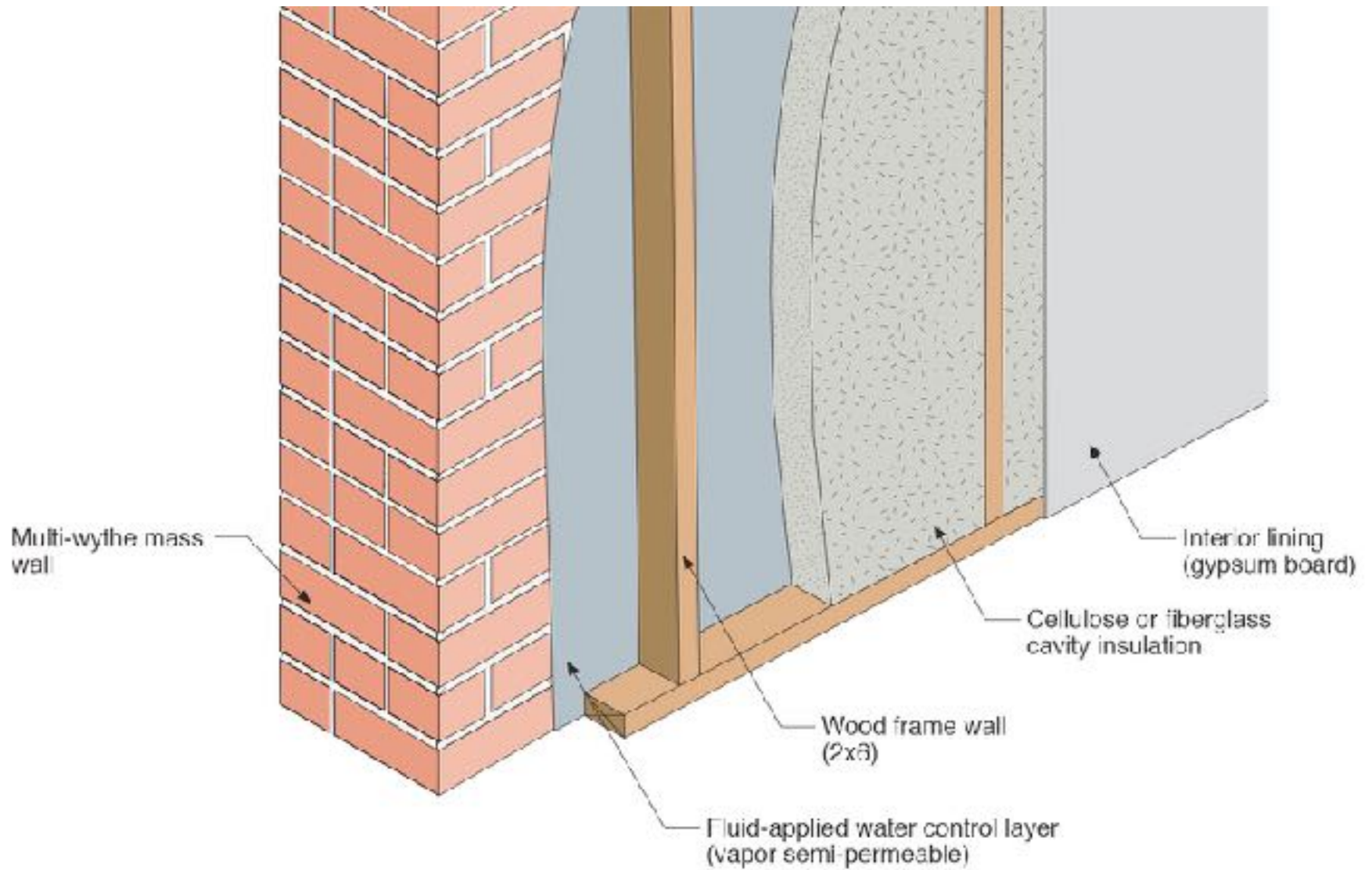


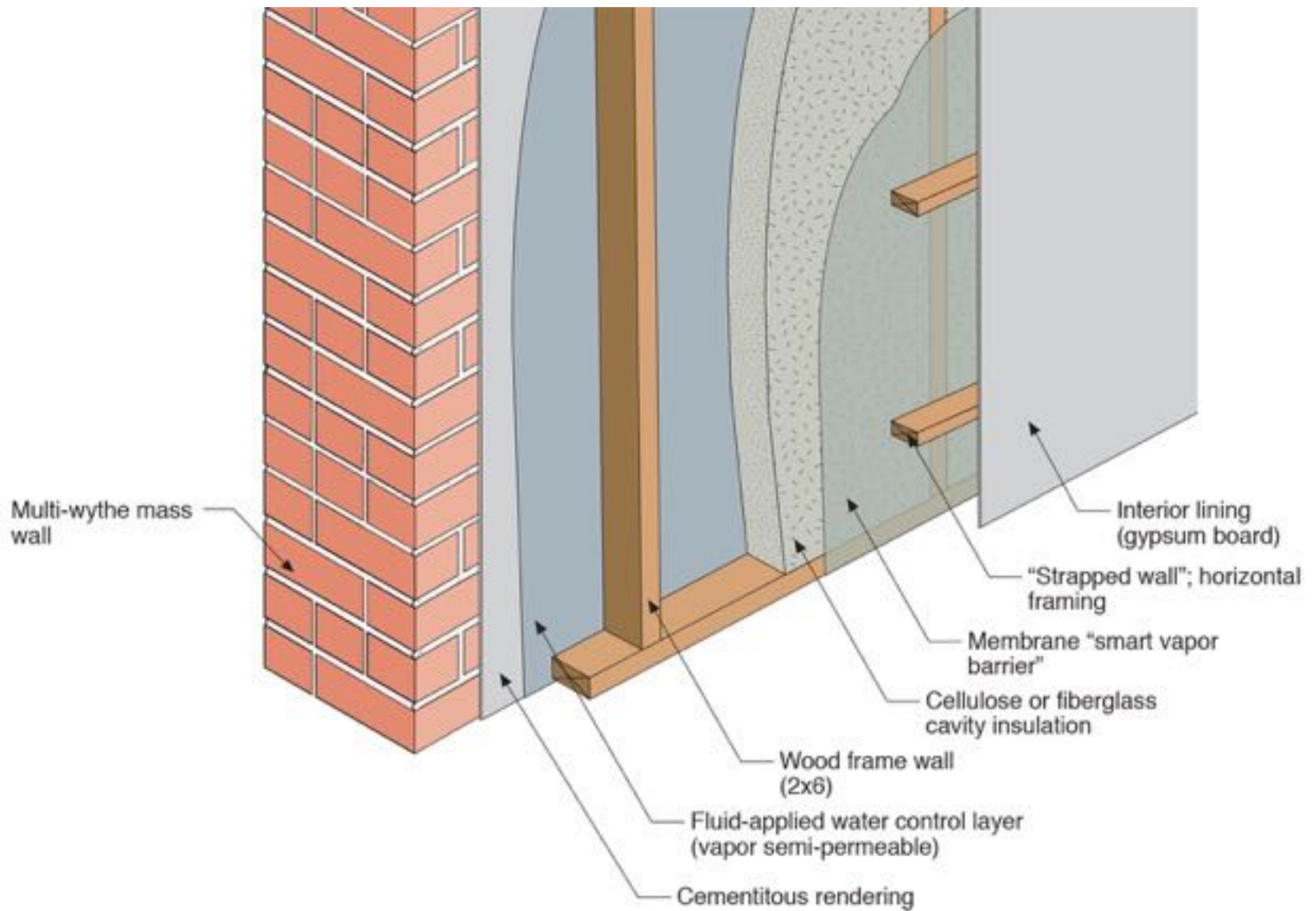
Interior lining  
(gypsum board)

Interior framing

Spray-applied polyurethane foam  
(2 lb/ft<sup>3</sup> density)







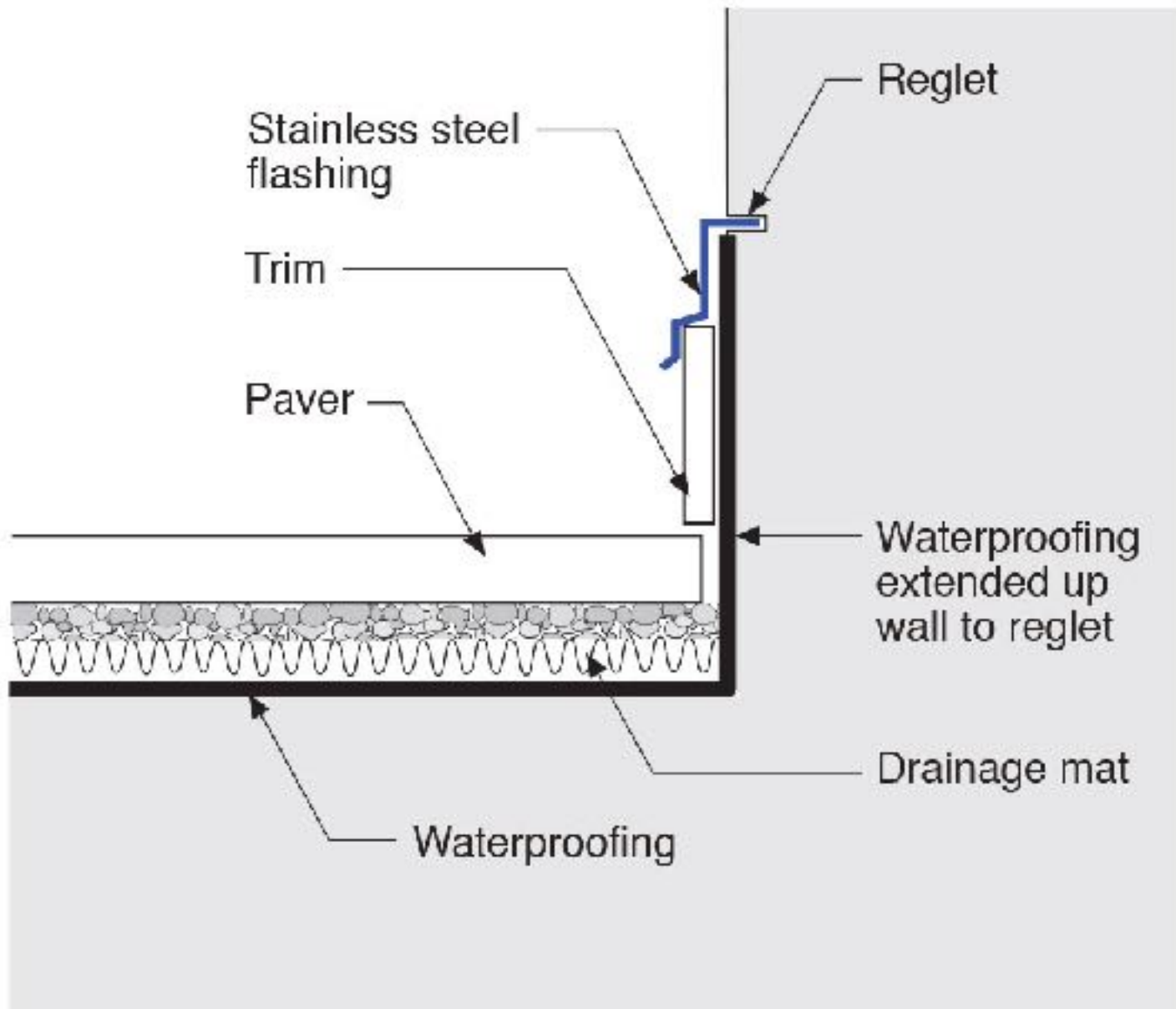








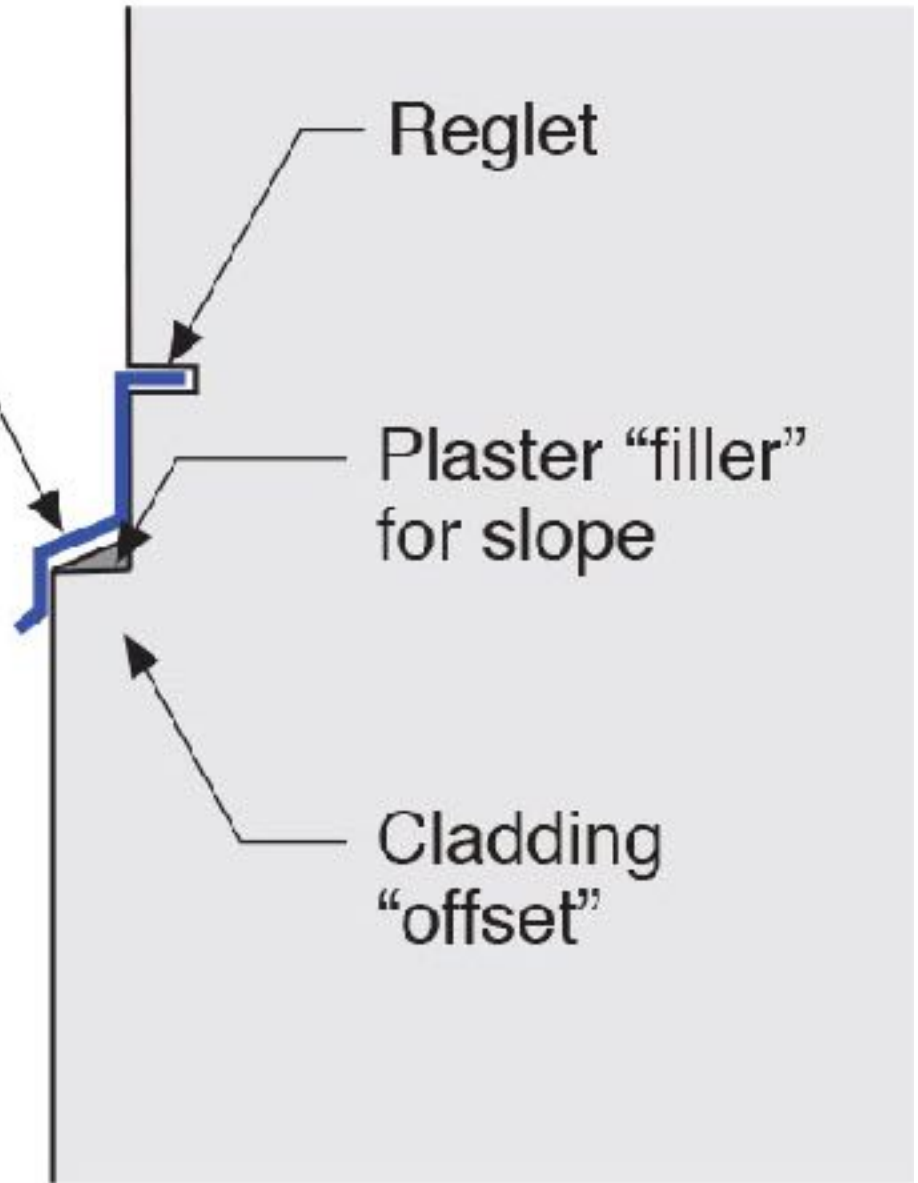








Stainless steel  
flashing



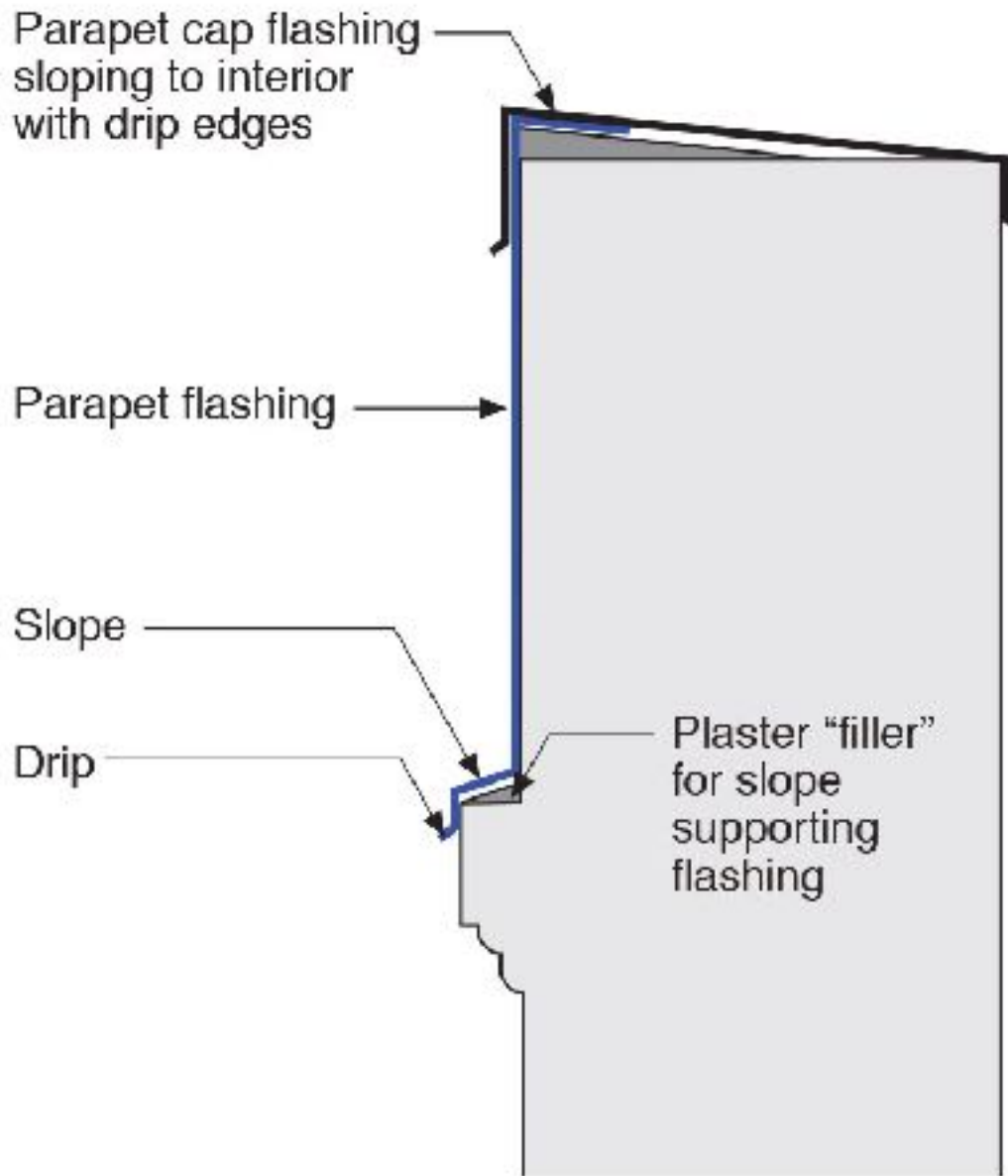
Reglet

Plaster "filler"  
for slope

Cladding  
"offset"













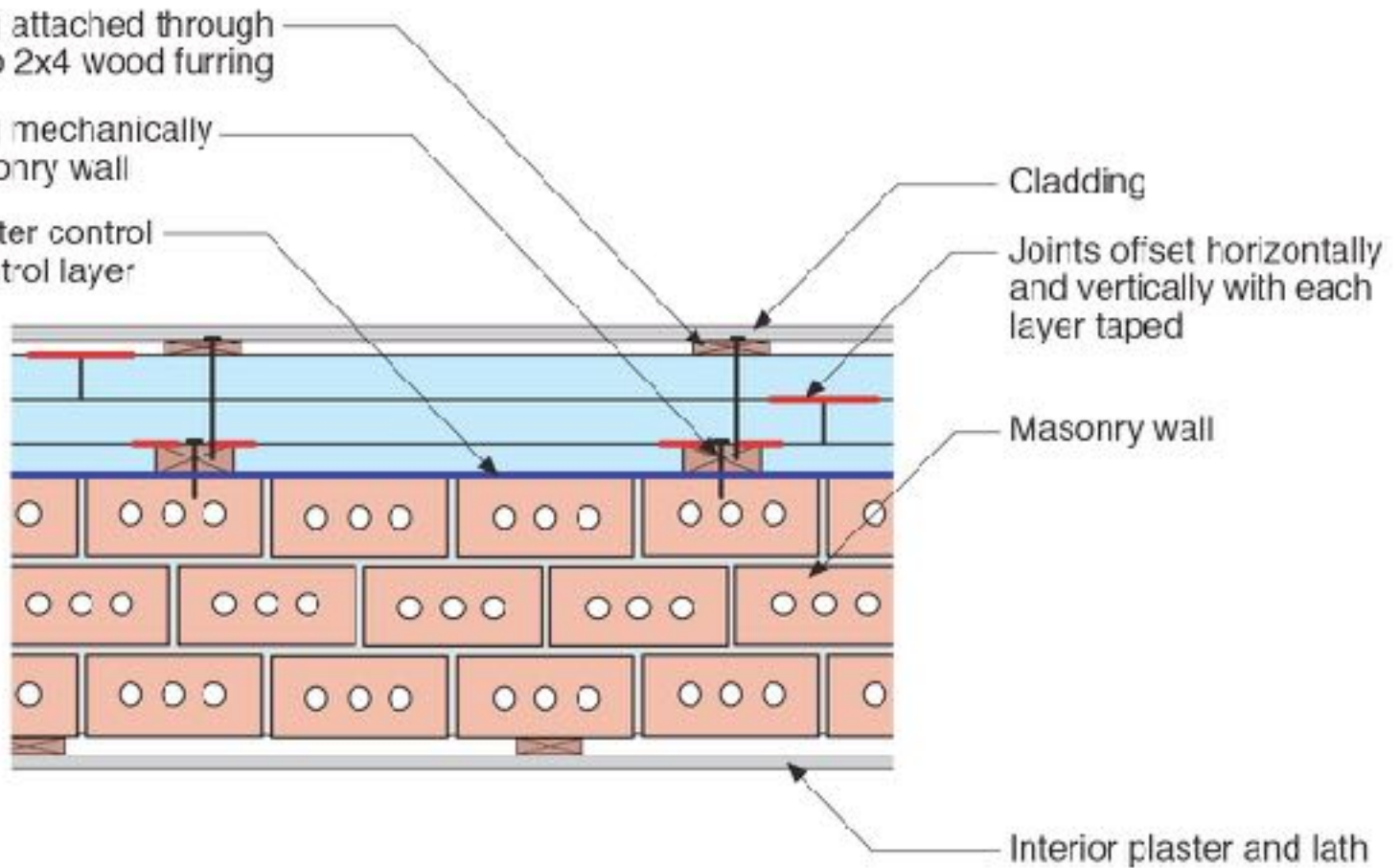




1x4 wood furring attached through rigid insulation to 2x4 wood furring

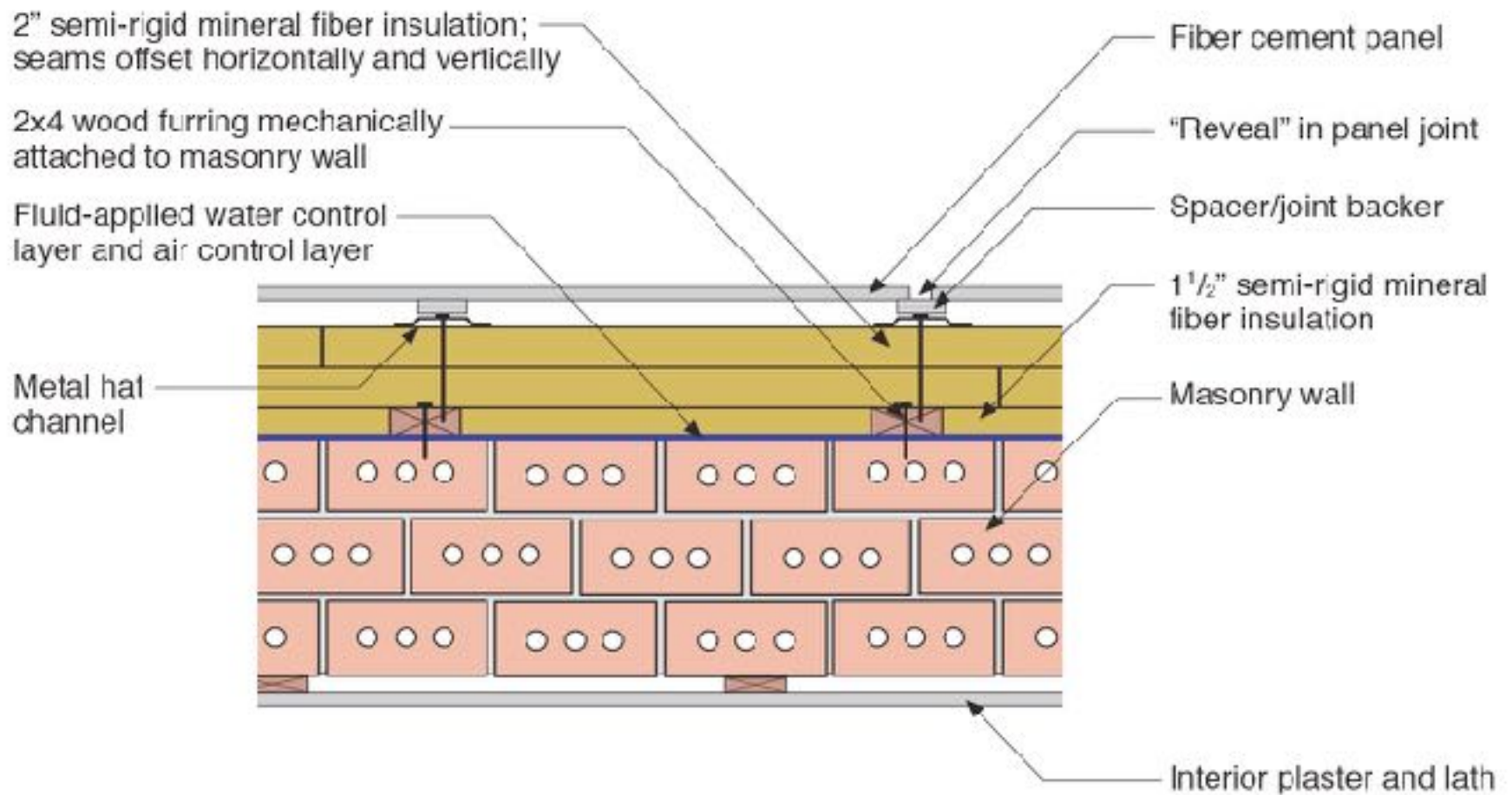
2x4 wood furring mechanically attached to masonry wall

Fluid-applied water control layer and air control layer

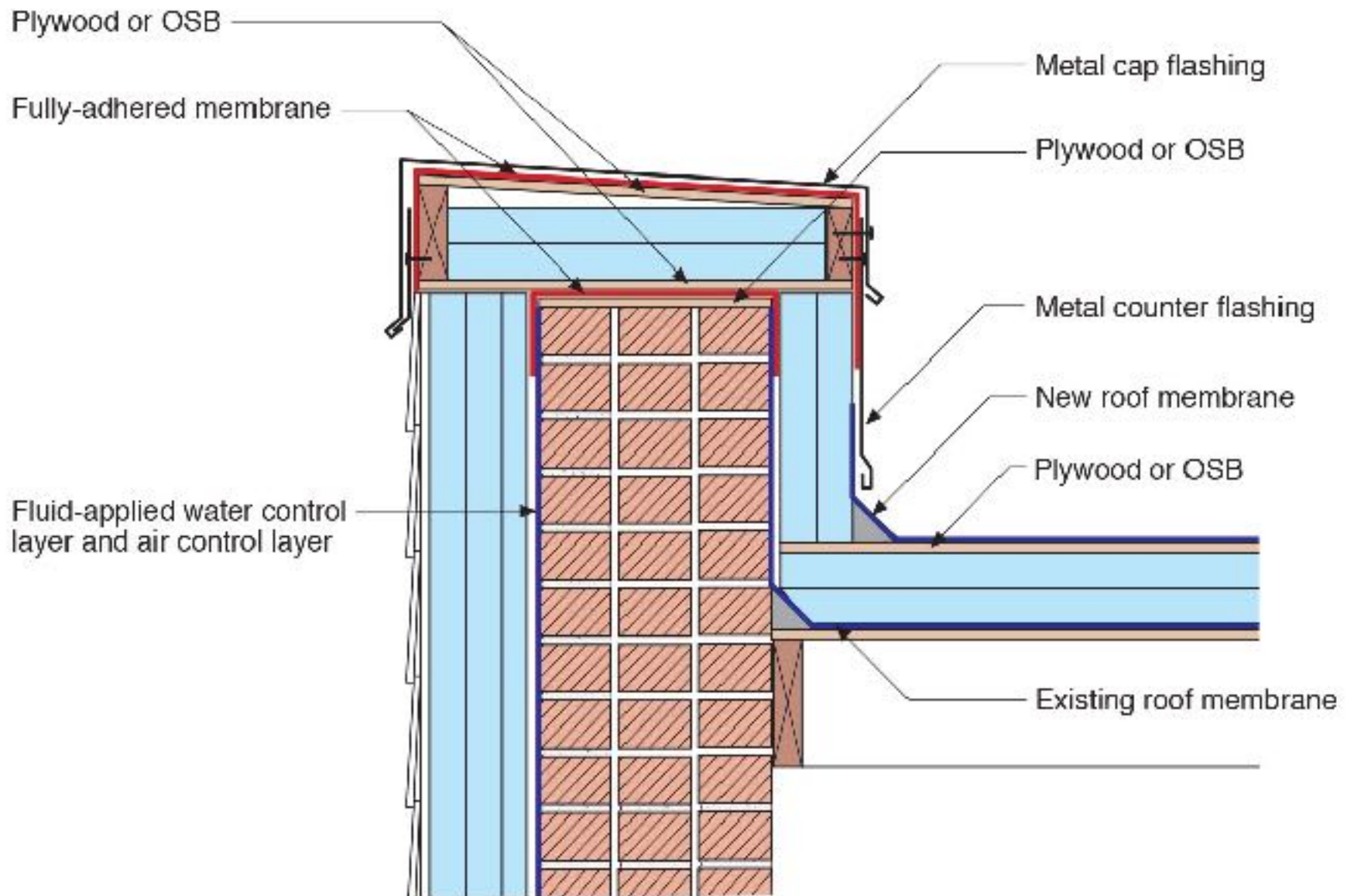


















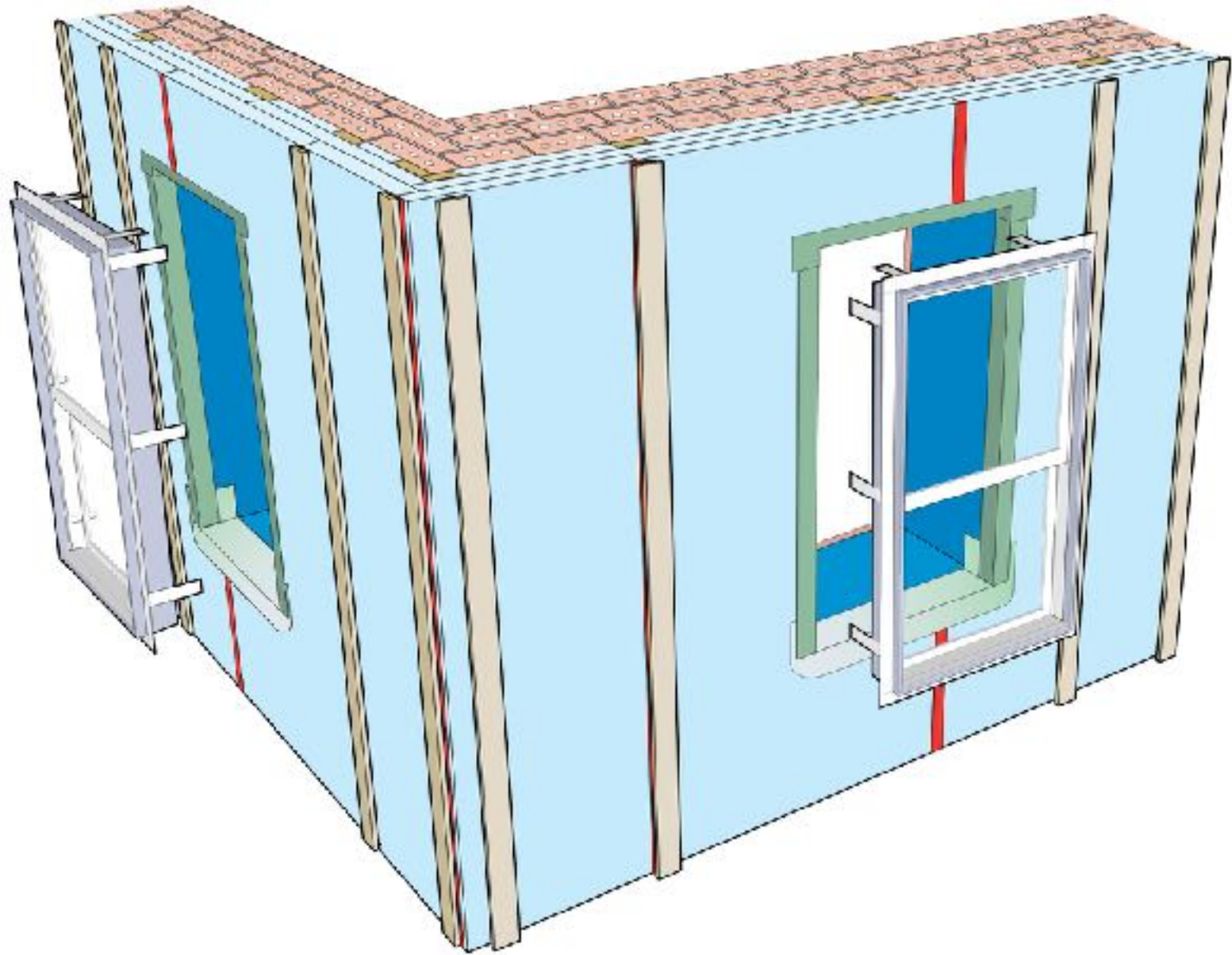


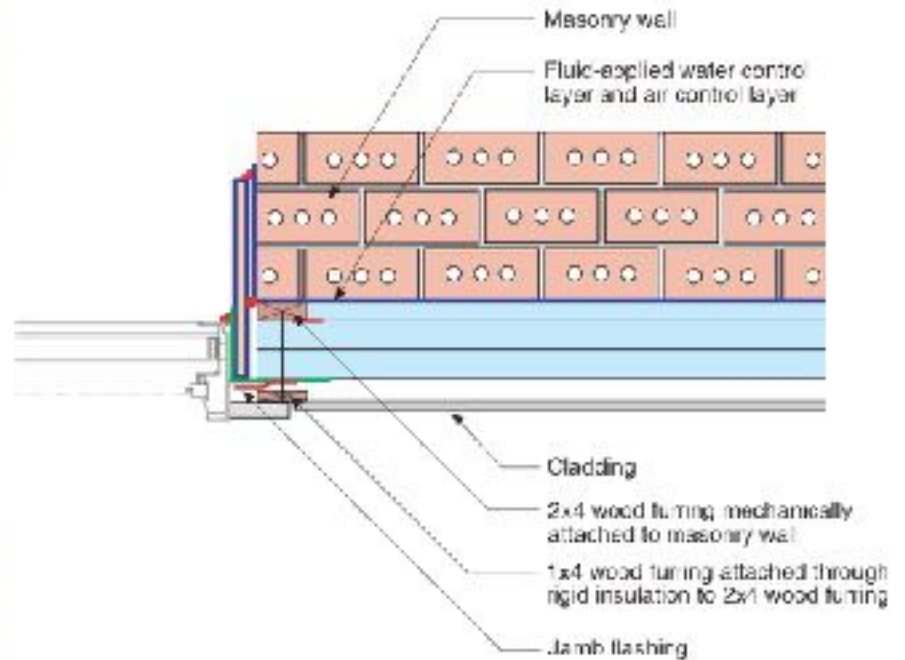
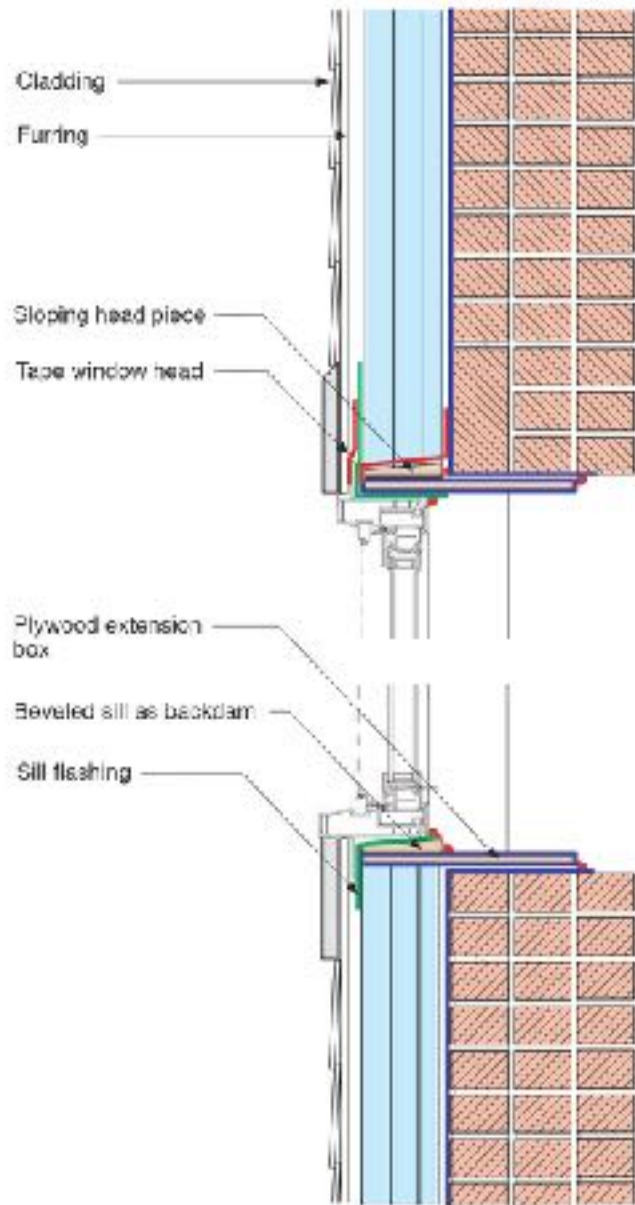














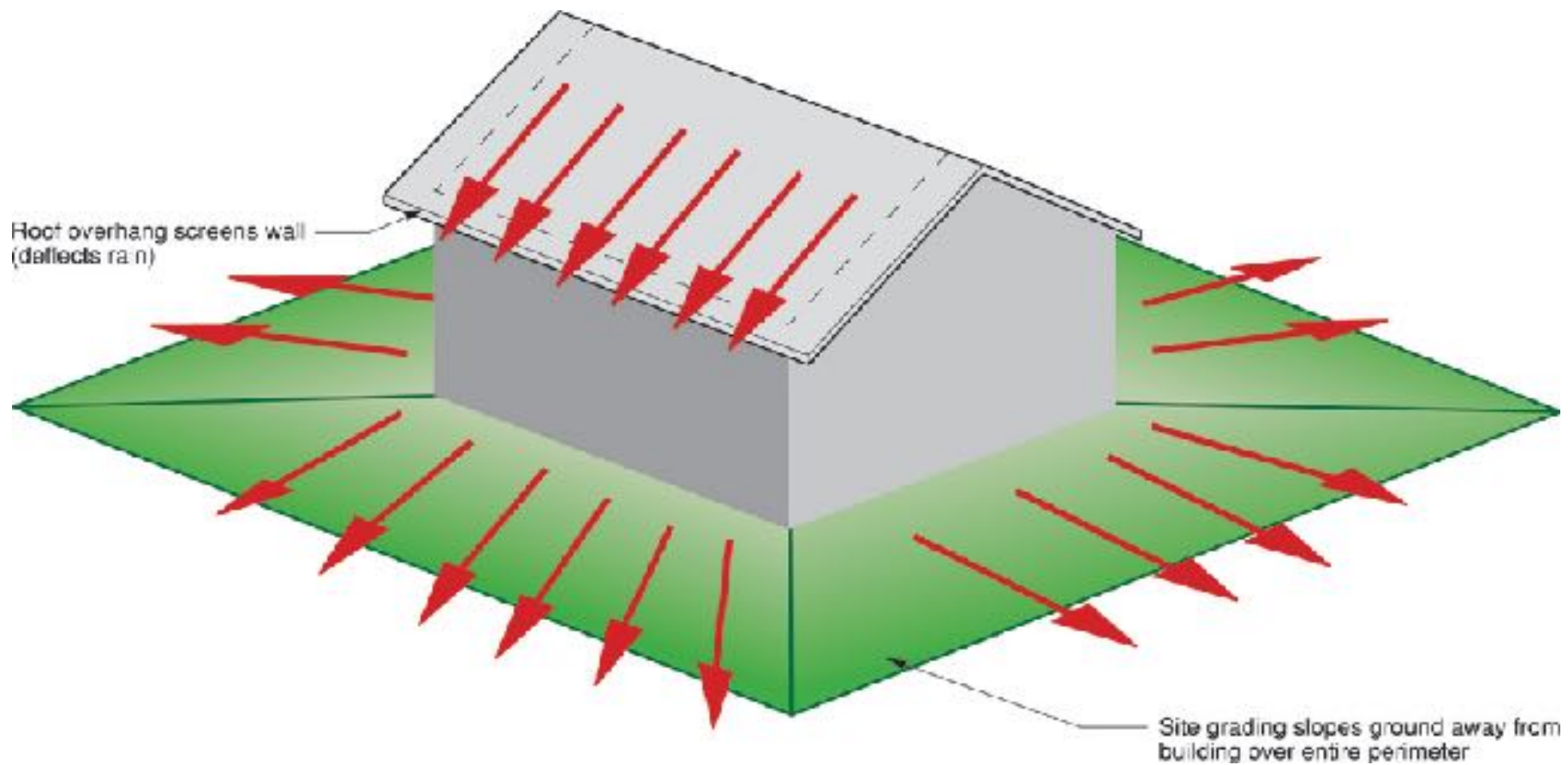


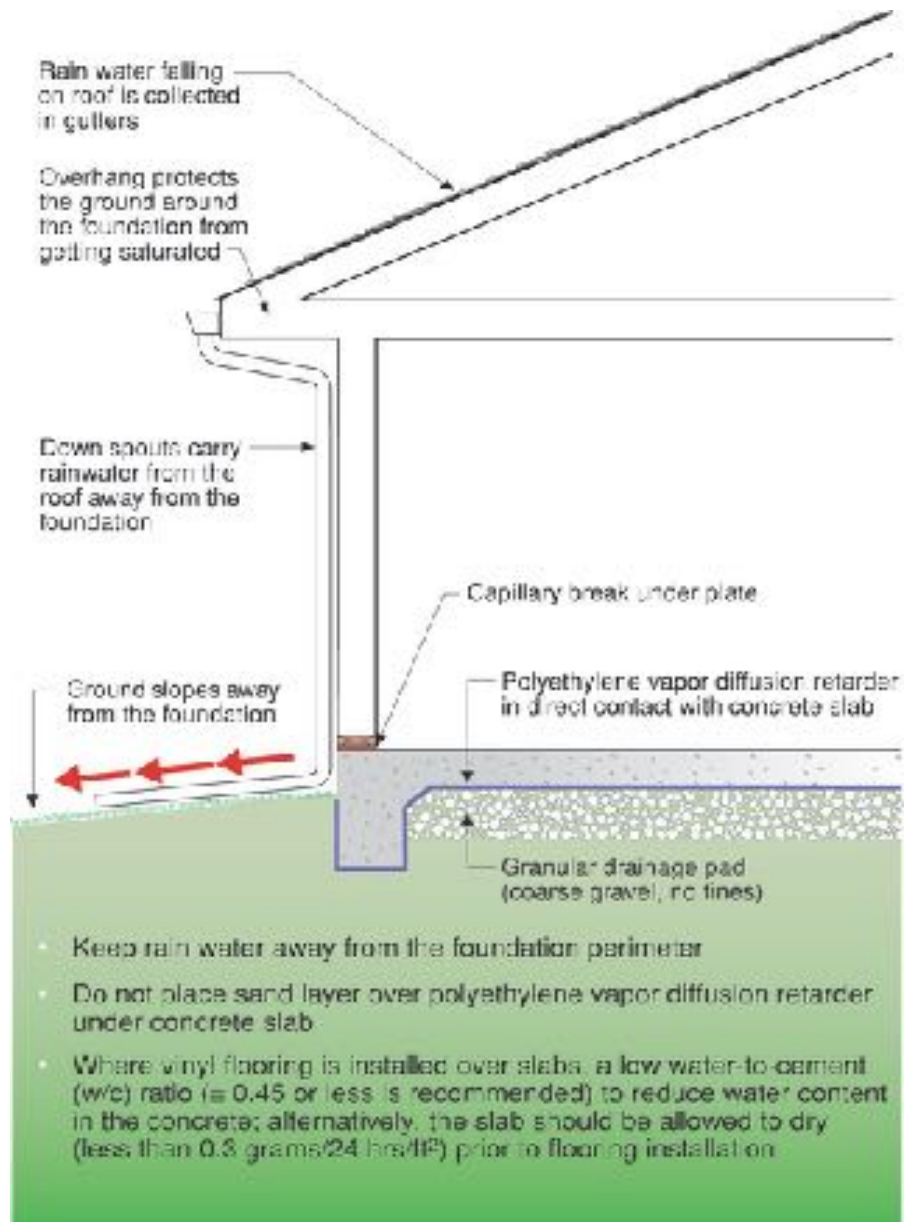


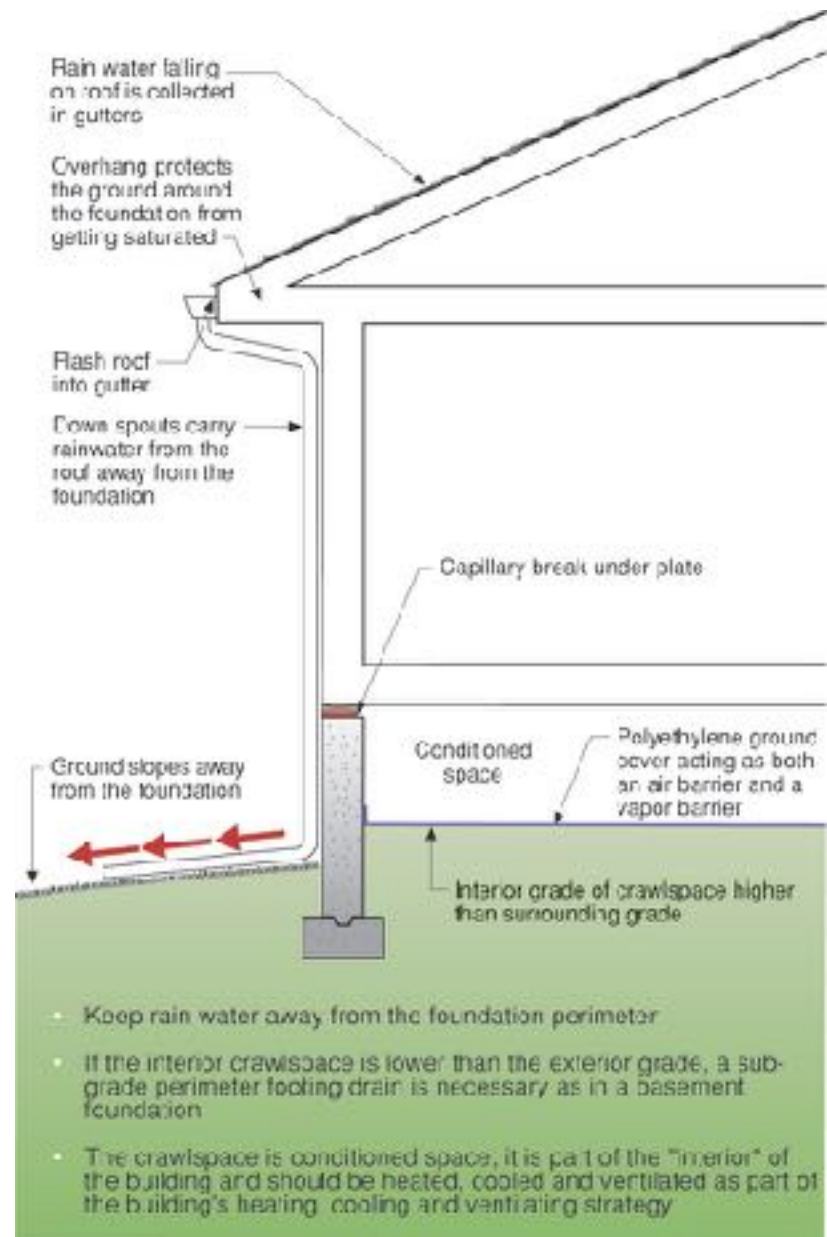


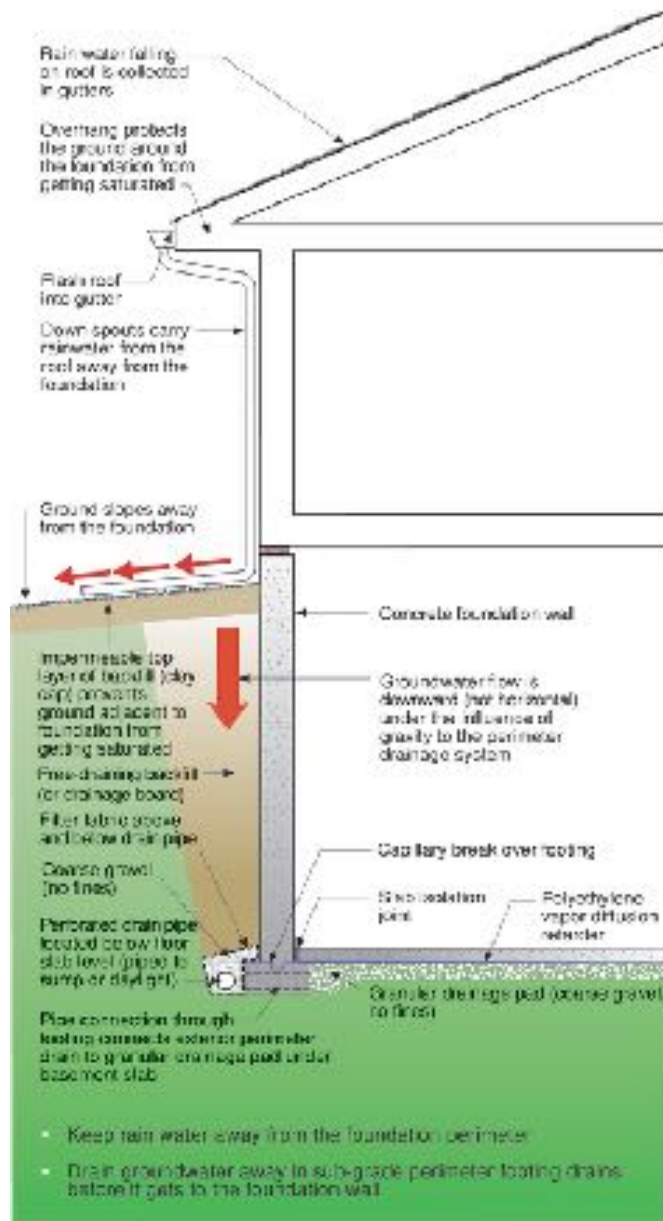




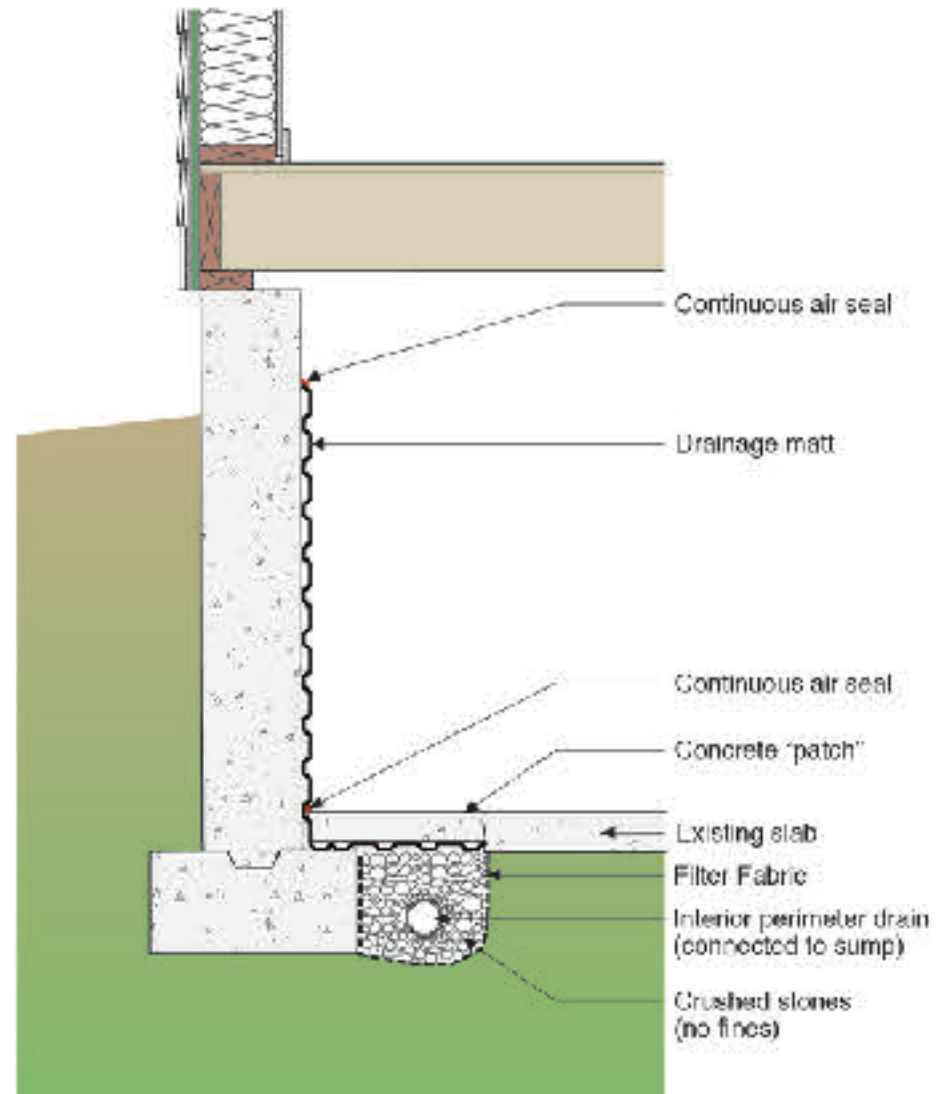






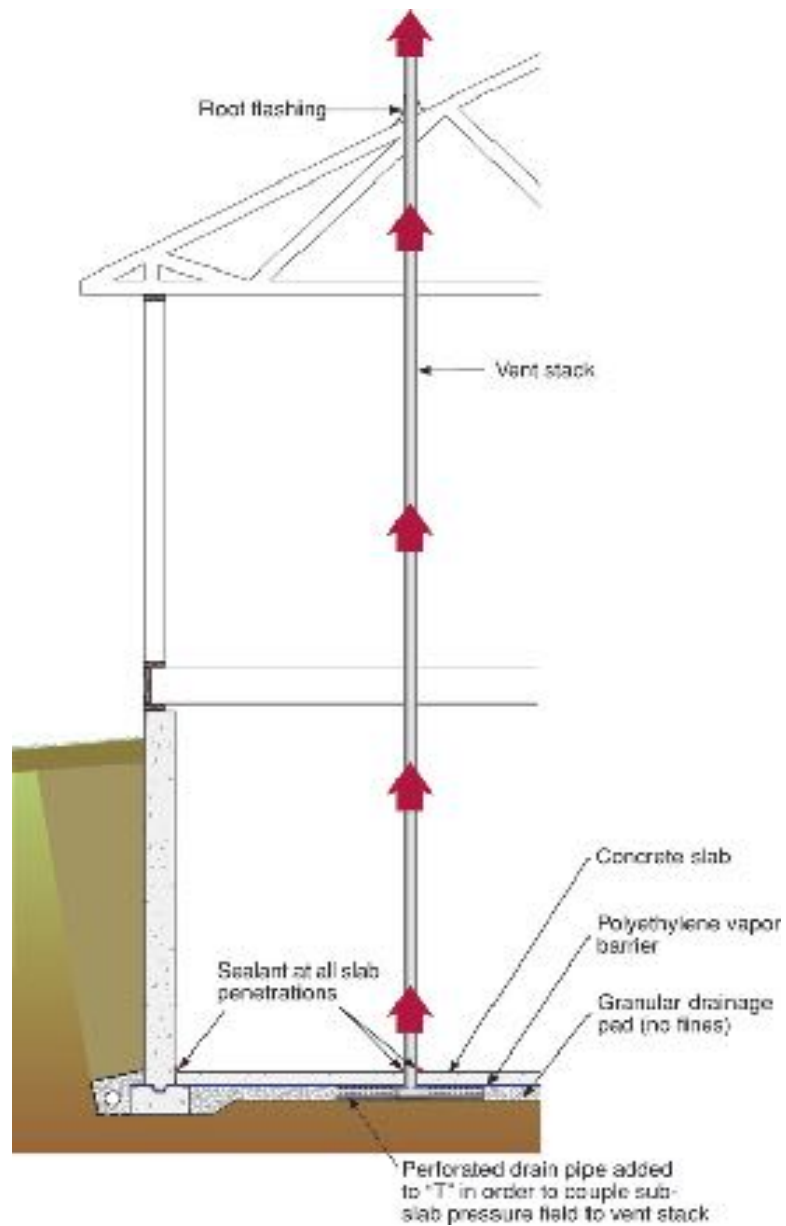


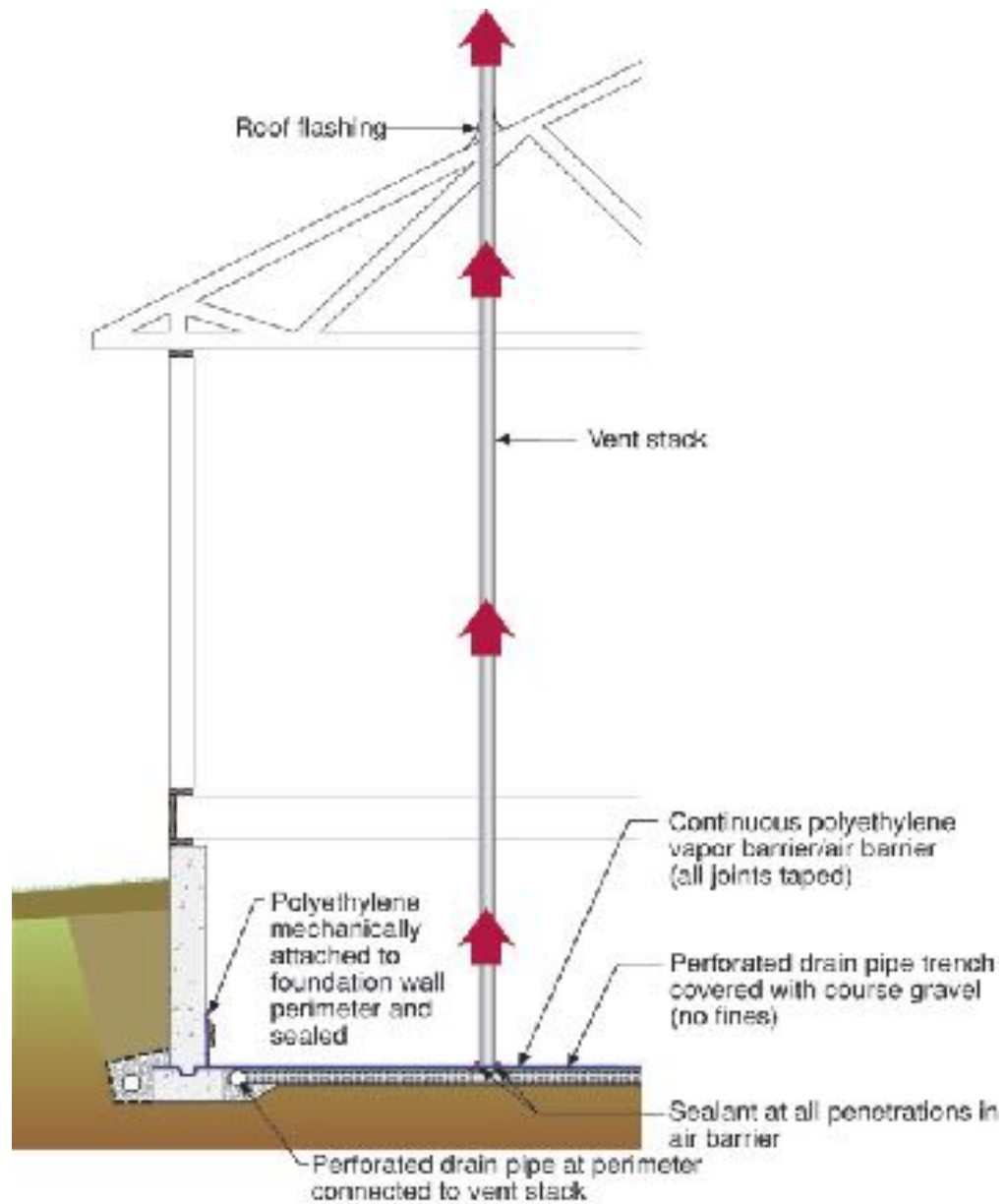


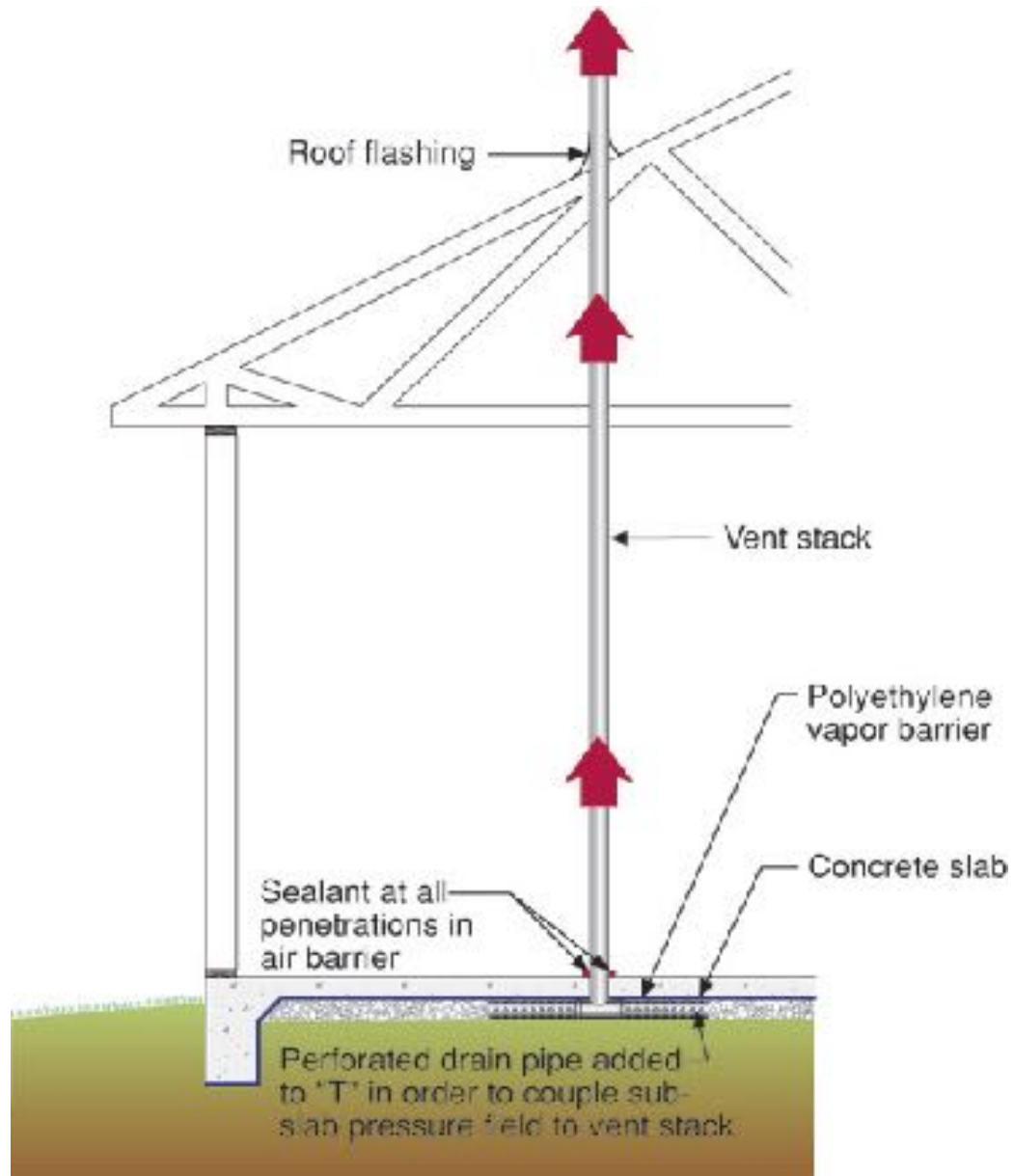






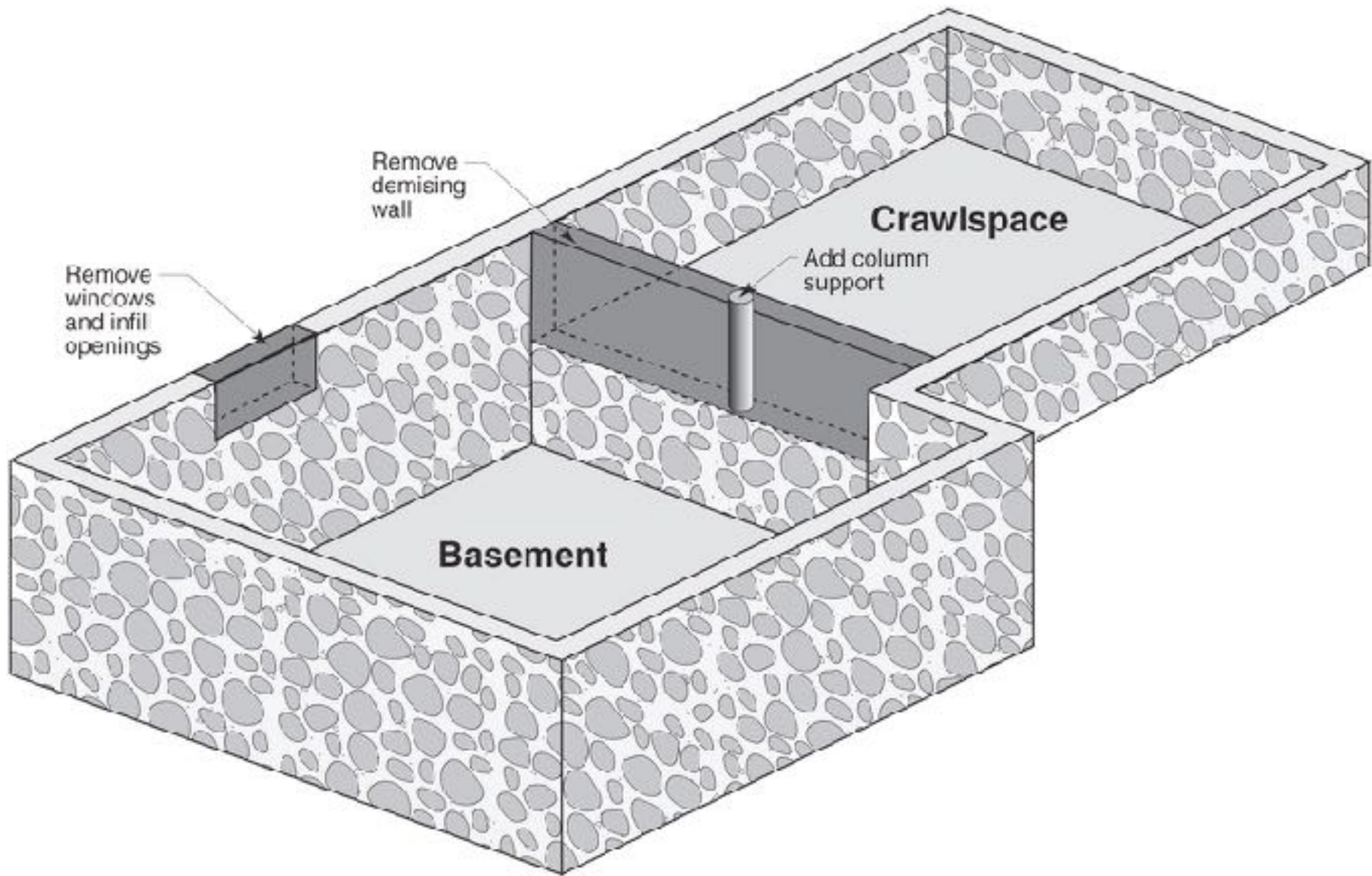










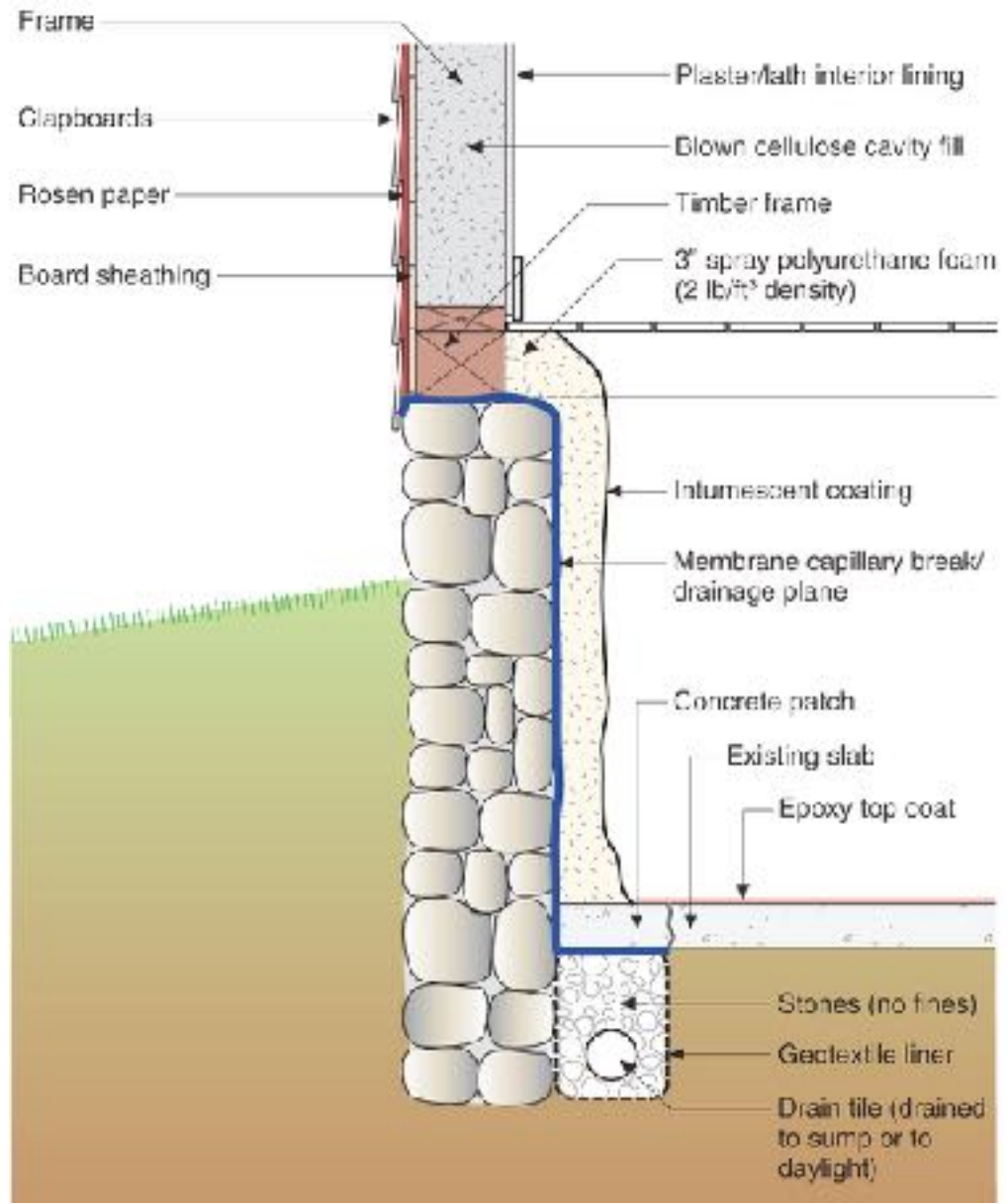














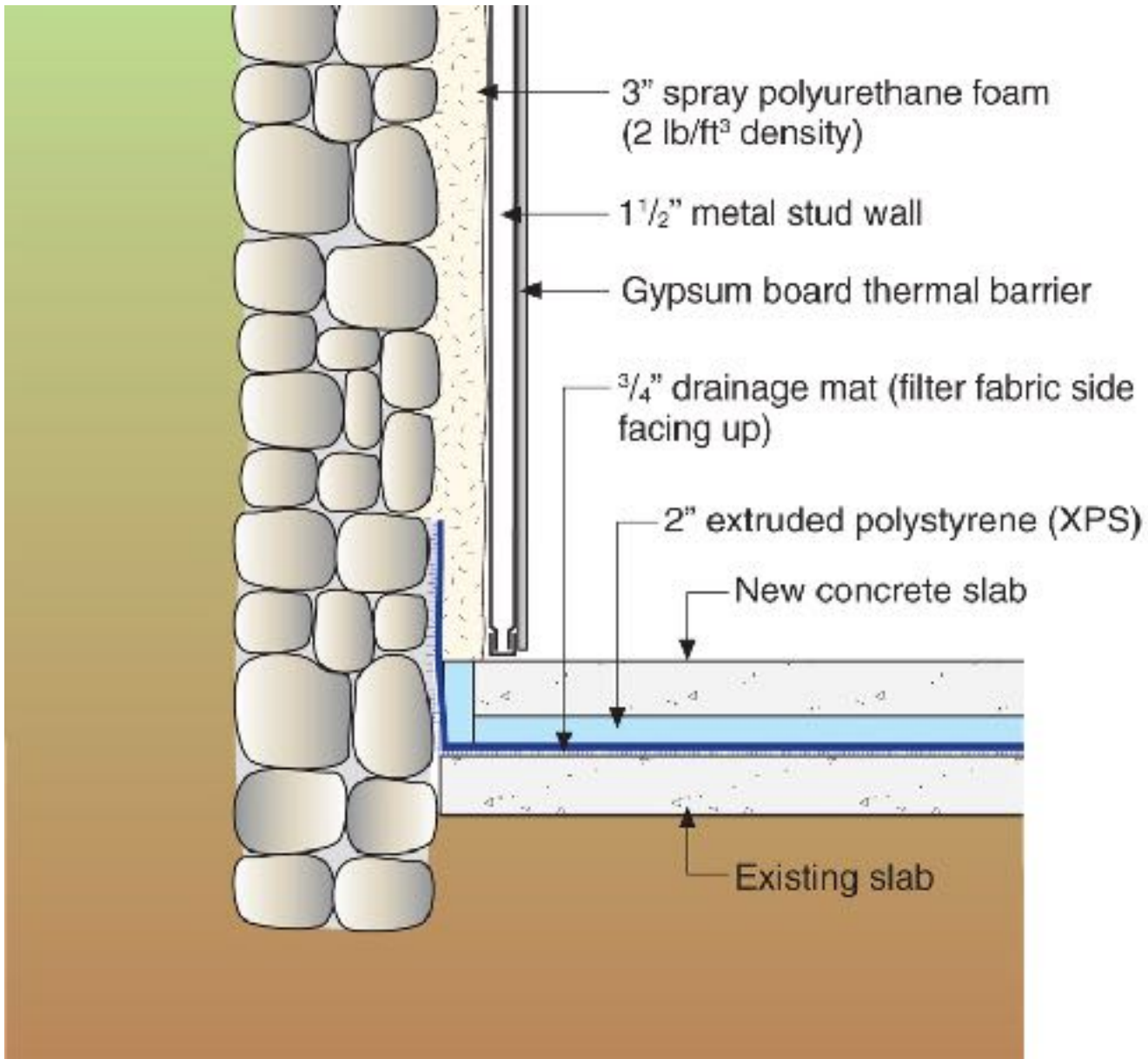


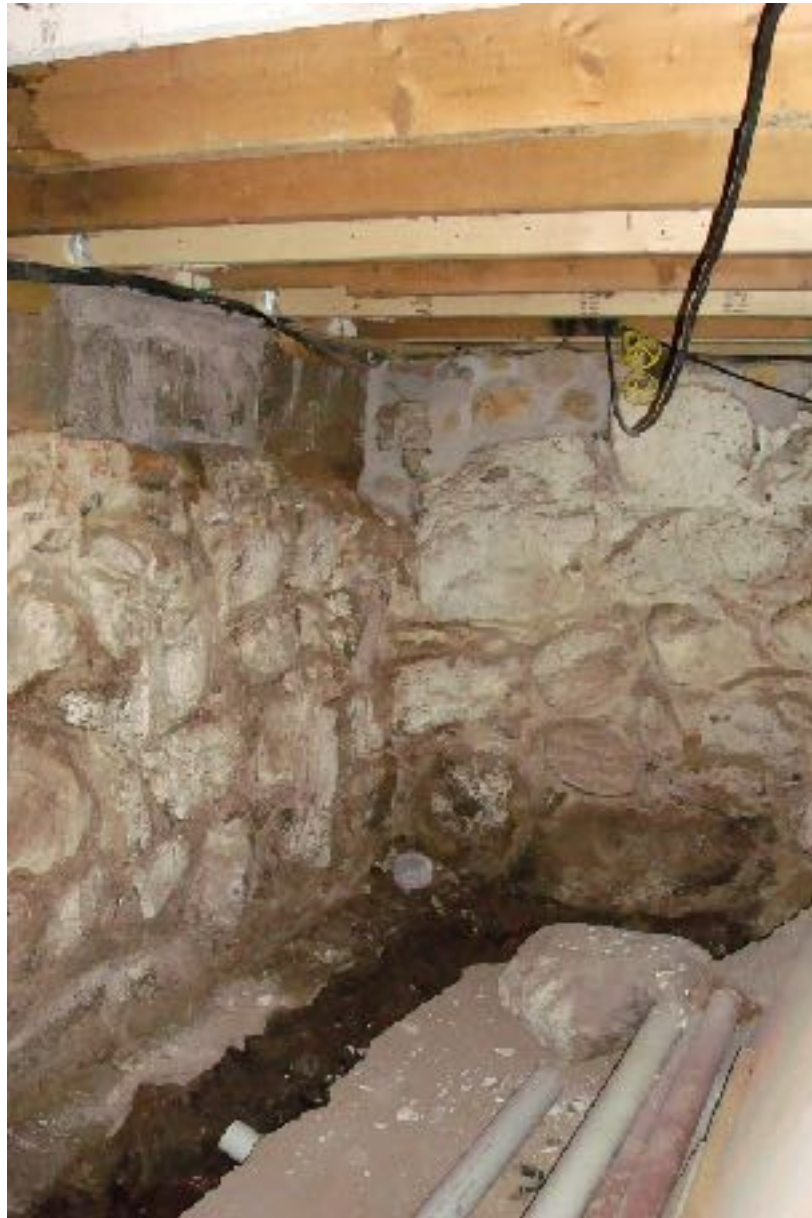






















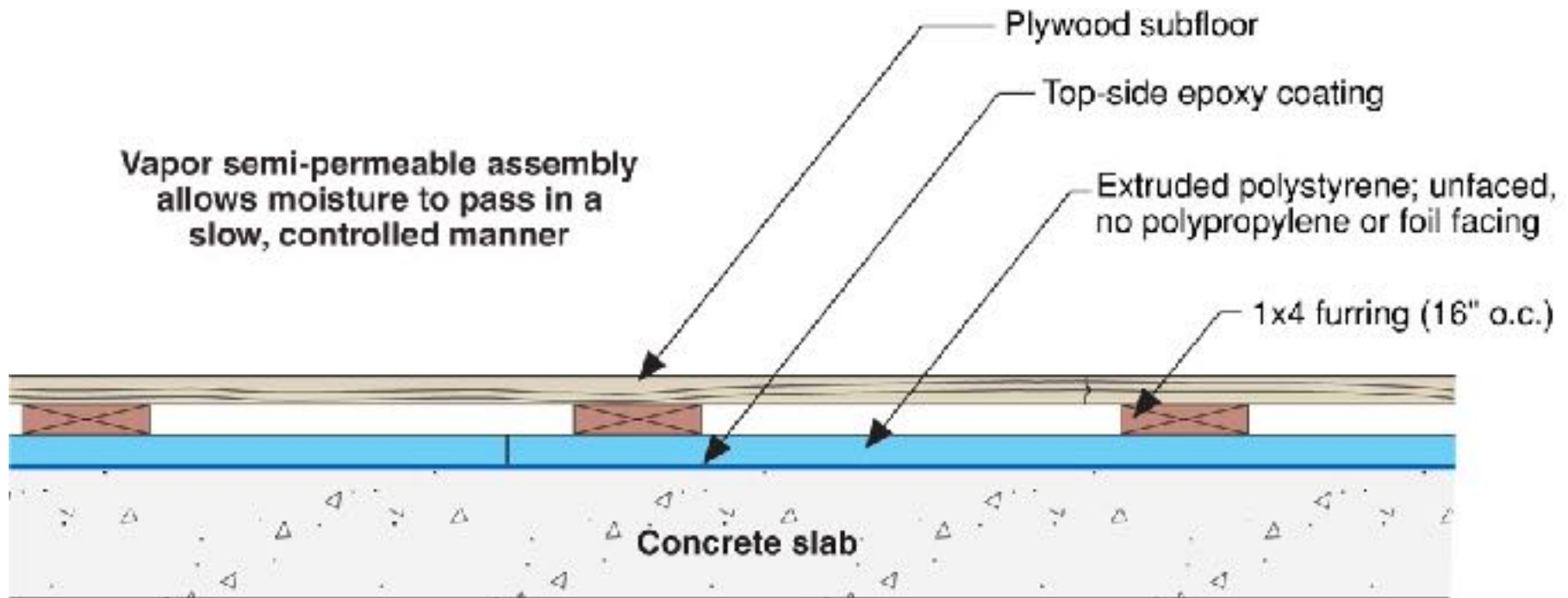








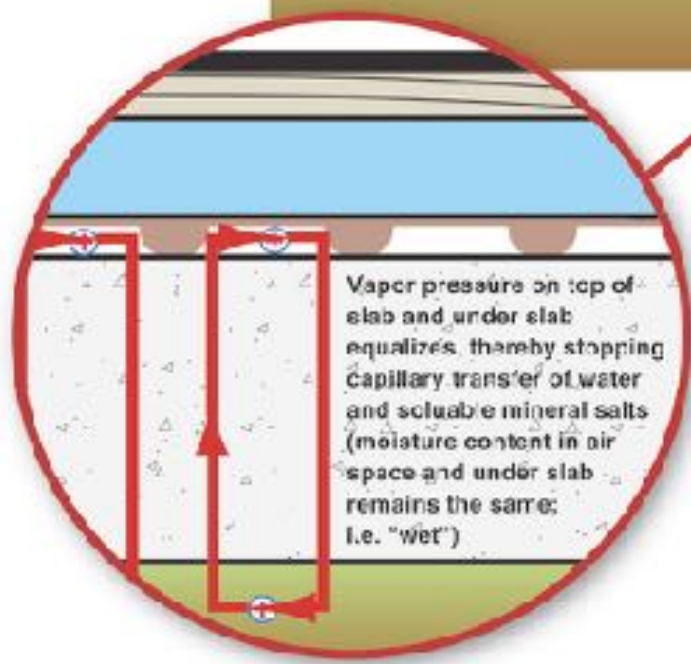
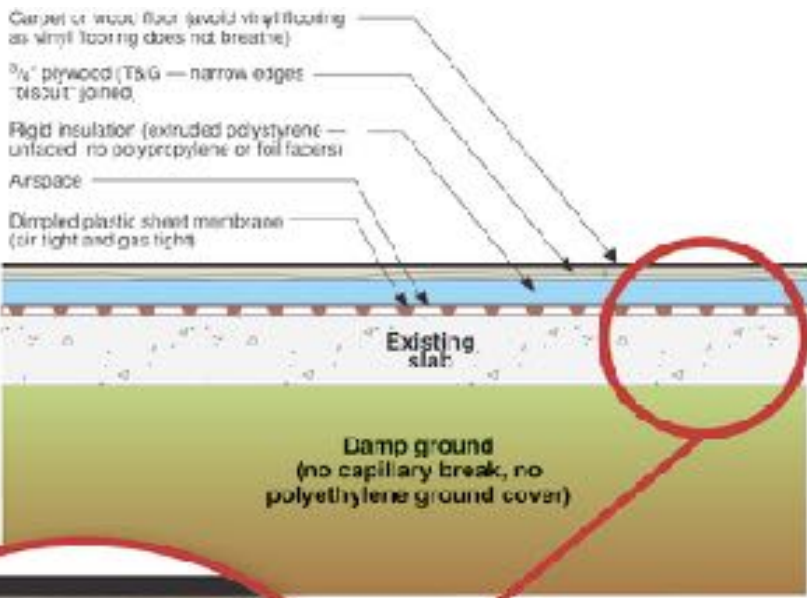
**Vapor semi-permeable assembly  
allows moisture to pass in a  
slow, controlled manner**











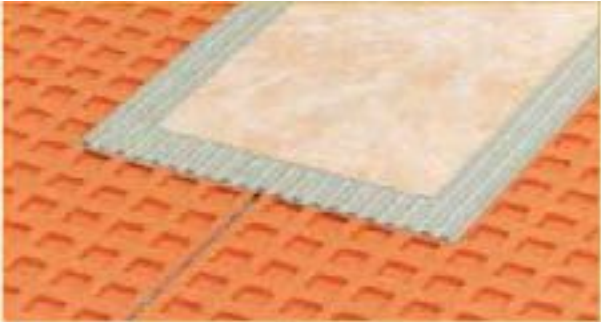






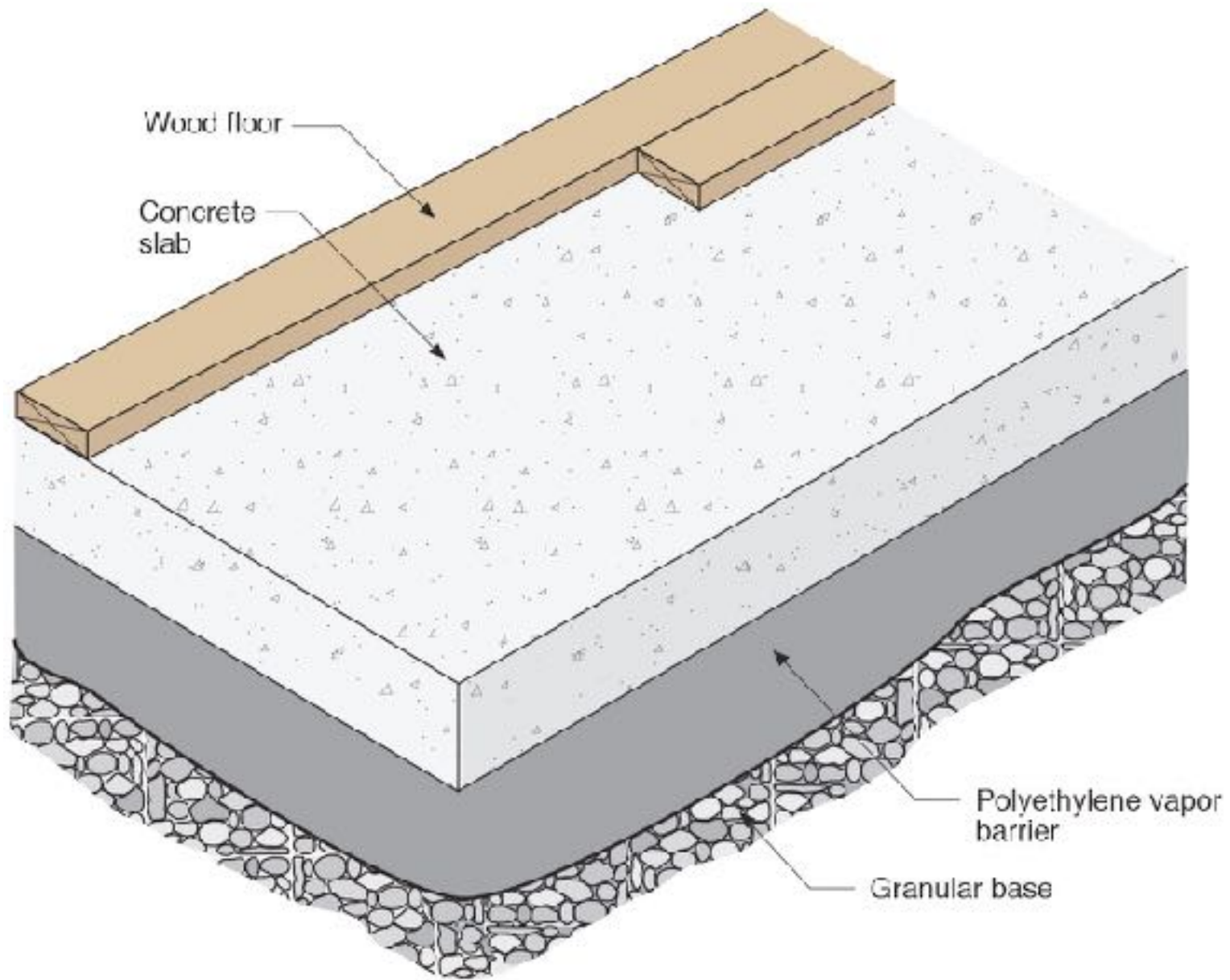










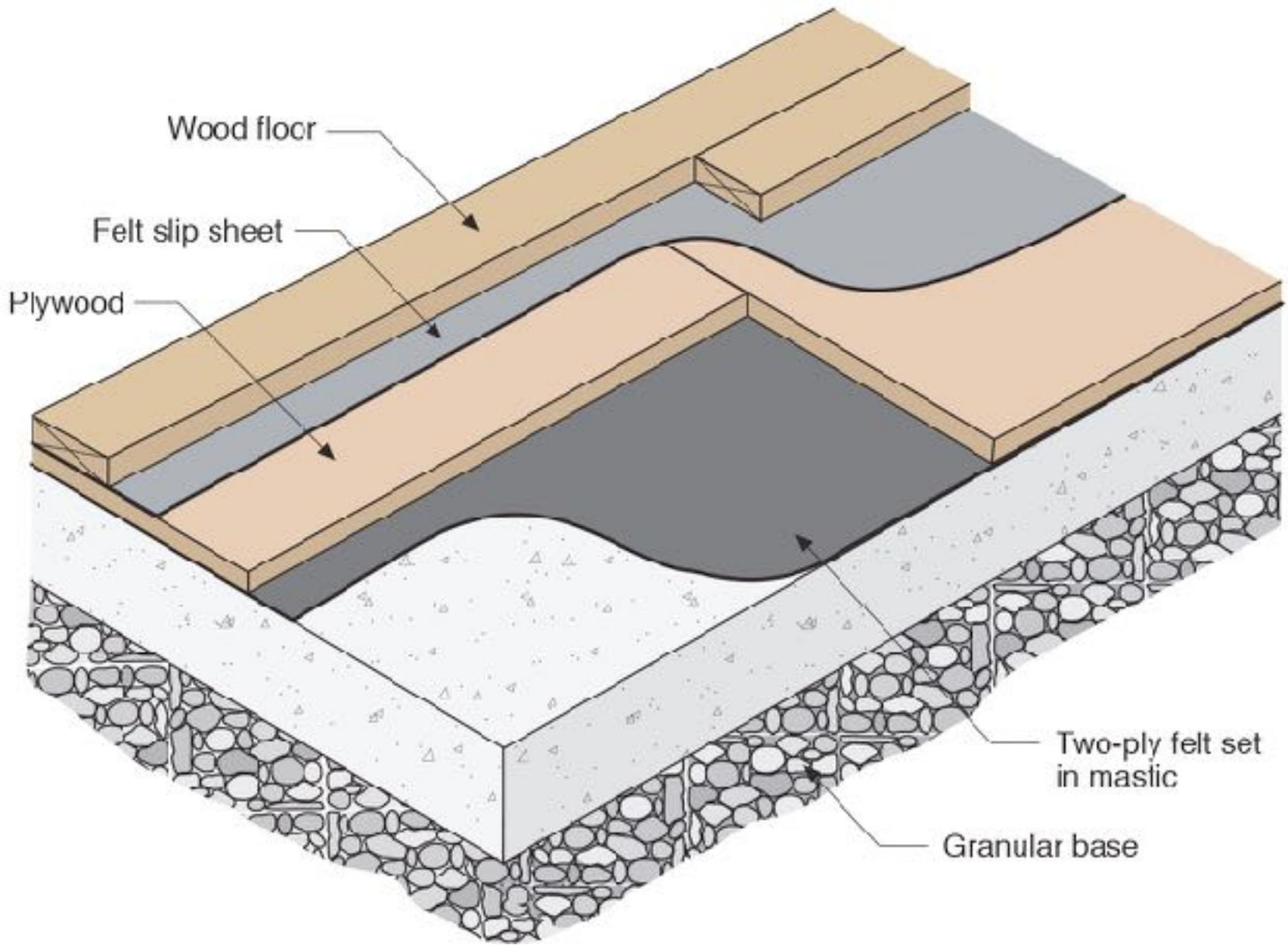


Wood floor

Concrete slab

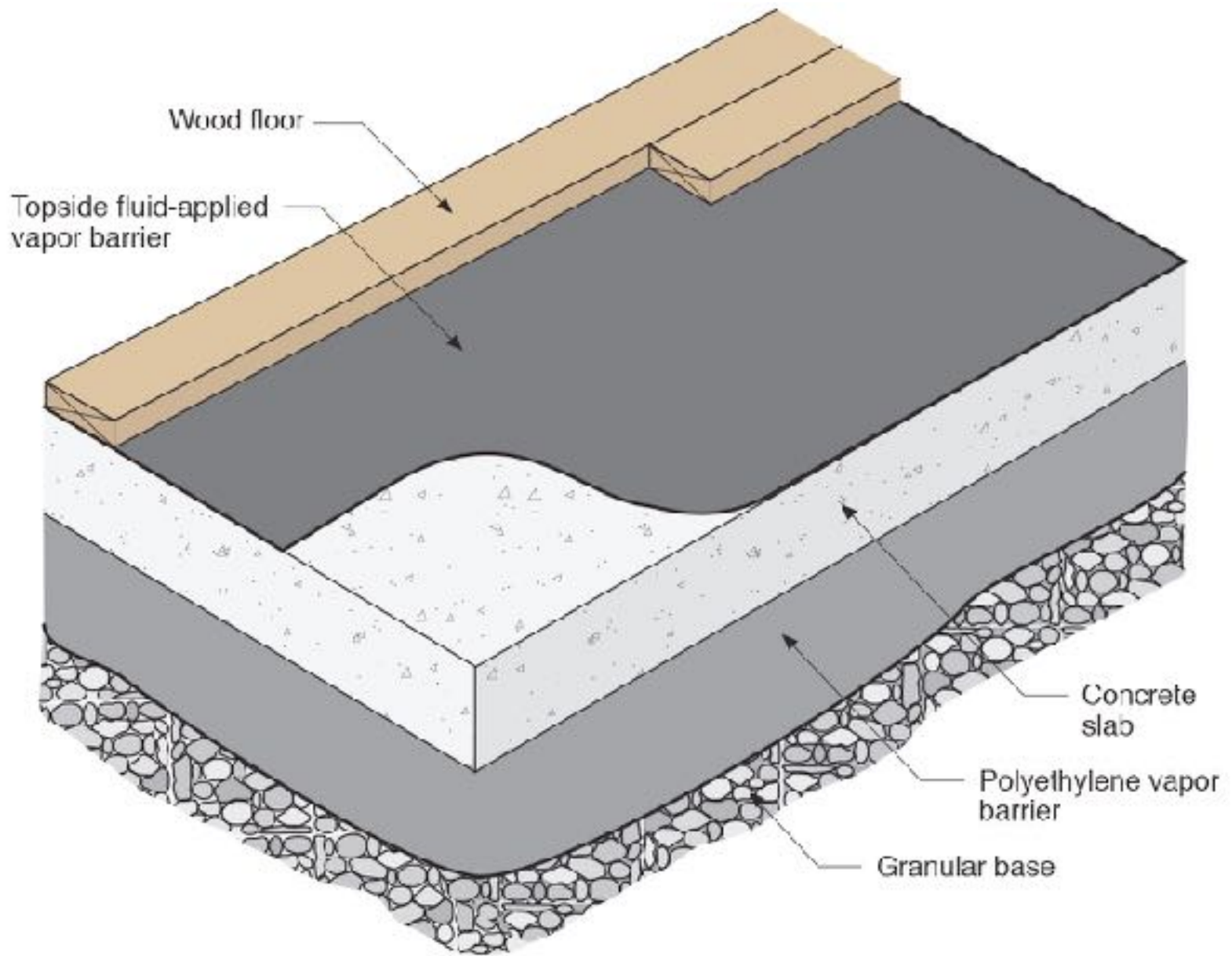
Polyethylene vapor barrier

Granular base



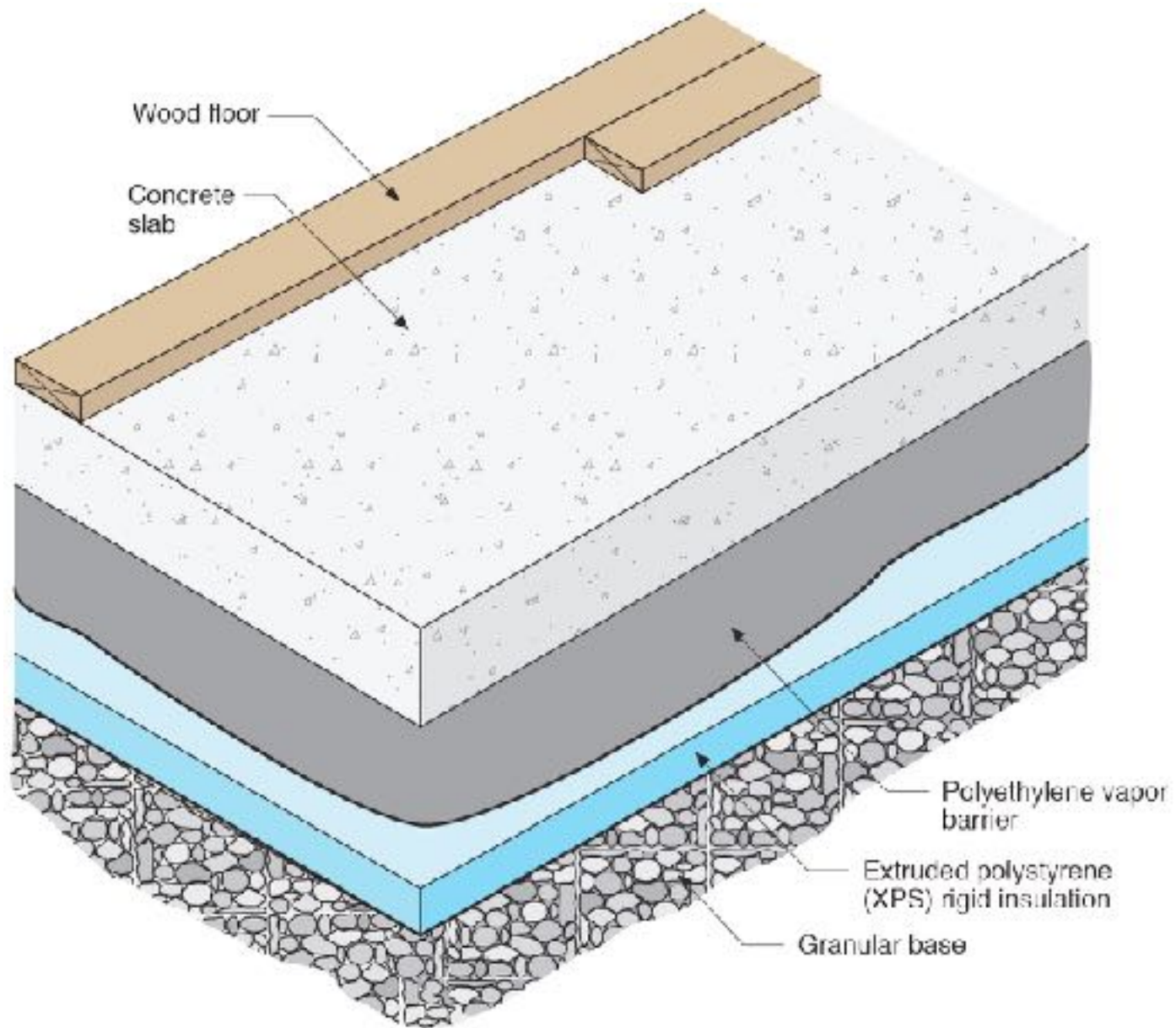


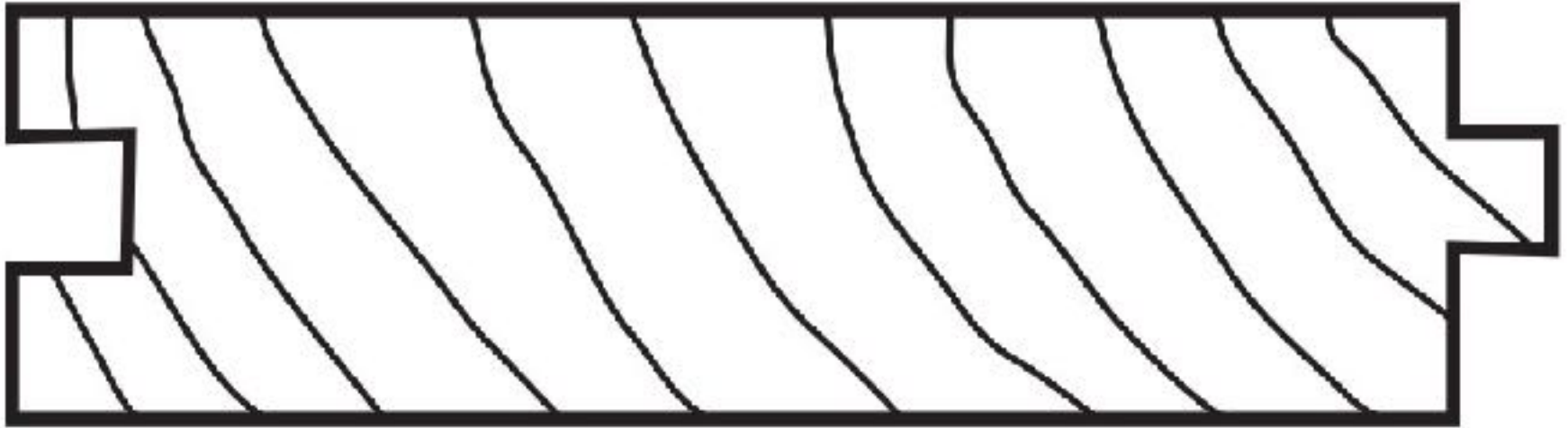




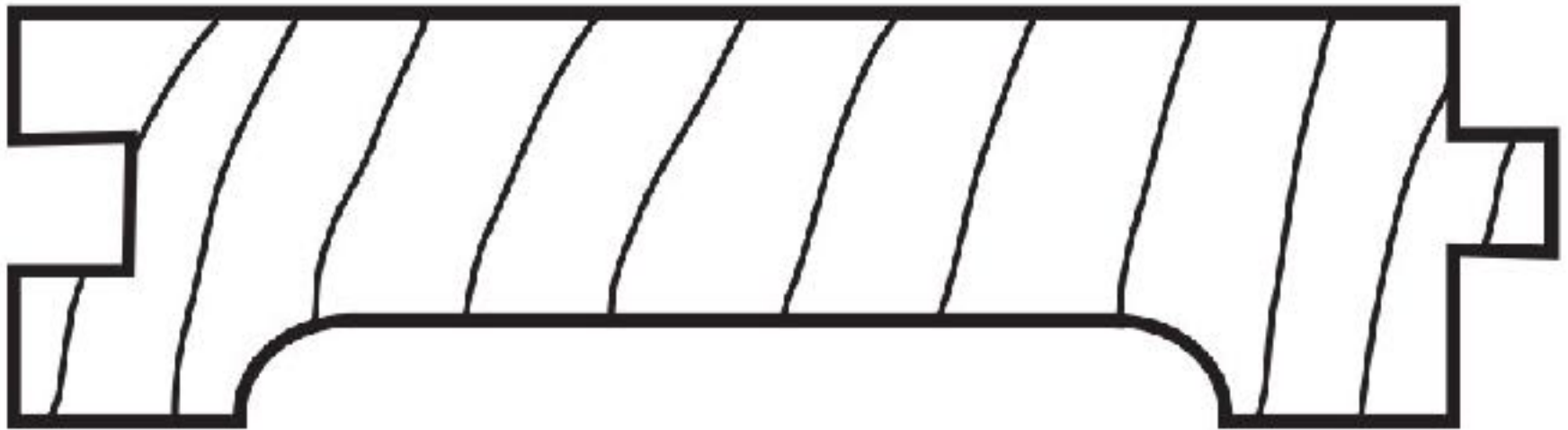




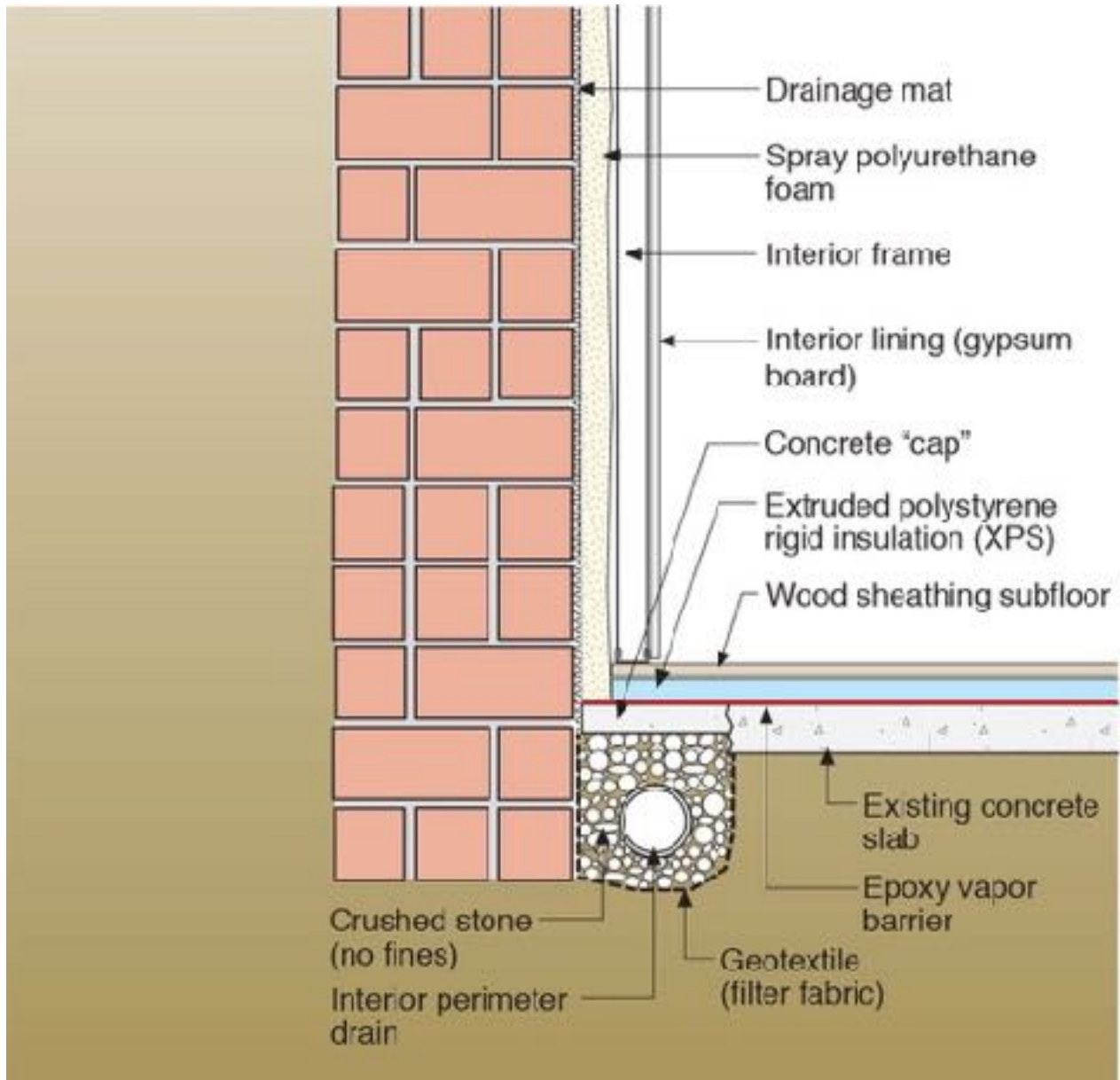




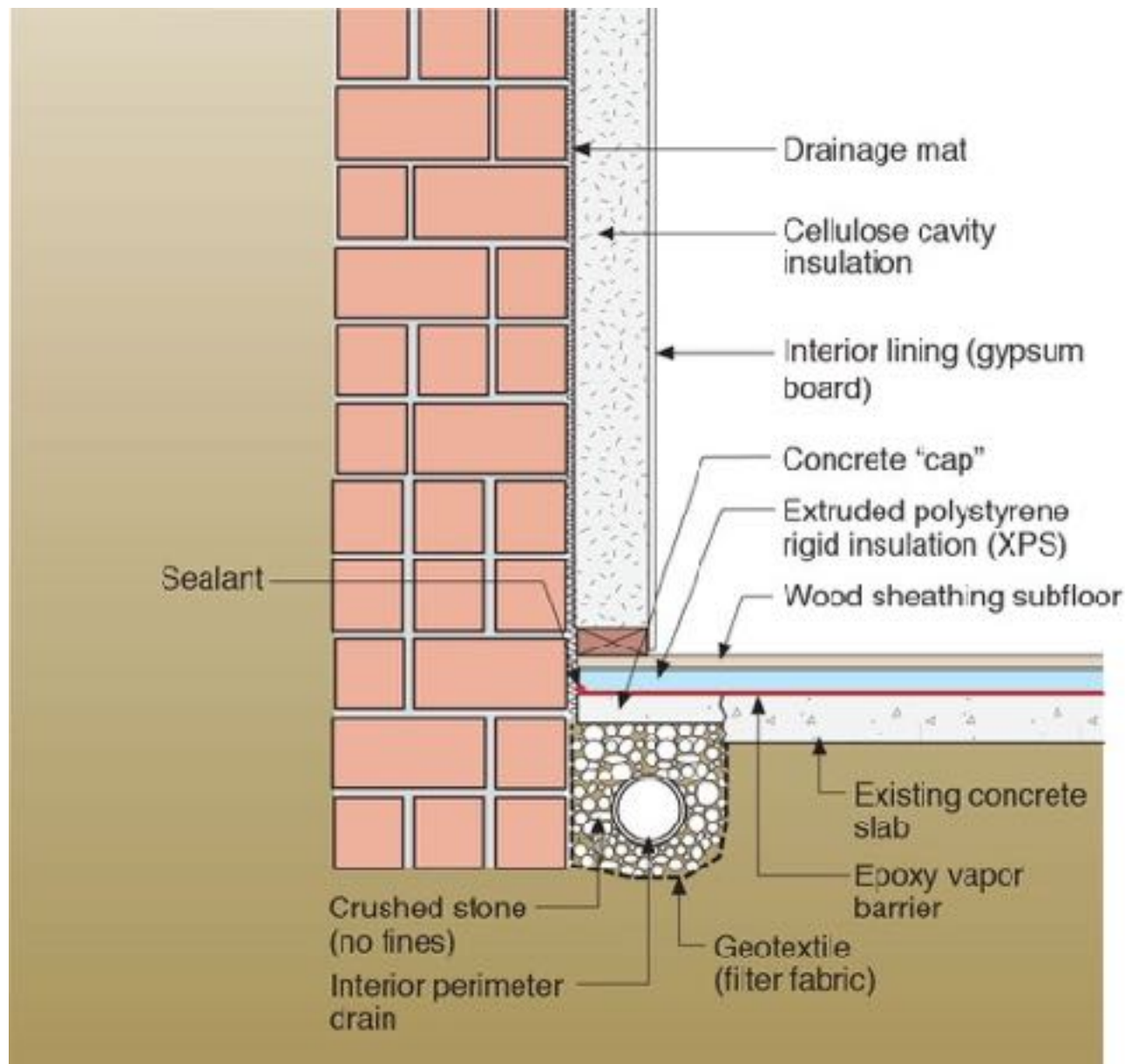
**Plain**

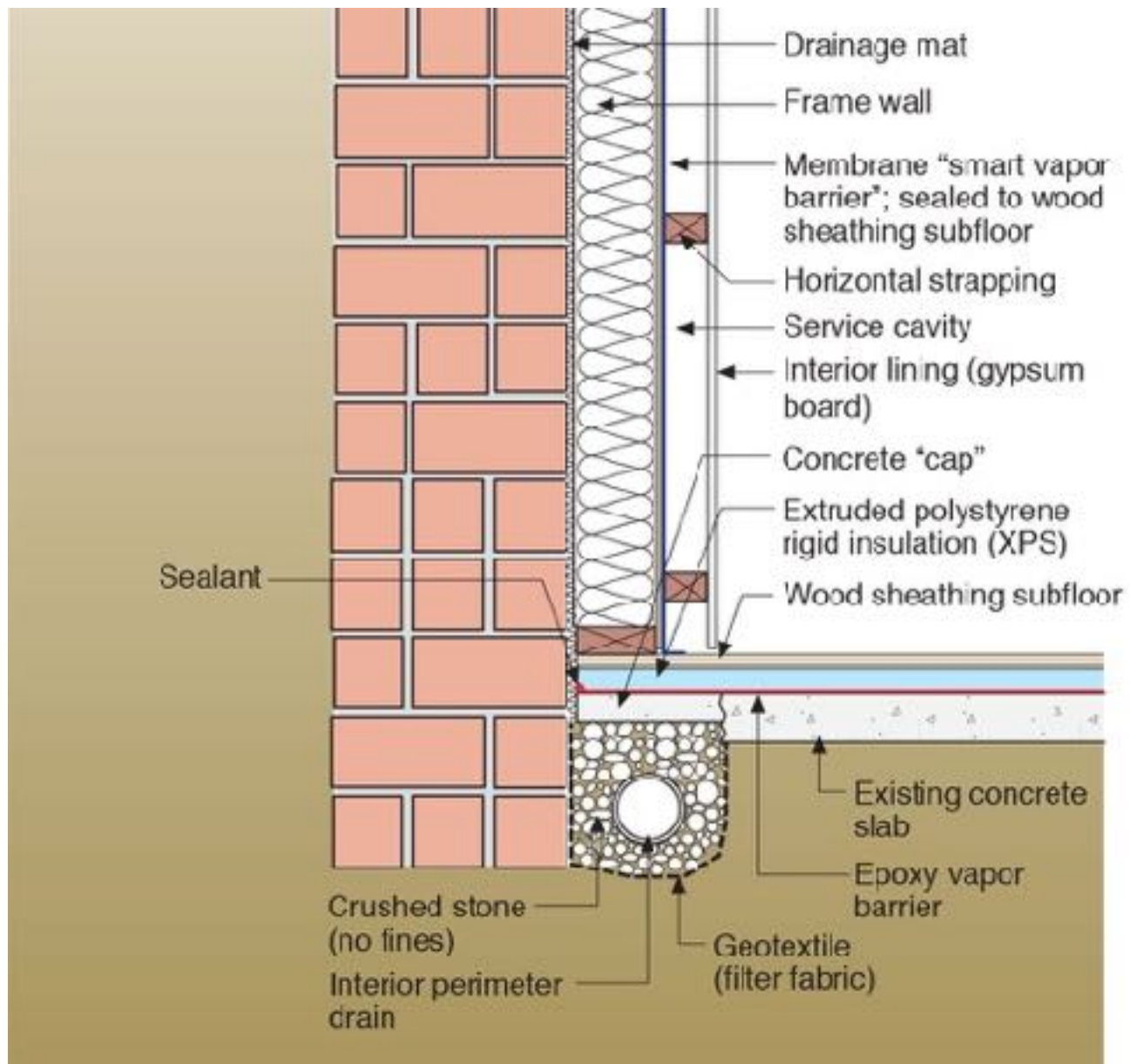


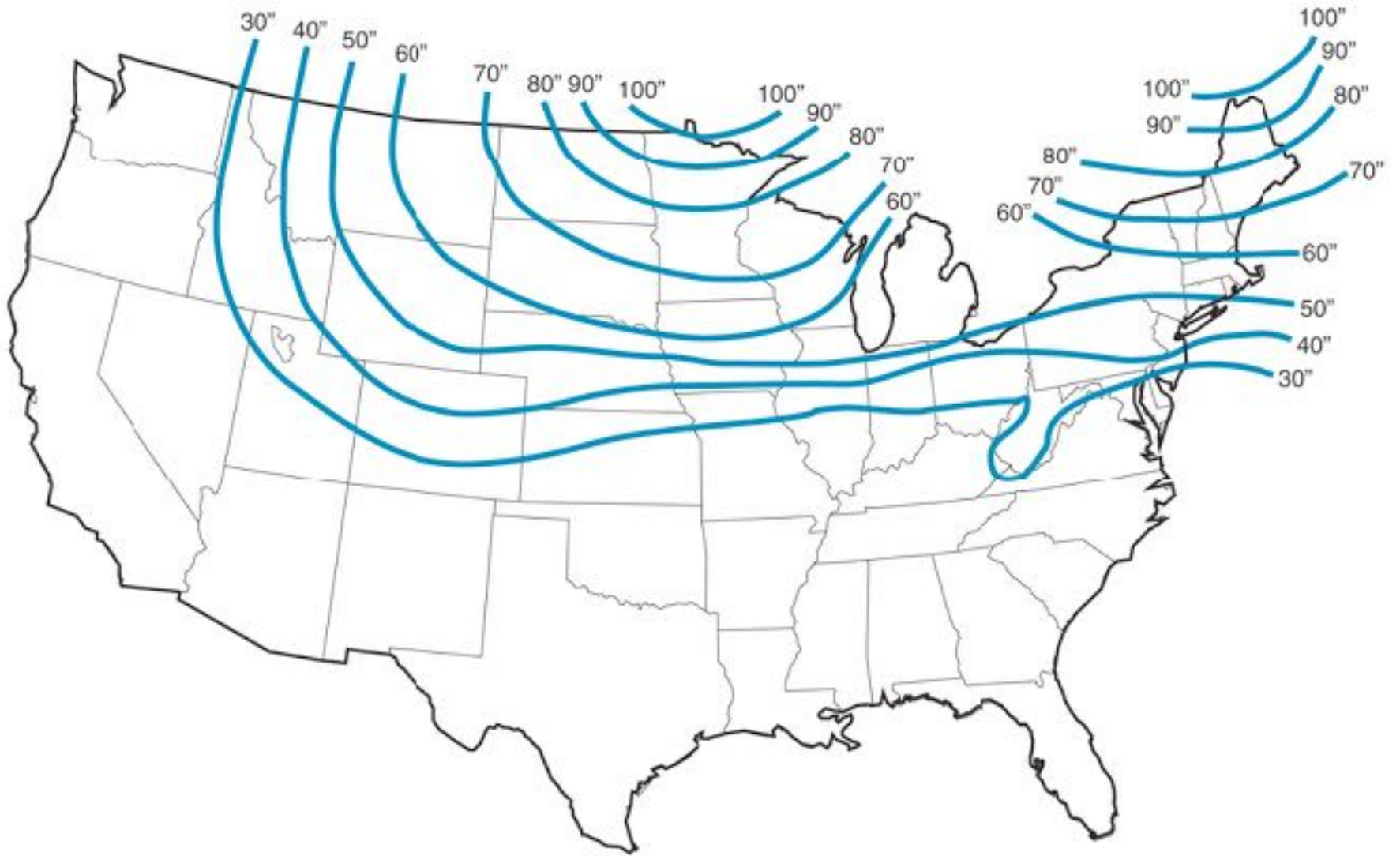
# Hollow Back











From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.

