

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

Building Science

Adventures In Building Science

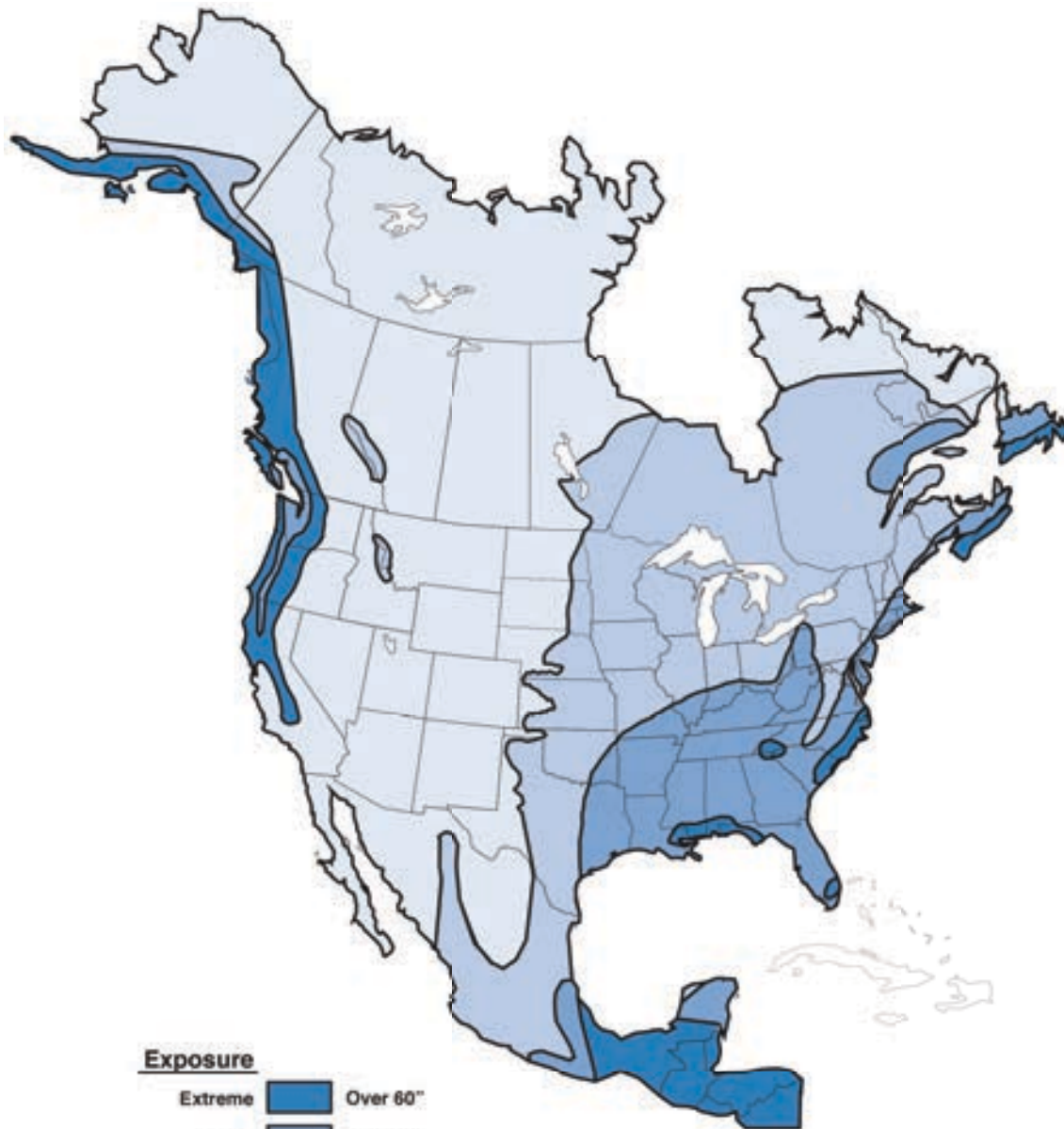
presented by www.buildingscience.com

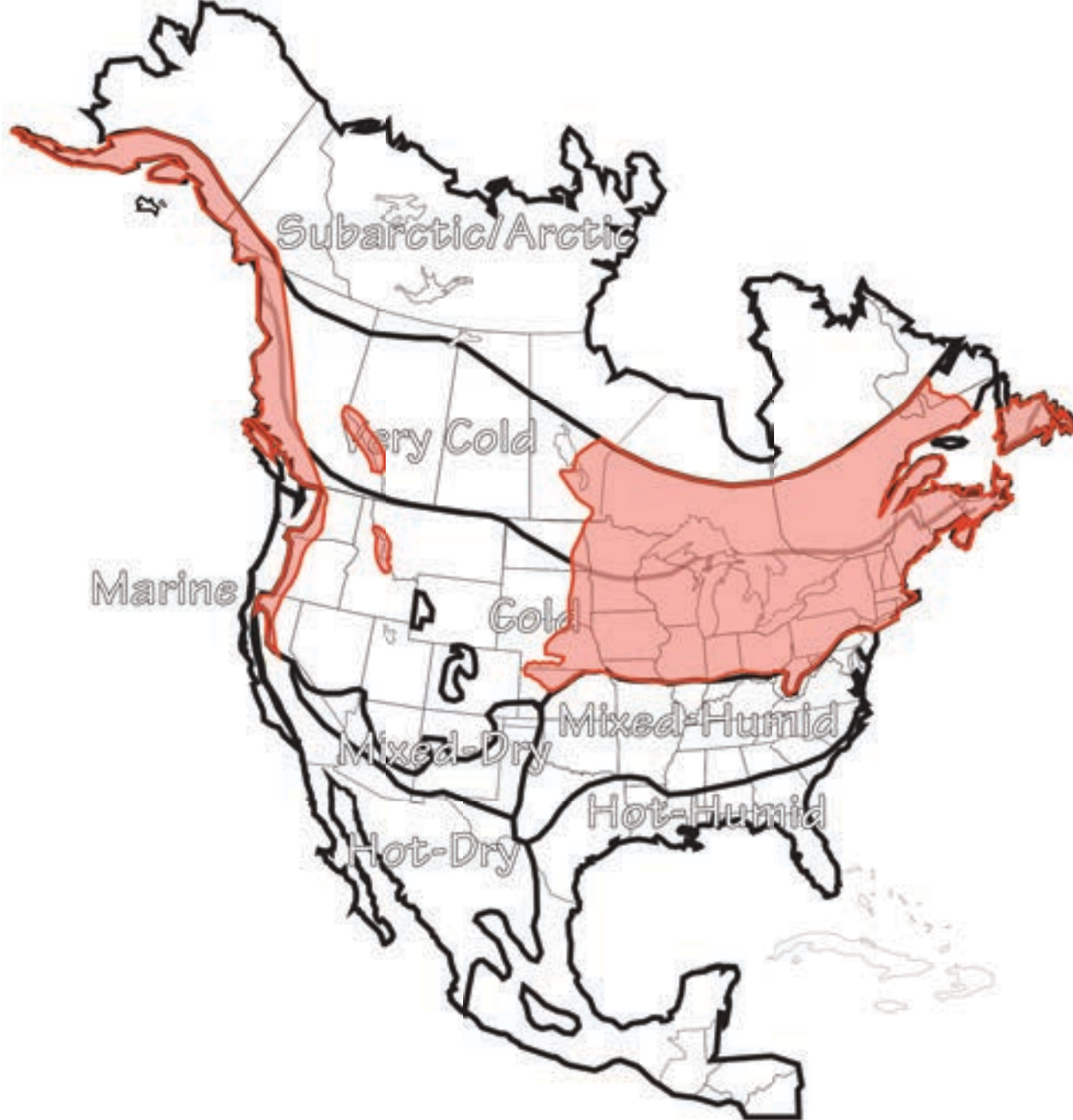


Freeze-Thaw Damage

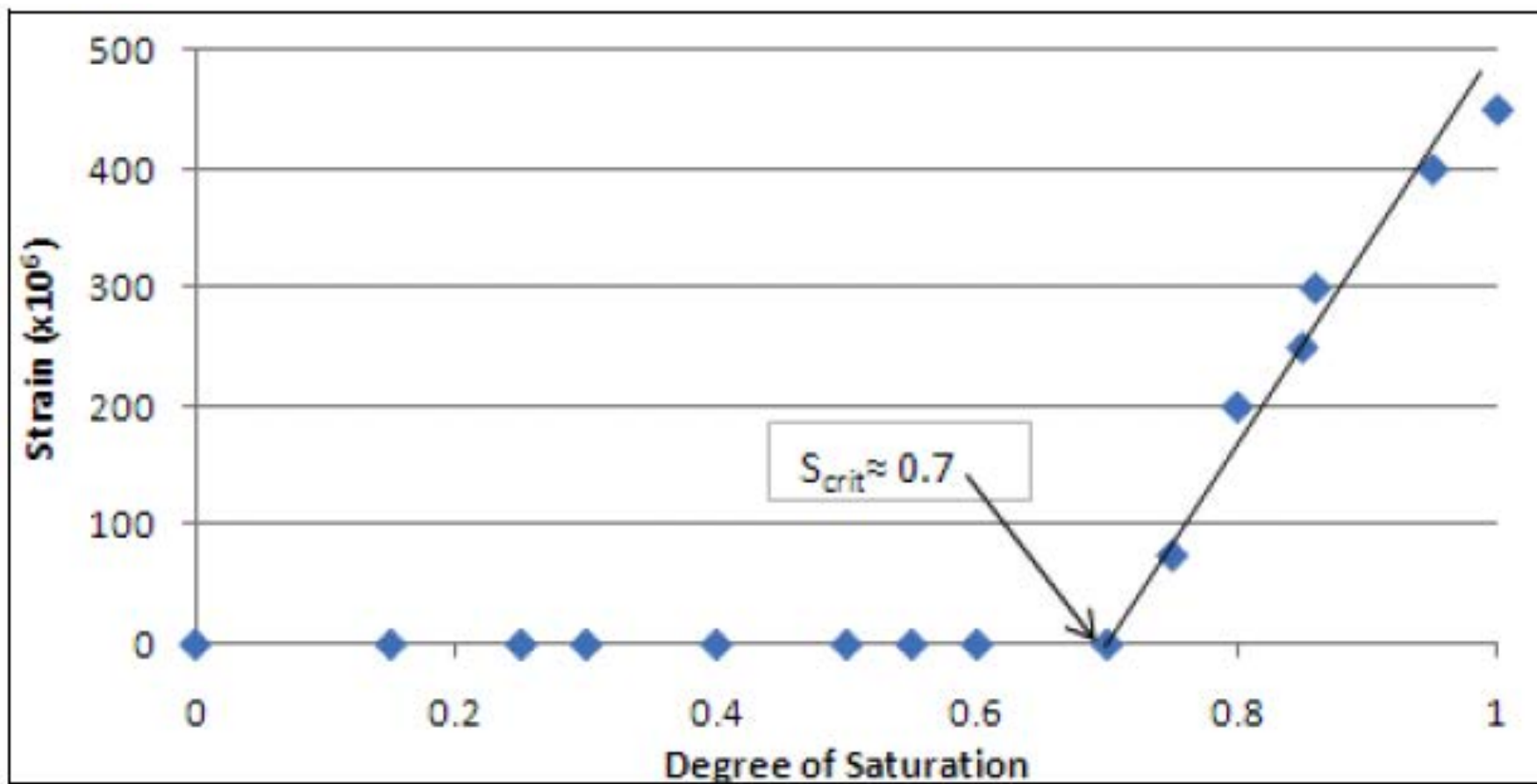
Freeze-Thaw Damage
Freezing Temperatures
Water
Susceptible Brick







Susceptible Brick Firing Temperature Vitrification

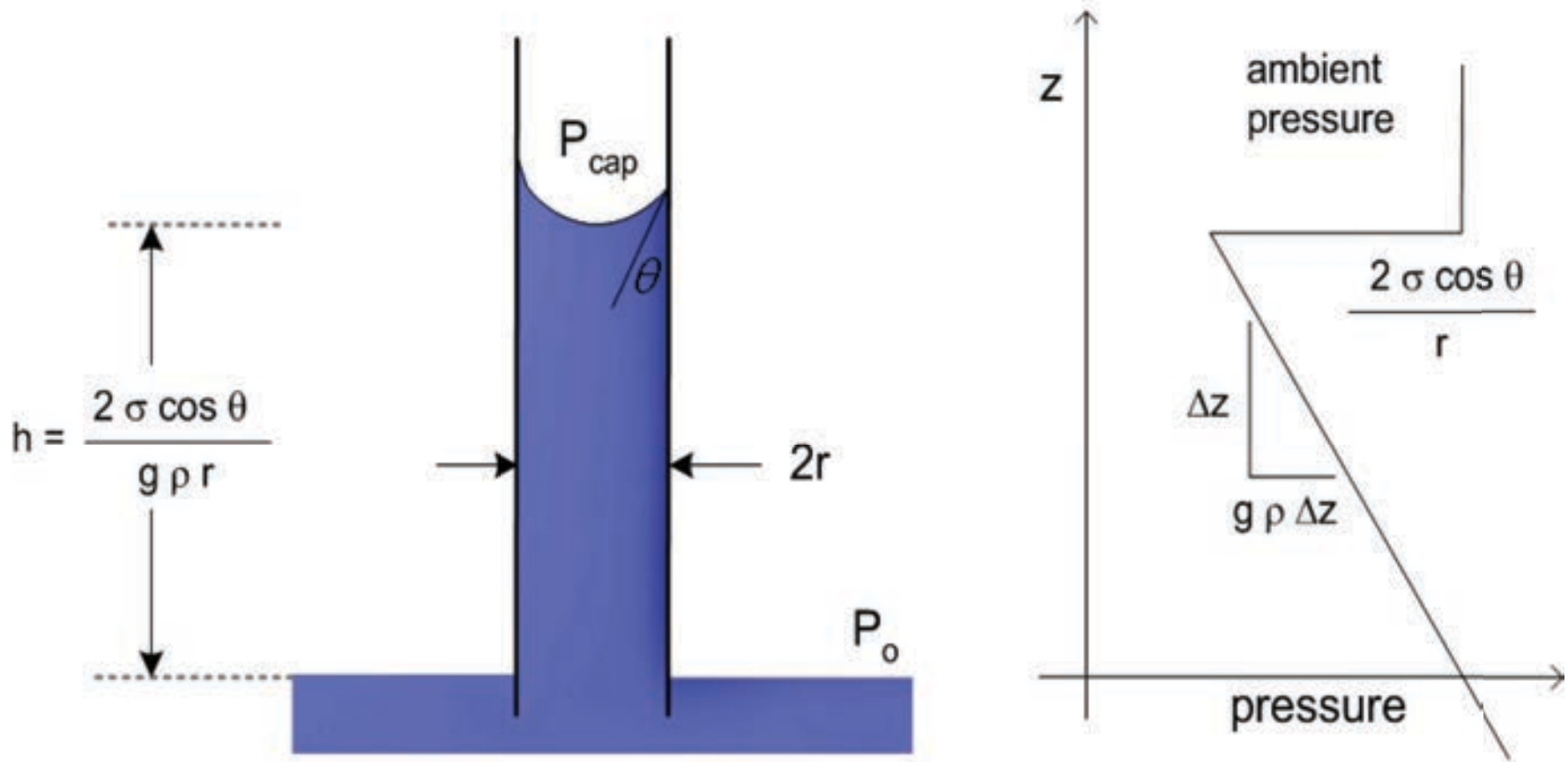




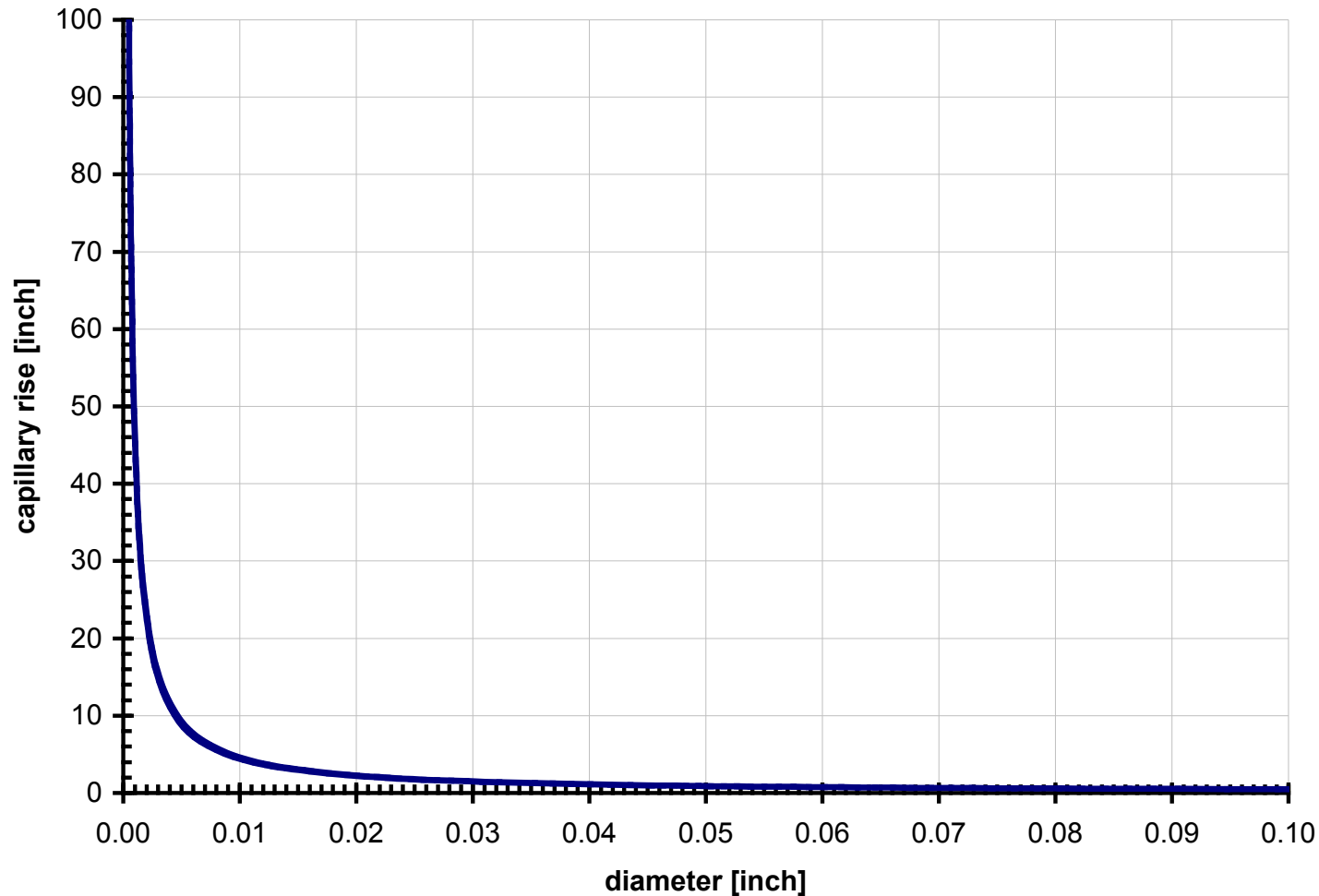
Kelvin Equation

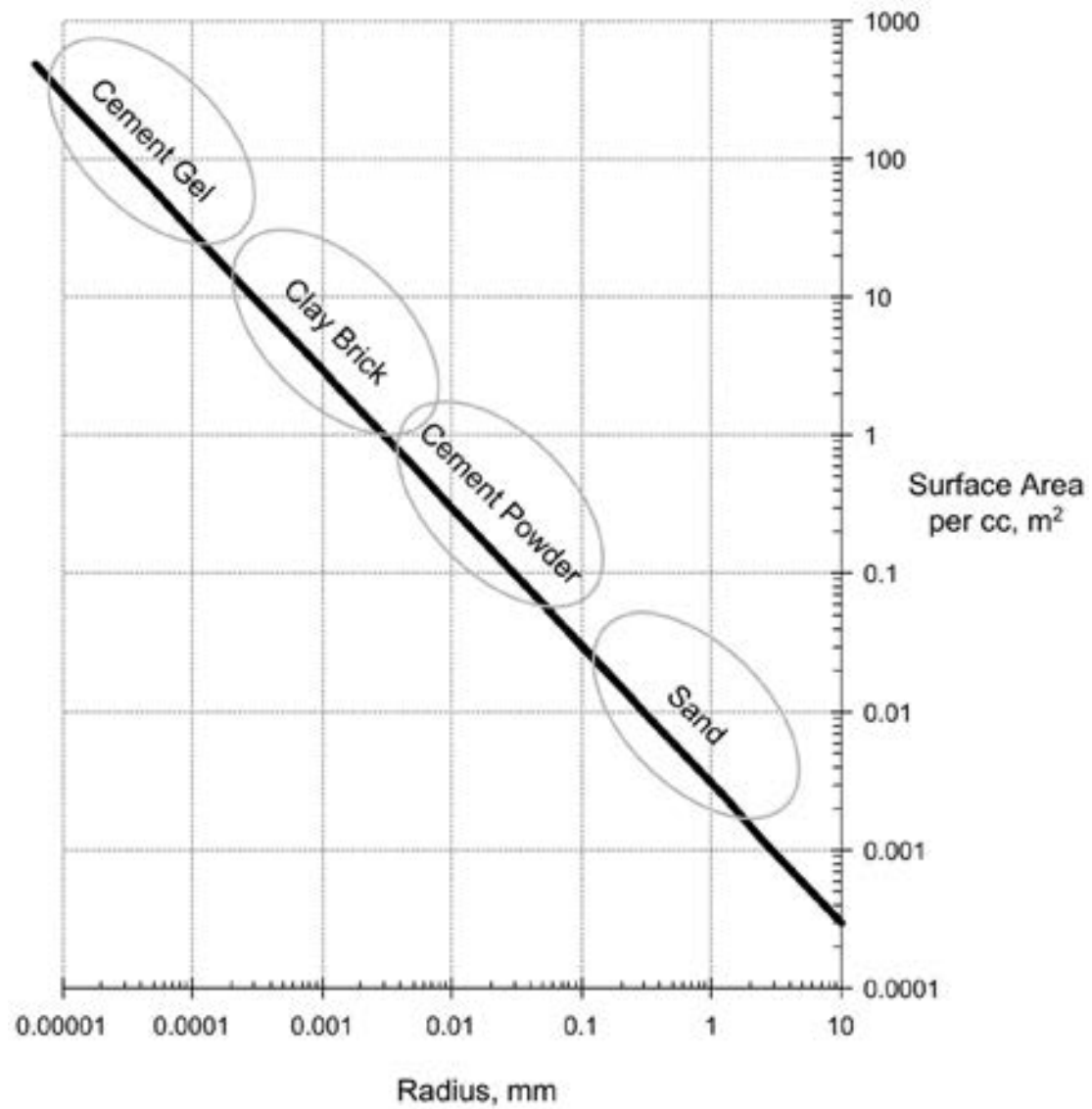
$$\ln \frac{p}{p_0} = \frac{2\gamma V_m}{rRT}$$

Calculating capillary rise

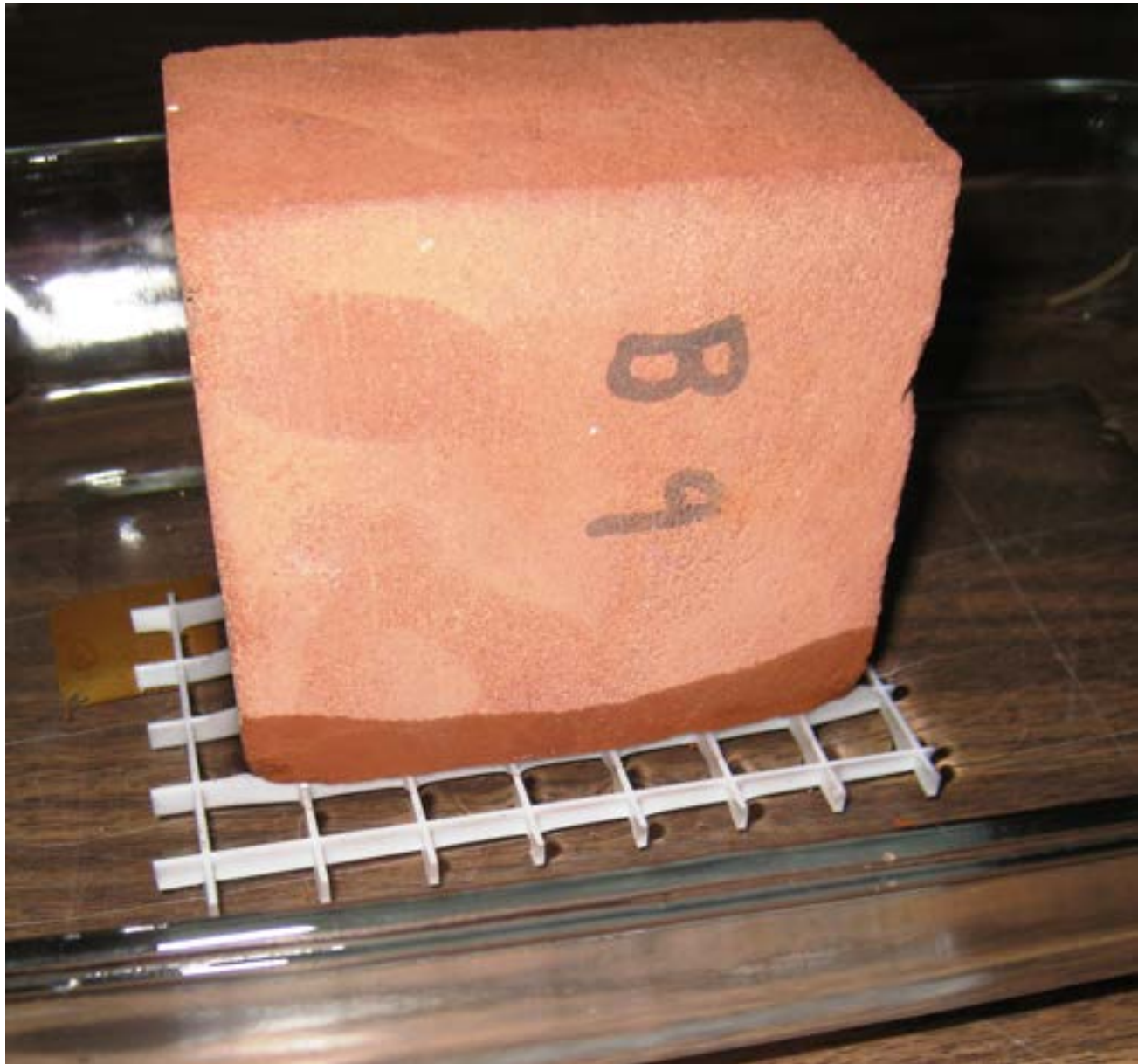


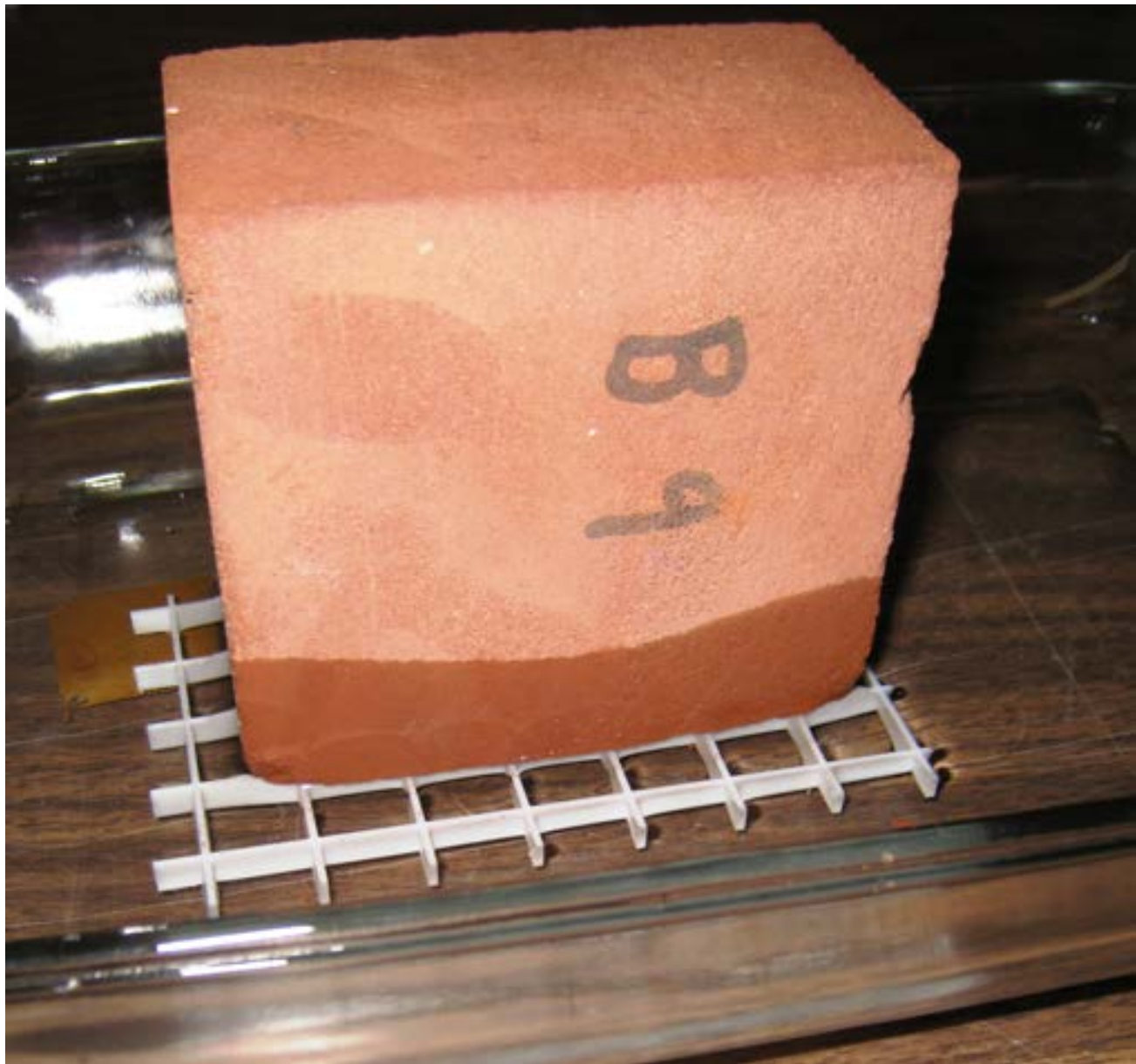
Capillary rise versus diameter

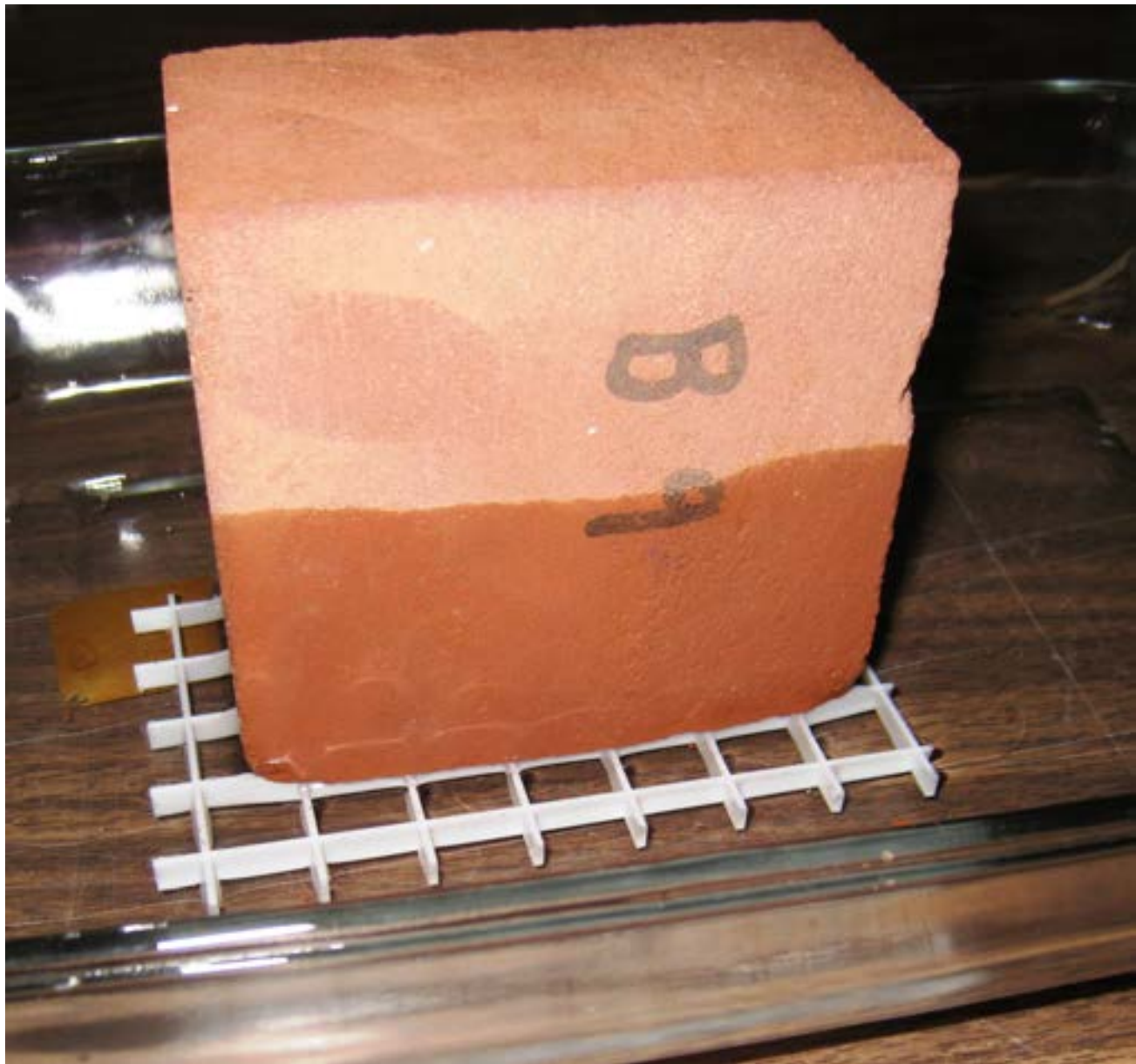


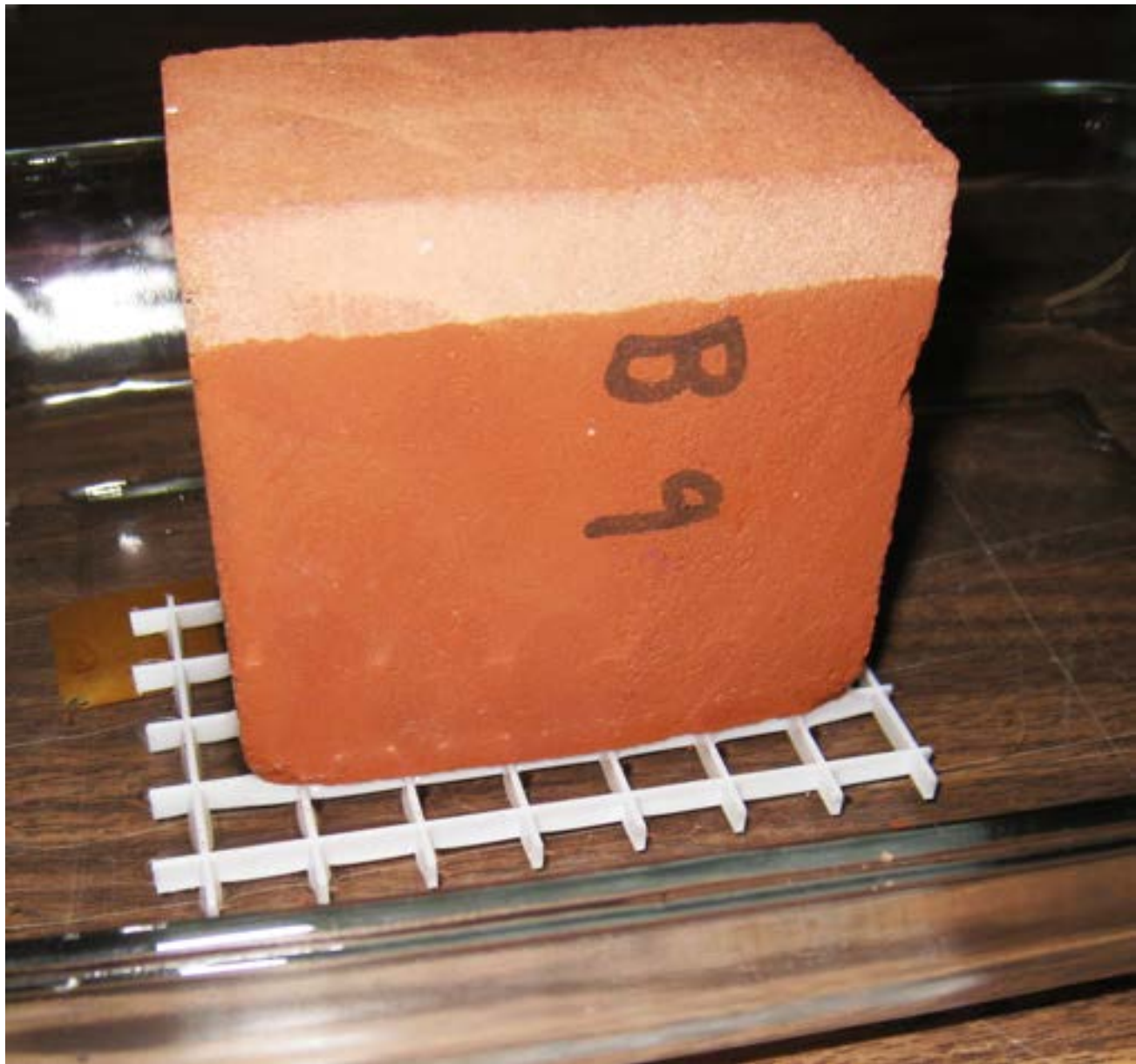


Surface area vs. particle size
From Straube & Burnett, 2005





















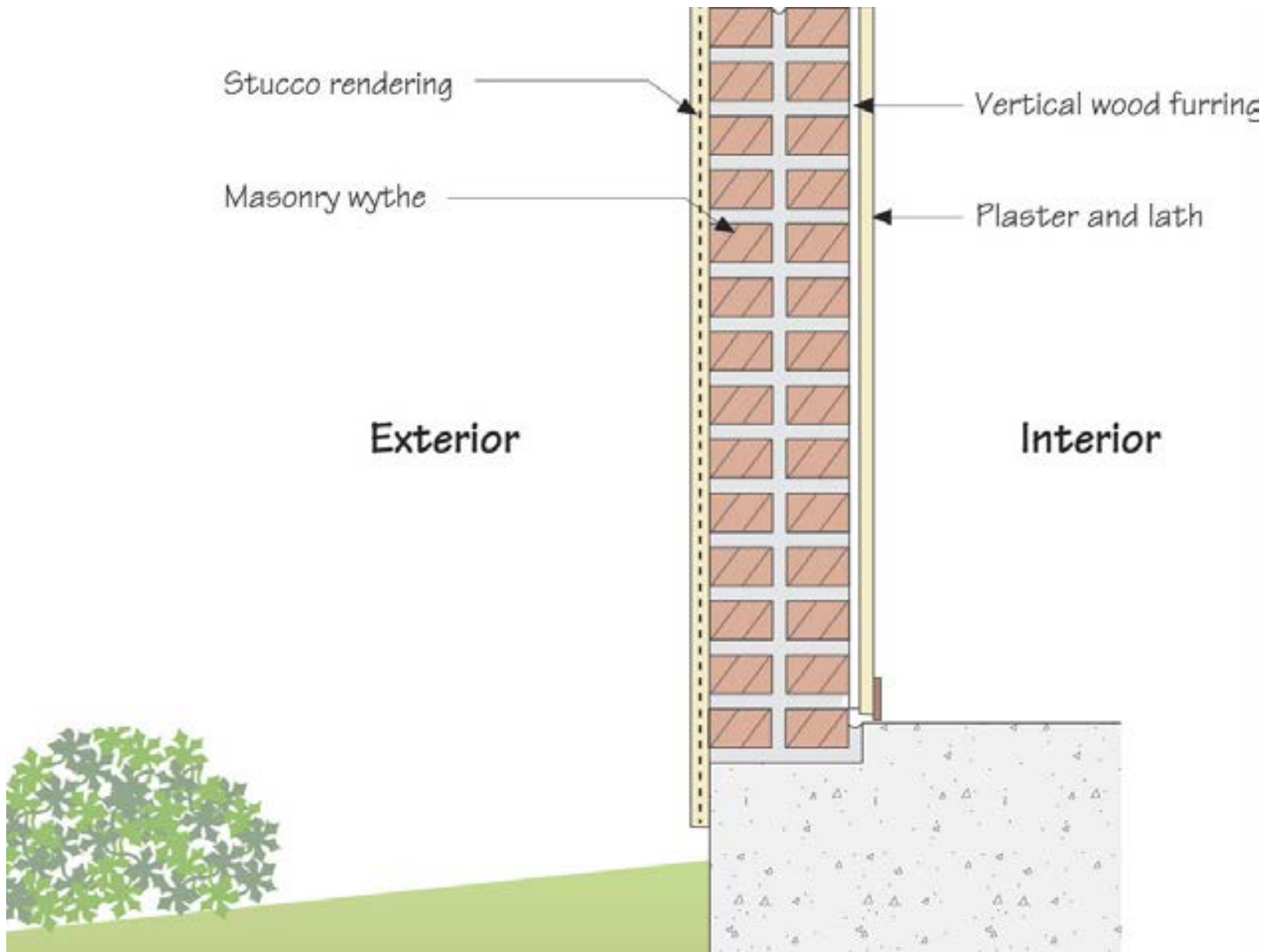












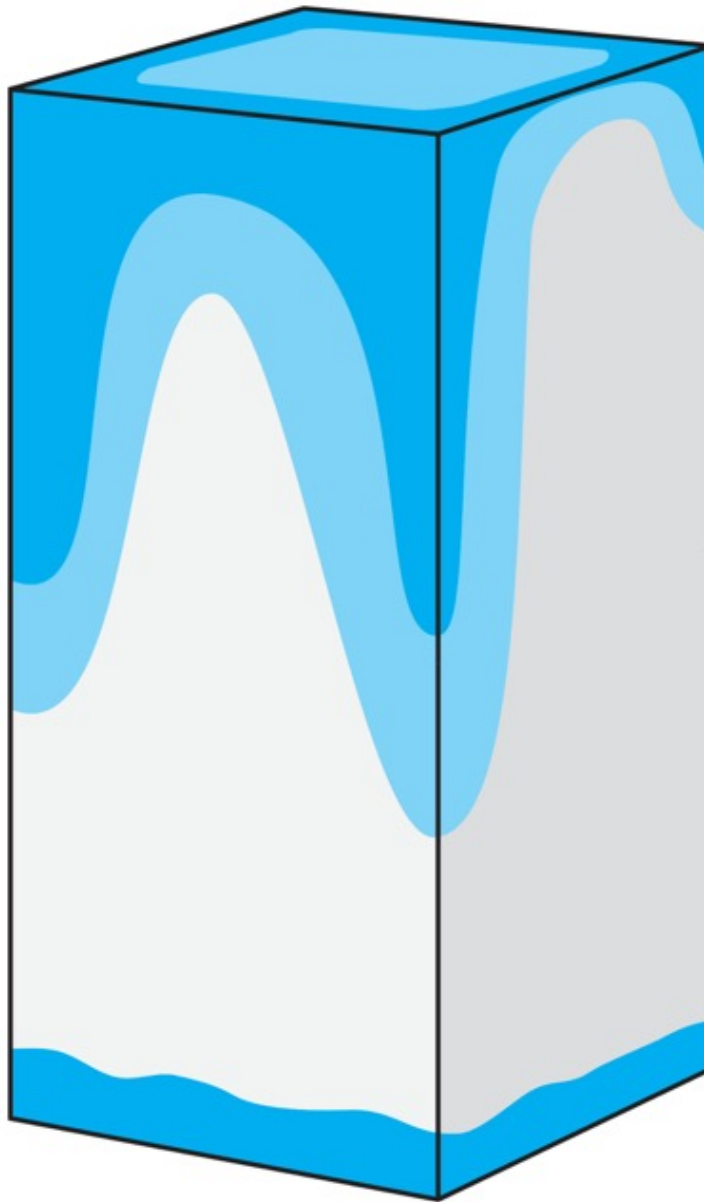


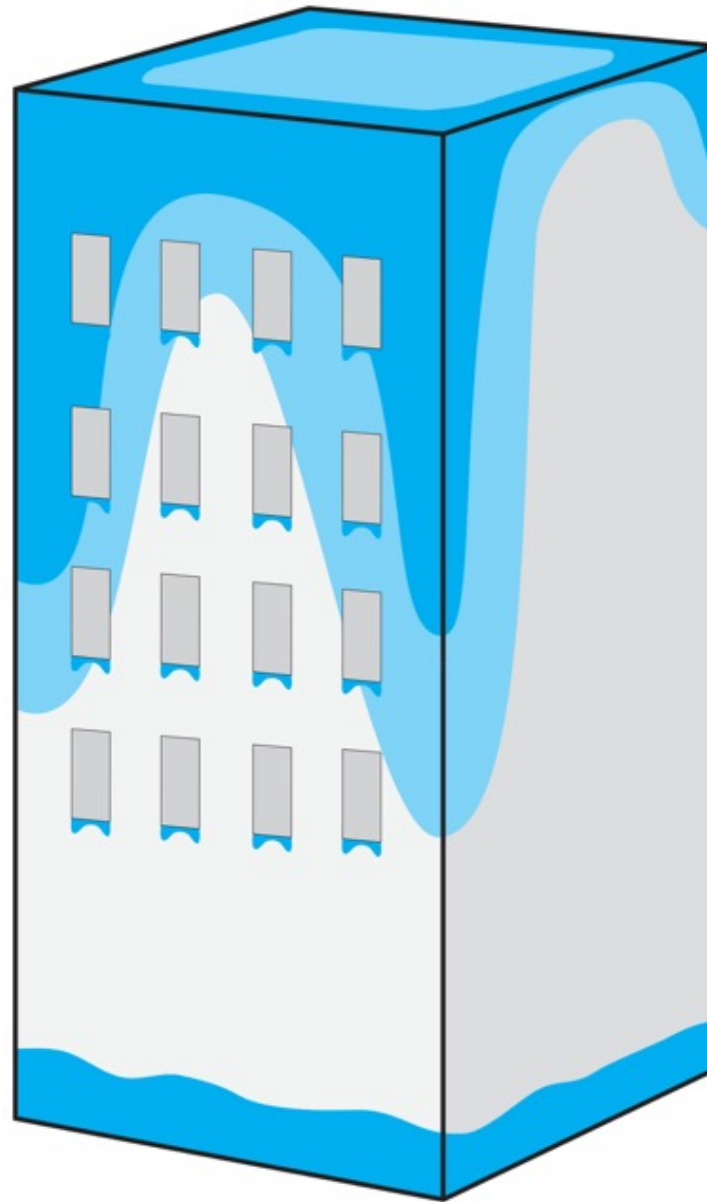




















































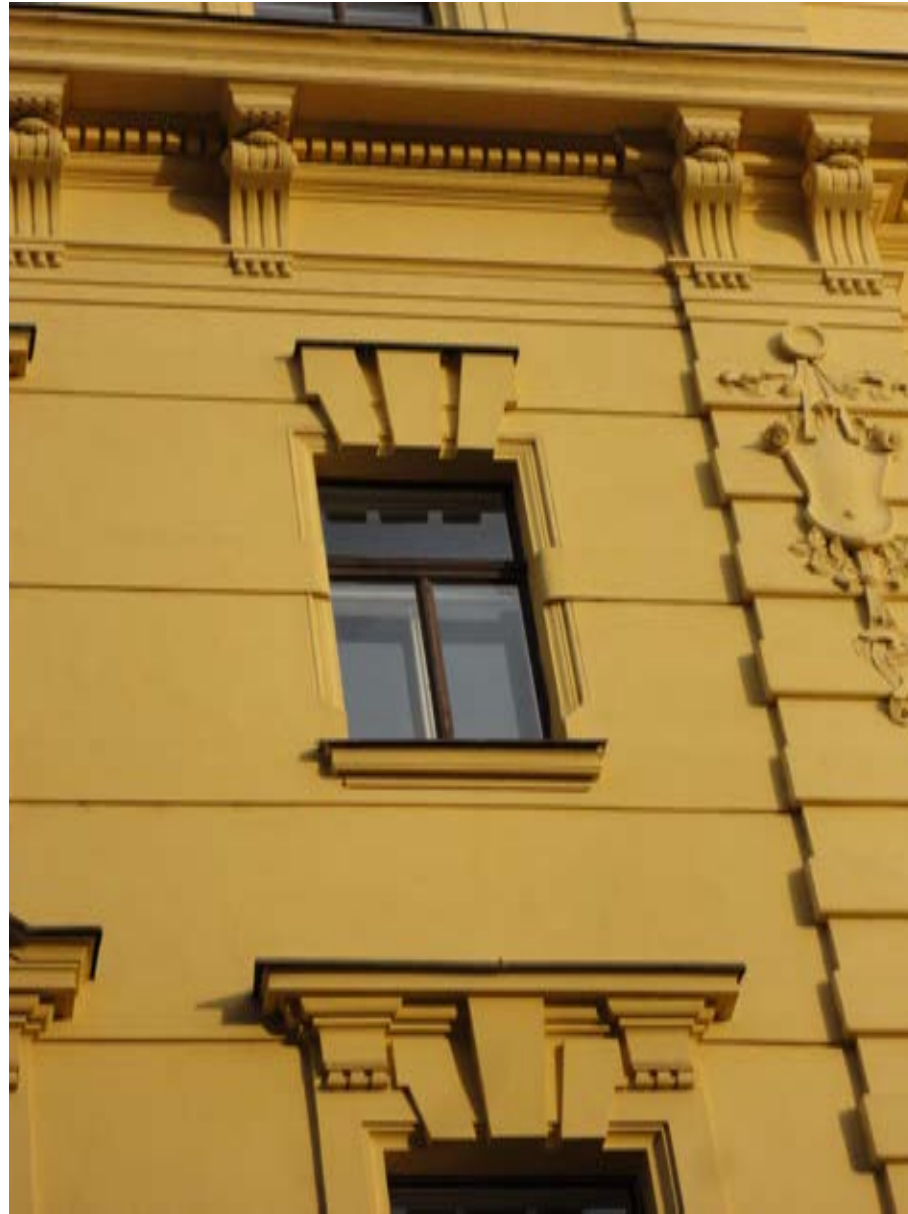












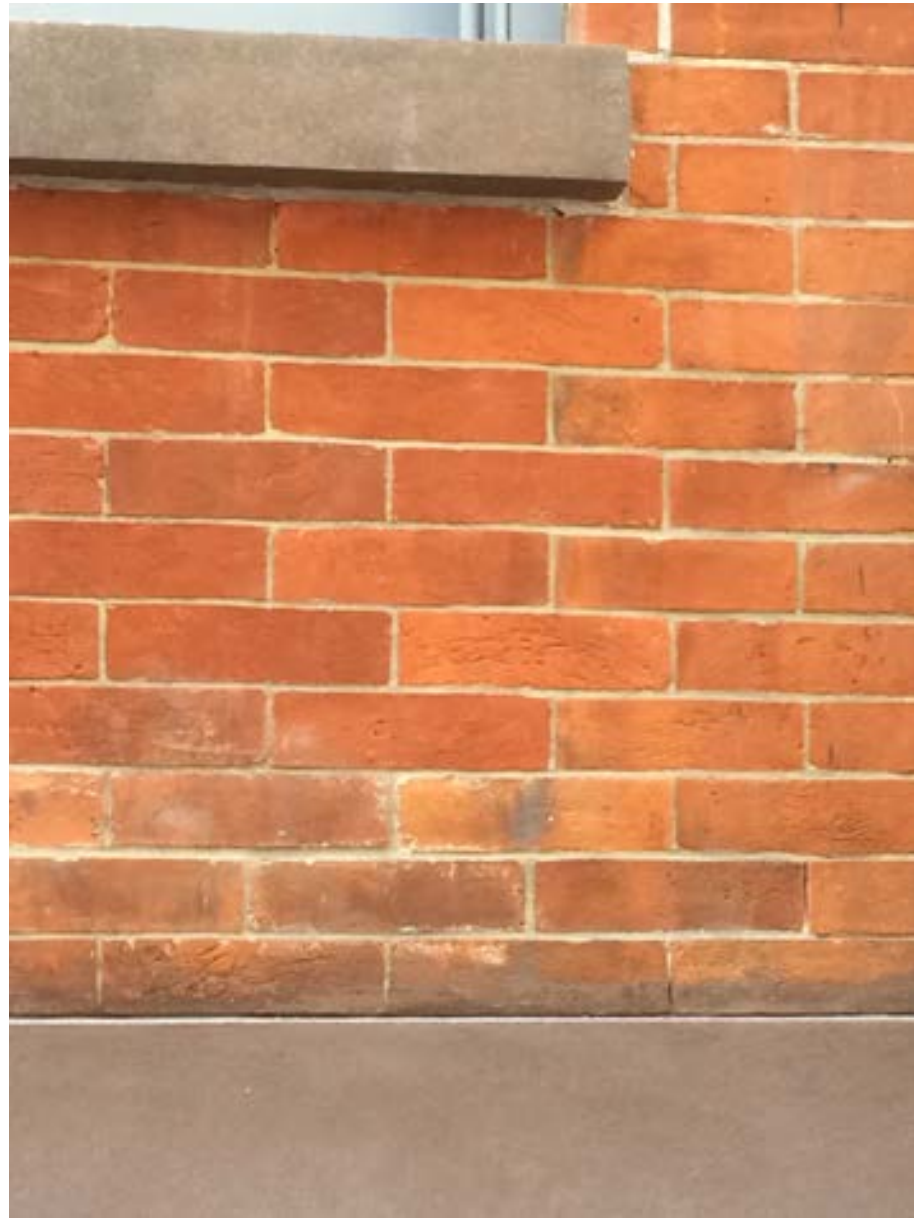
























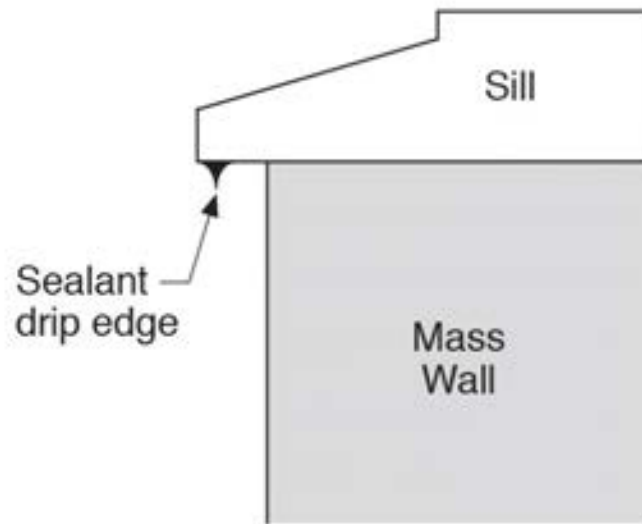
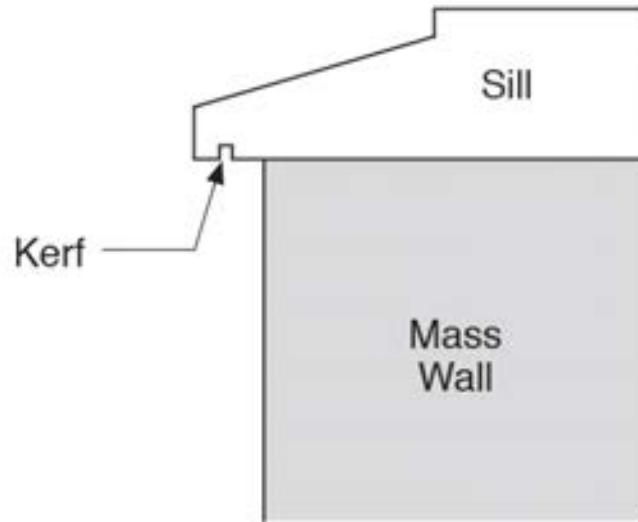


























































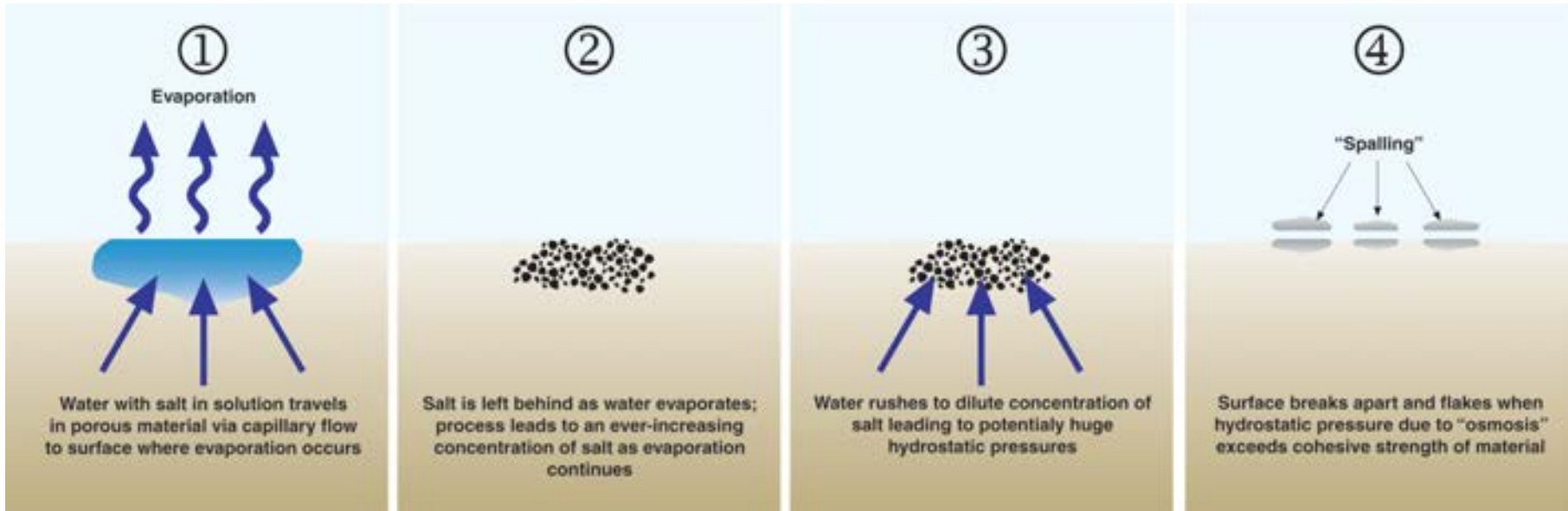










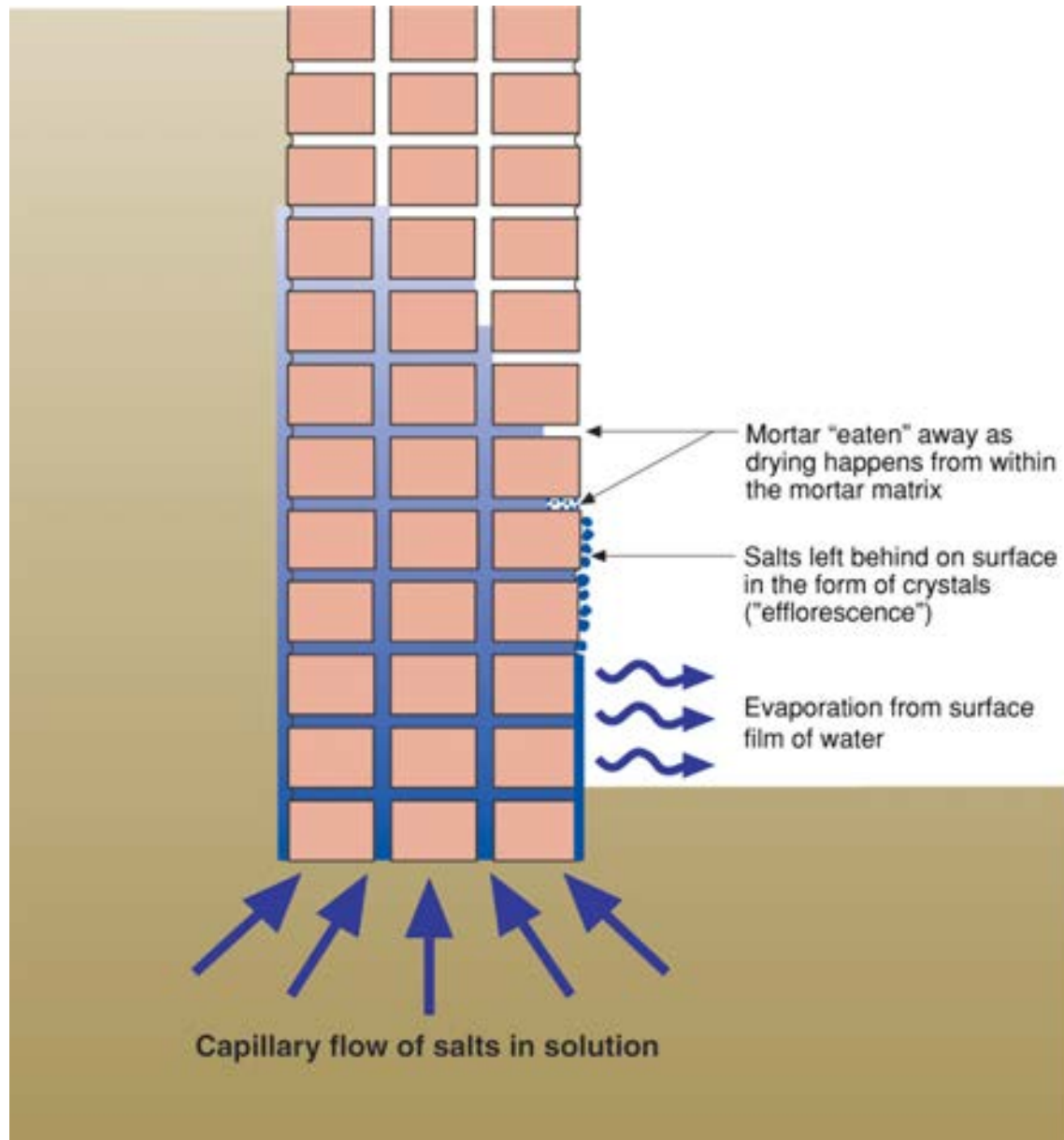


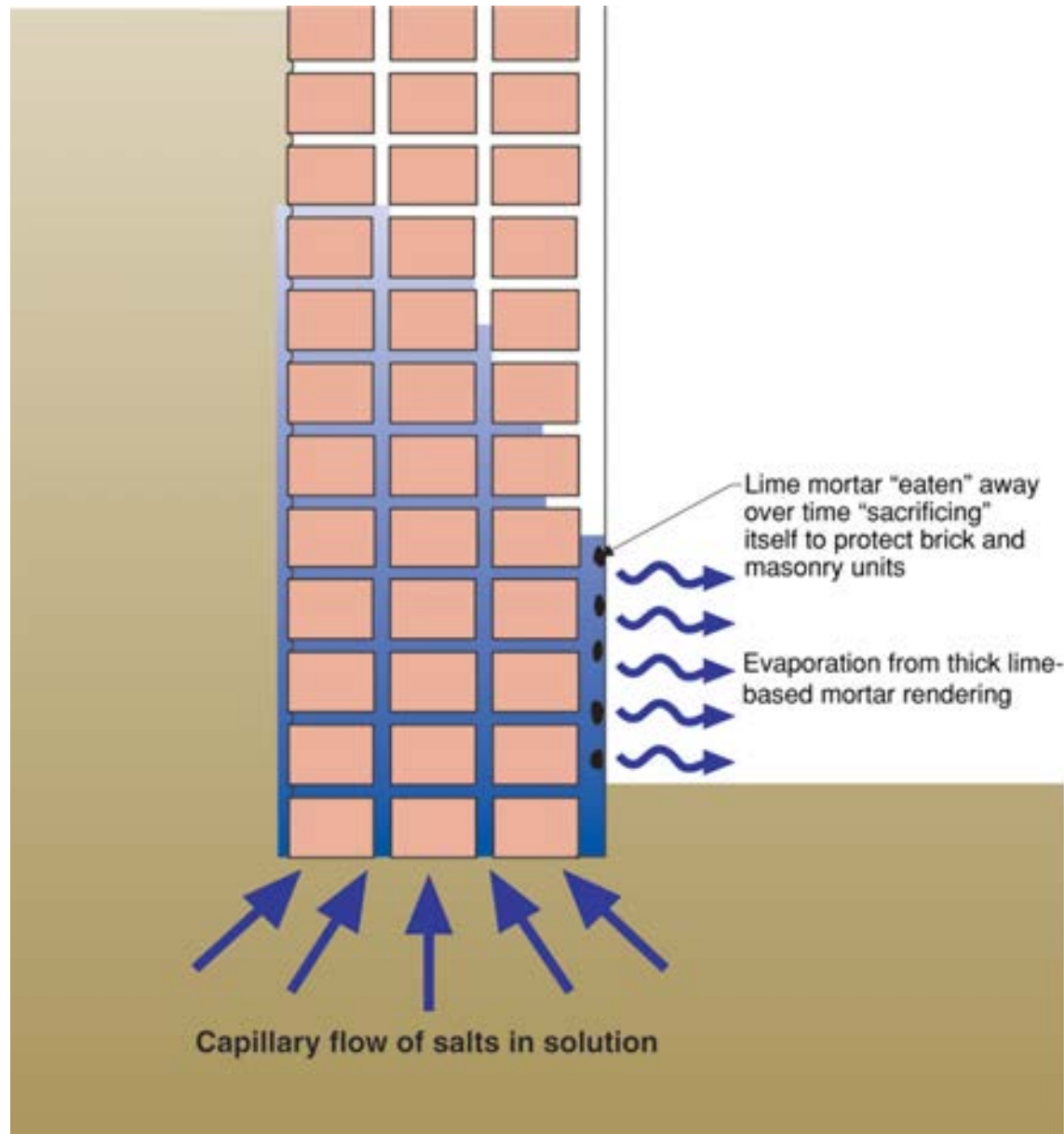
Diffusion + Capillarity + Osmosis = Problem

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













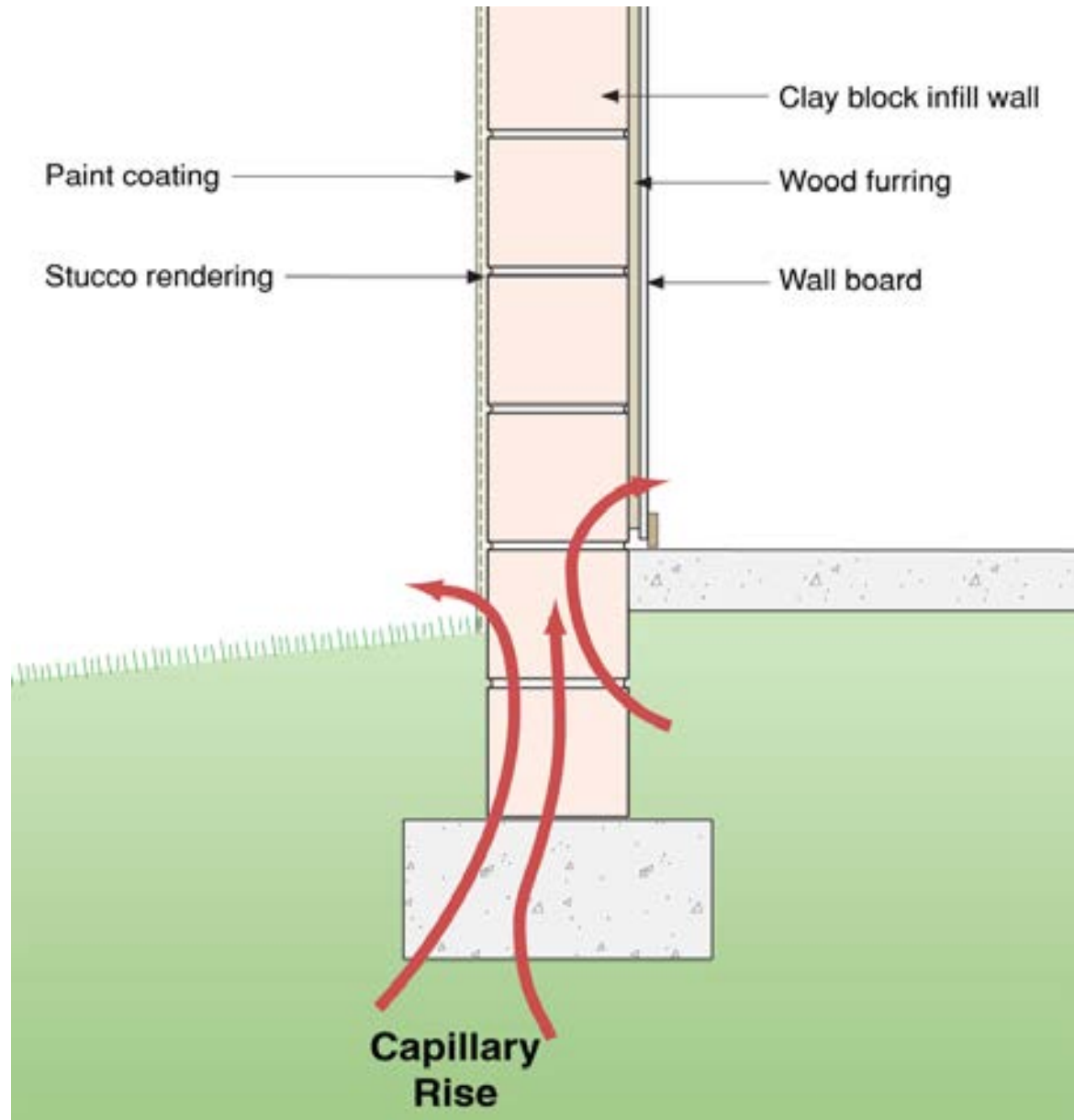


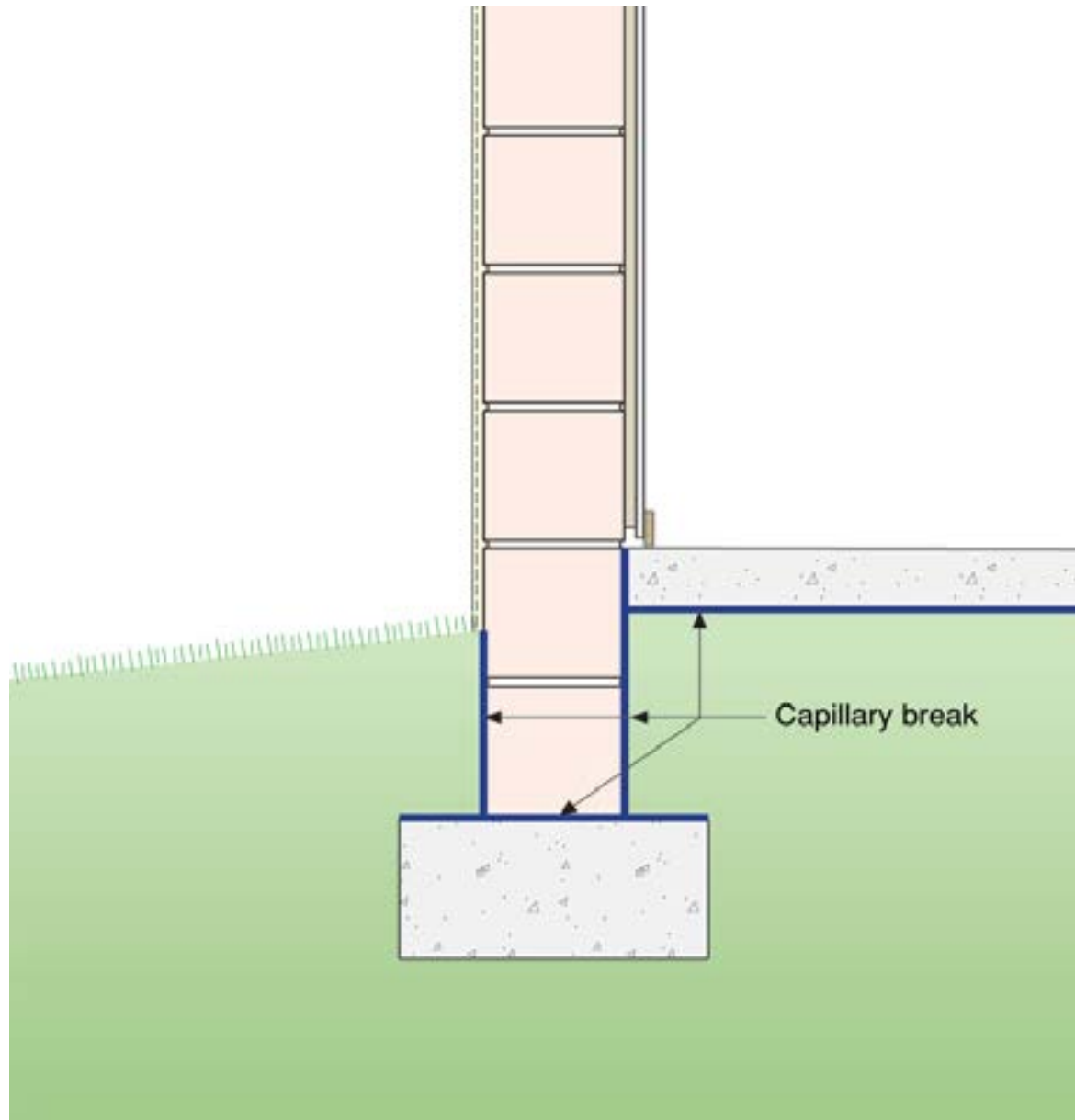




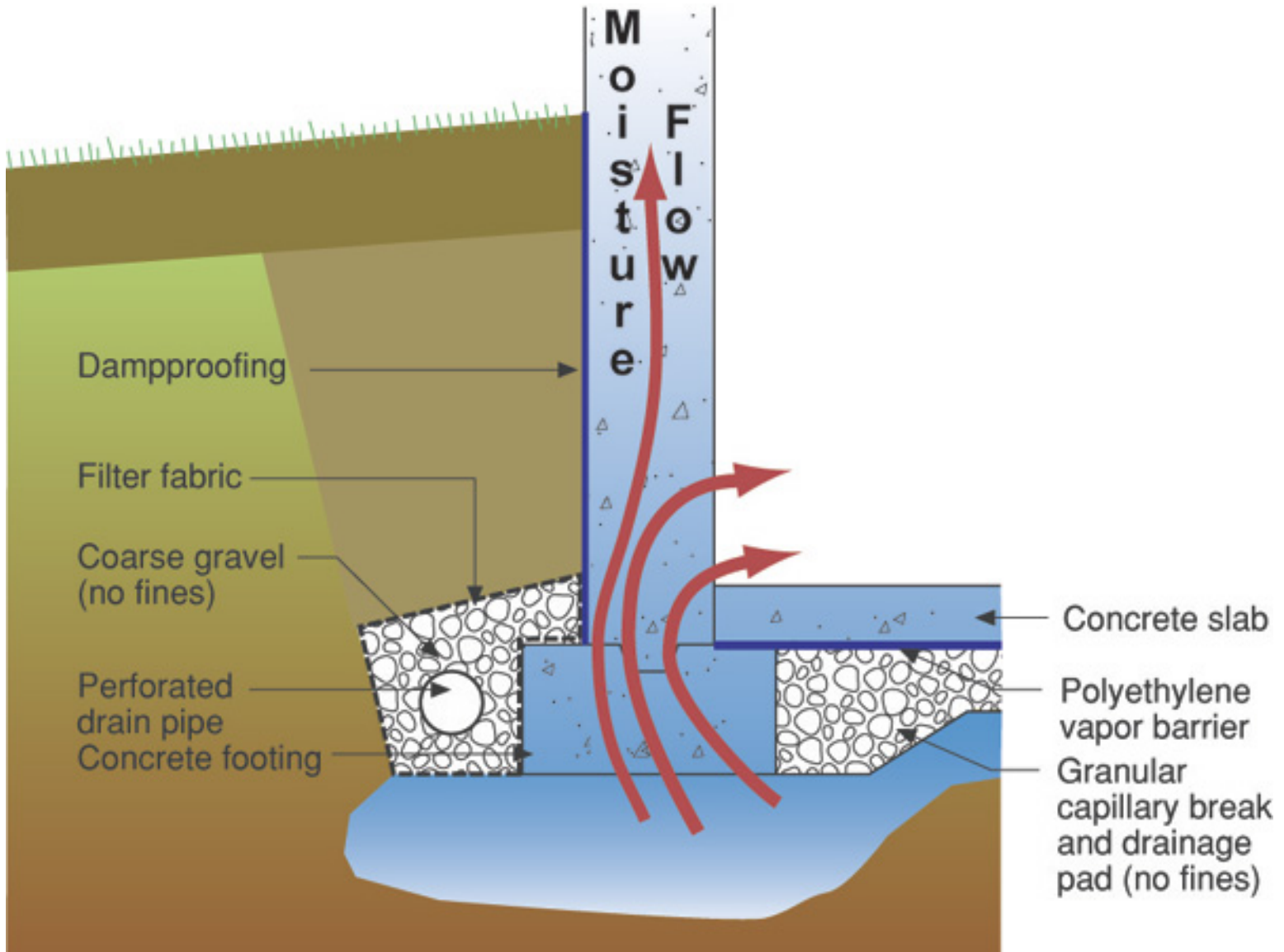


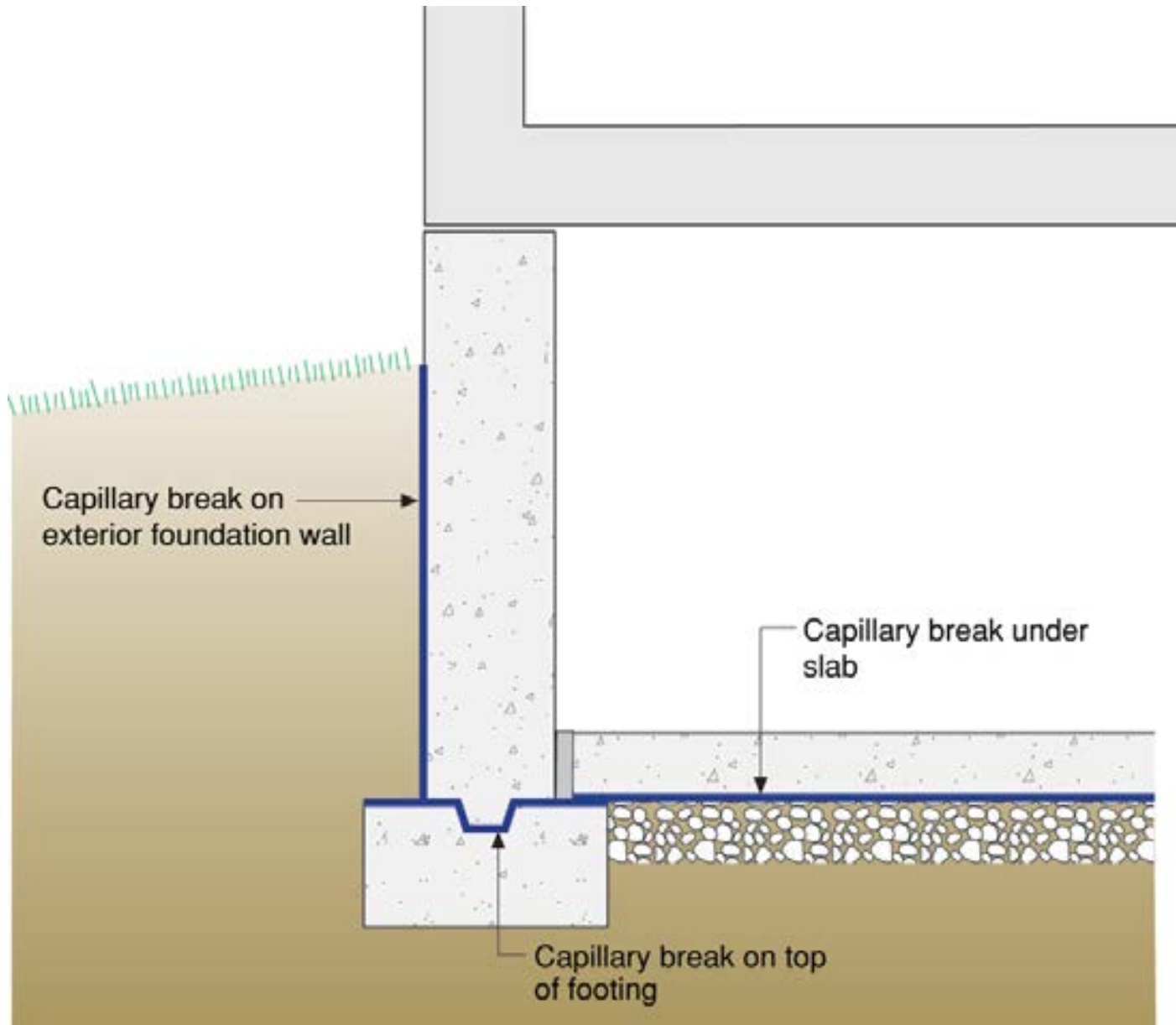












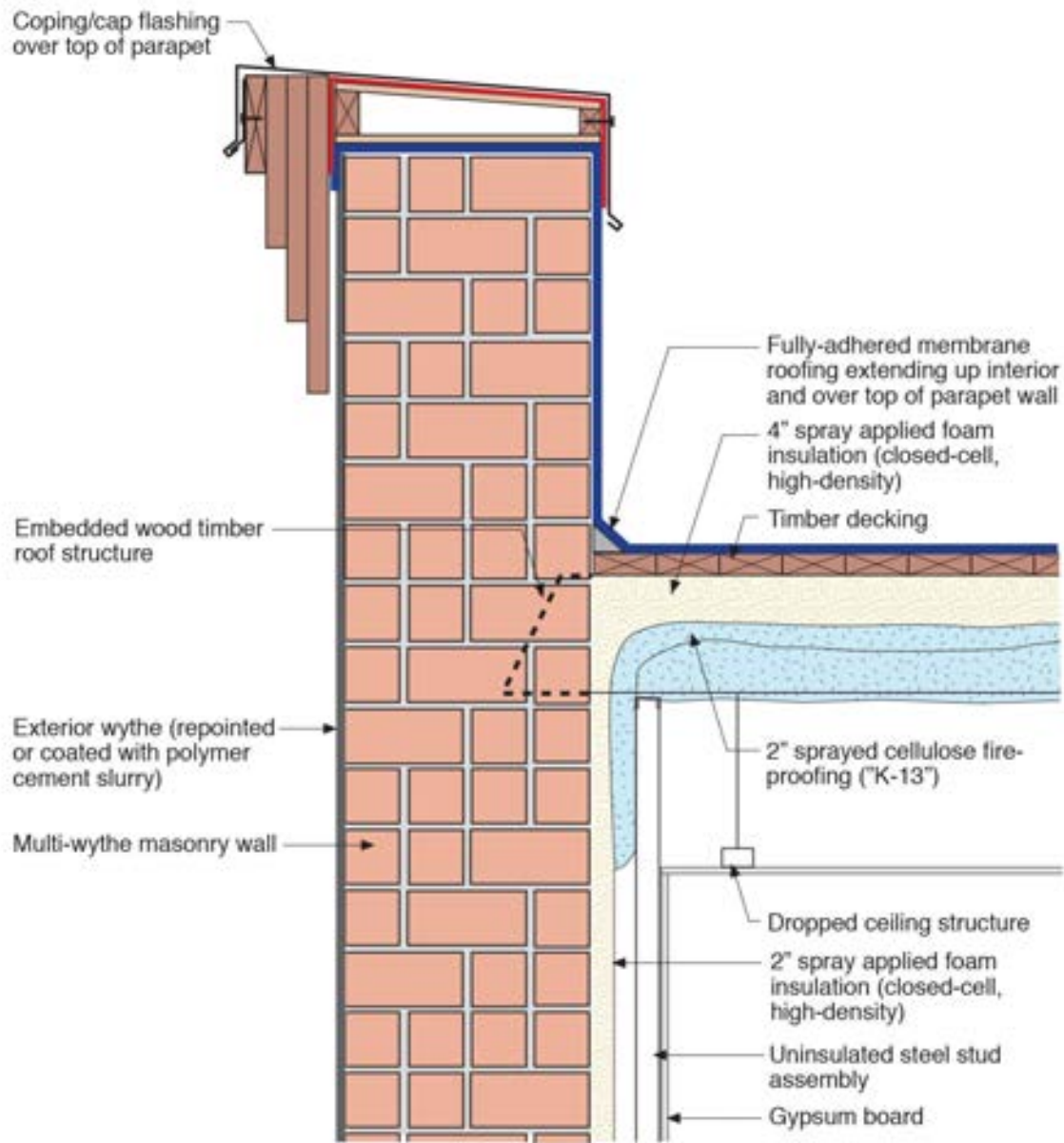






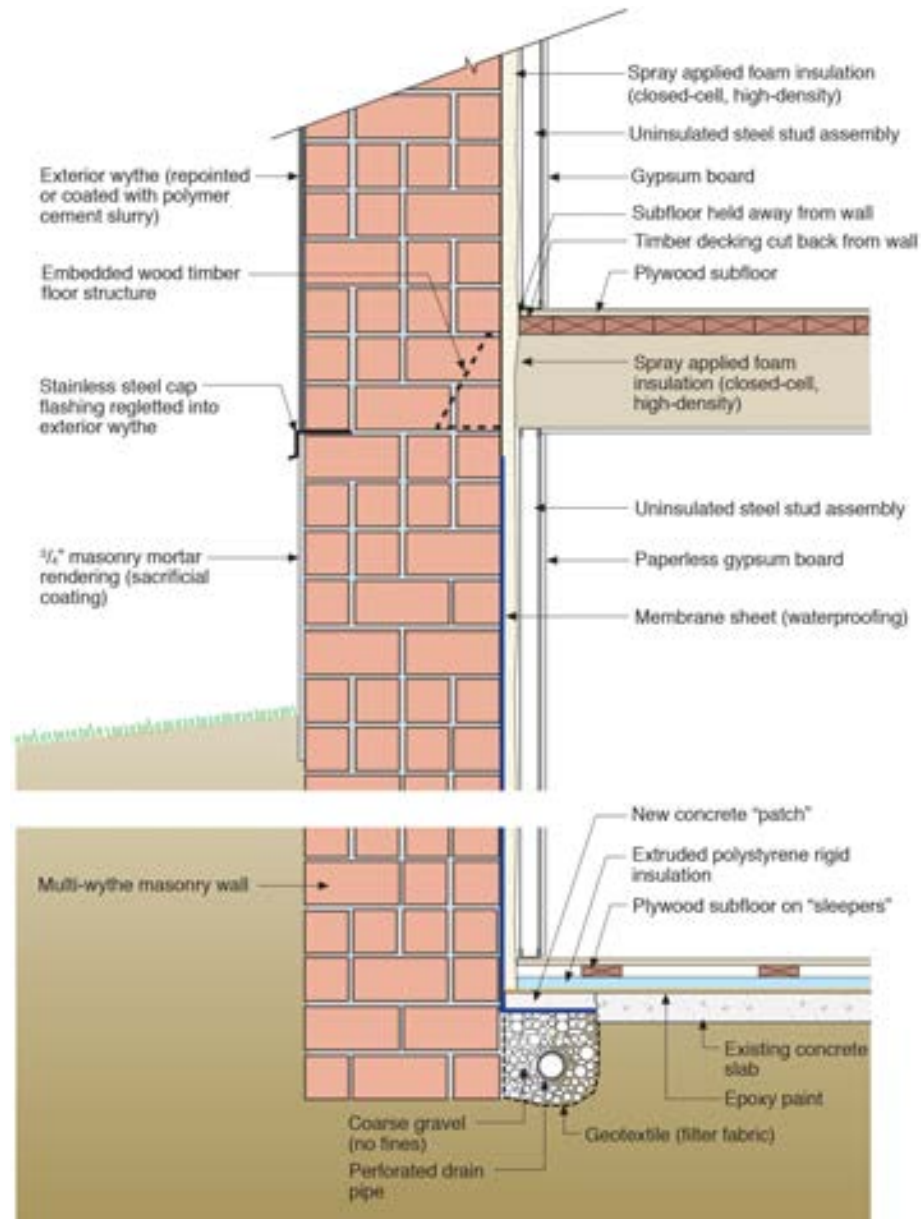


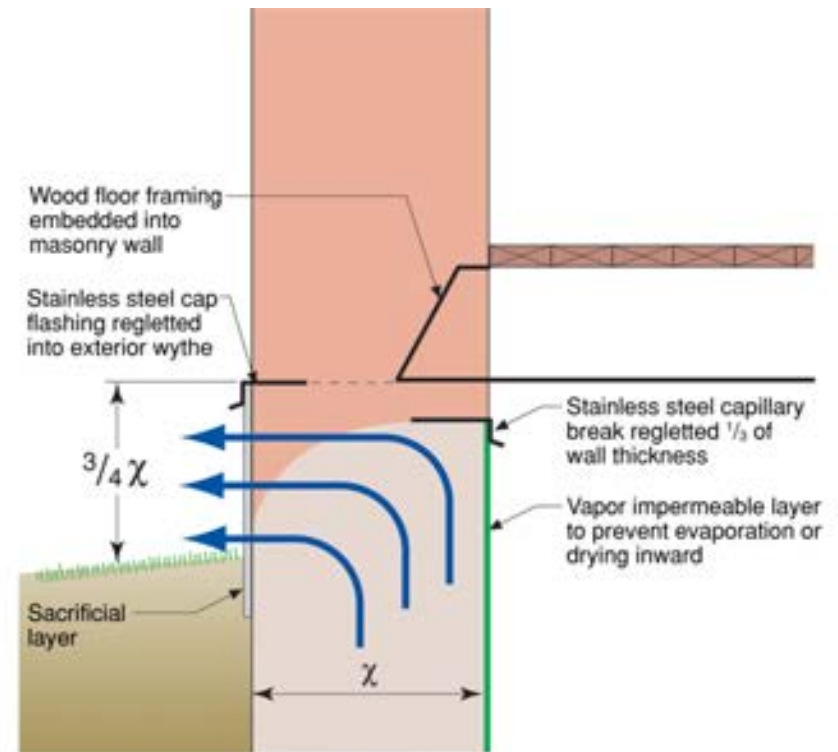
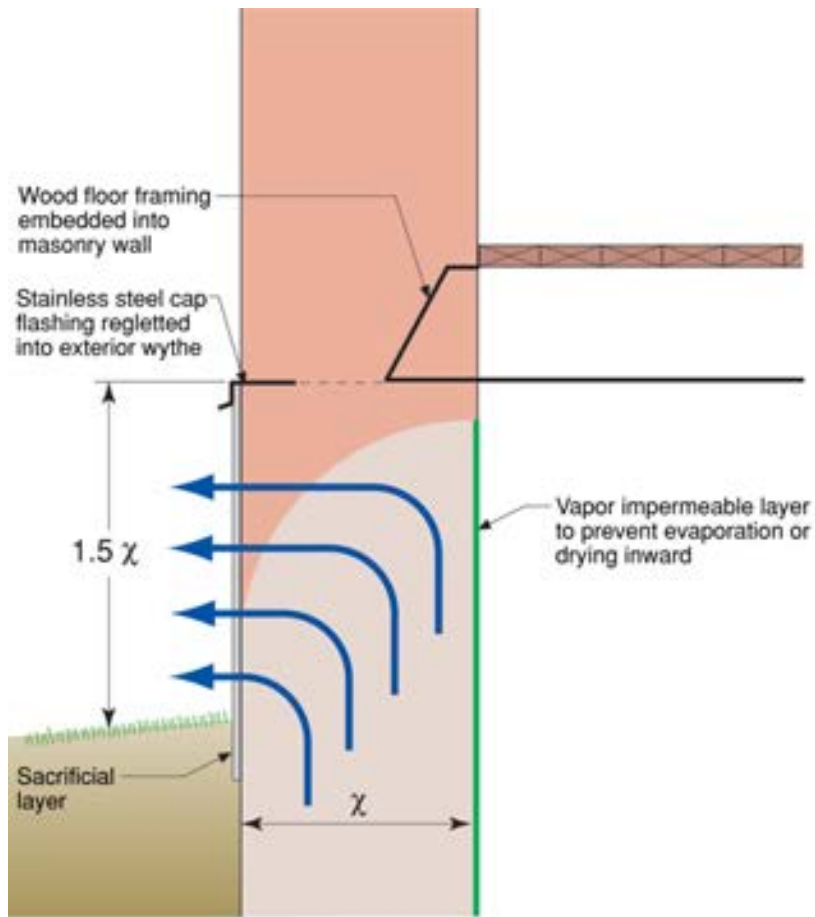


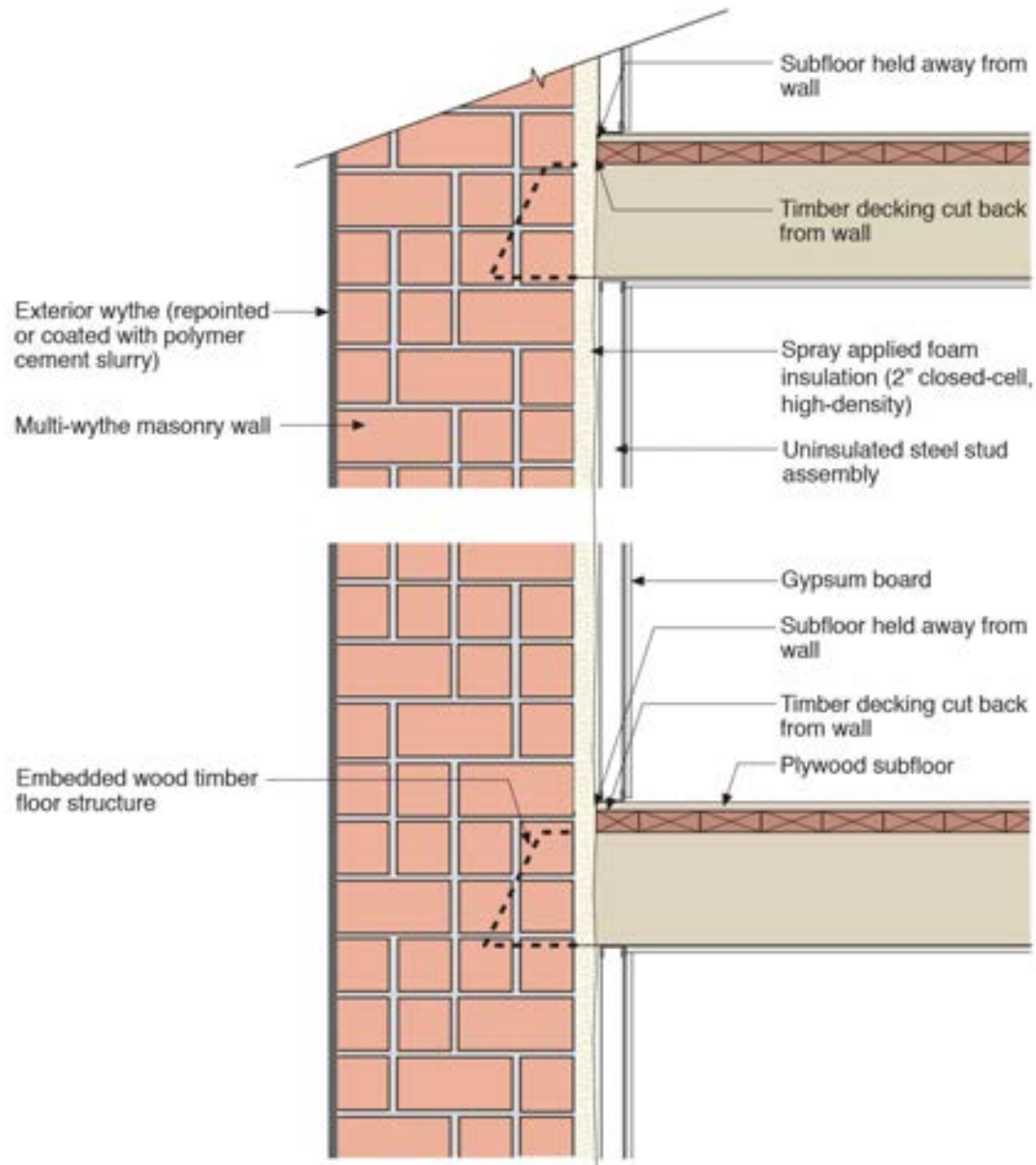




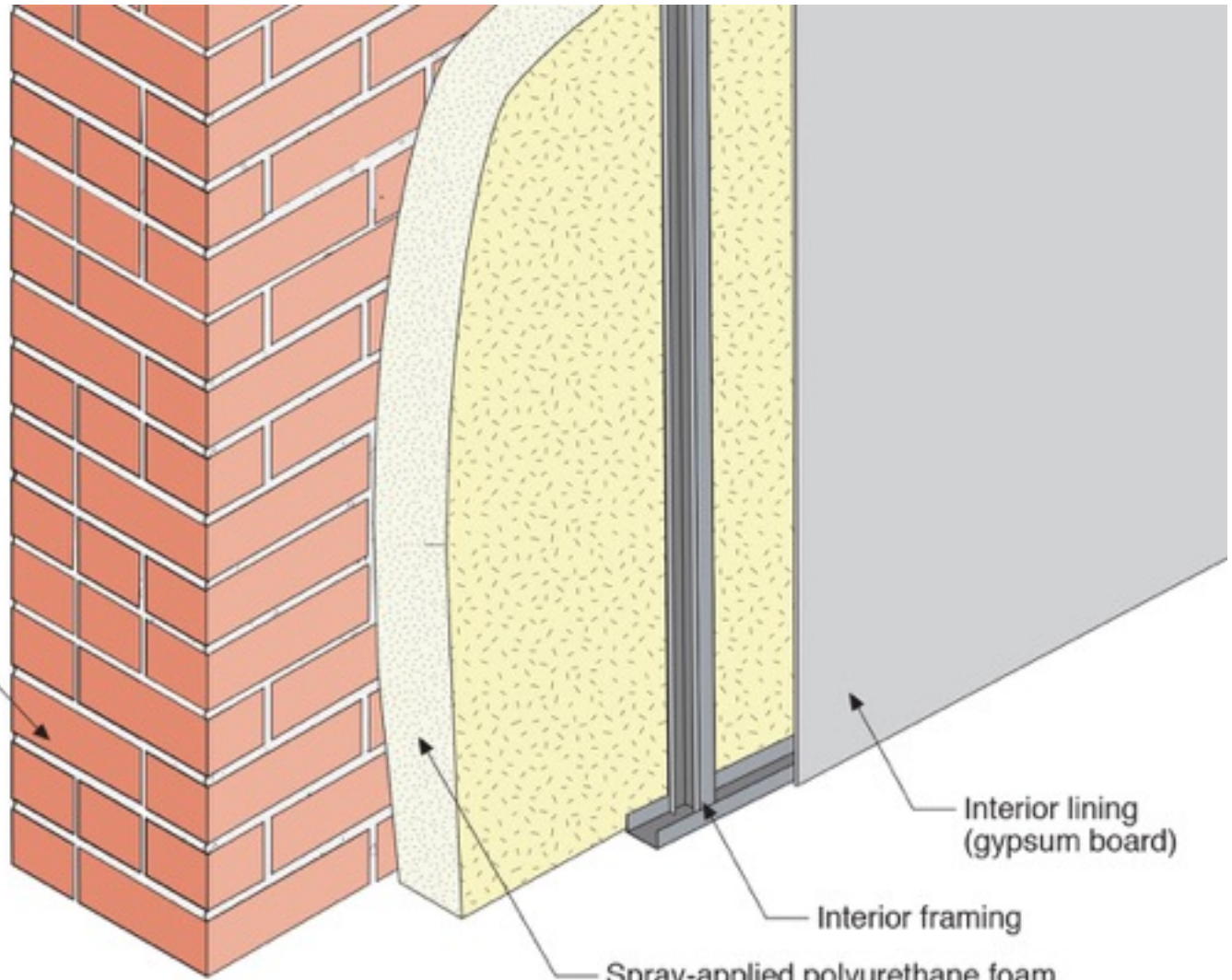








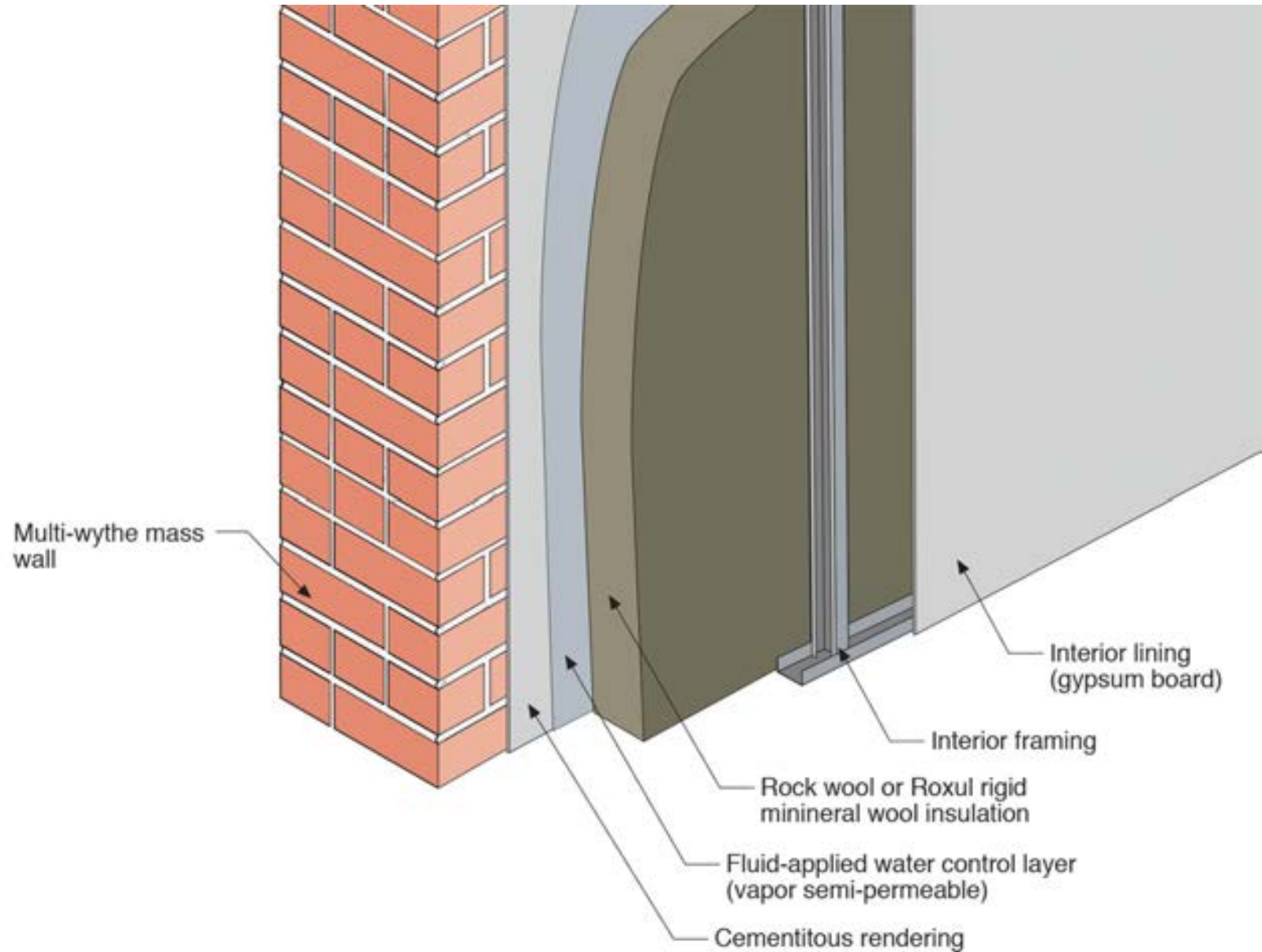
Multi-wythe mass wall

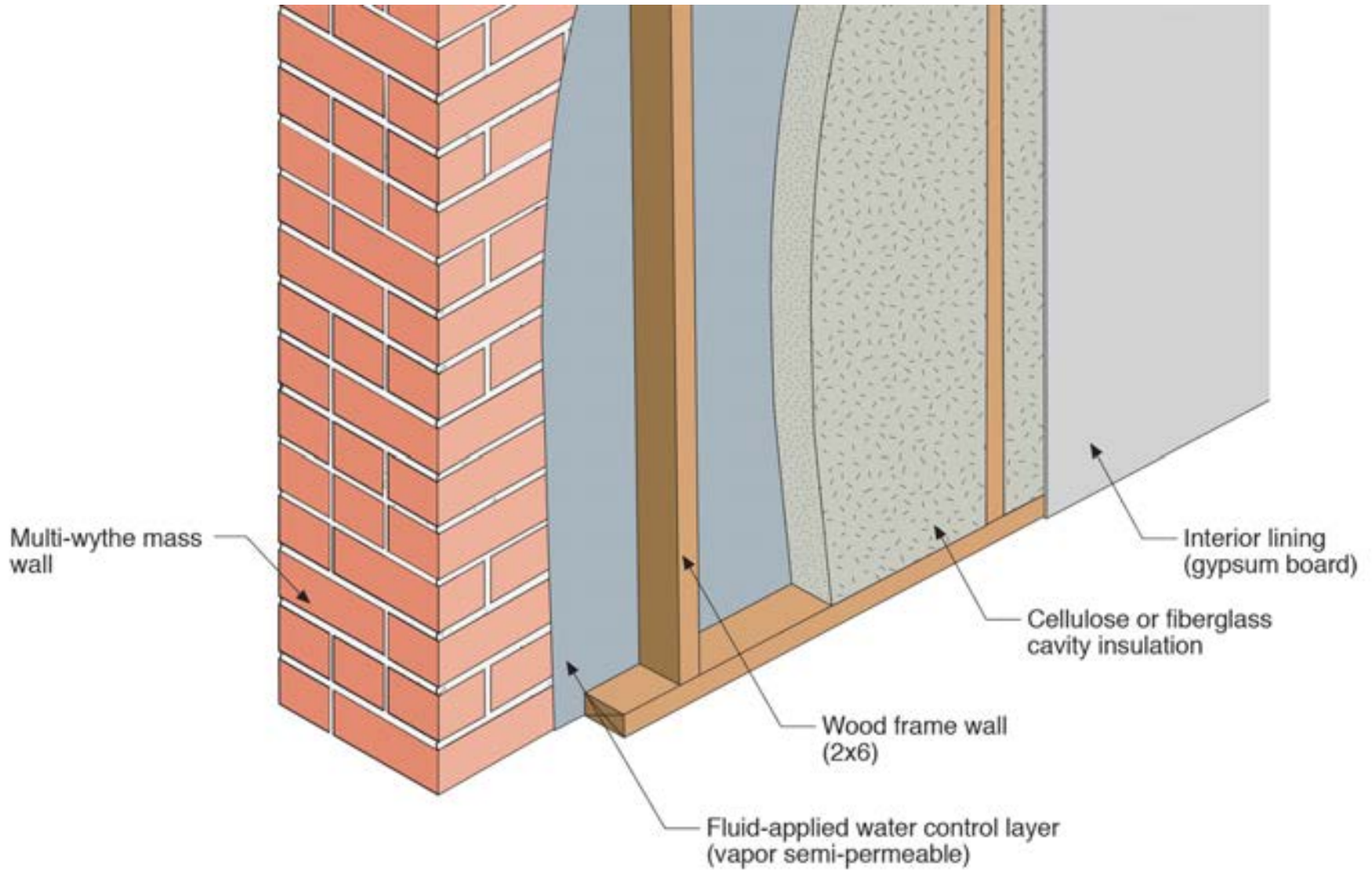


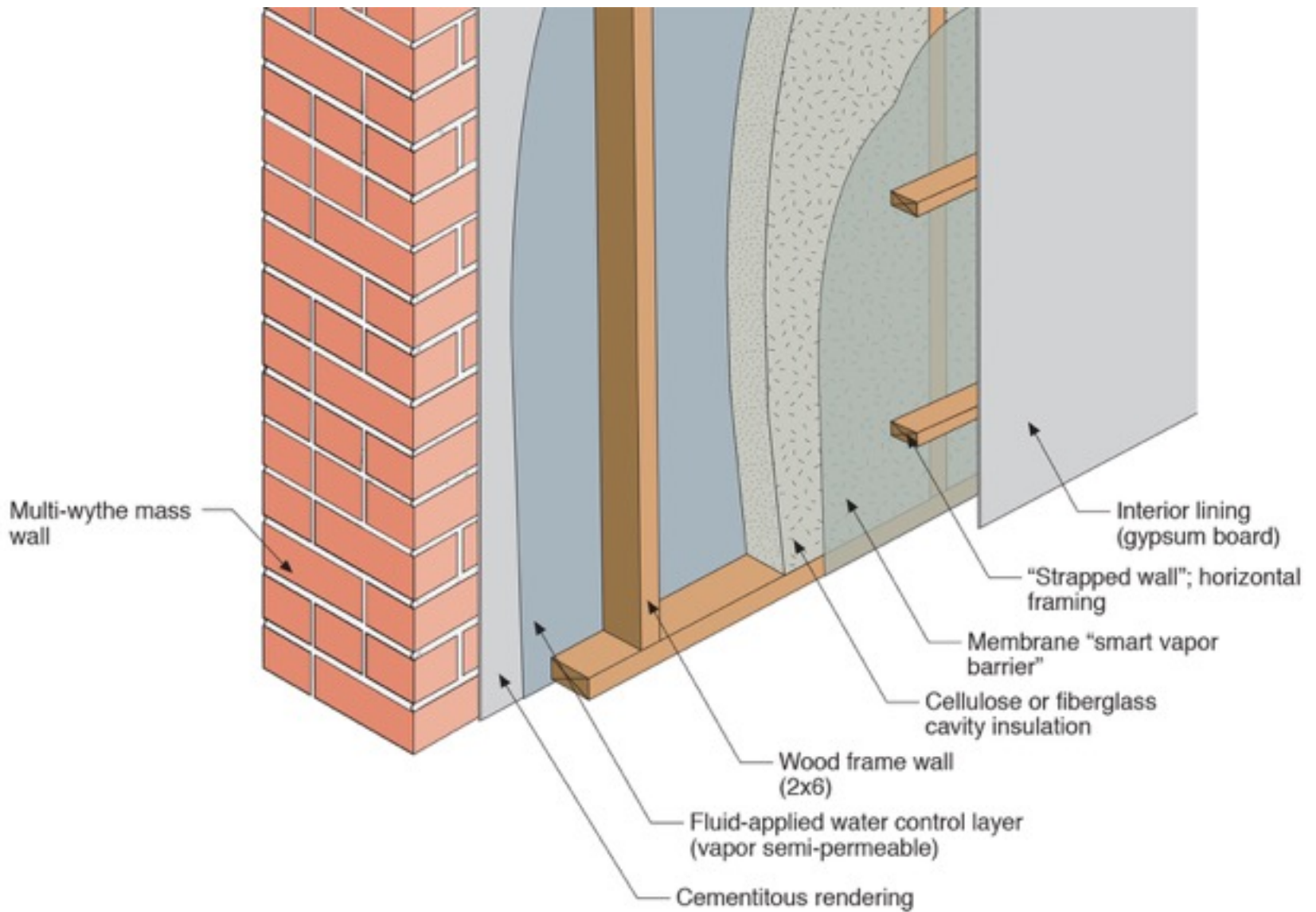
Interior lining (gypsum board)

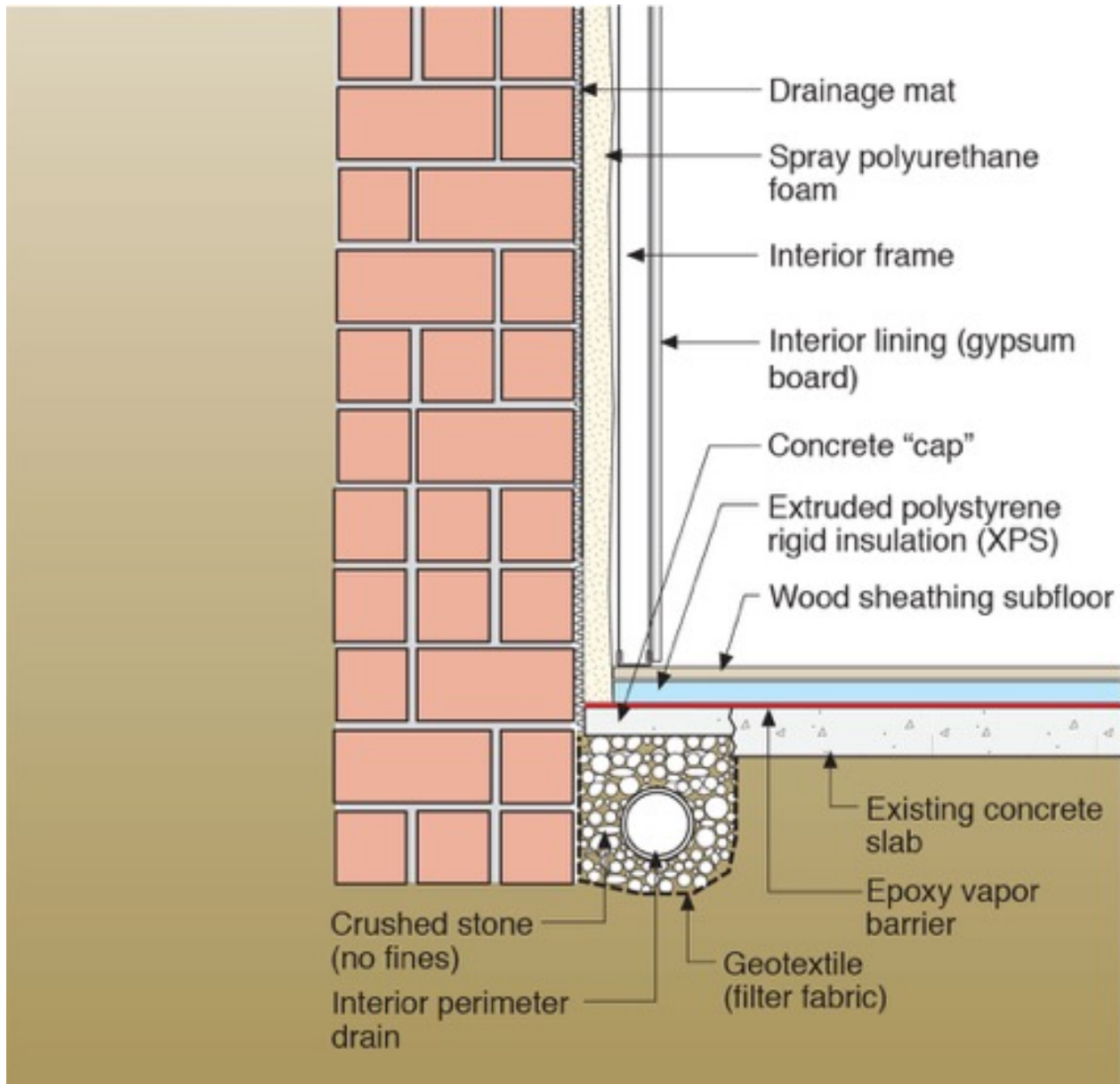
Interior framing

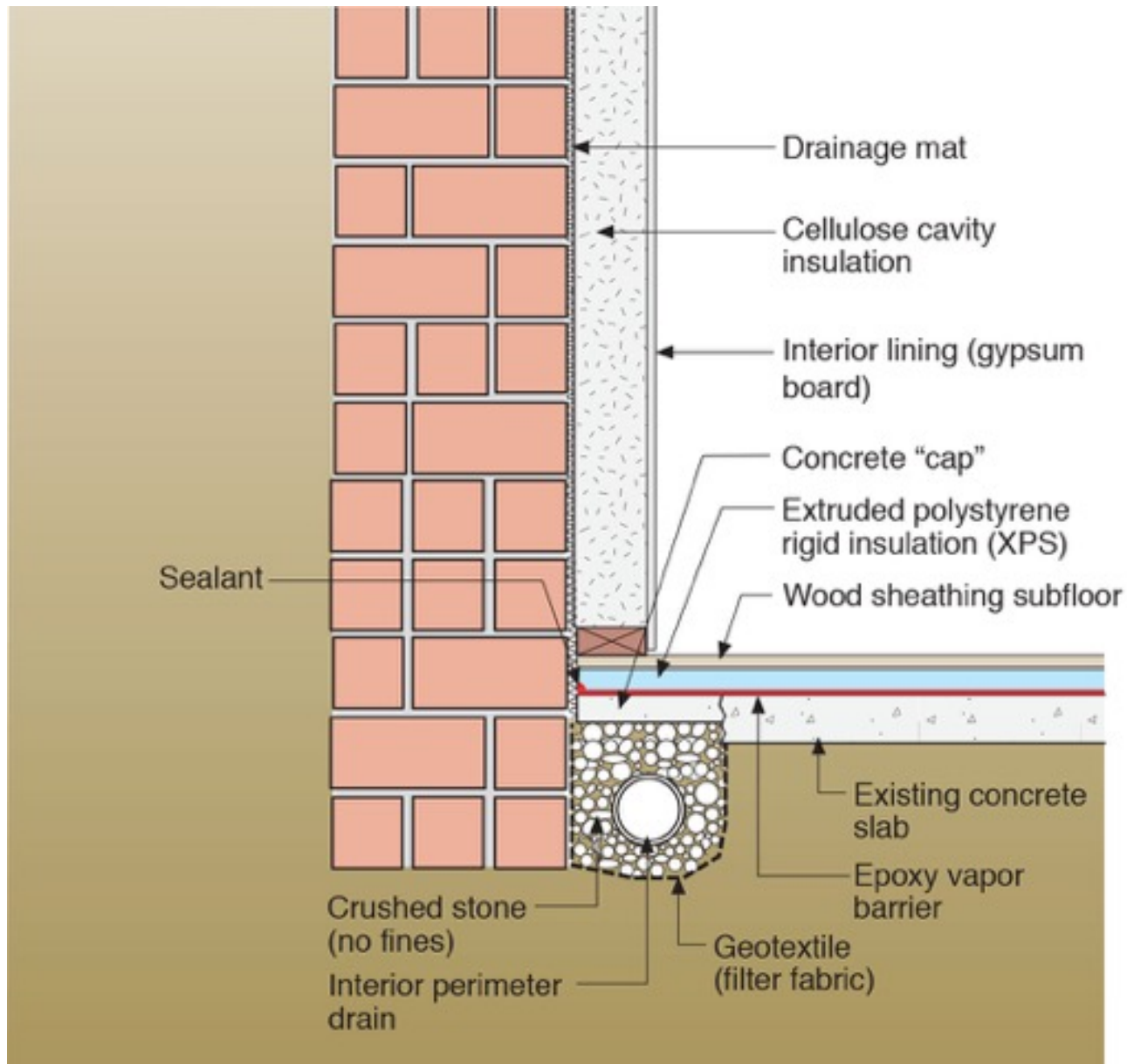
Spray-applied polyurethane foam (2 lb/ft³ density)

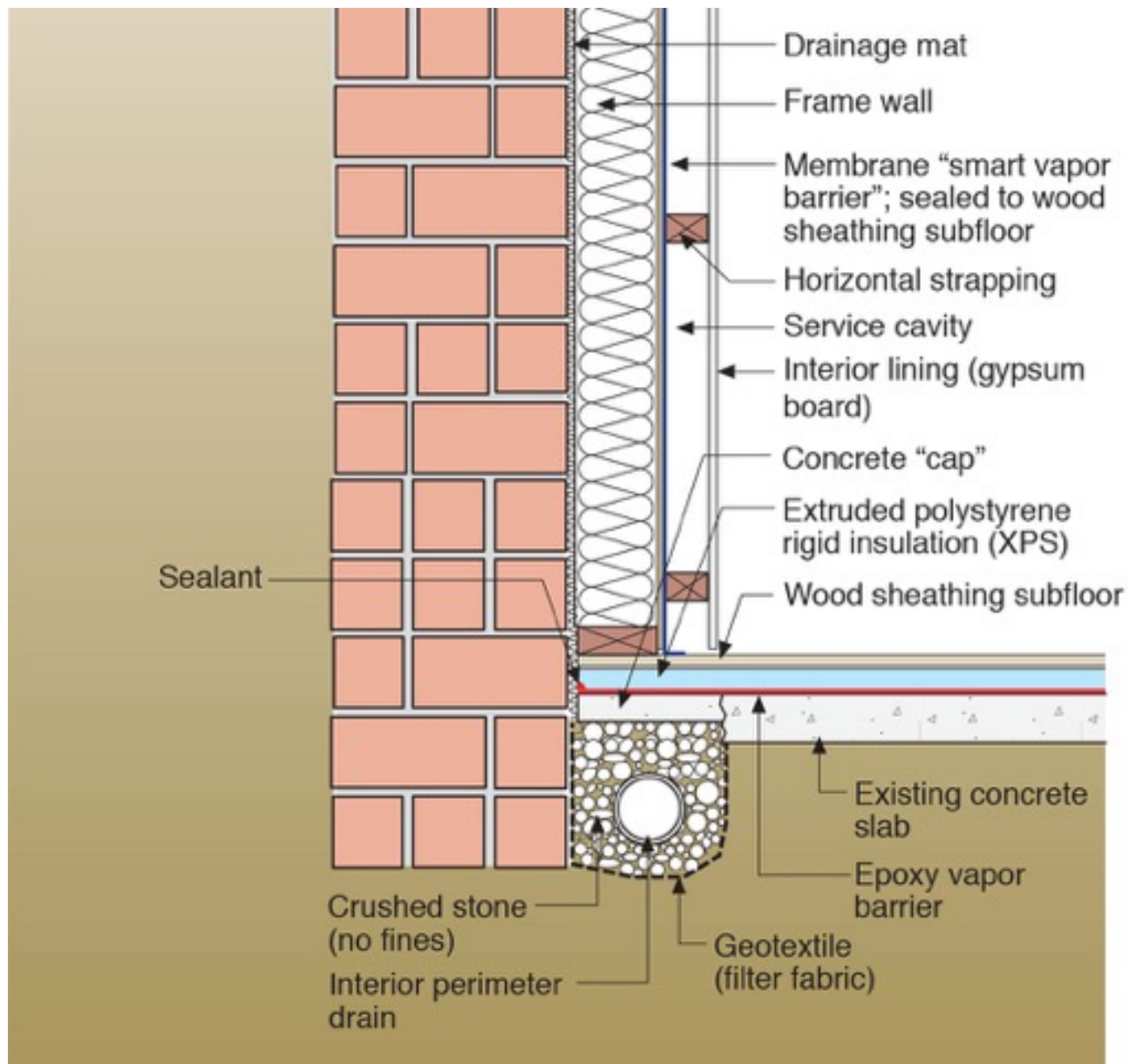


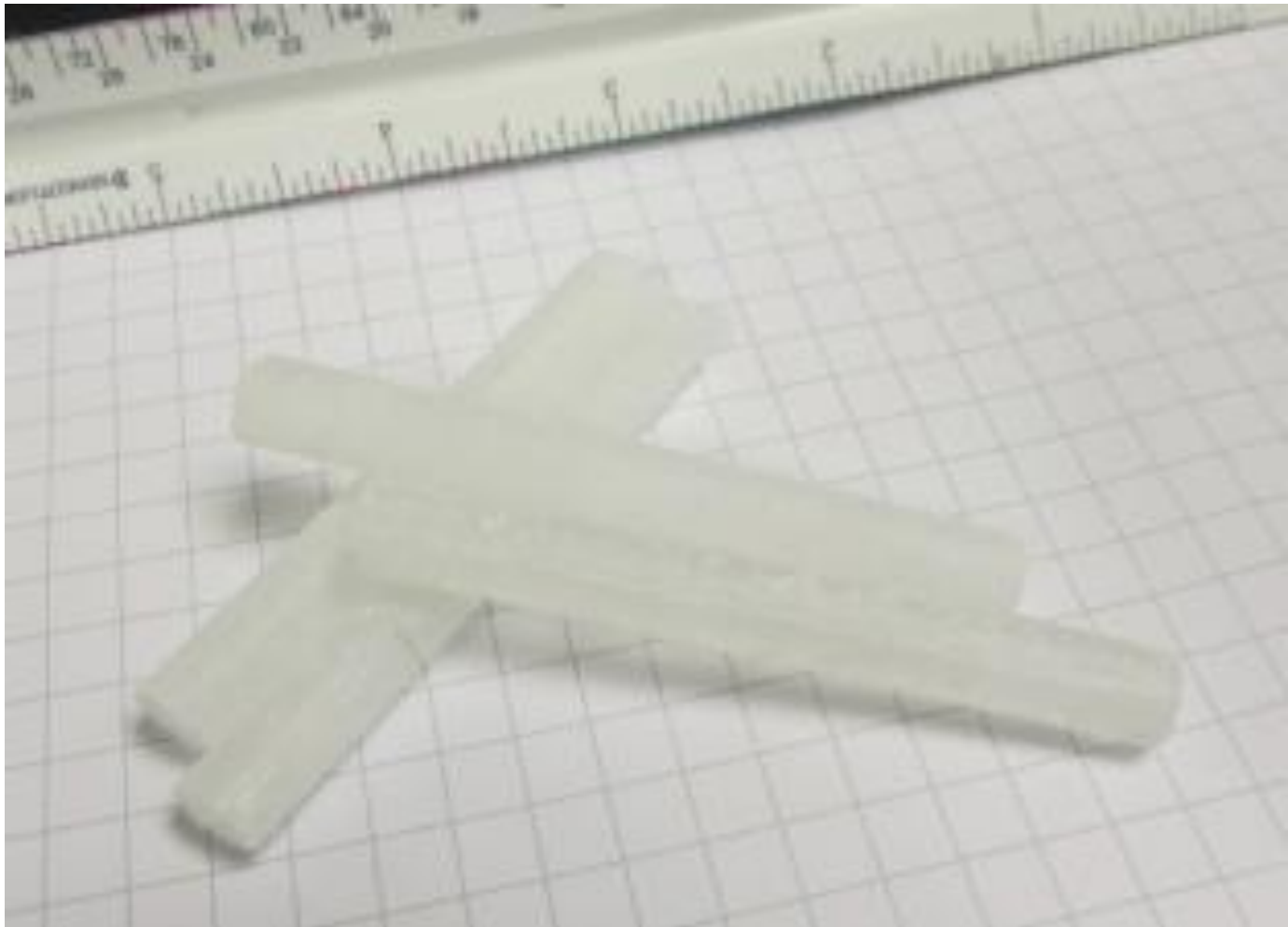


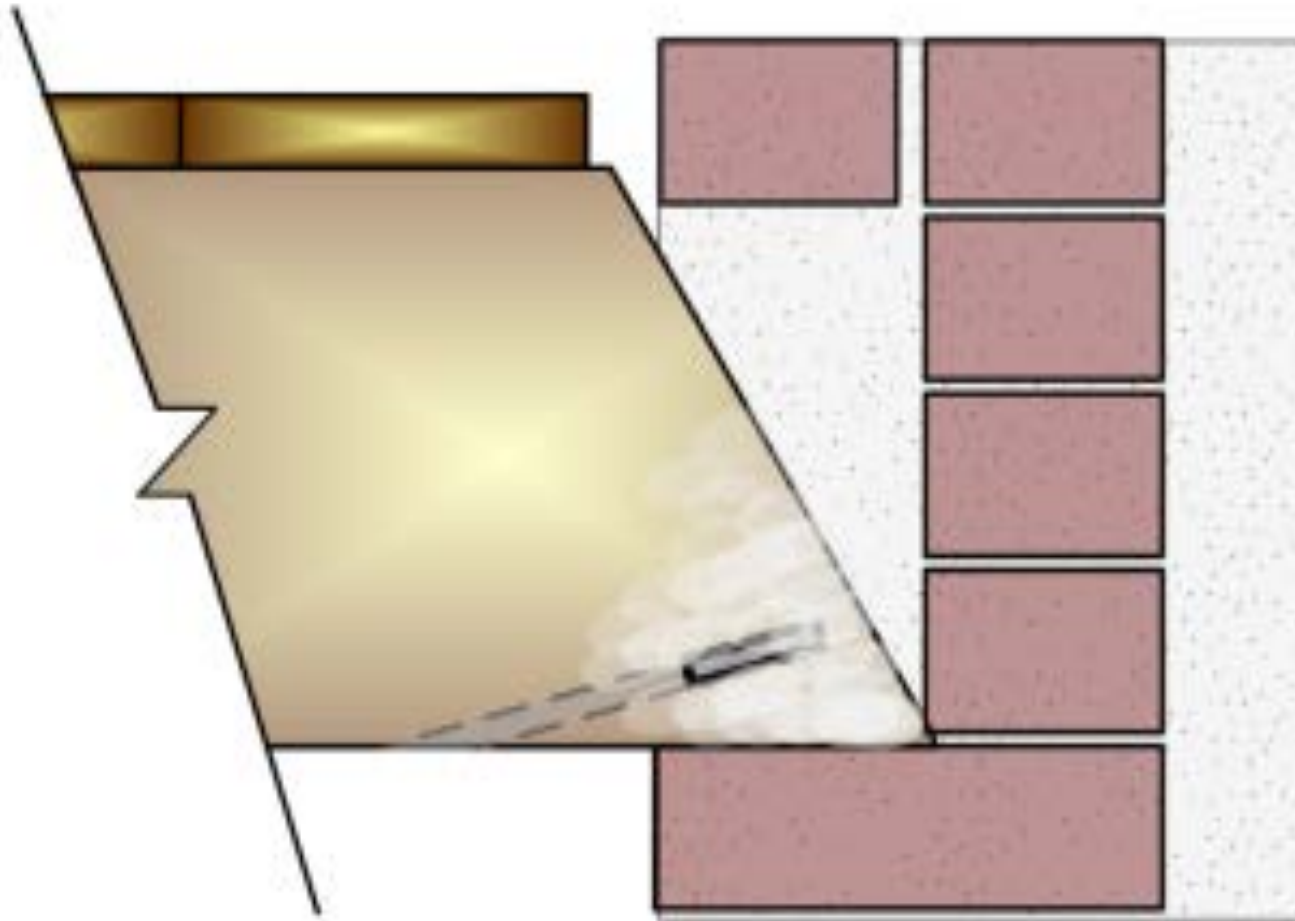


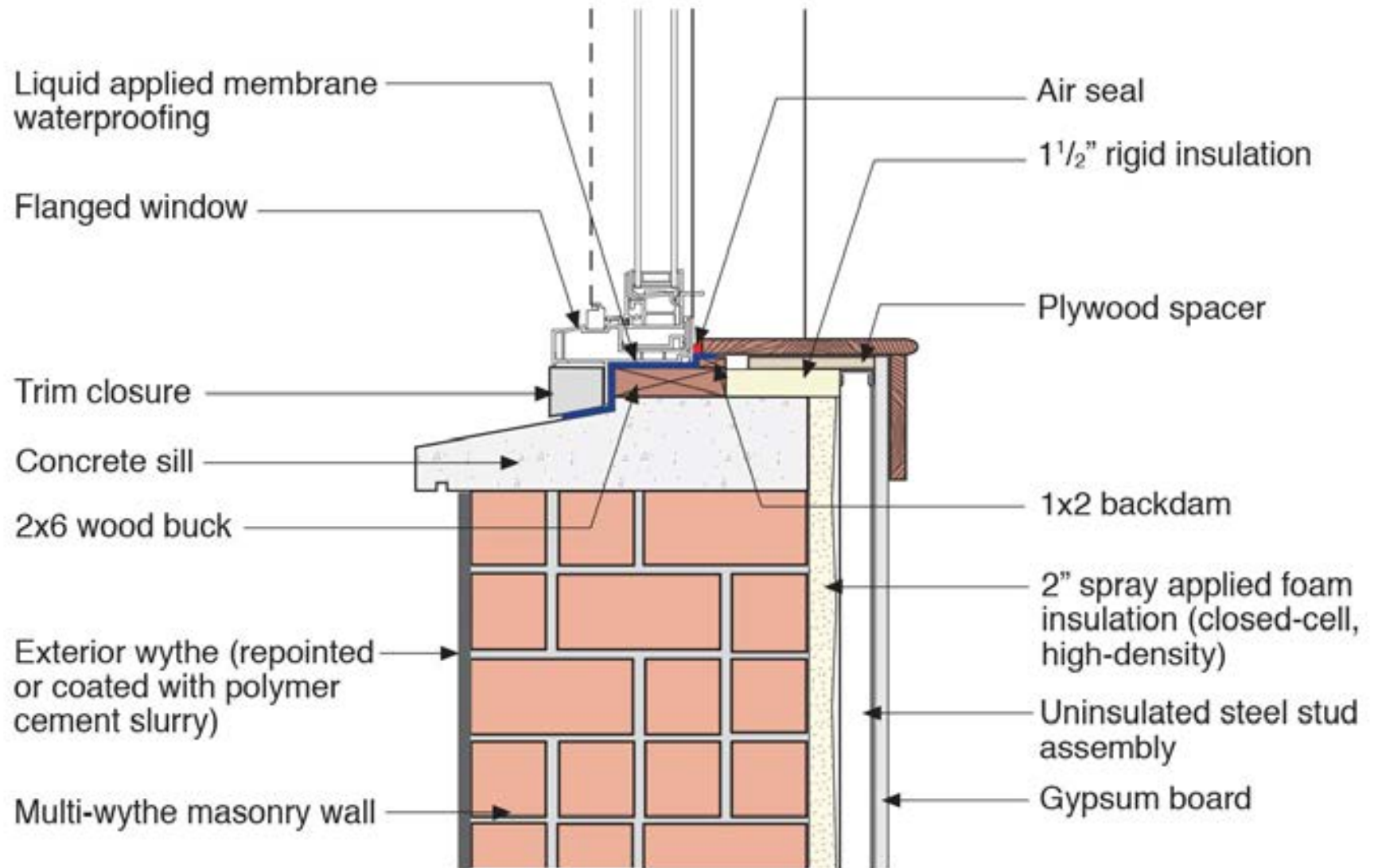




































Stucco

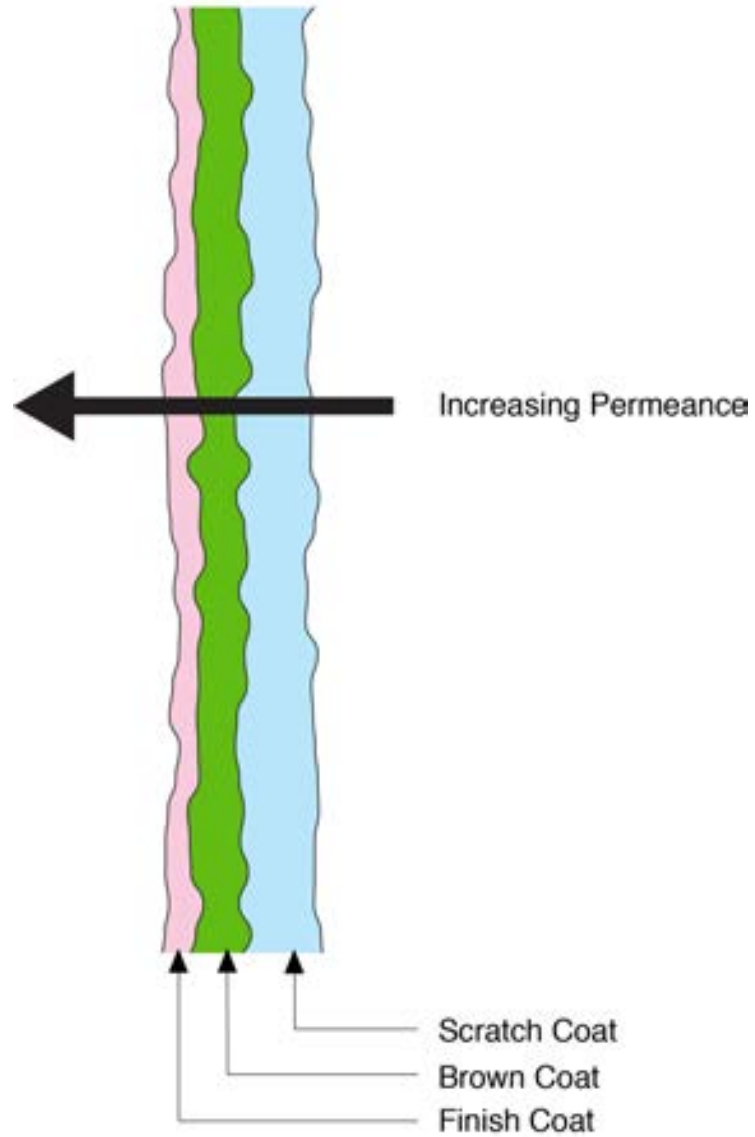




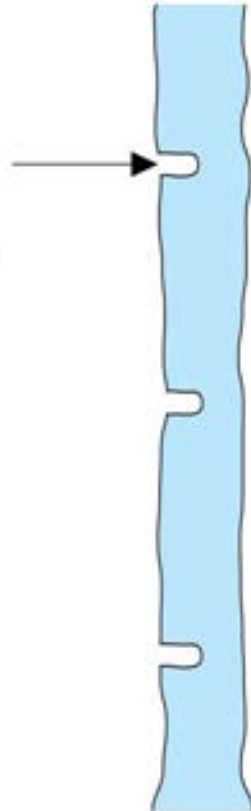


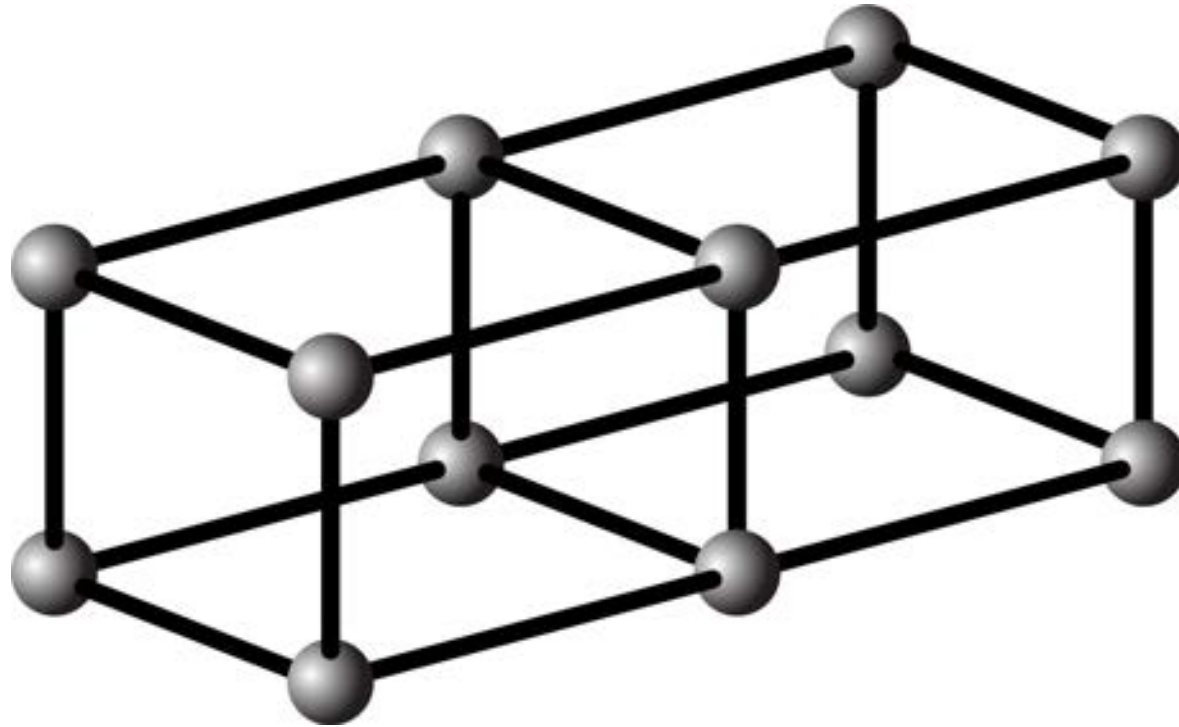


Traditional Lime Stucco	Greater than 20 perms
Lime/Portland Cement Stucco	5 to 10 perms
Portland Cement Stucco	1 to 5 perms
Polymer Modification	Less than 1



Horizontal "scoring"
provides mechanical
bond and "shelf"
for water during "wet" curing





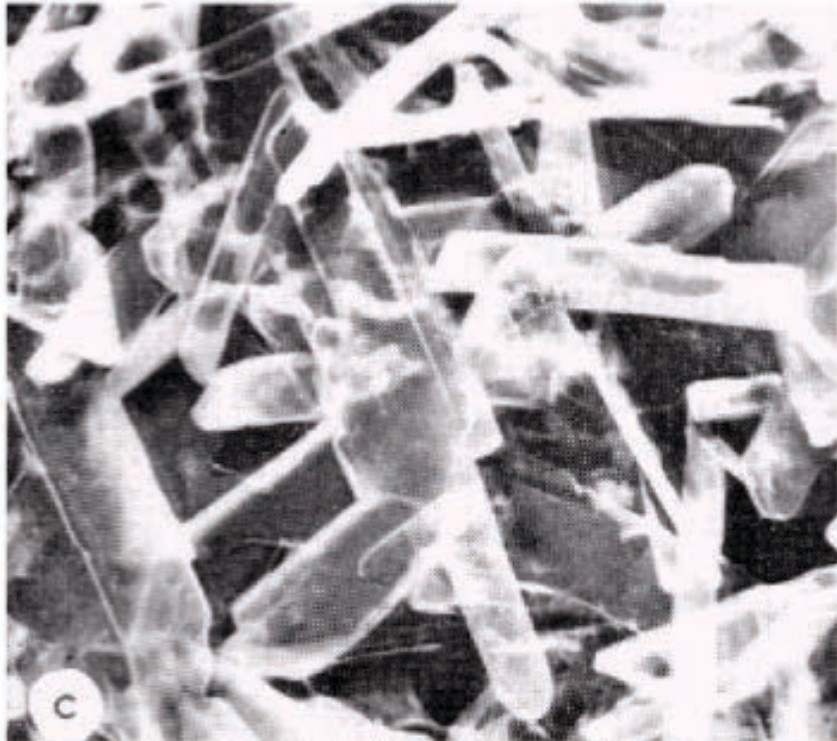


Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

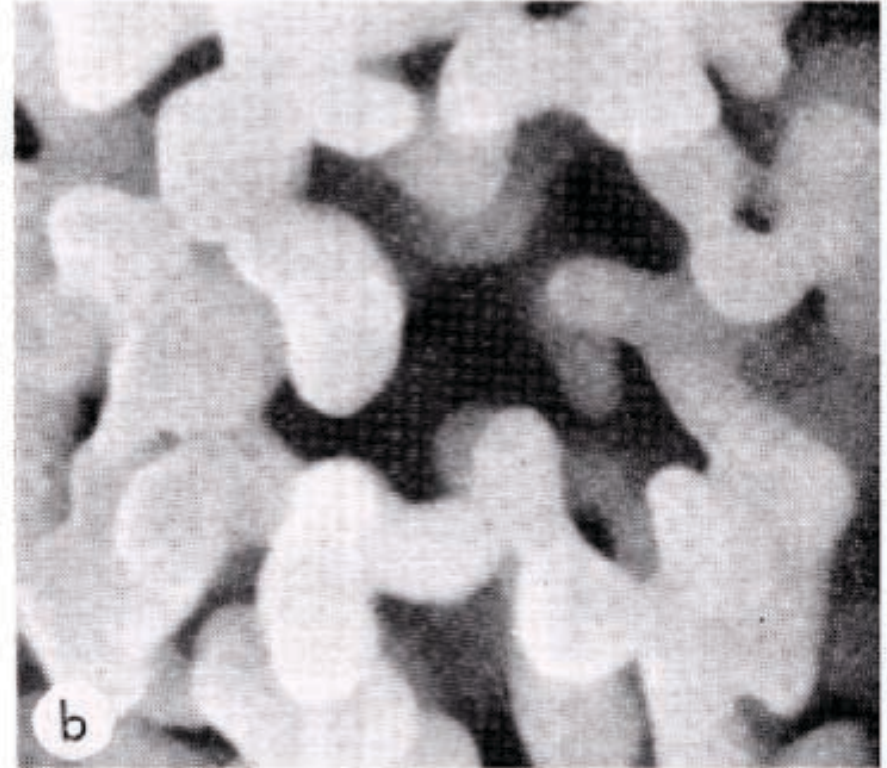
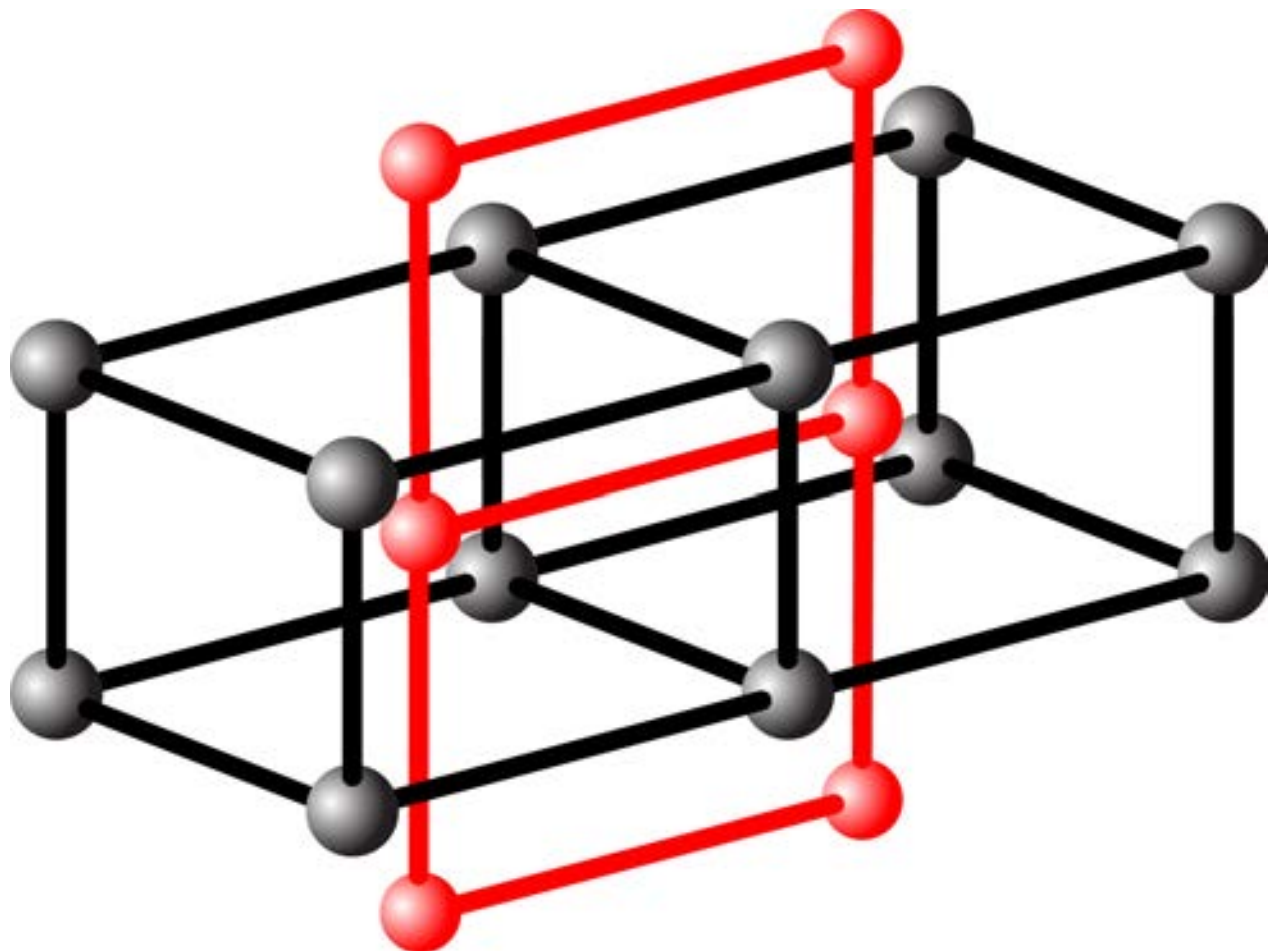


Figure 1b. Brick, sintered clay, porosity 40 per cent.



Ancient Modification Additives

Cow Dung

Egg Whites

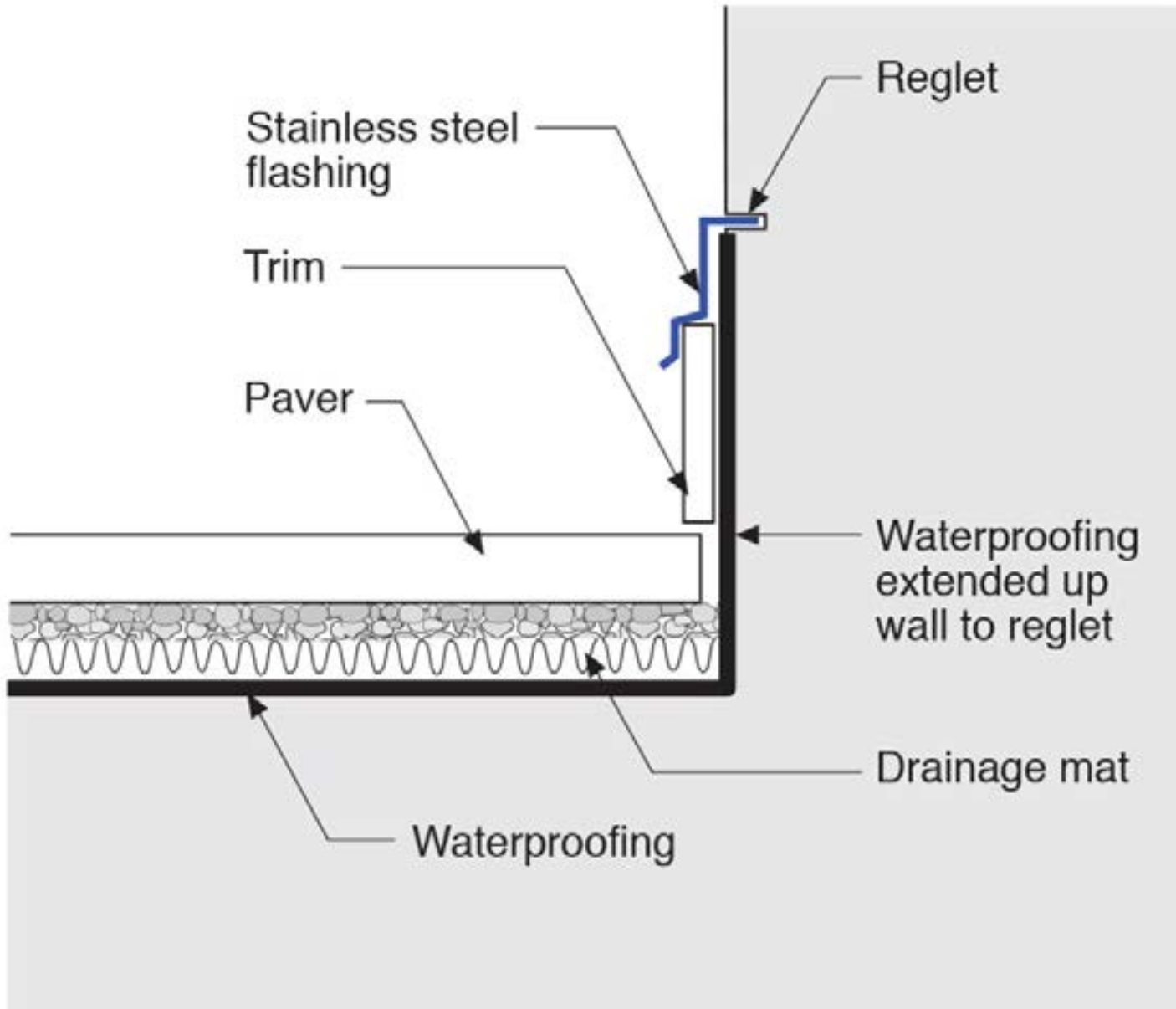
Pig Blood





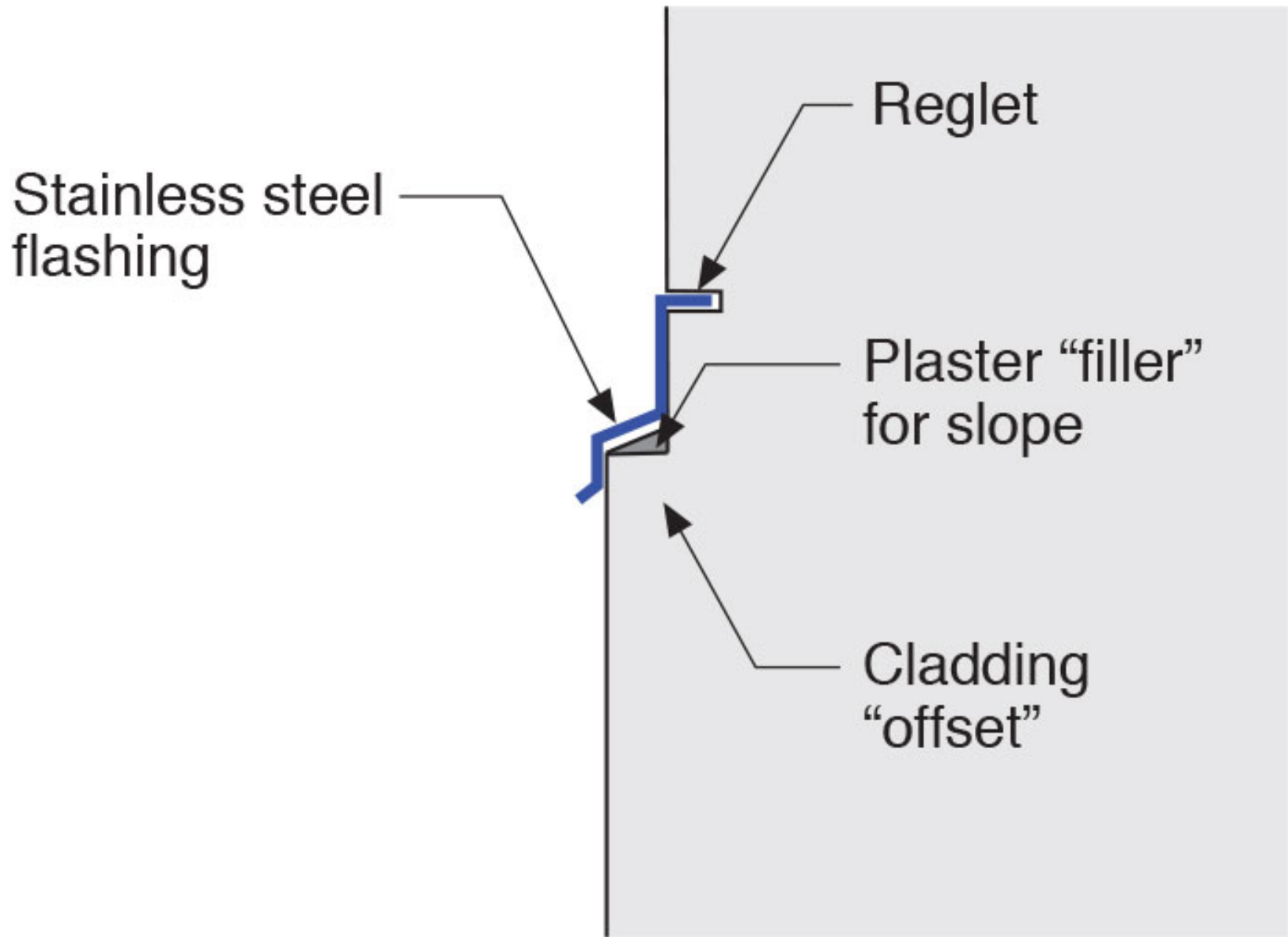




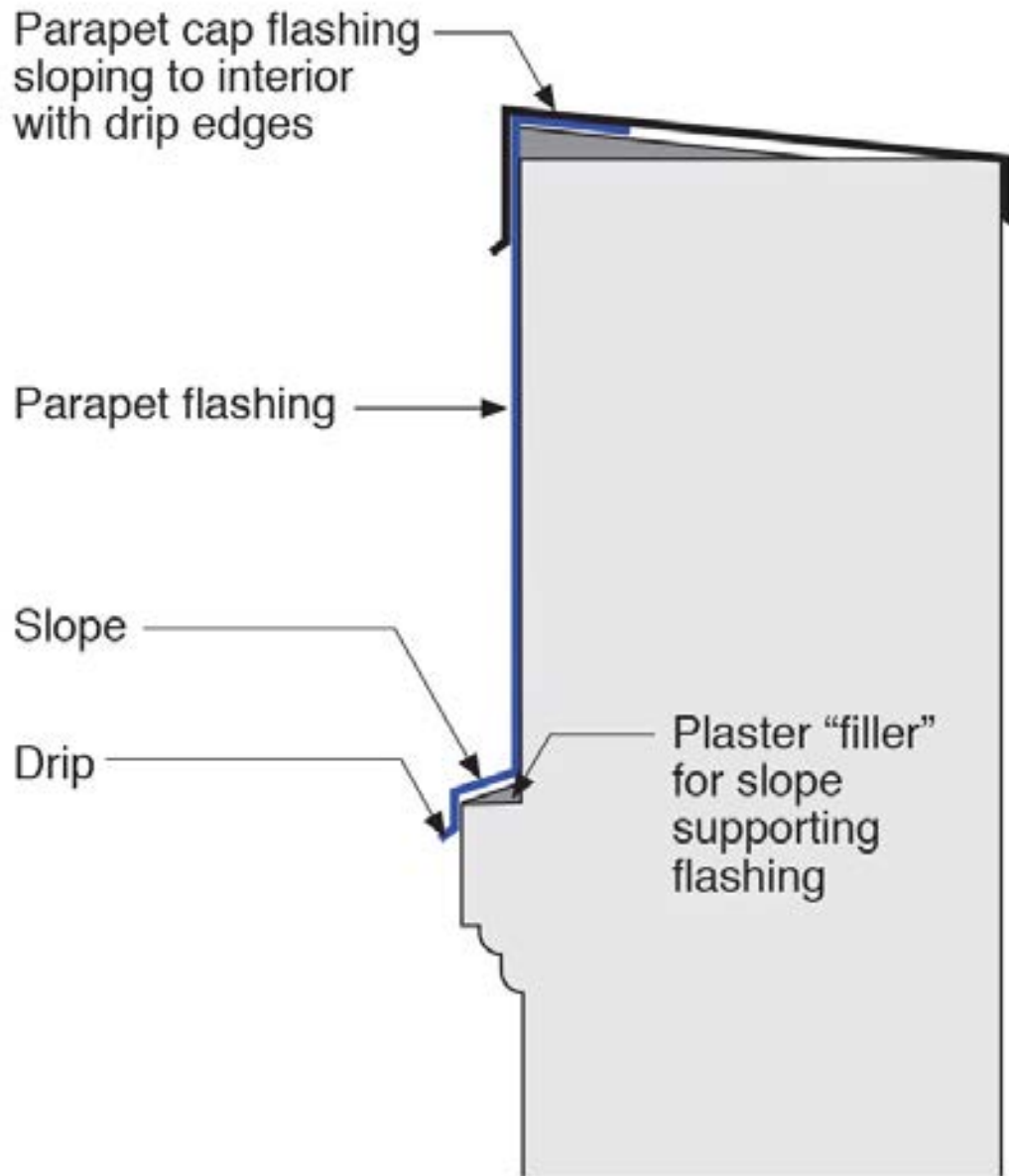


















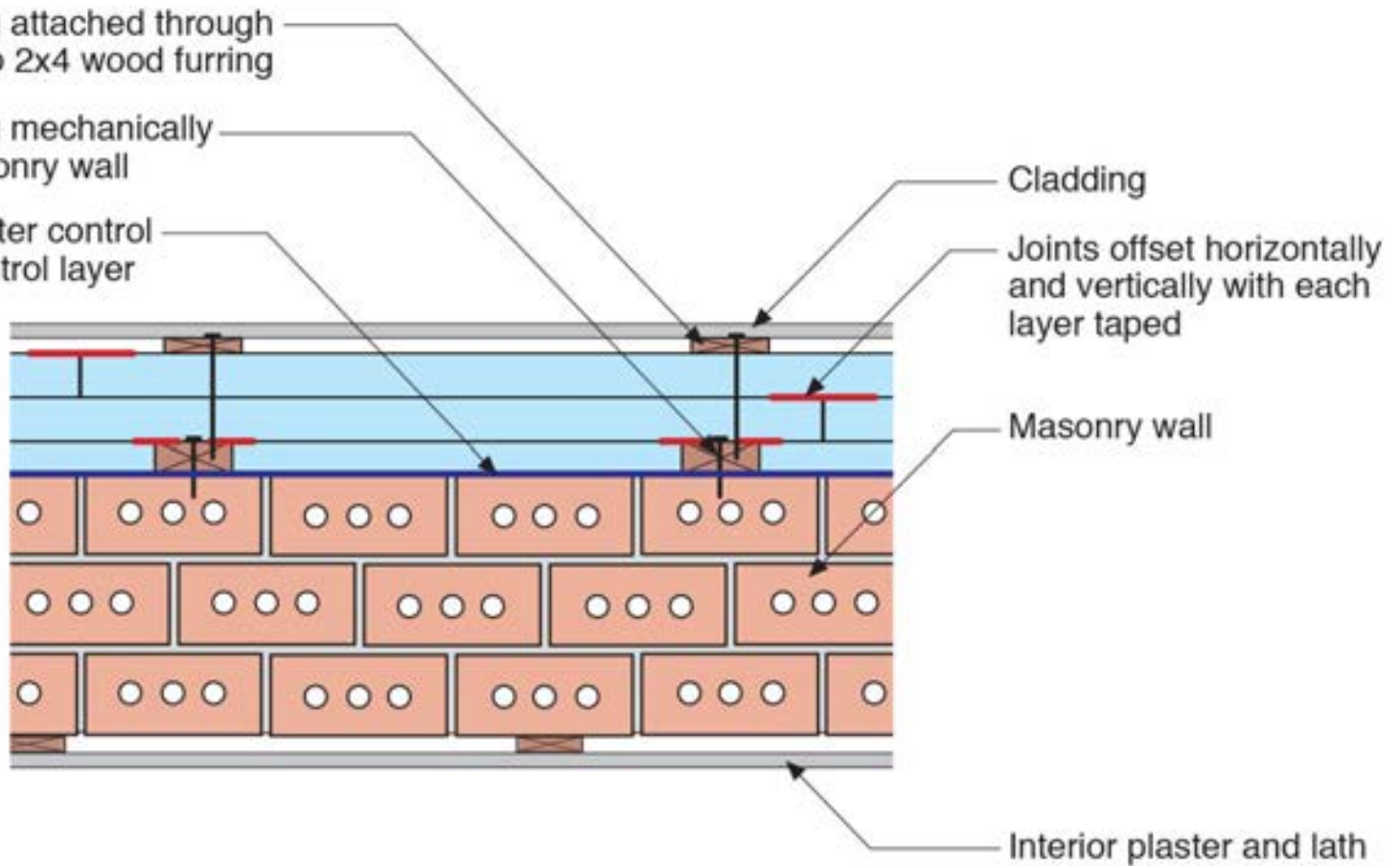




1x4 wood furring attached through rigid insulation to 2x4 wood furring

2x4 wood furring mechanically attached to masonry wall

Fluid-applied water control layer and air control layer



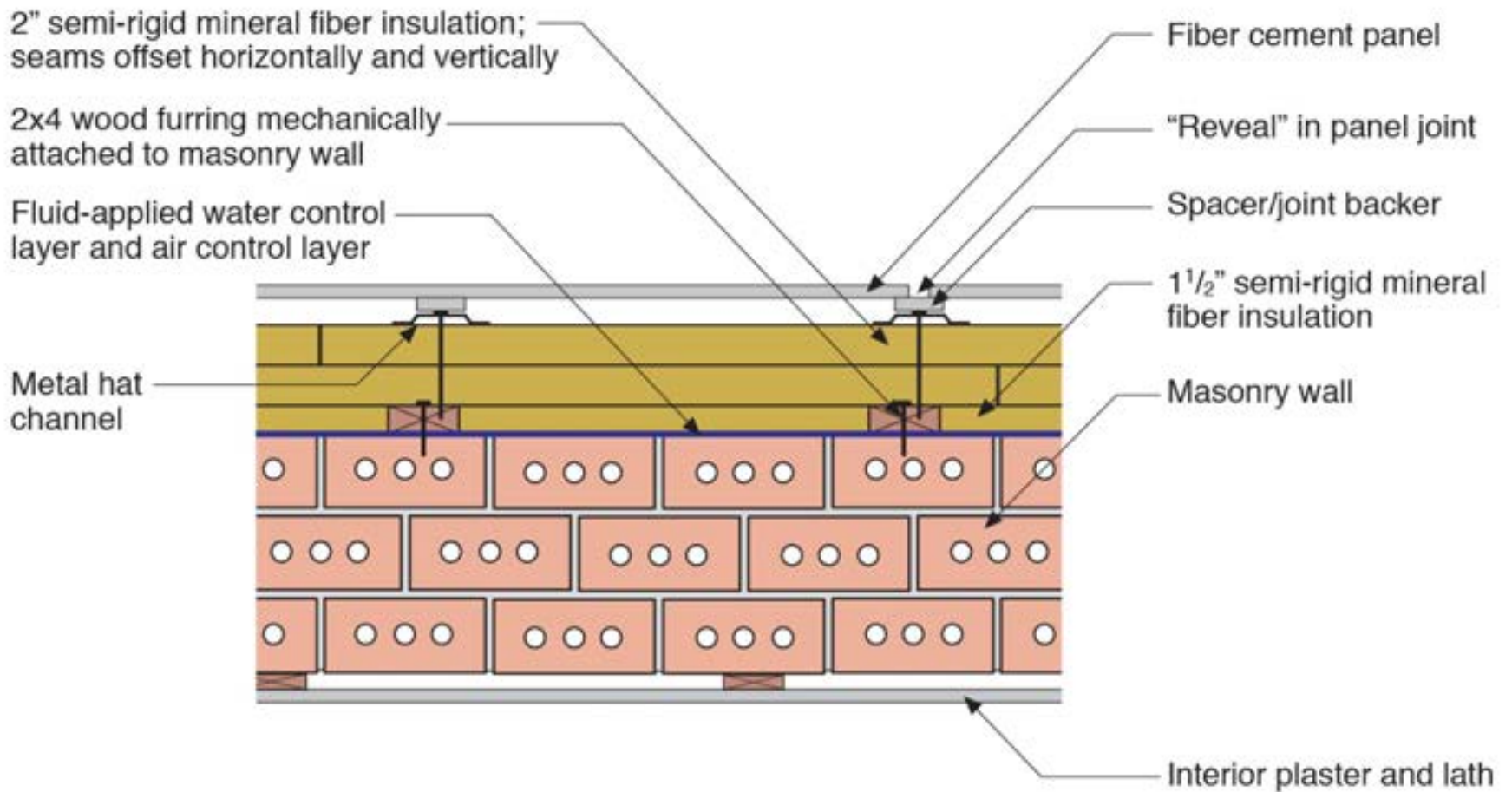
Cladding

Joints offset horizontally and vertically with each layer taped

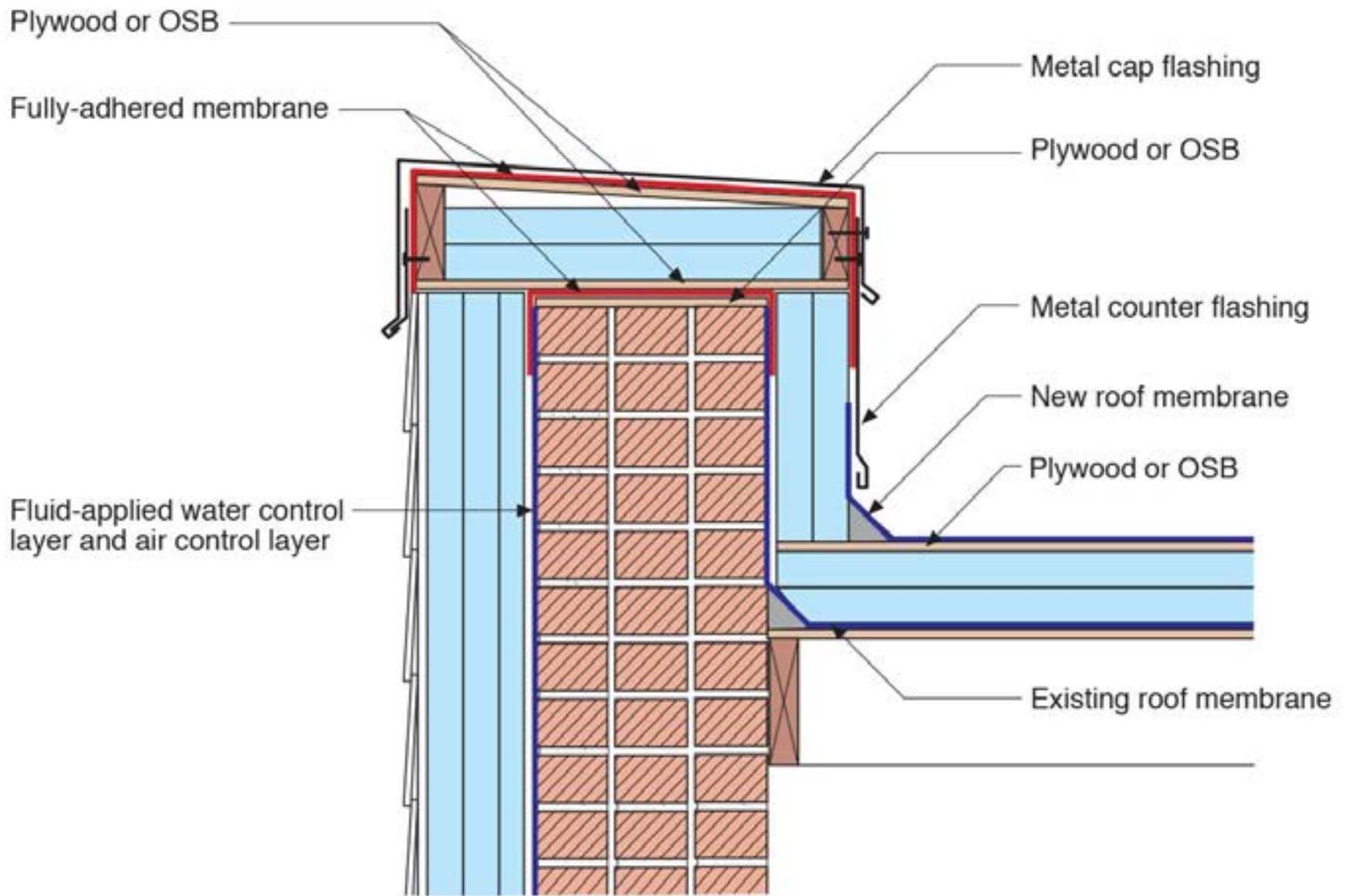
Masonry wall

Interior plaster and lath













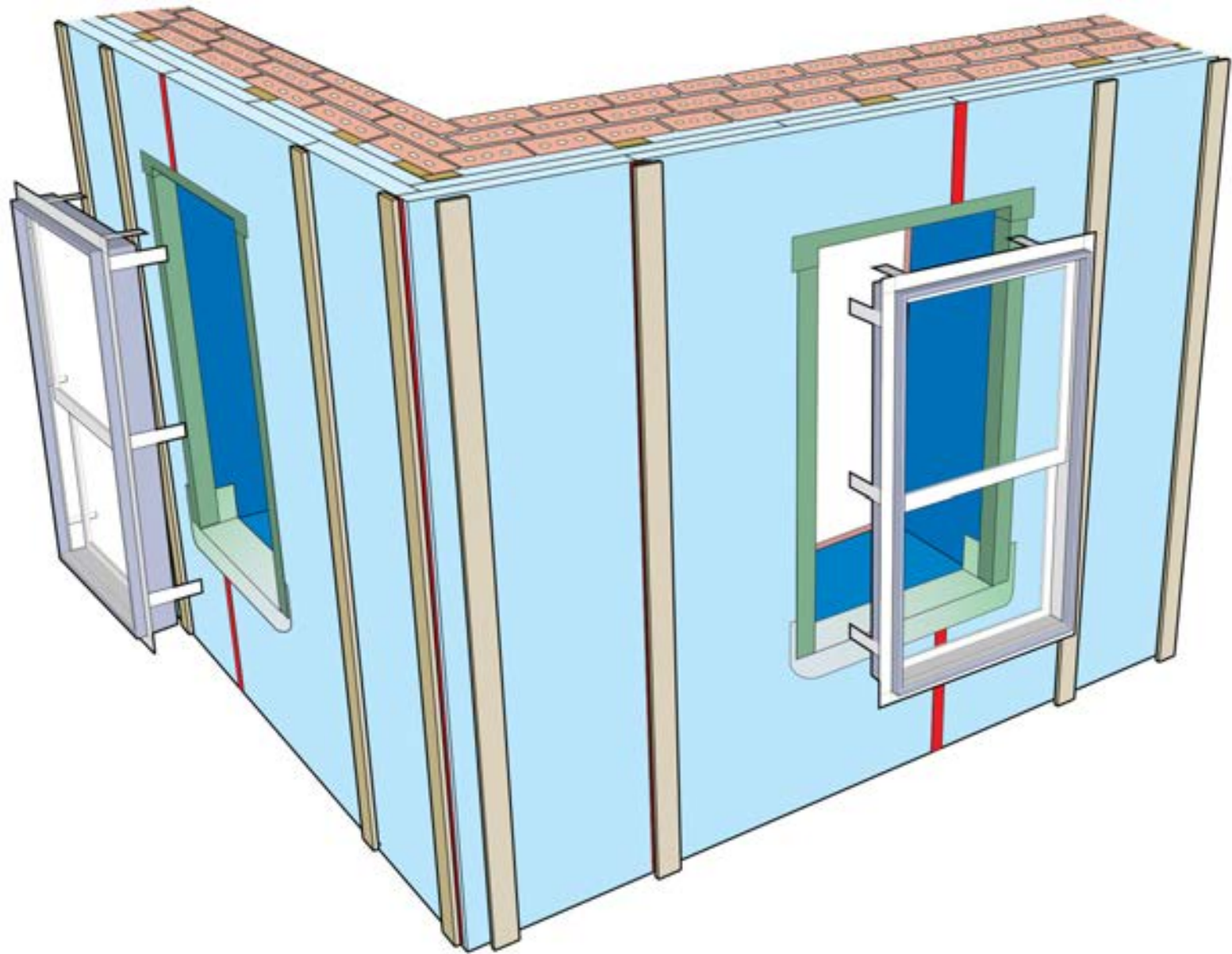












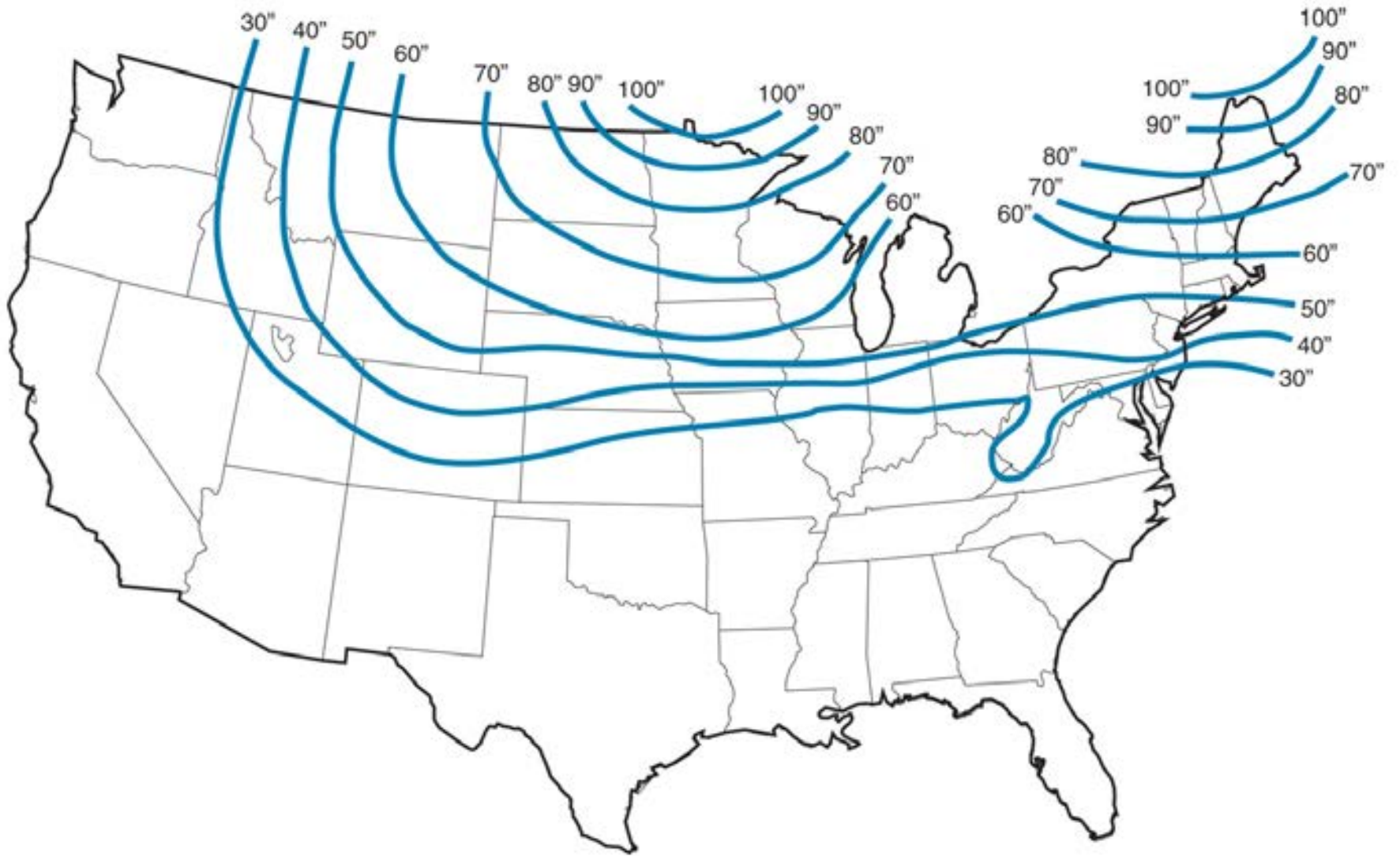












From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.

