

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

Building Science

Adventures In Building Science

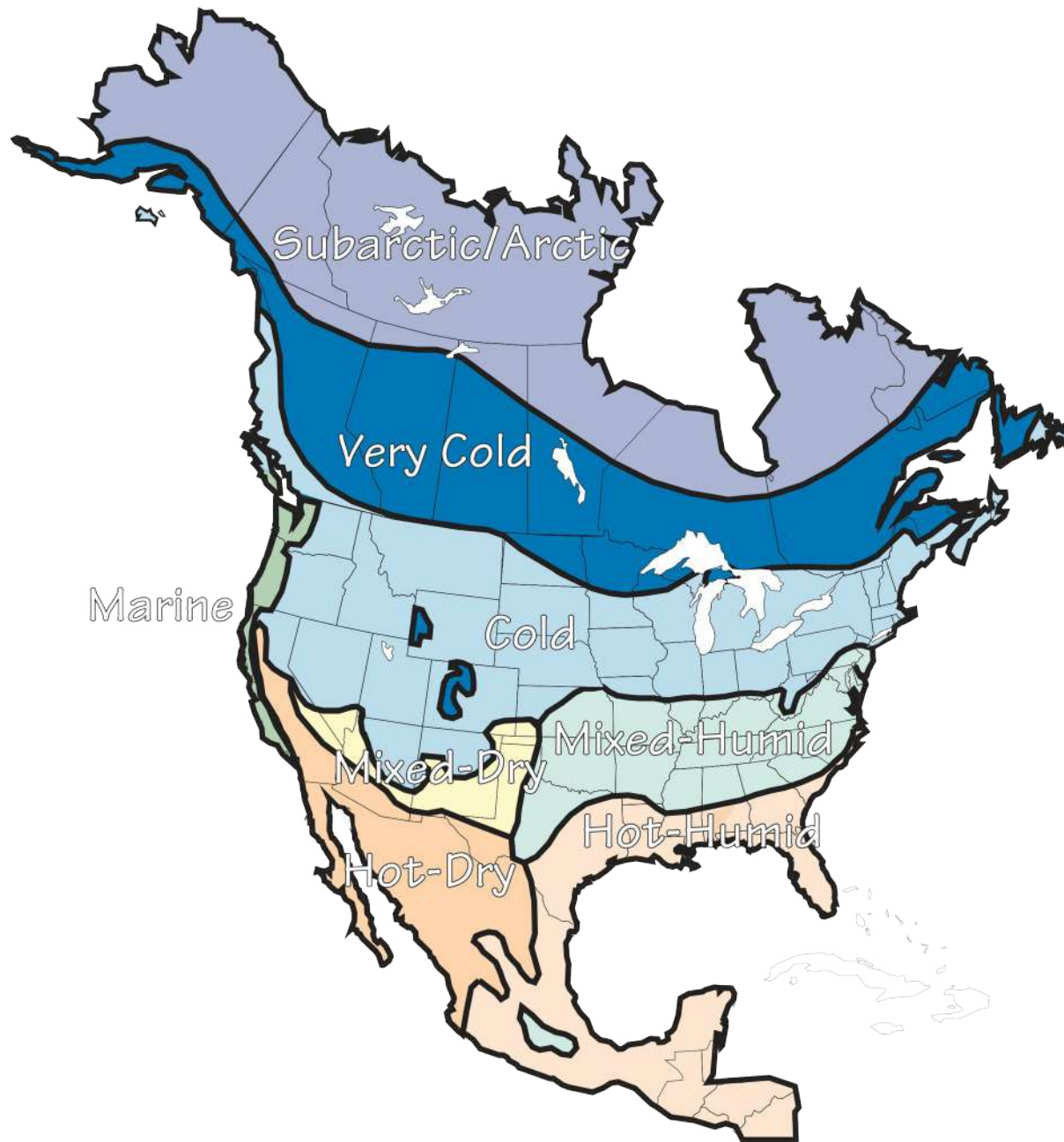
www.buildingscience.com

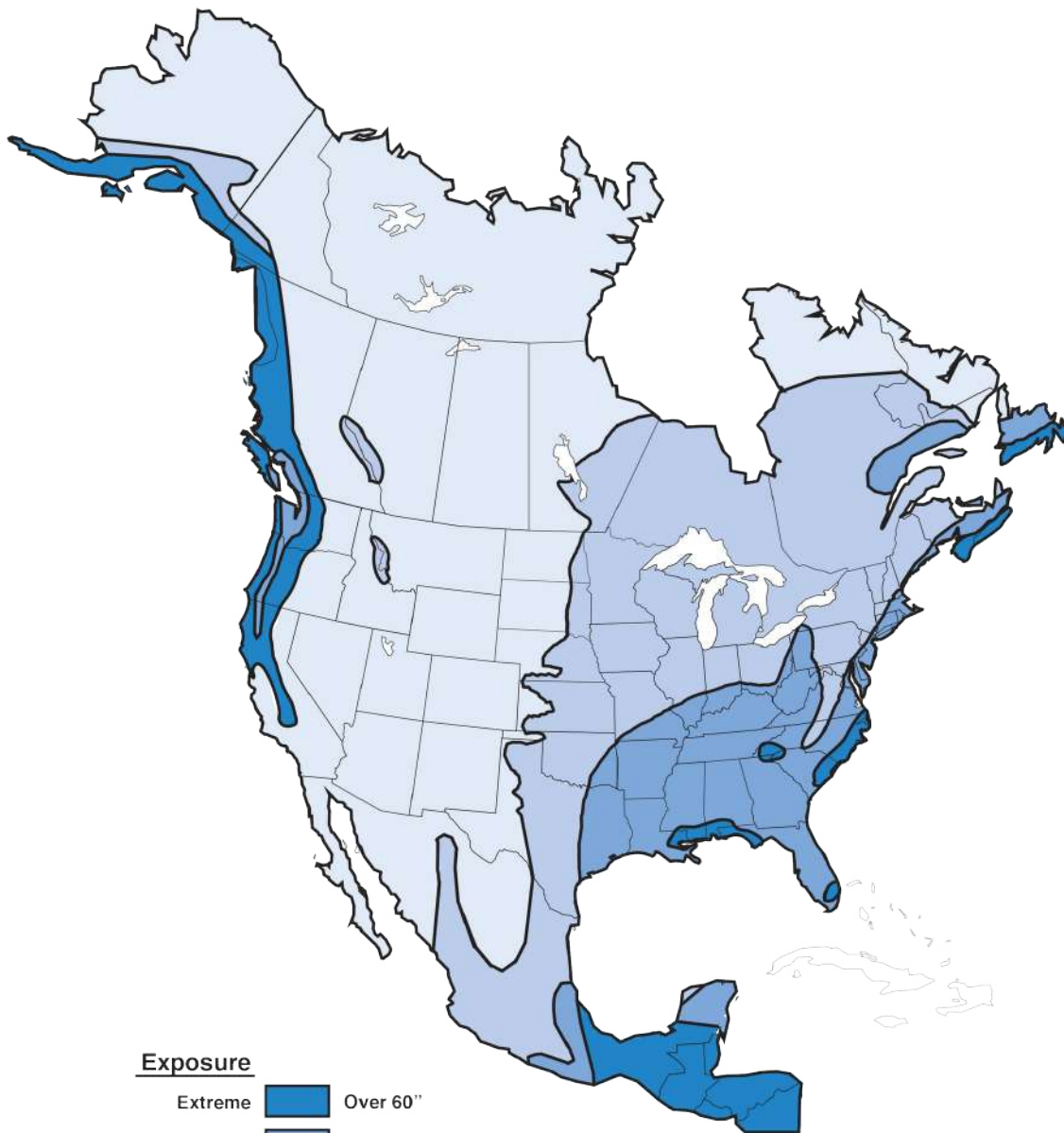
Retrofits – Mass Buildings







Freeze-Thaw Damage

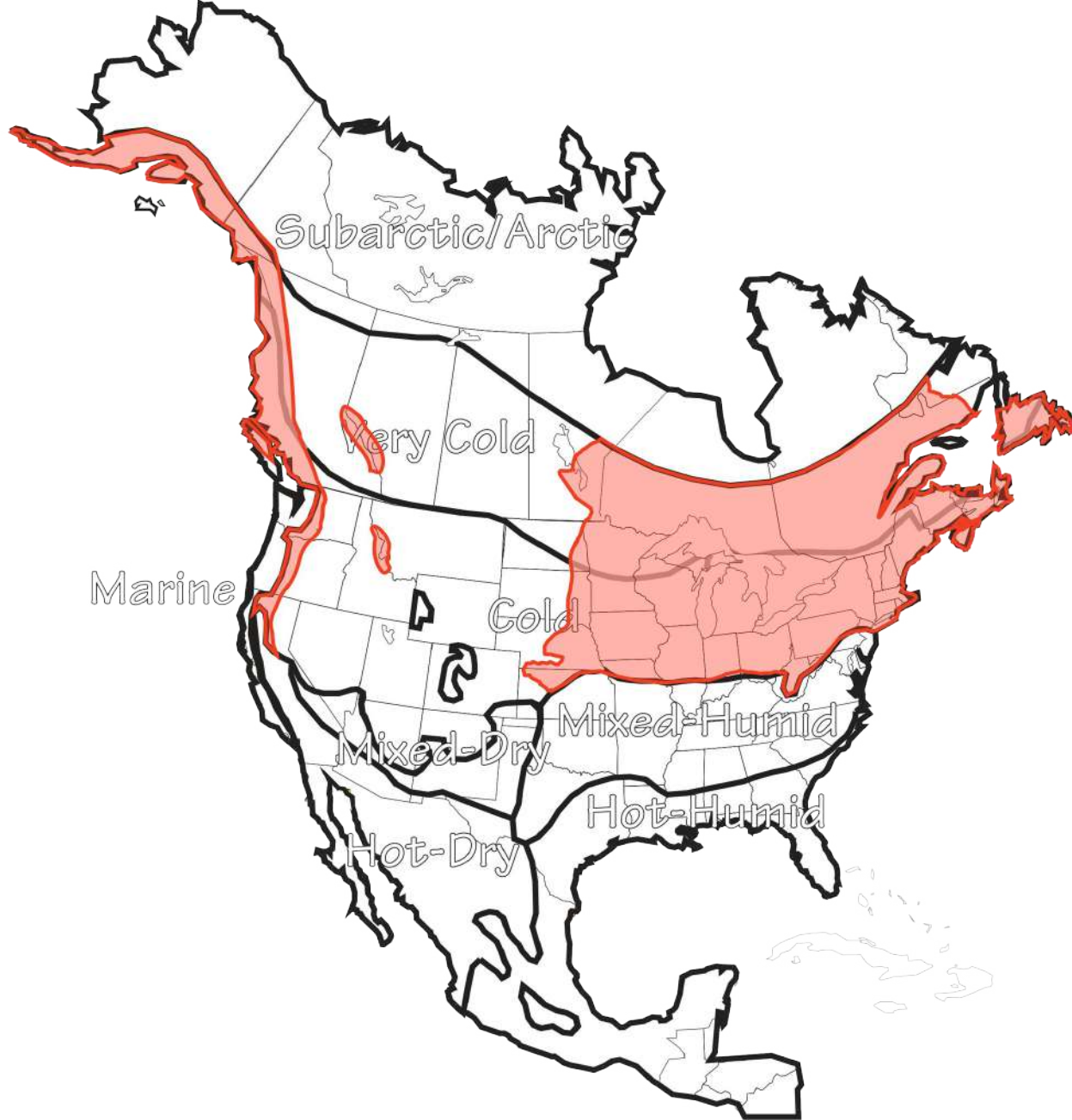
Freeze-Thaw Damage
Freezing Temperatures
Water
Susceptible Brick



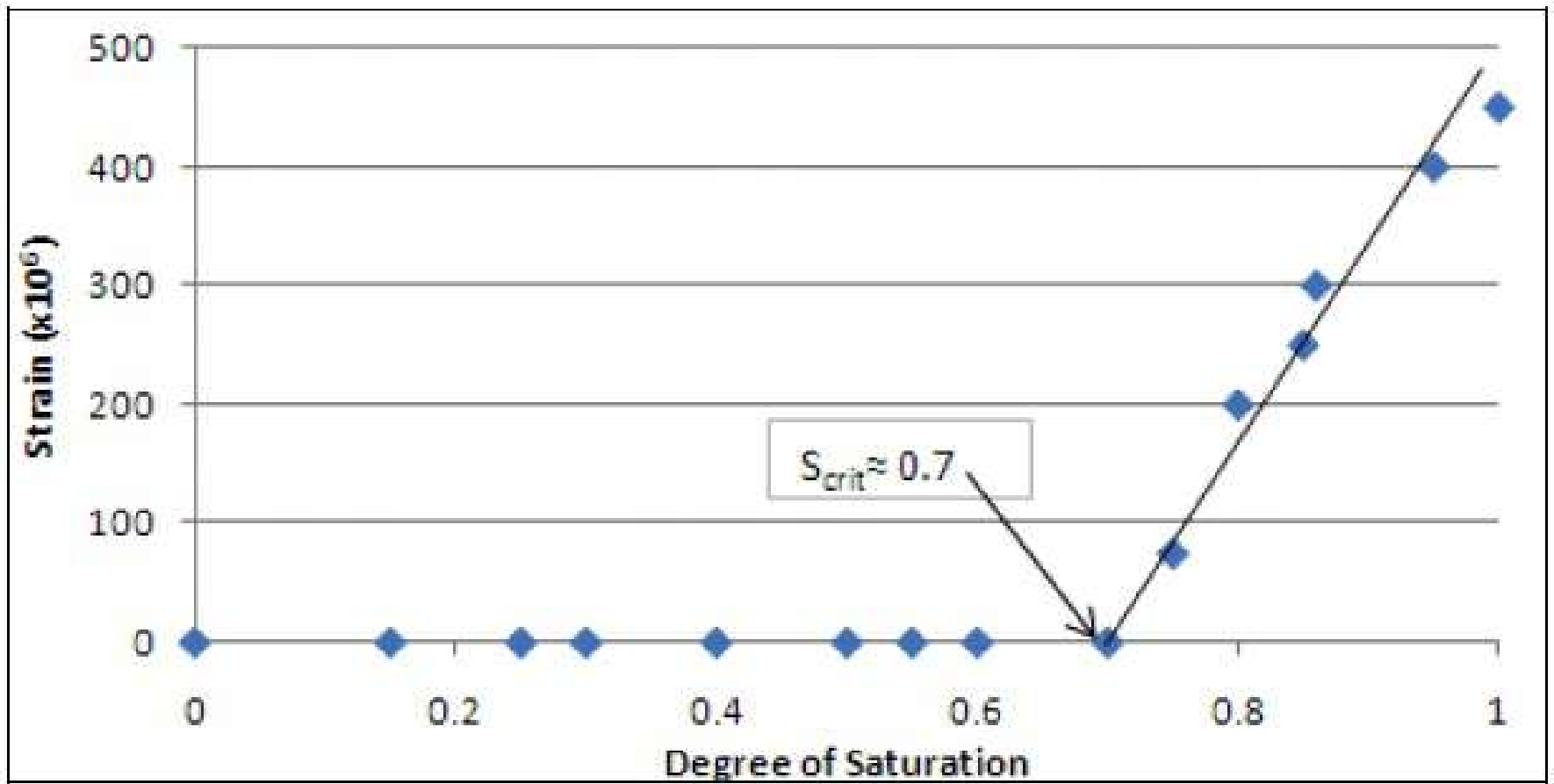


Exposure

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



Susceptible Brick Firing Temperature Vitrification

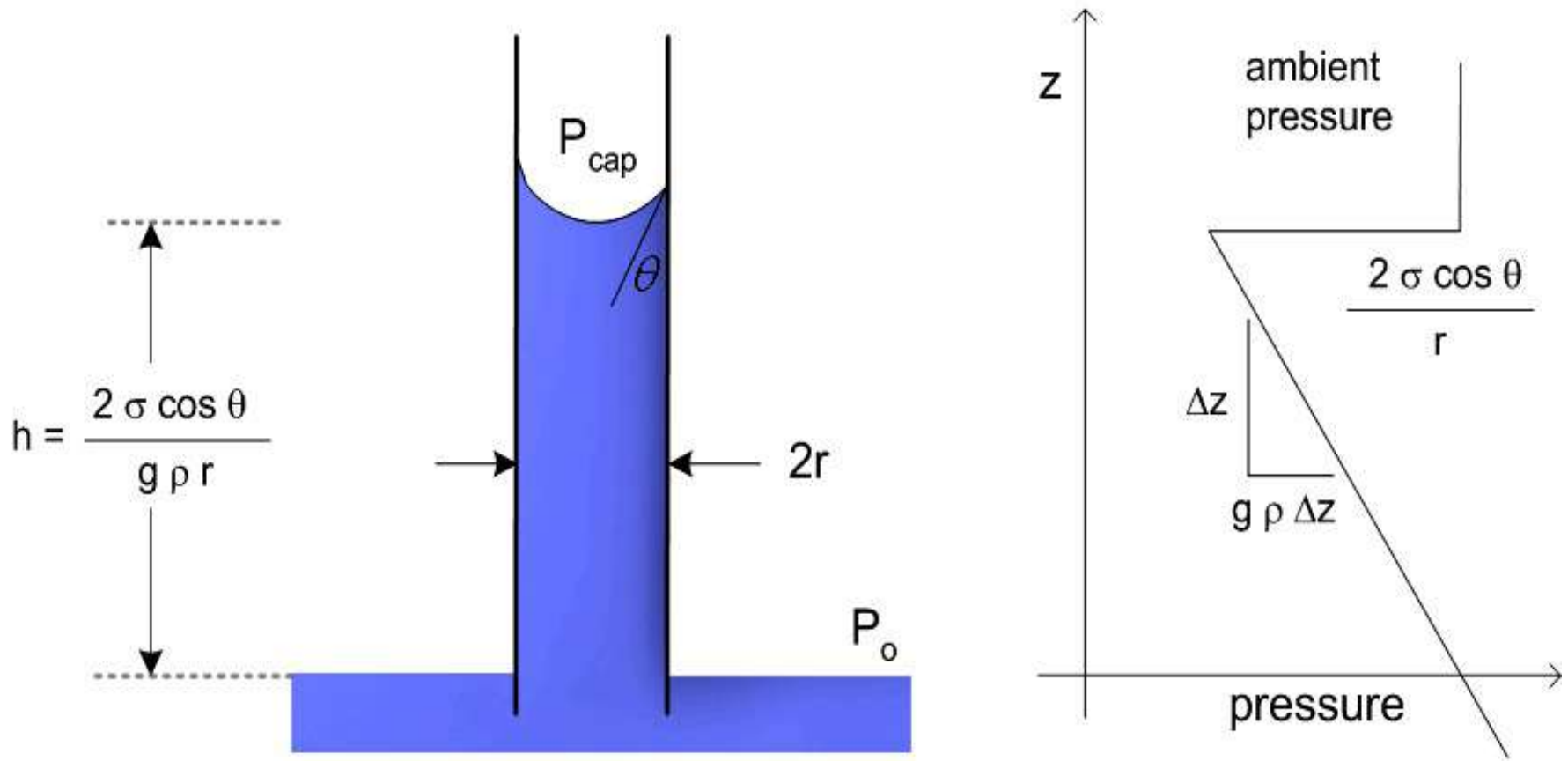




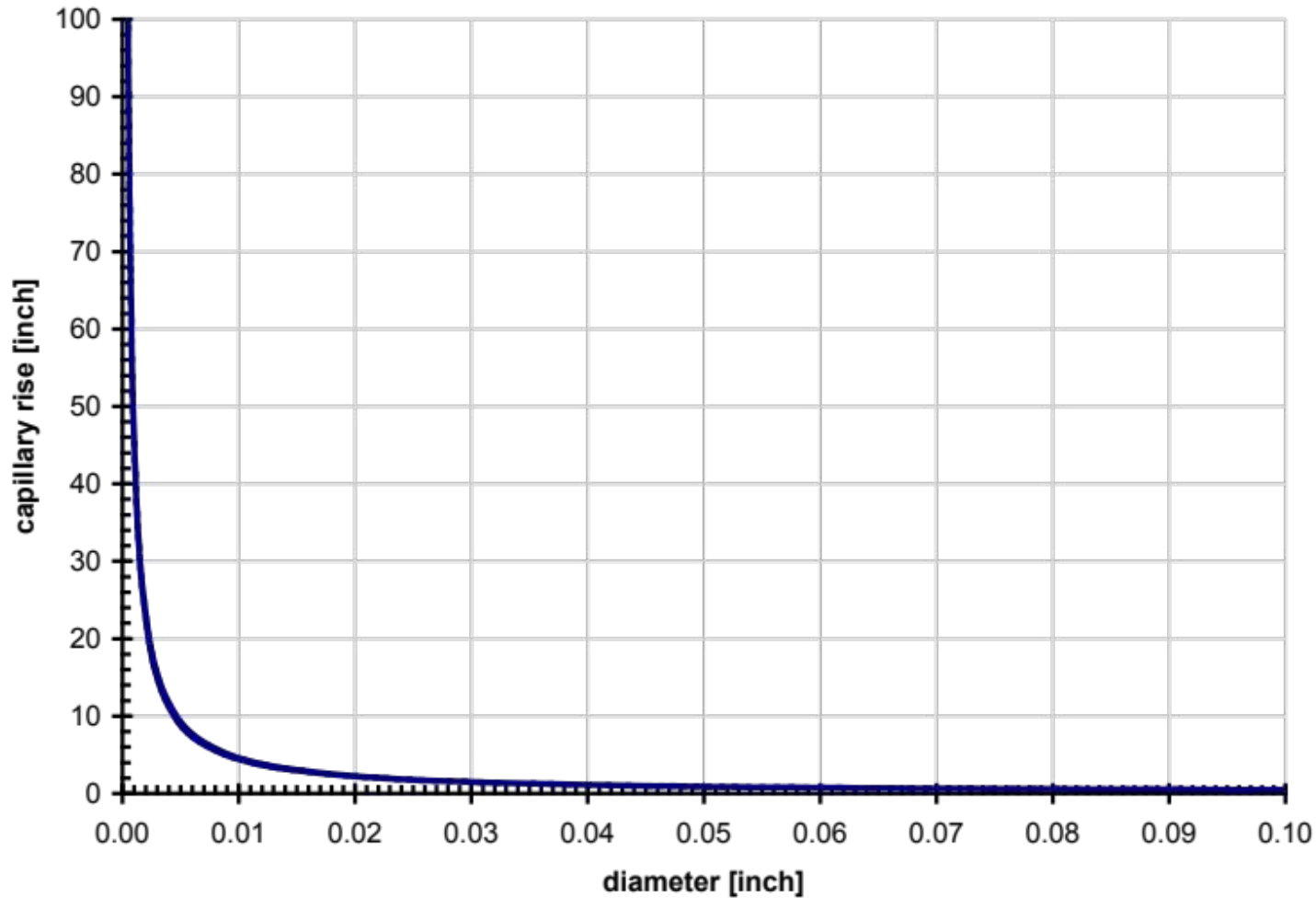
Kelvin Equation

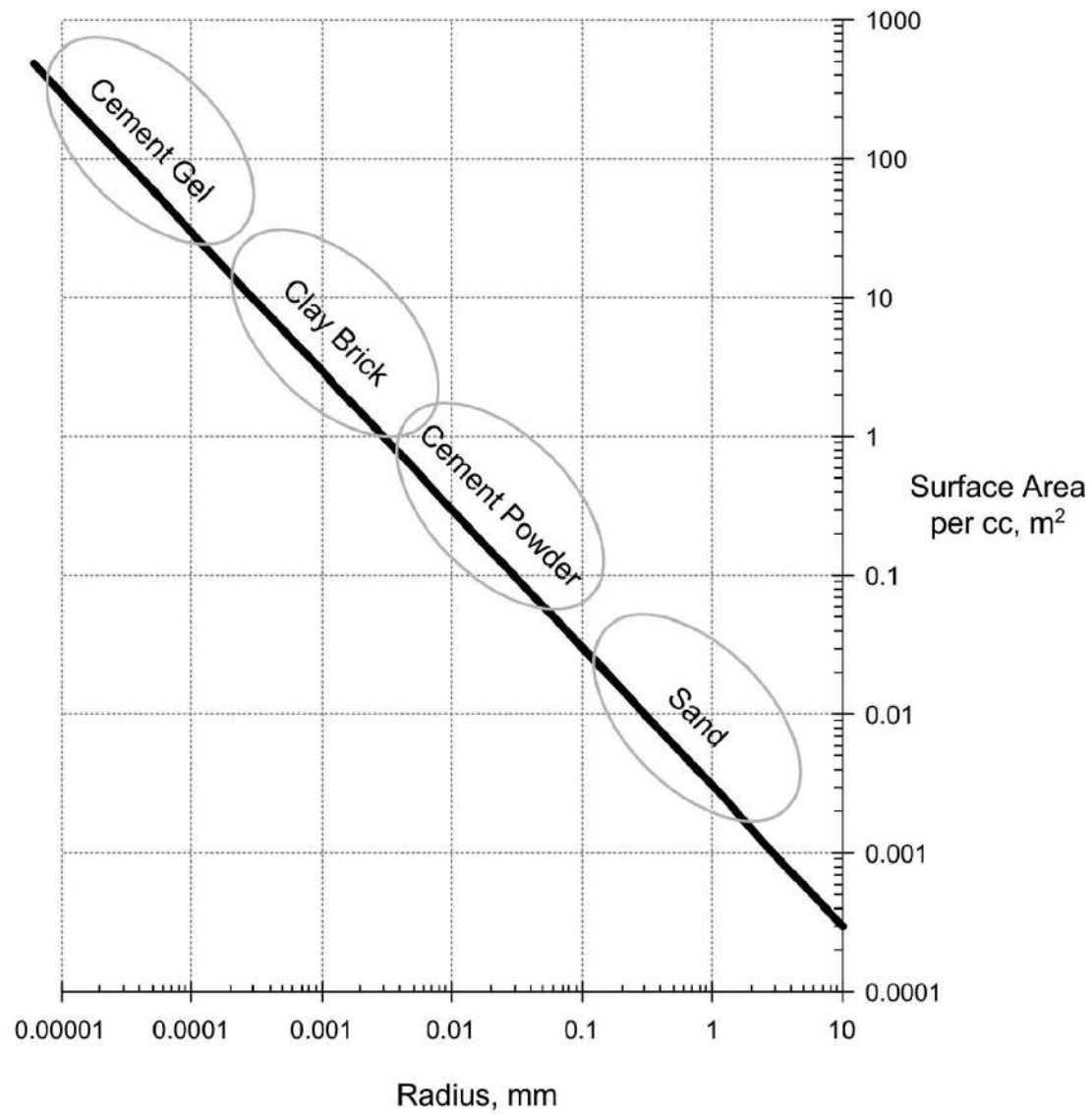
$$\ln \frac{p}{p_0} = \frac{2\gamma V_m}{rRT}$$

Calculating capillary rise

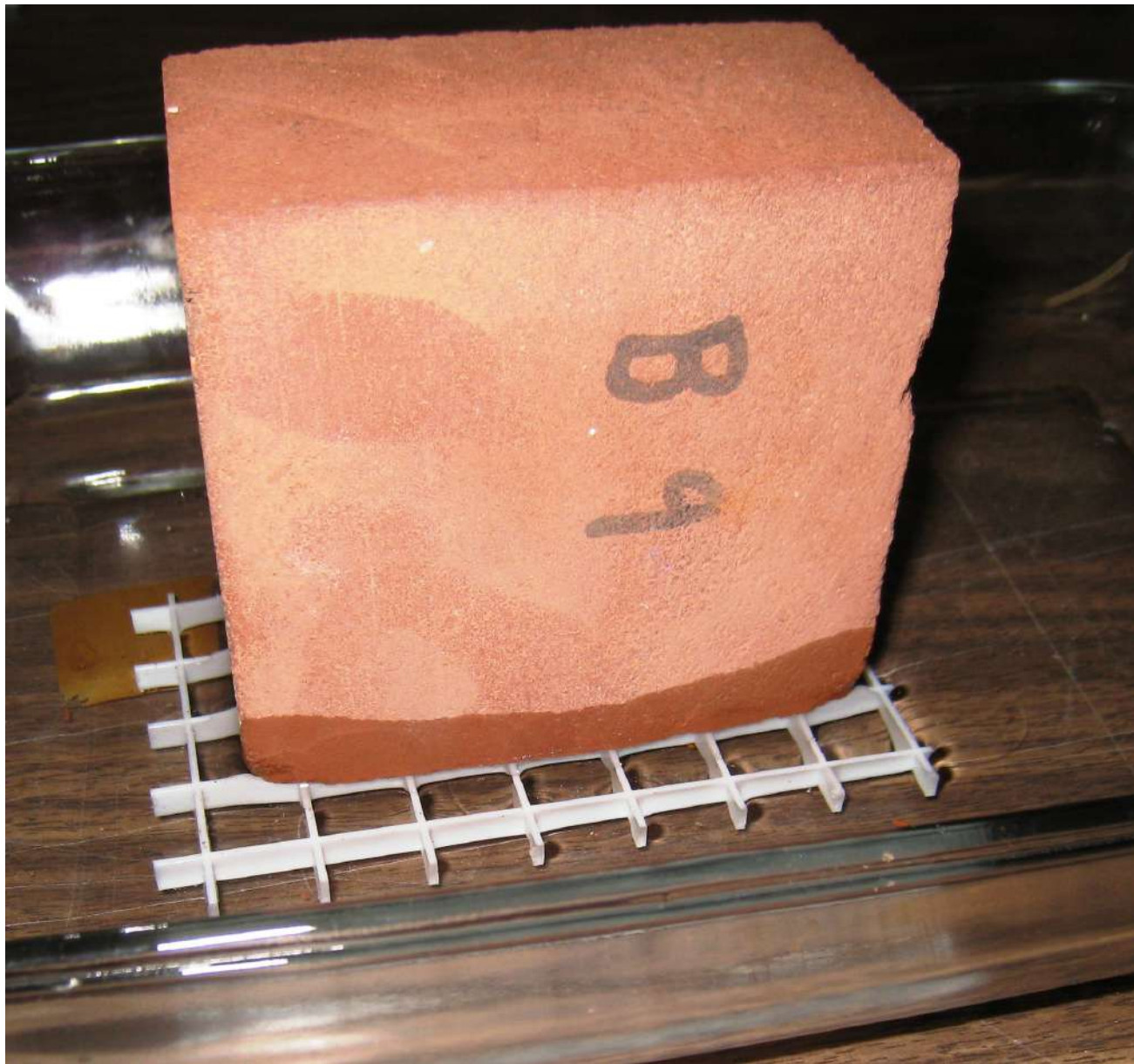


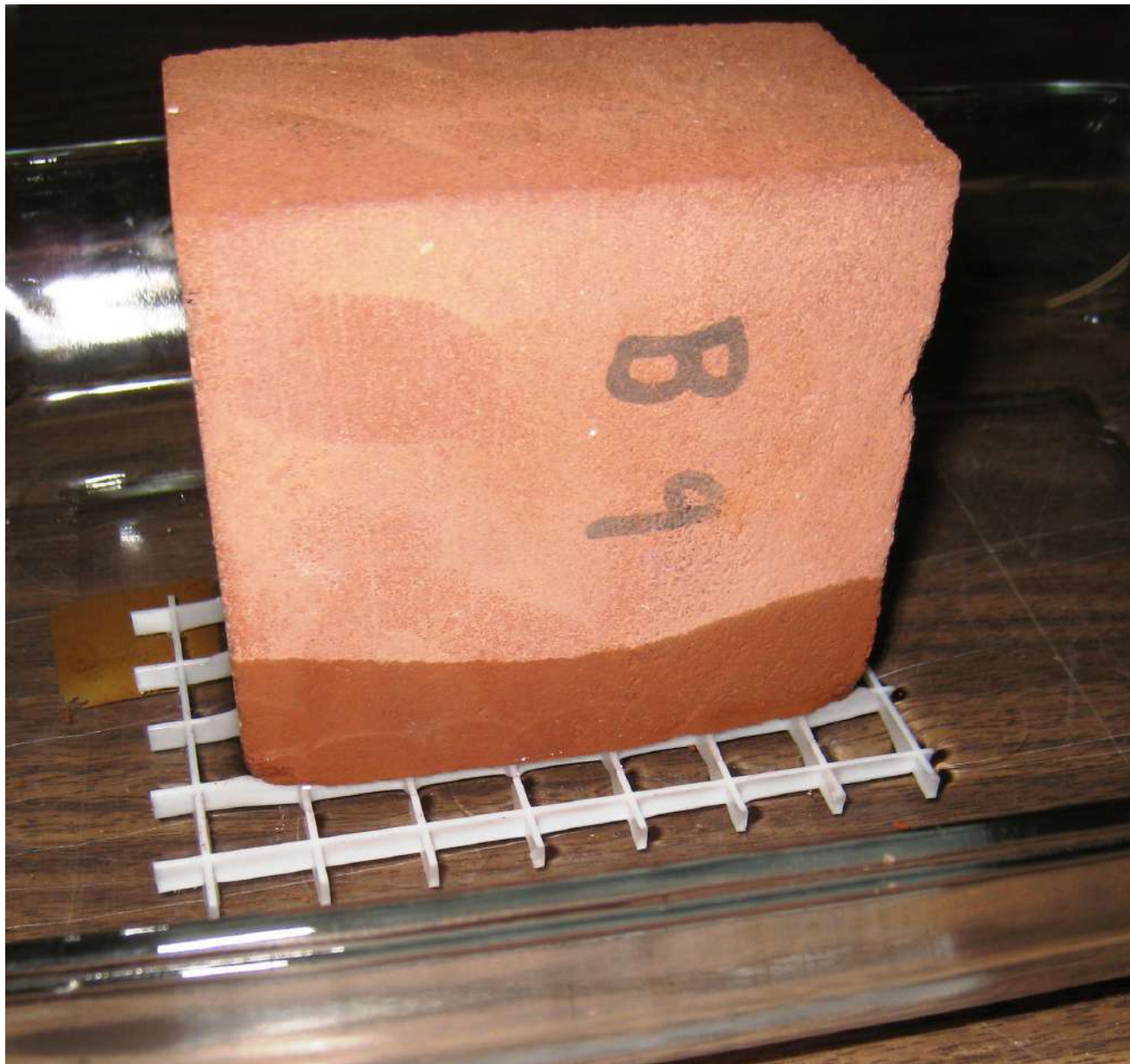
Capillary rise versus diameter

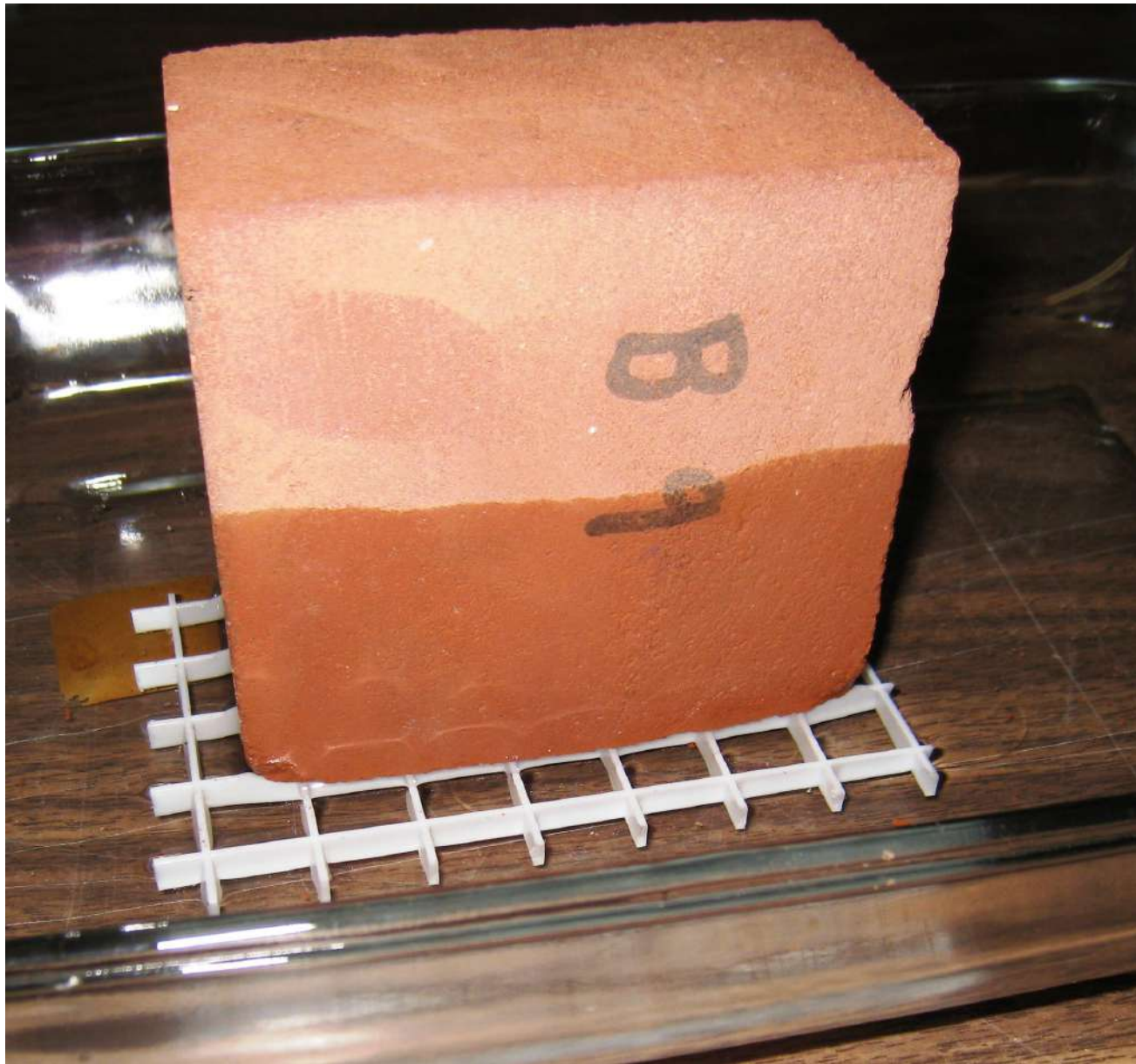


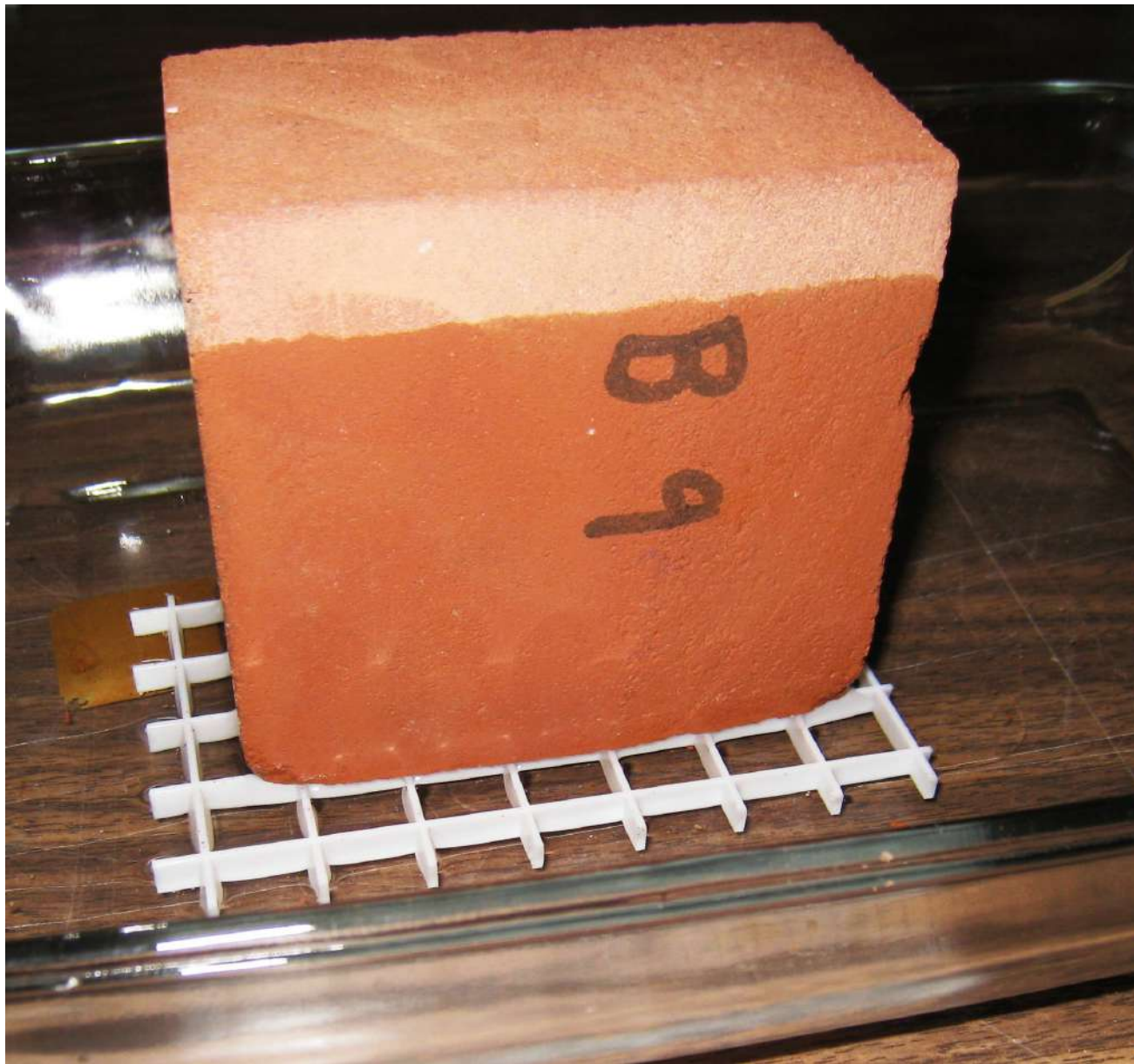


Surface area vs. particle size
From Straube & Burnett, 2005











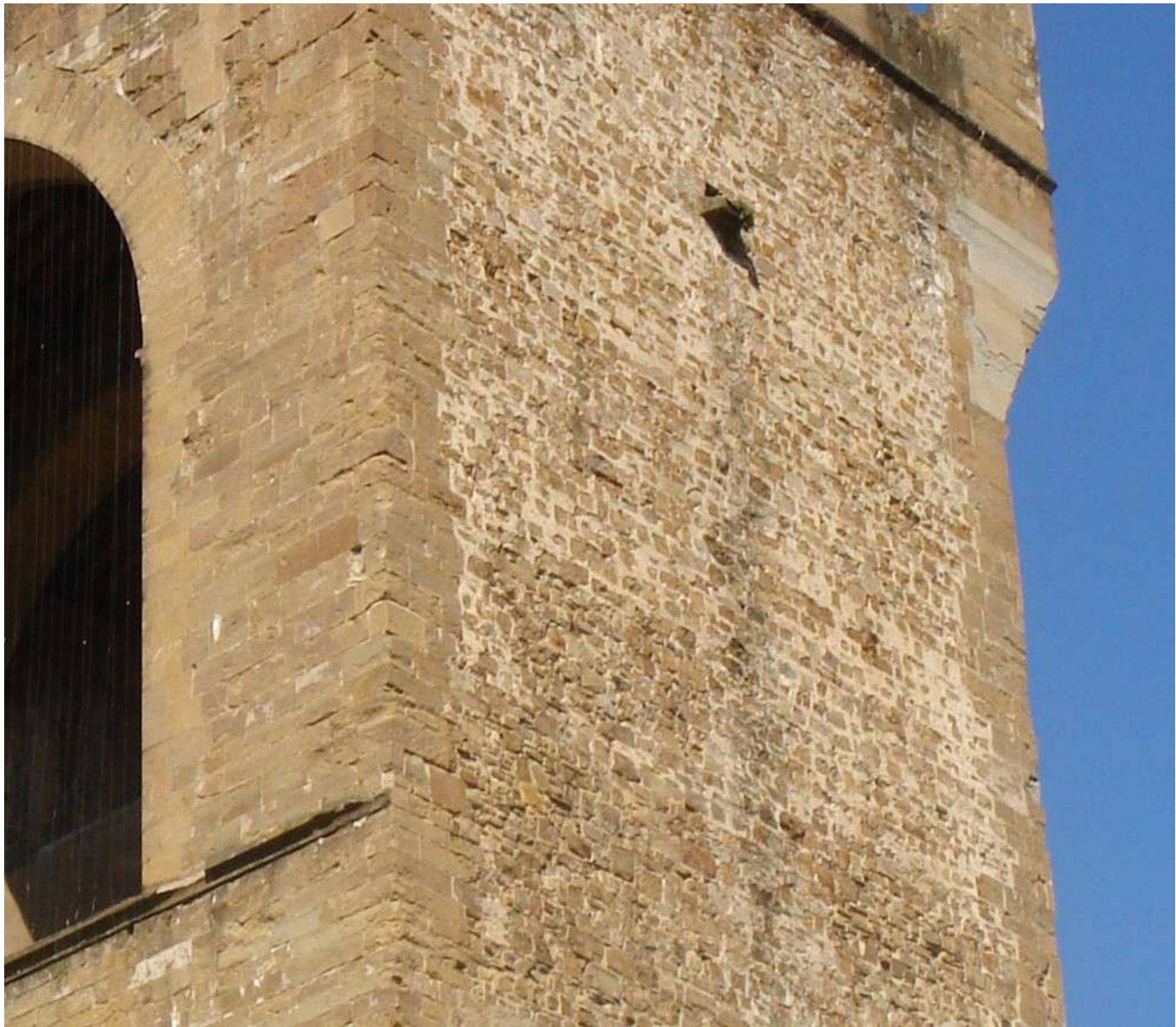










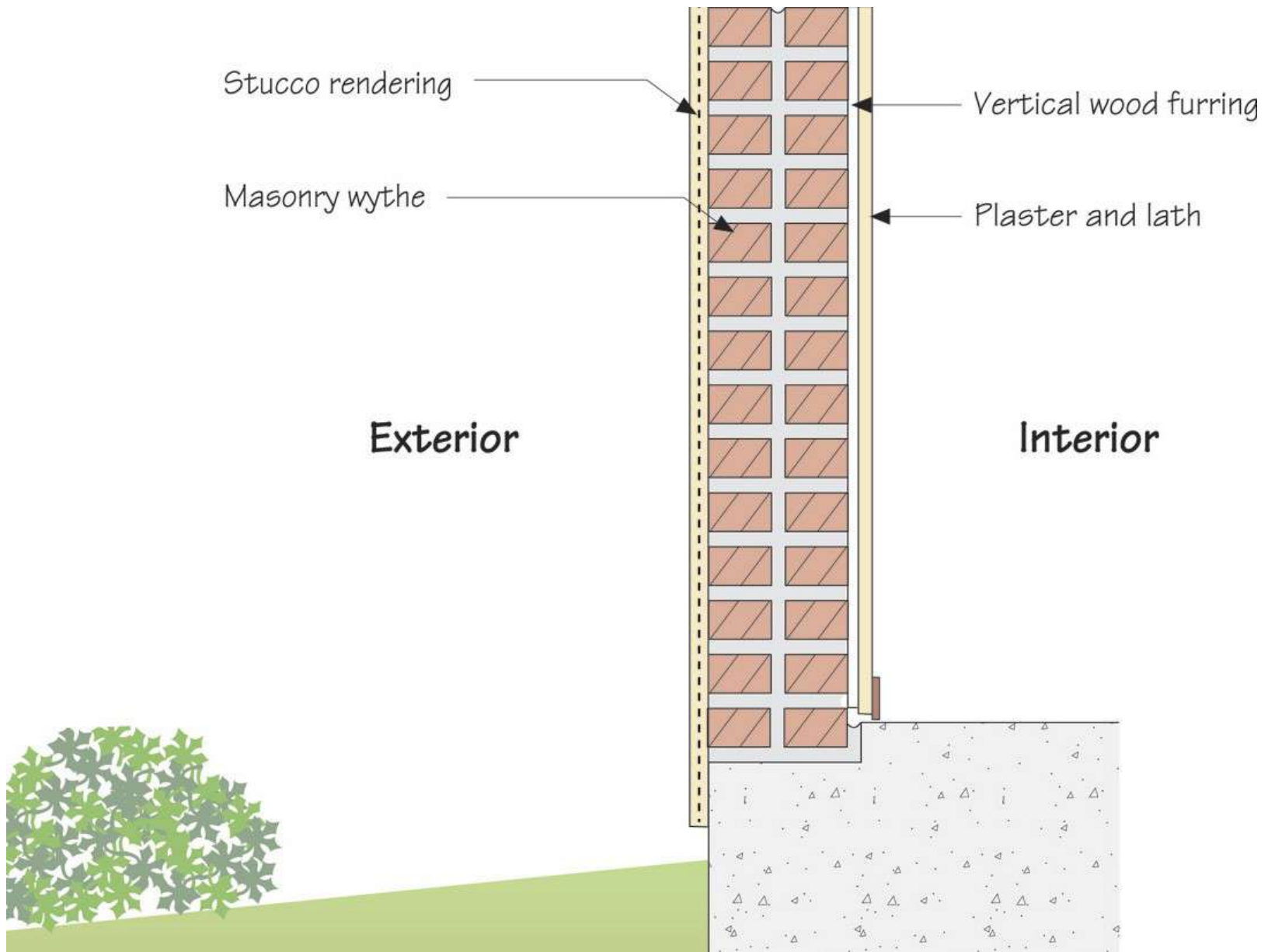












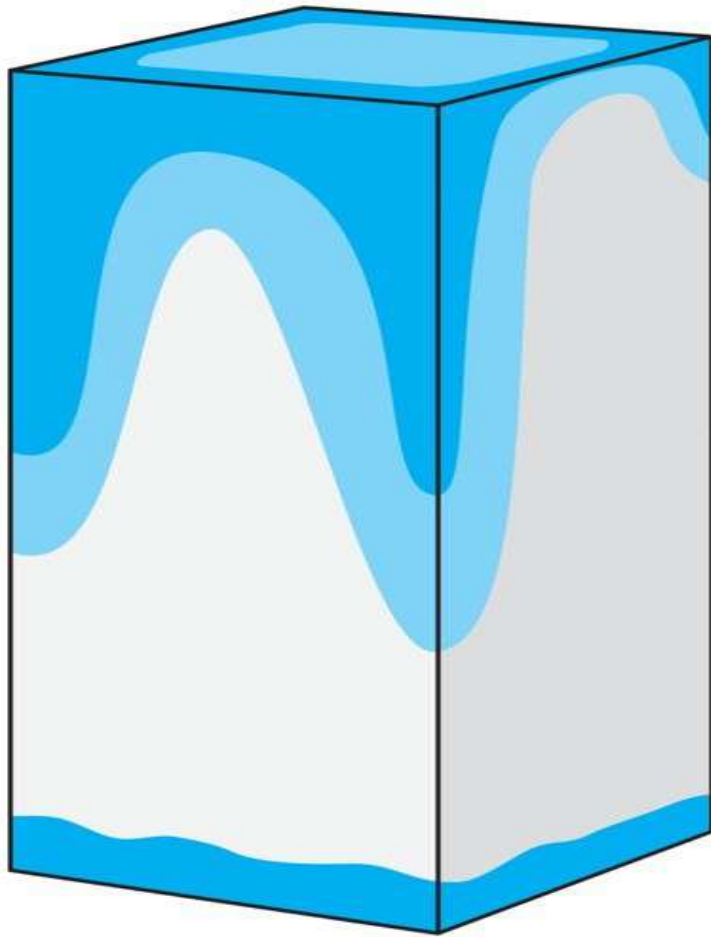


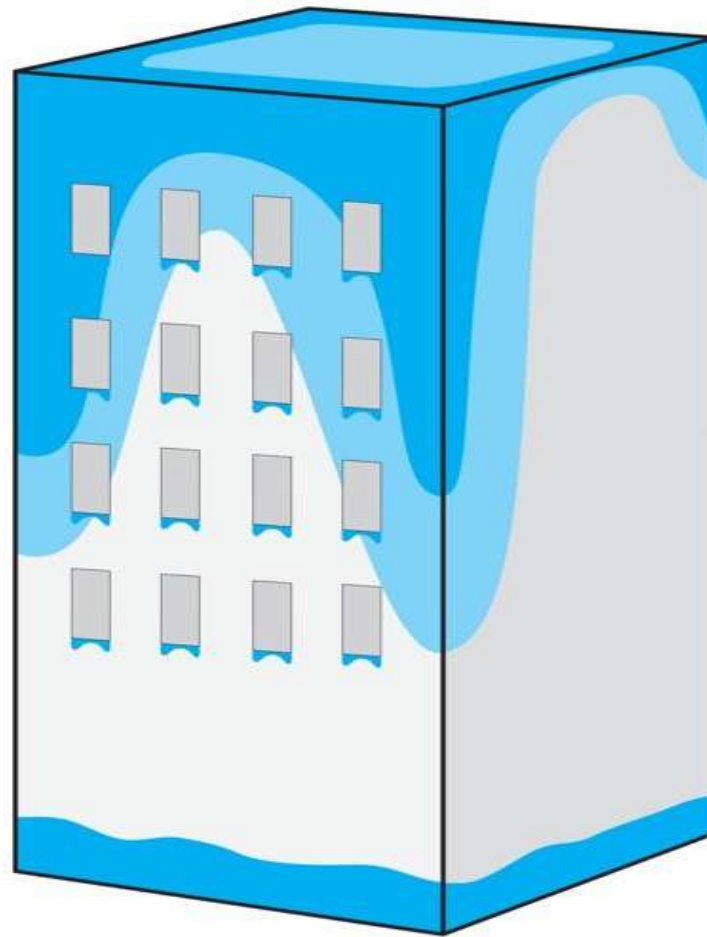










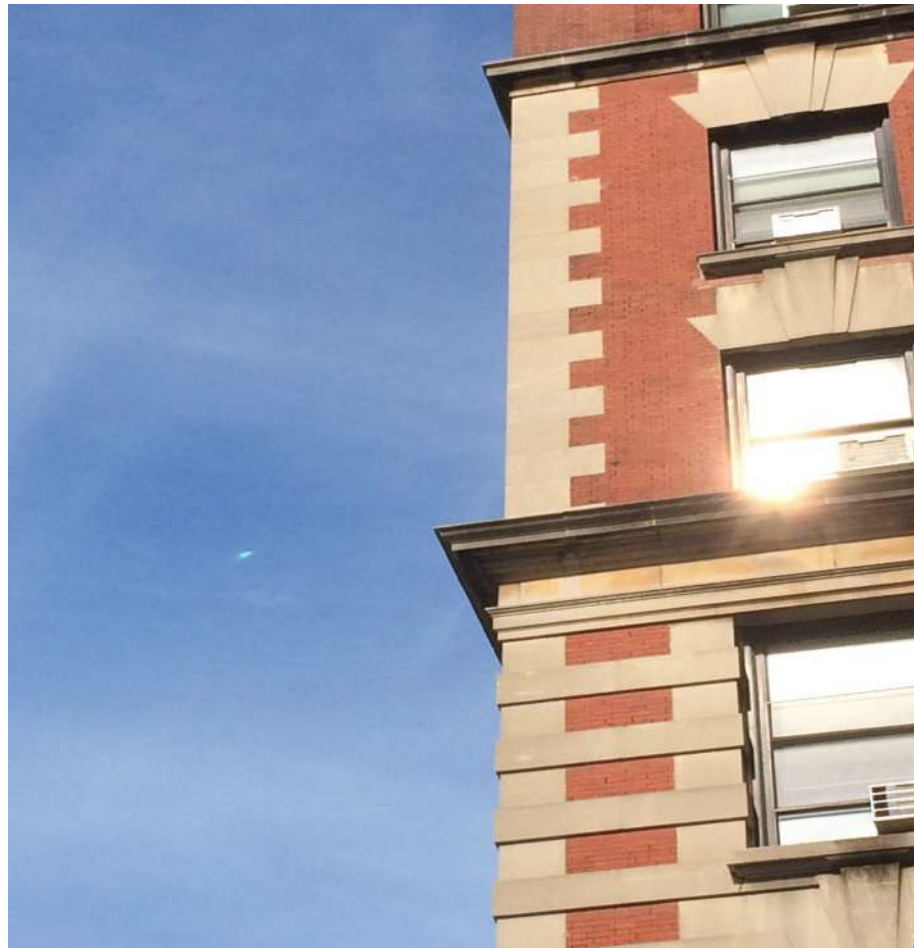




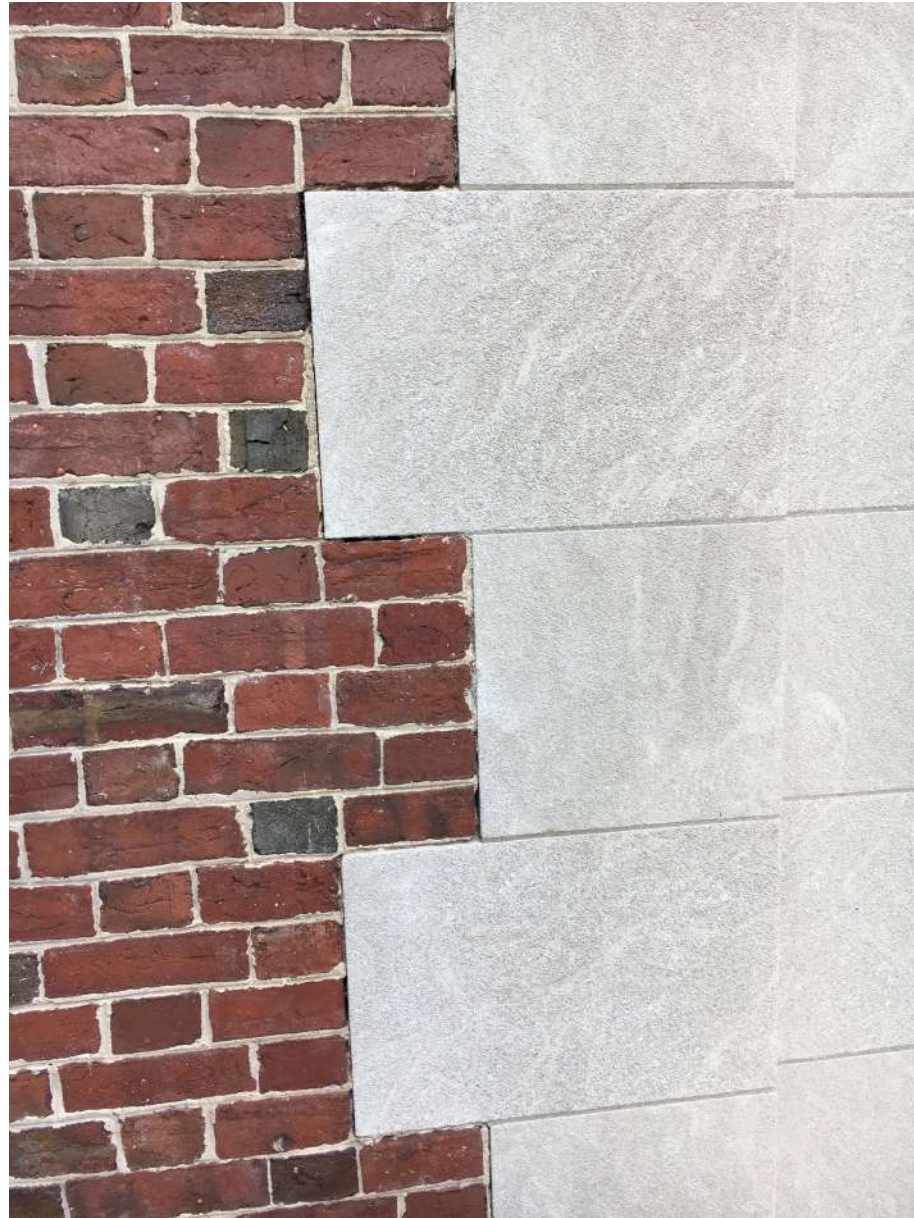




























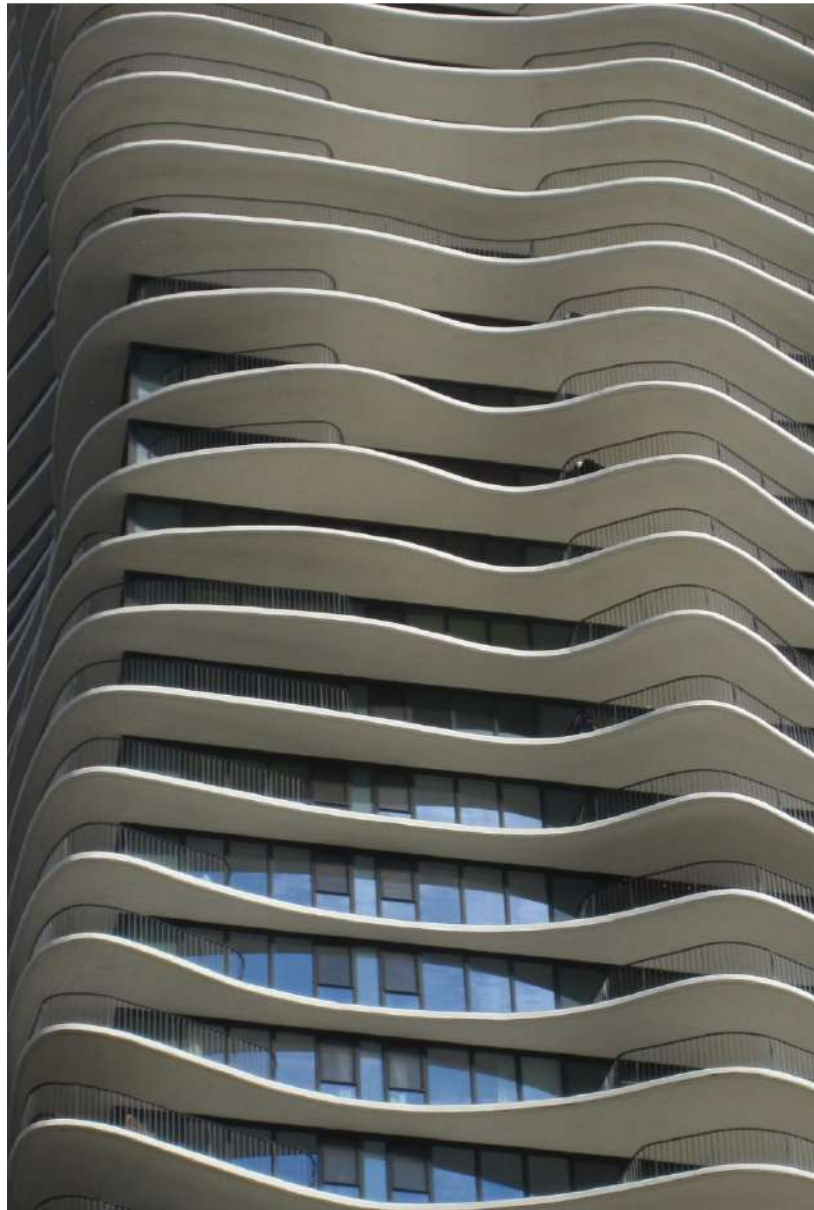






















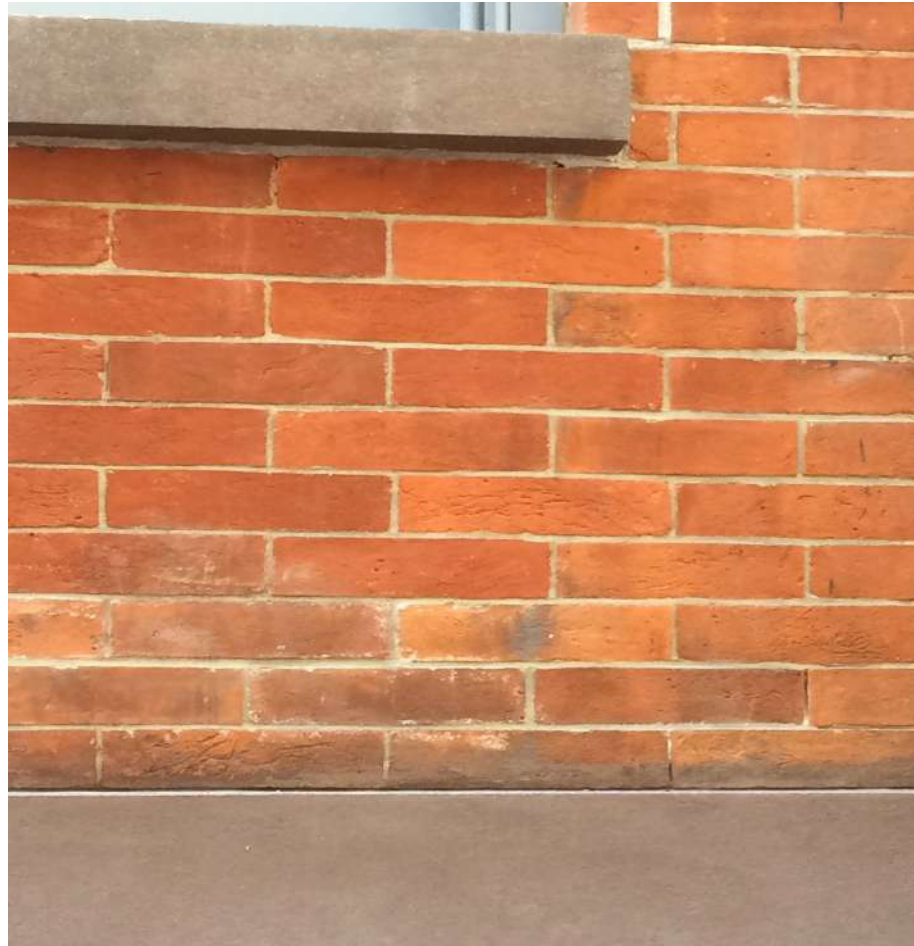








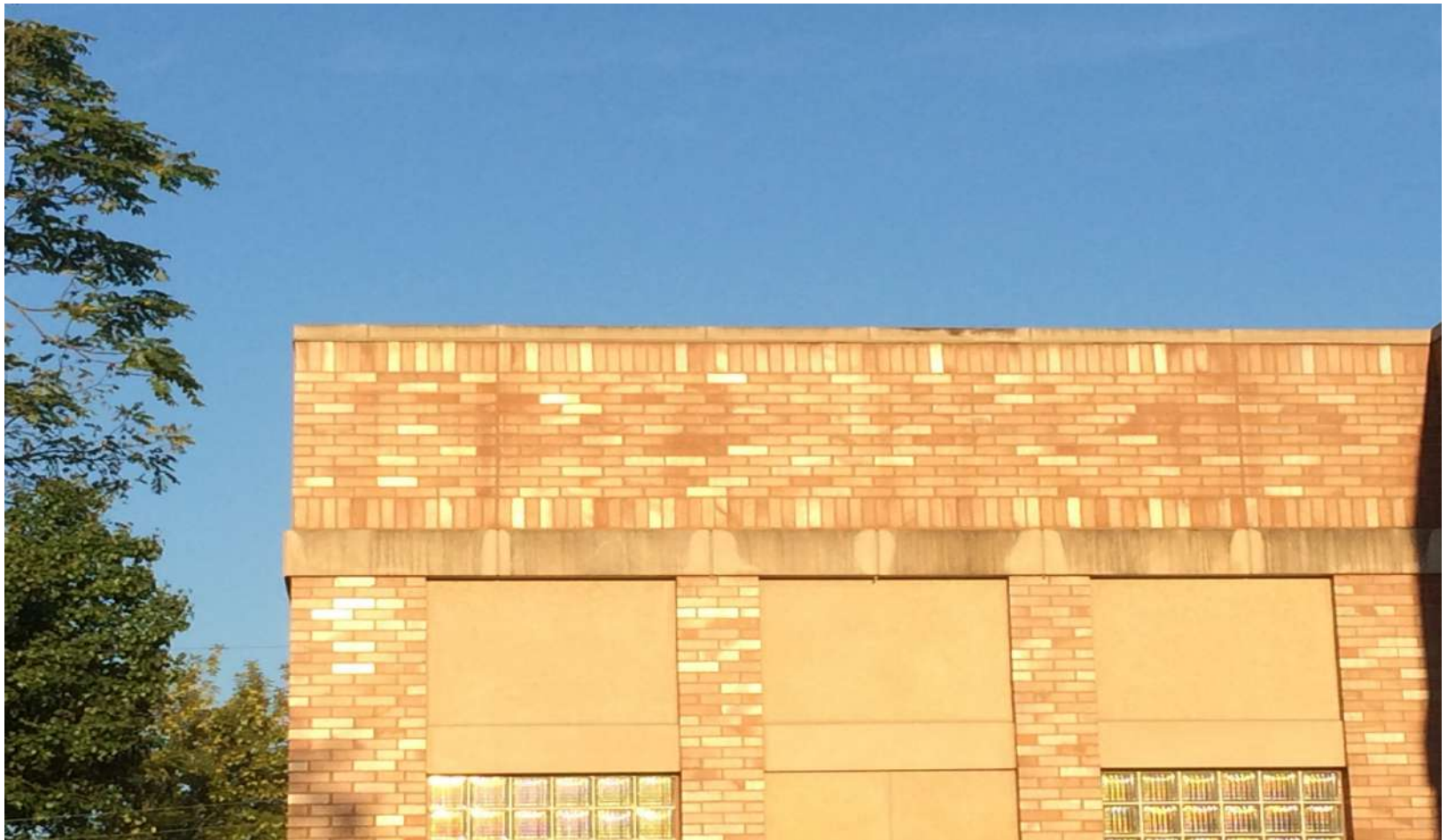


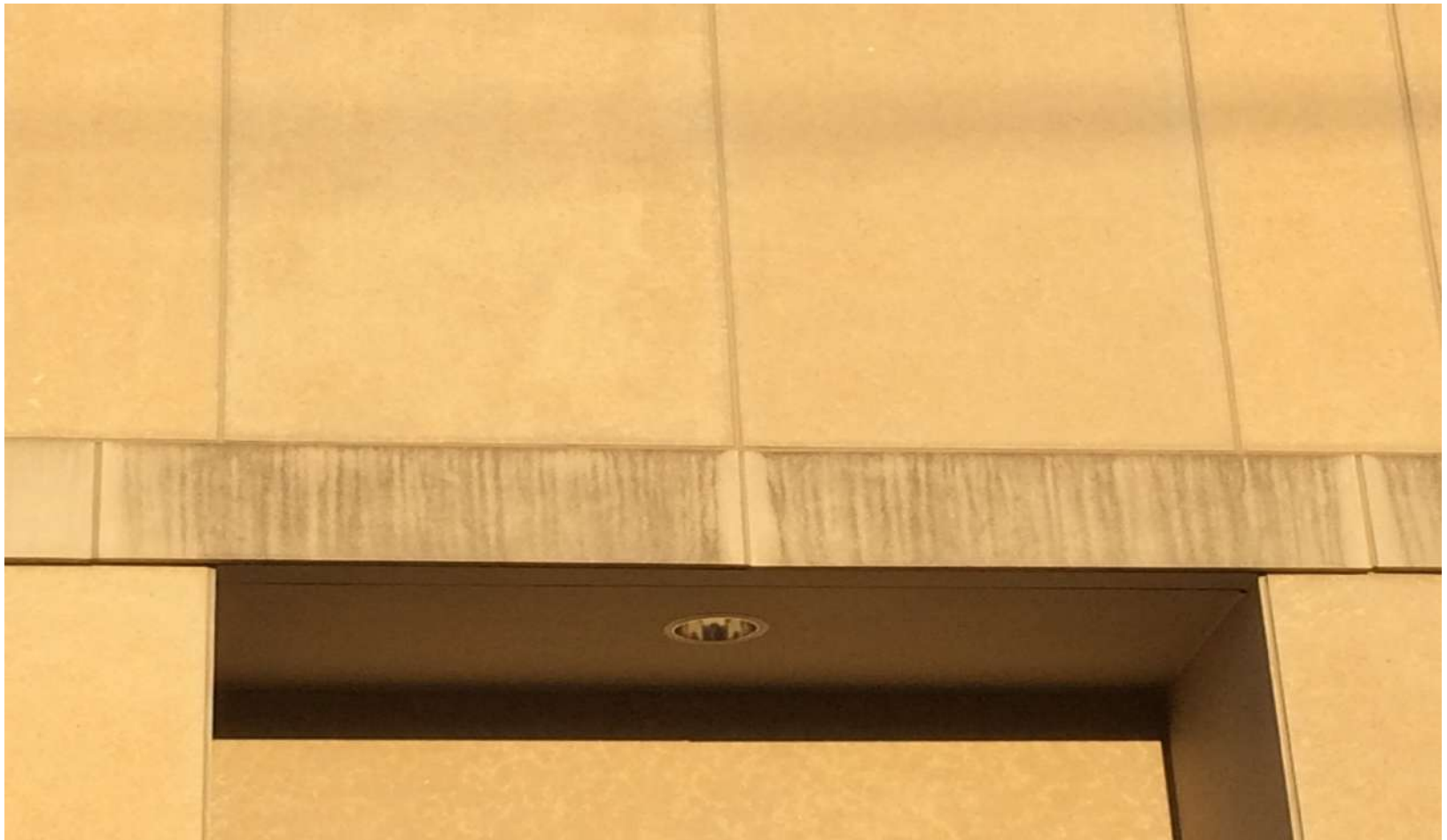














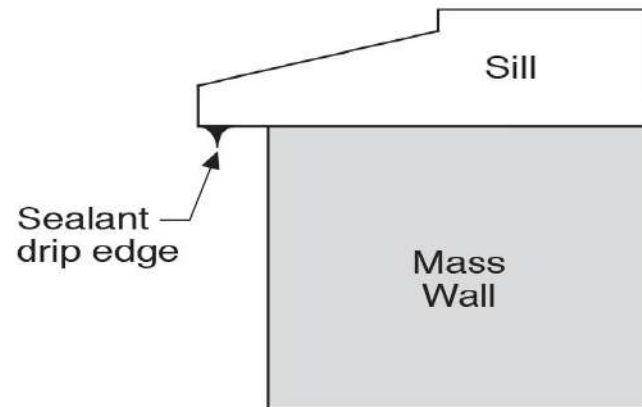
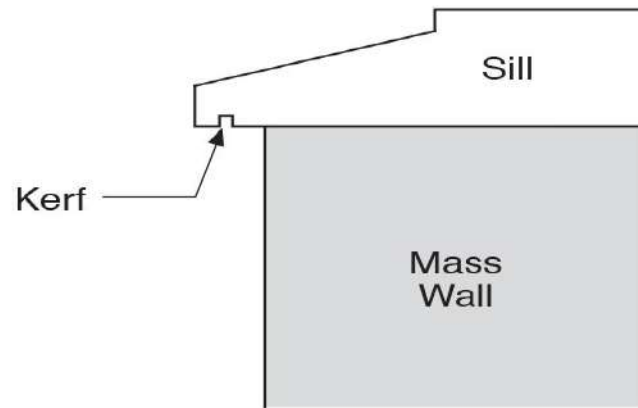




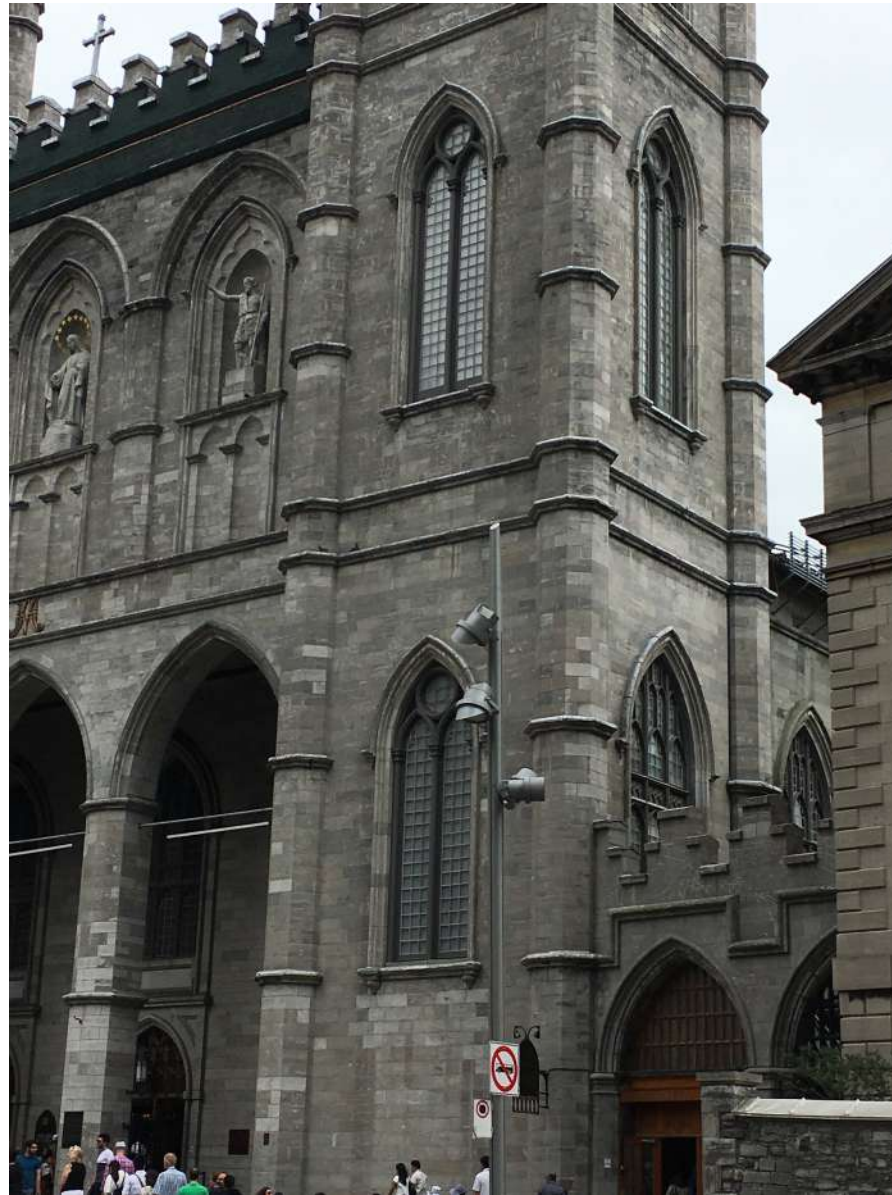


























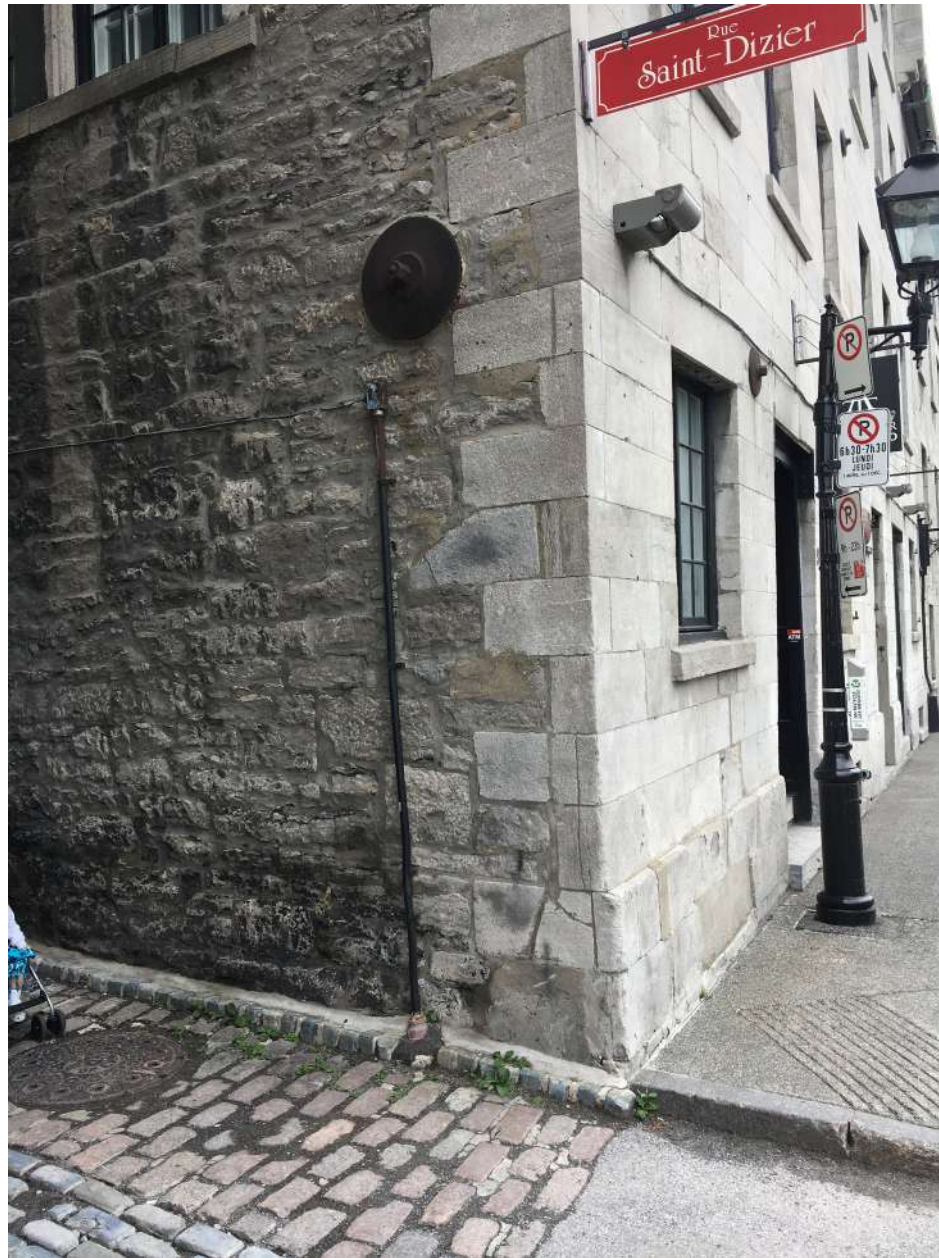








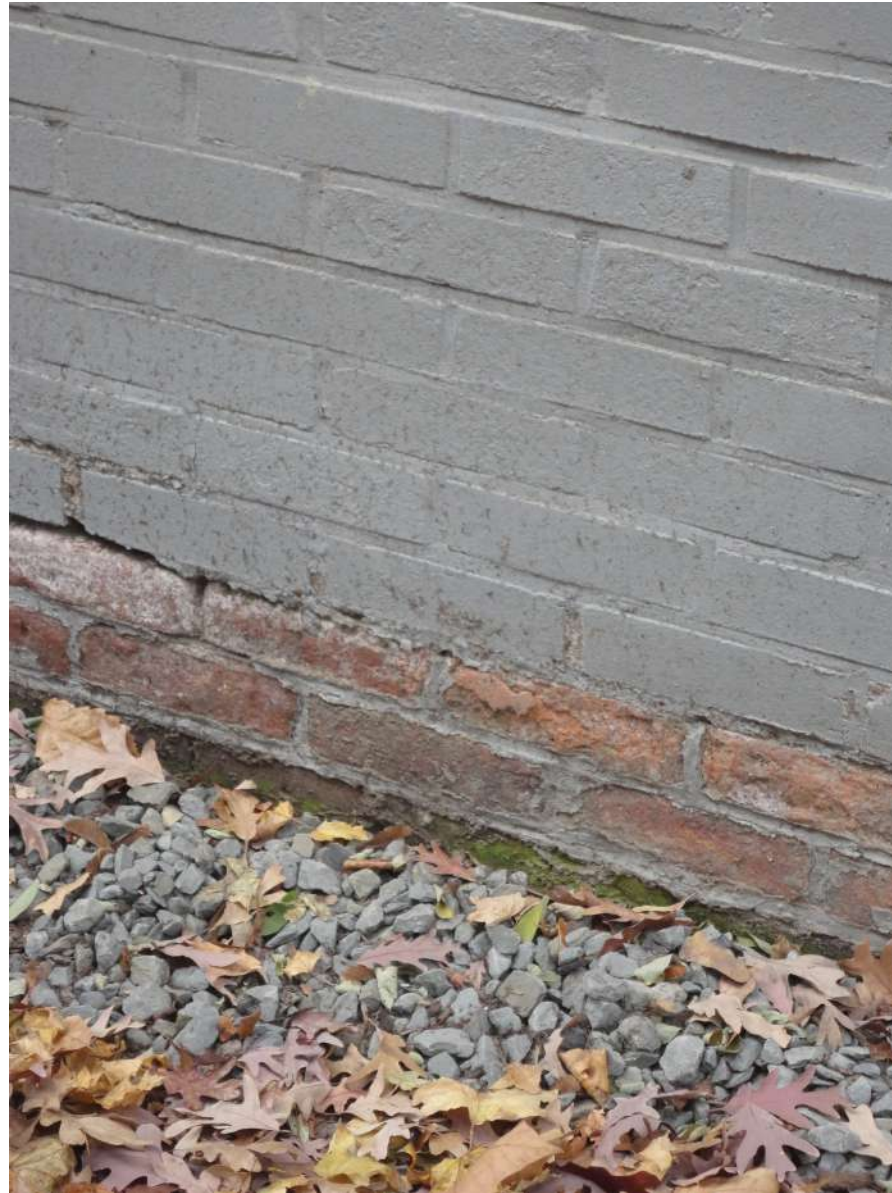




















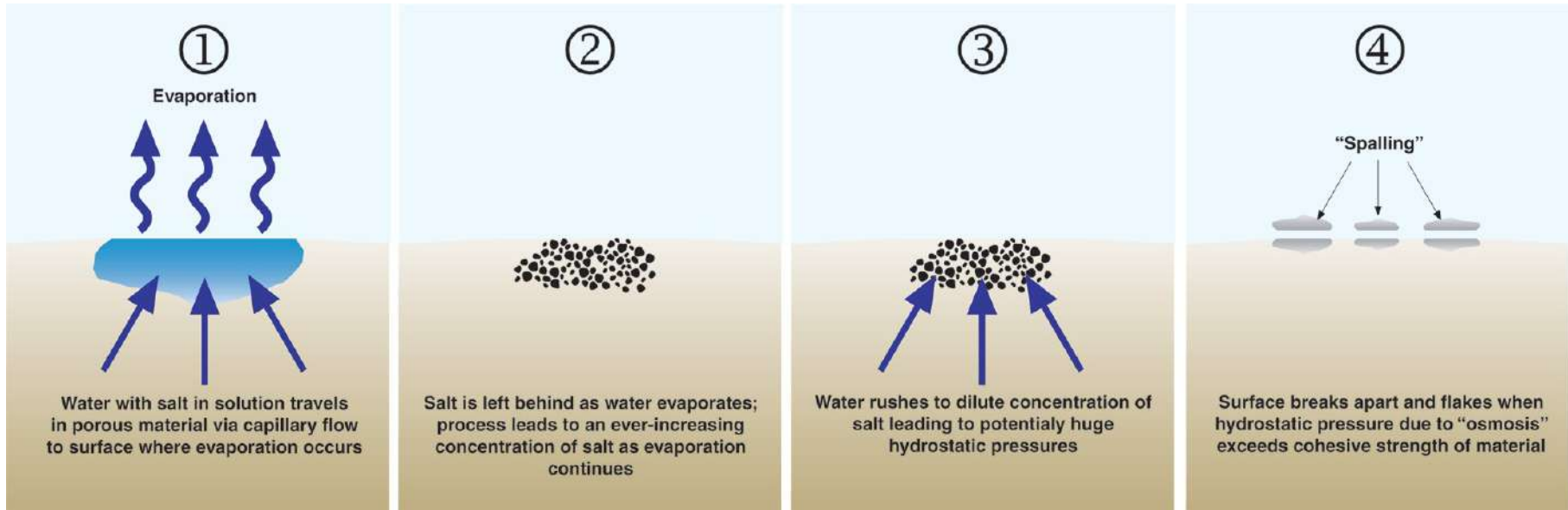










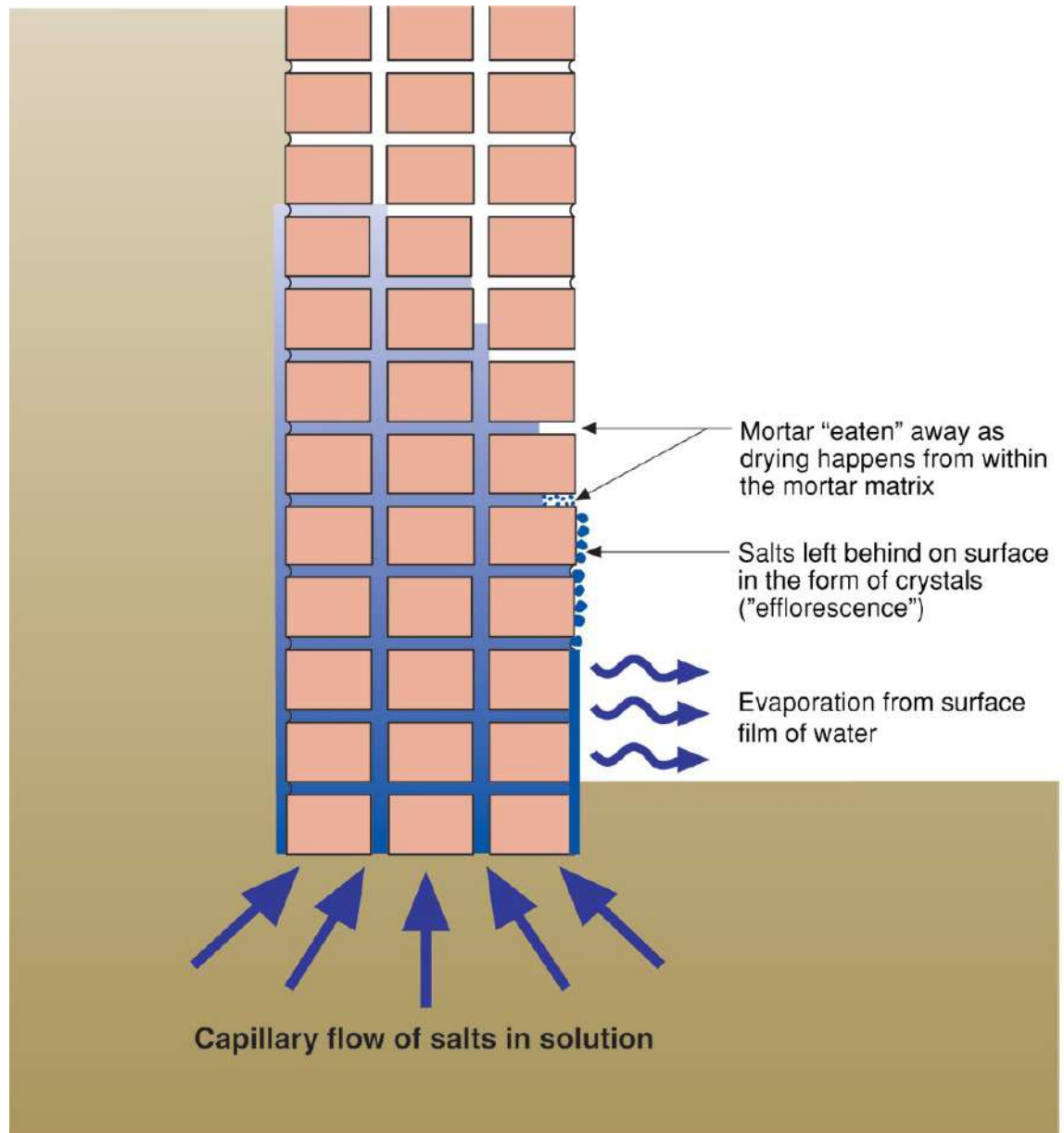


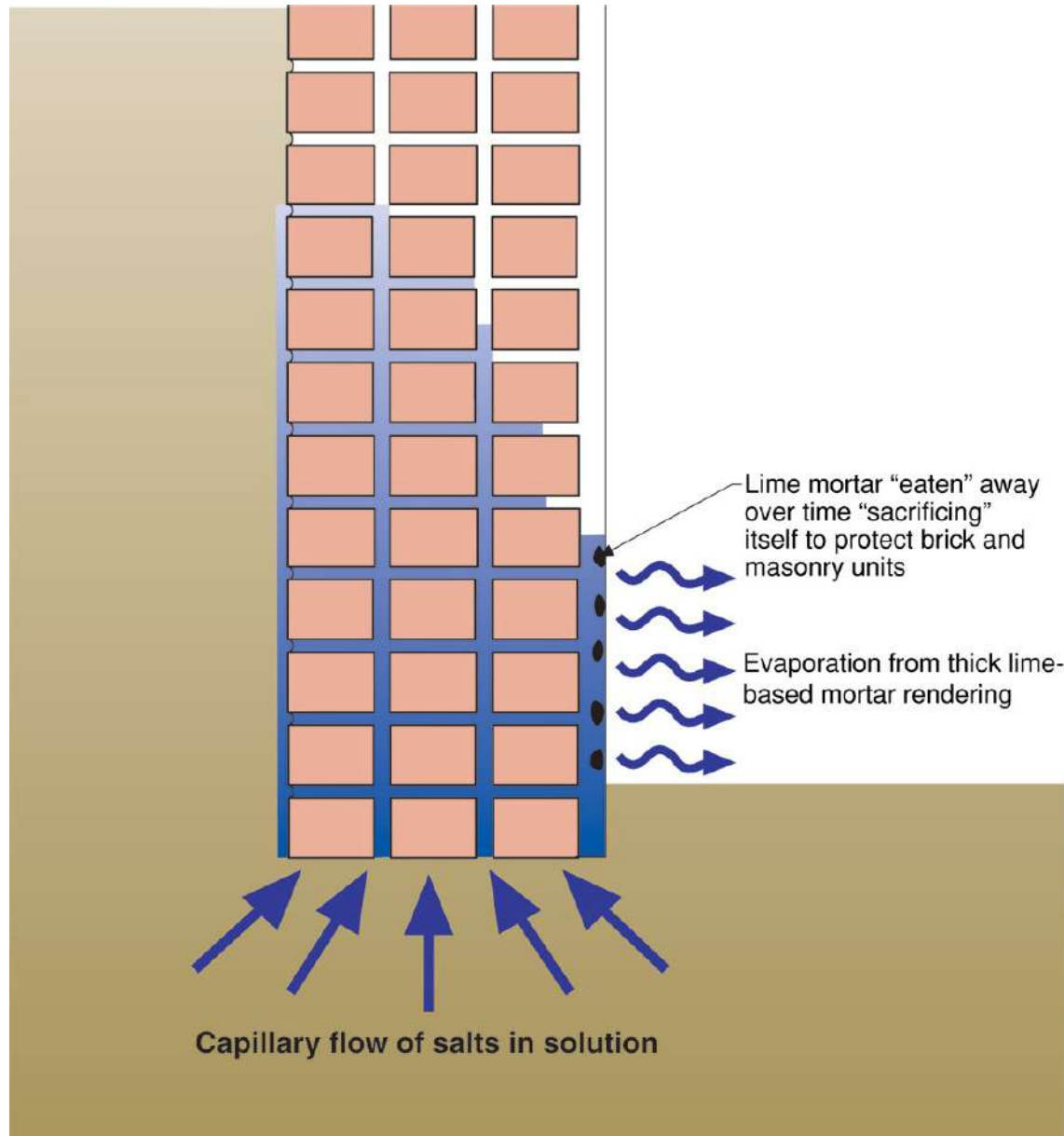
Diffusion + Capillarity + Osmosis = Problem

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













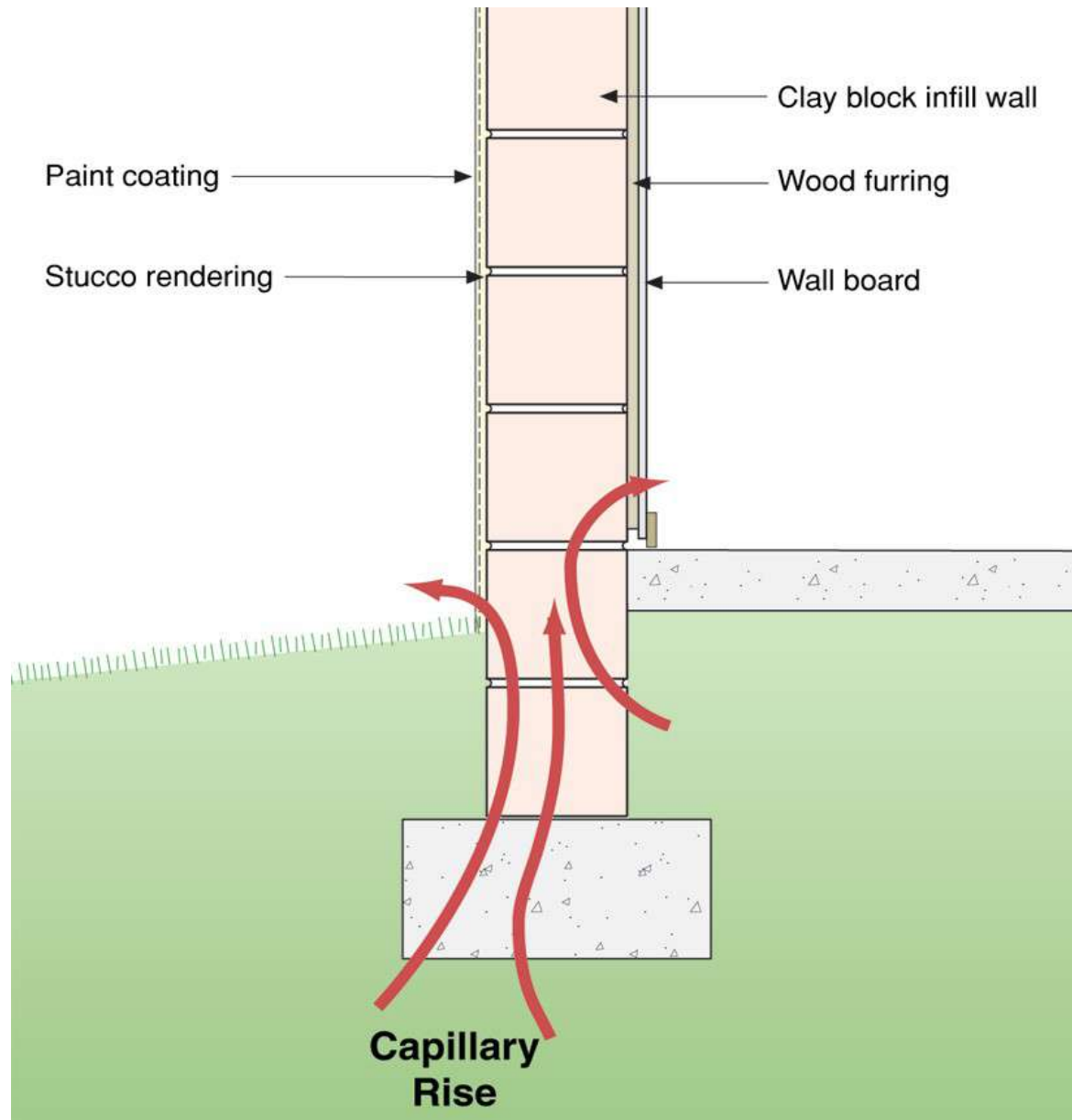


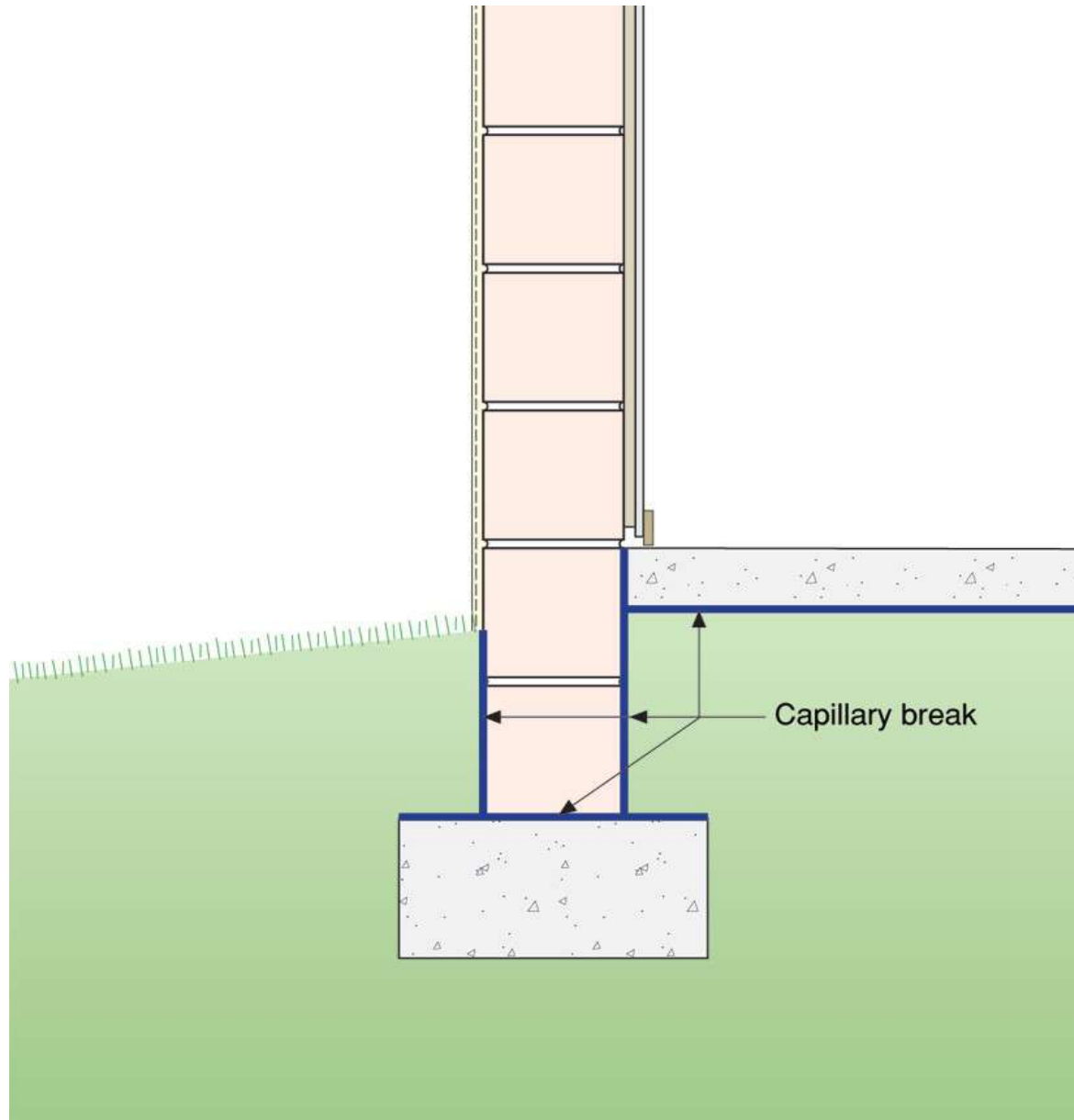




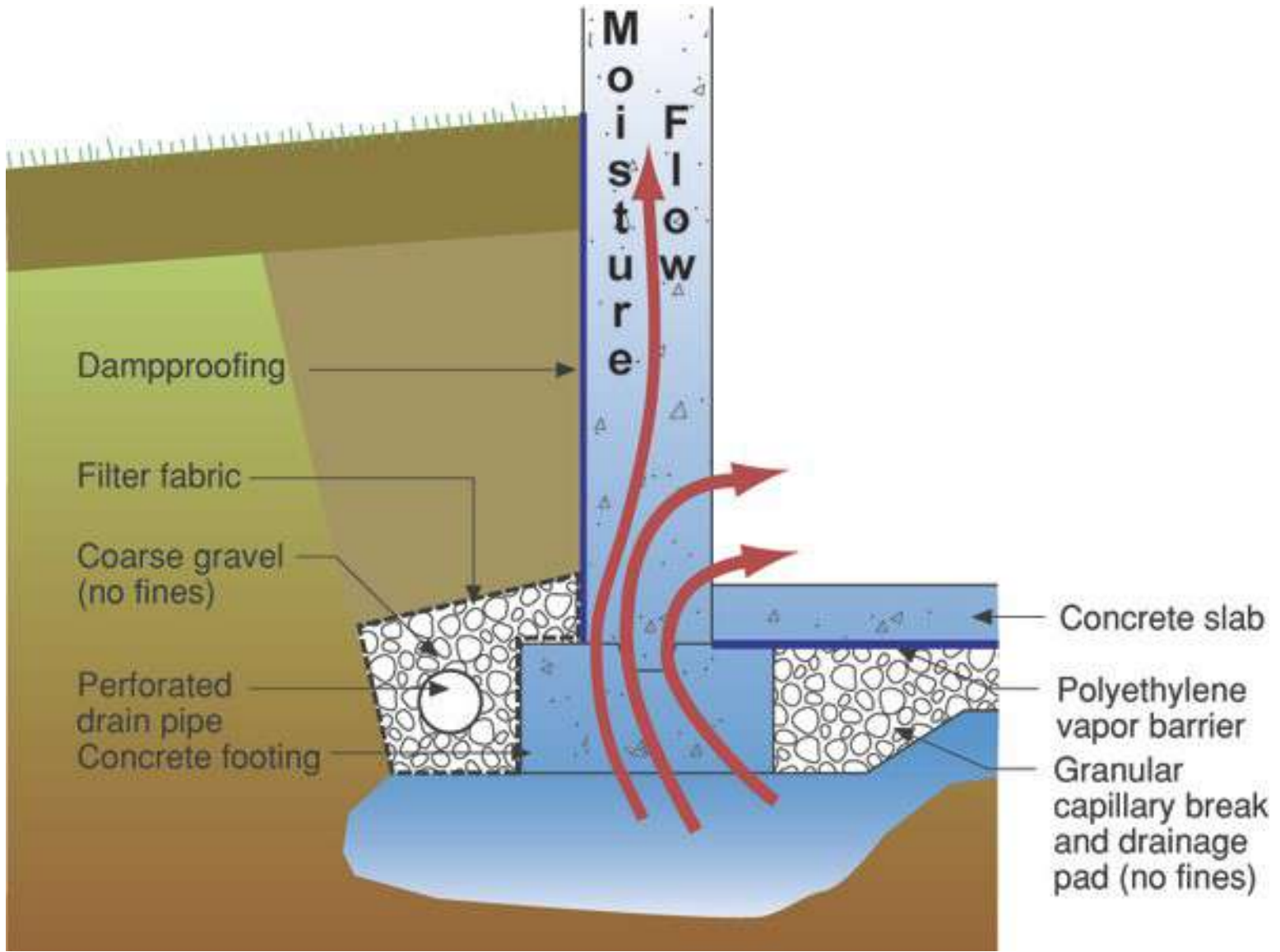


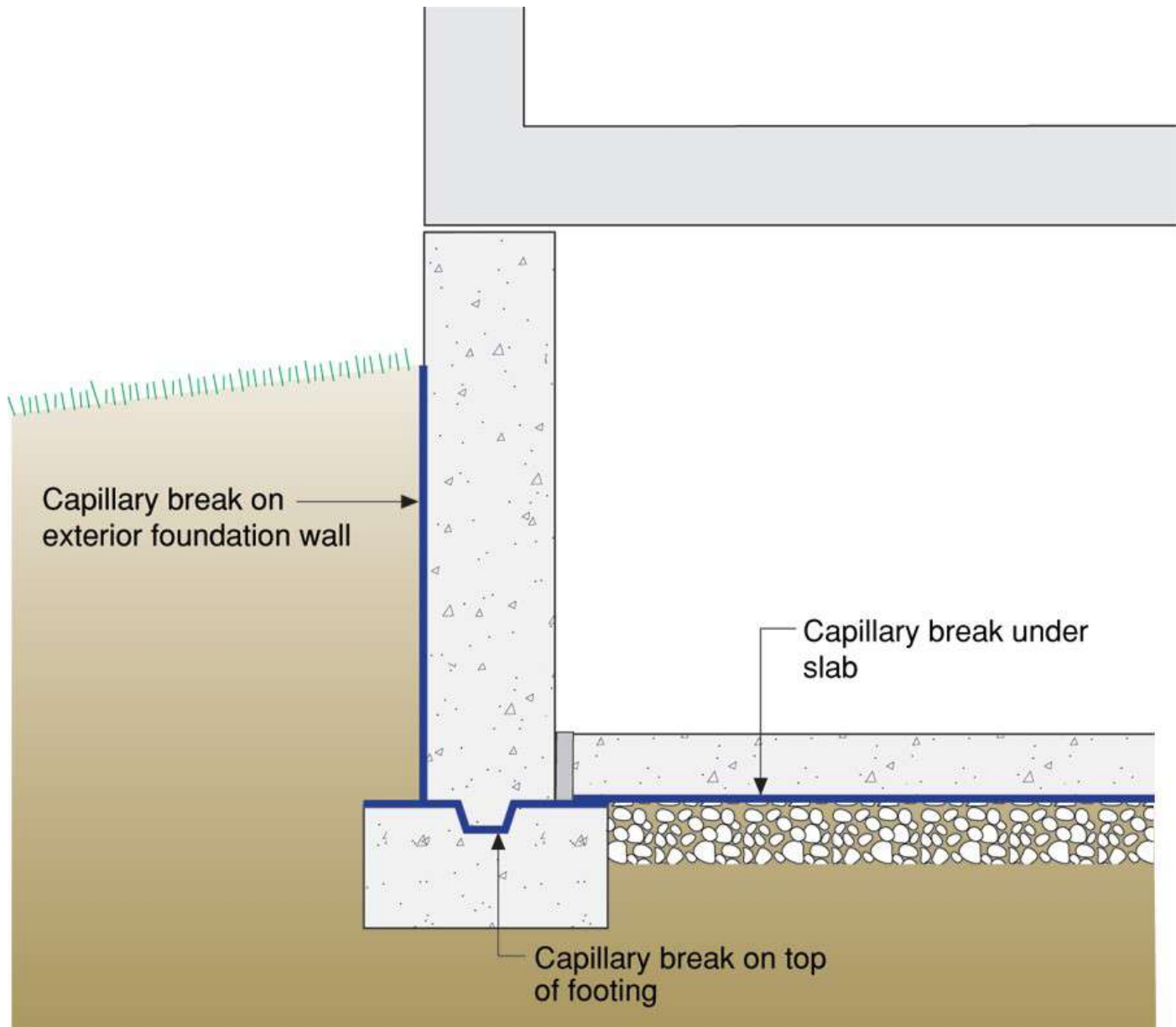












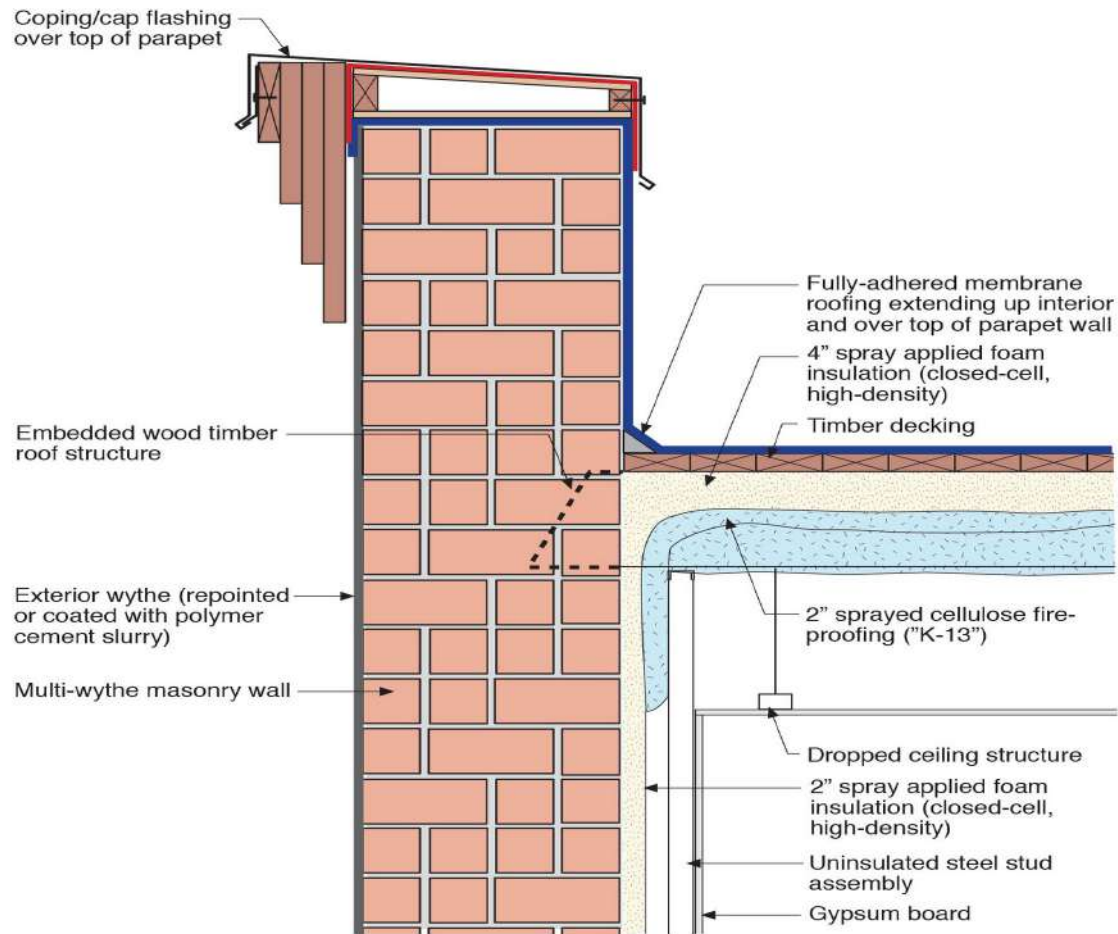






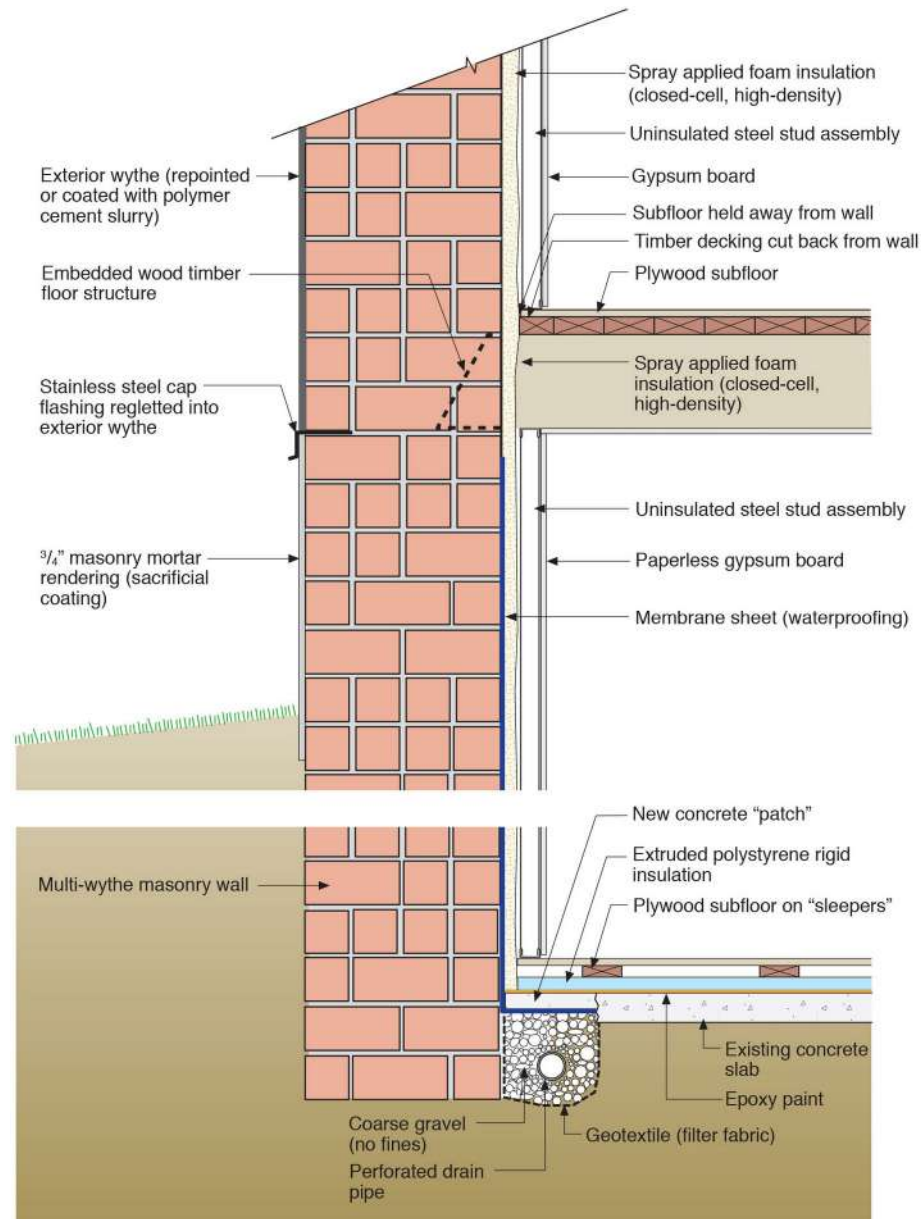


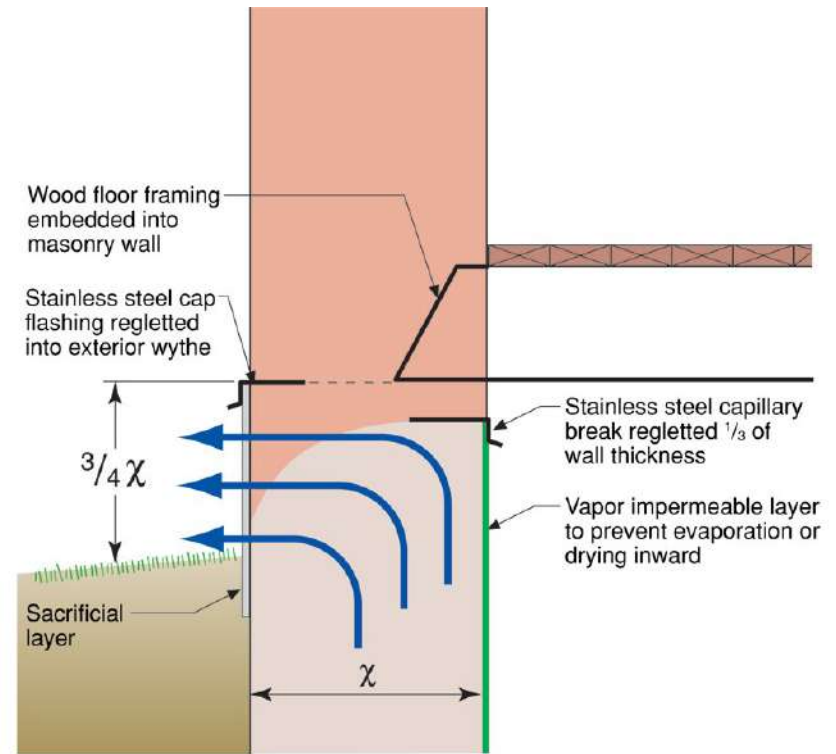
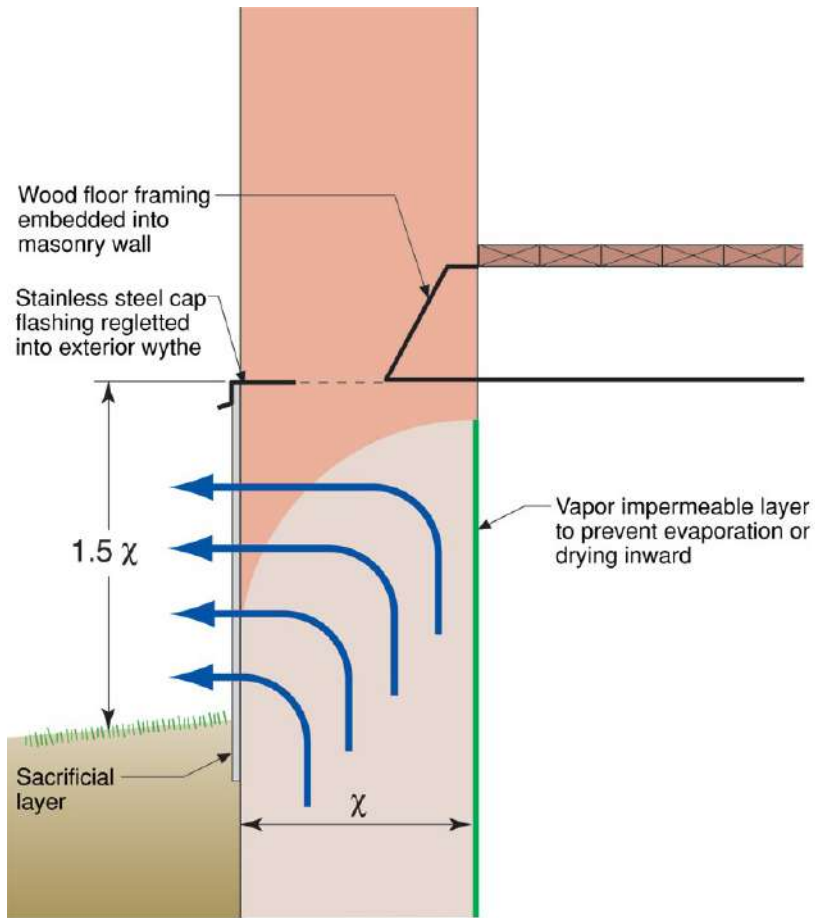


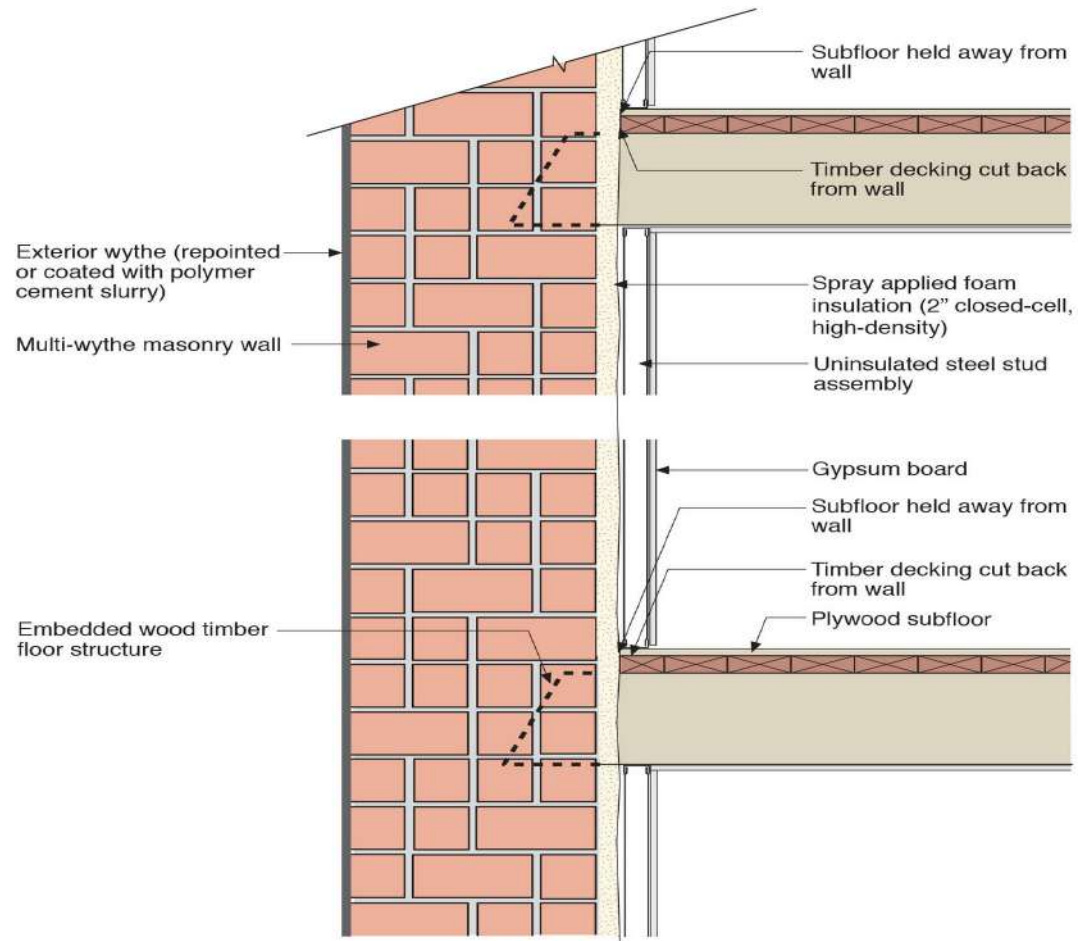


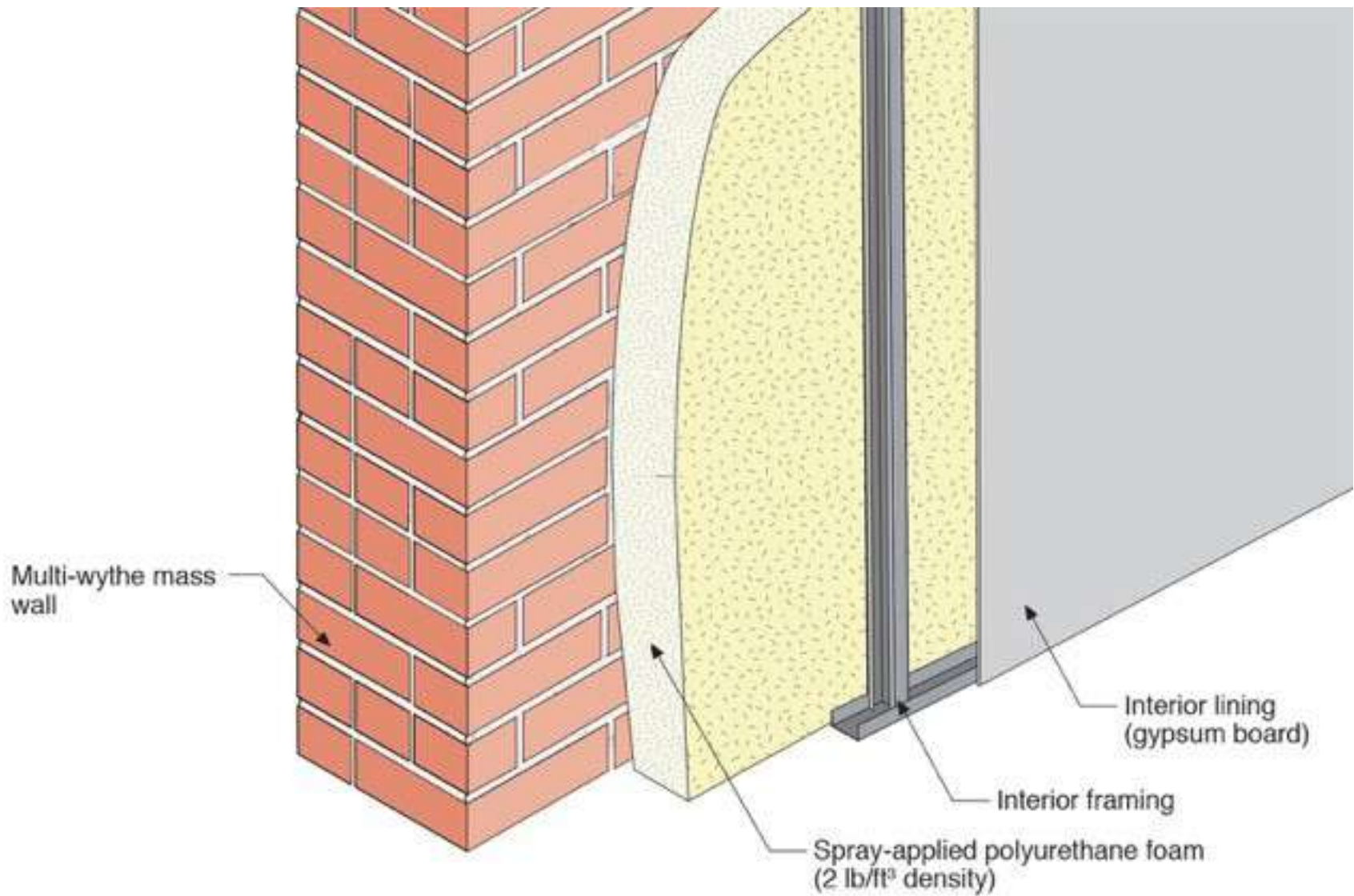


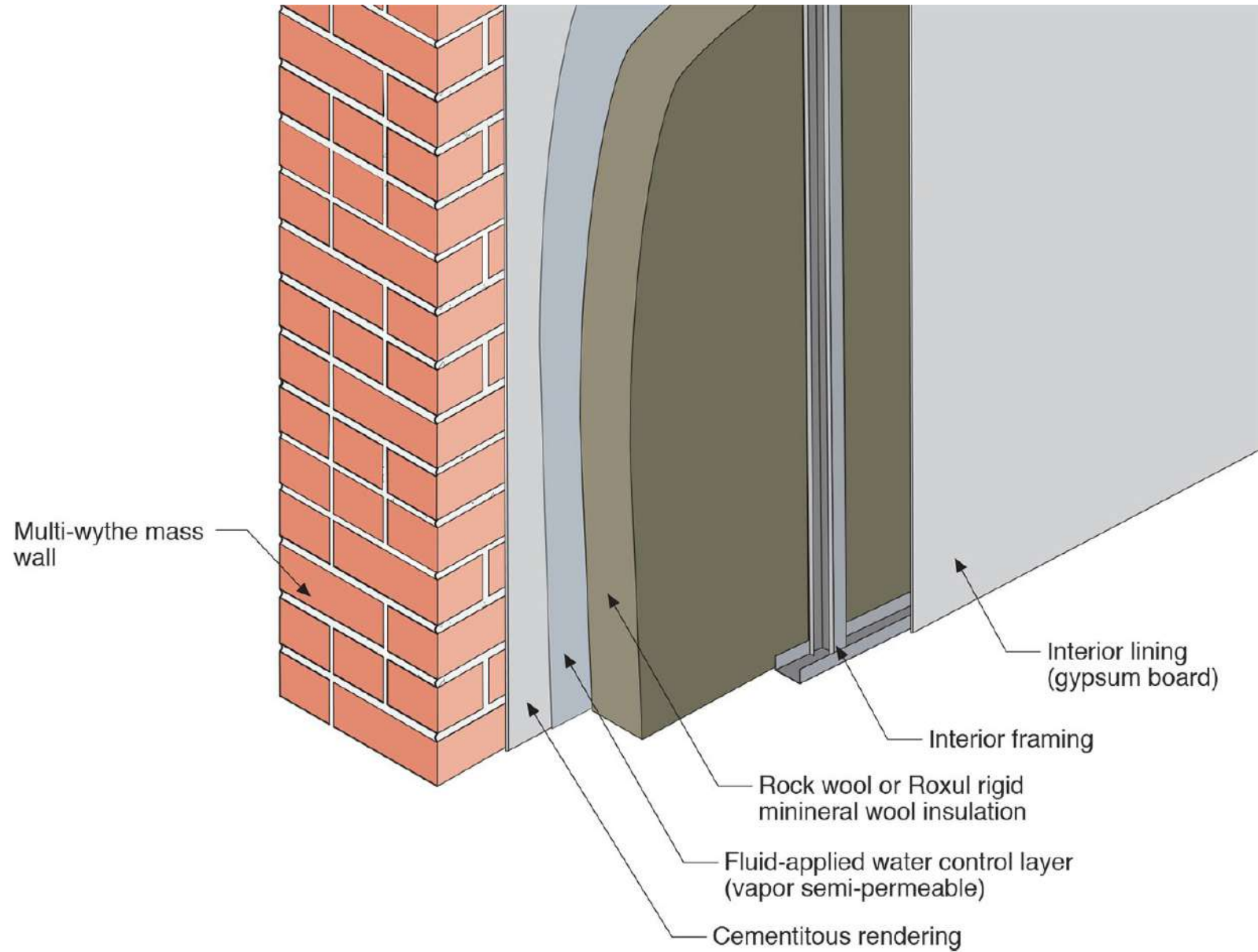


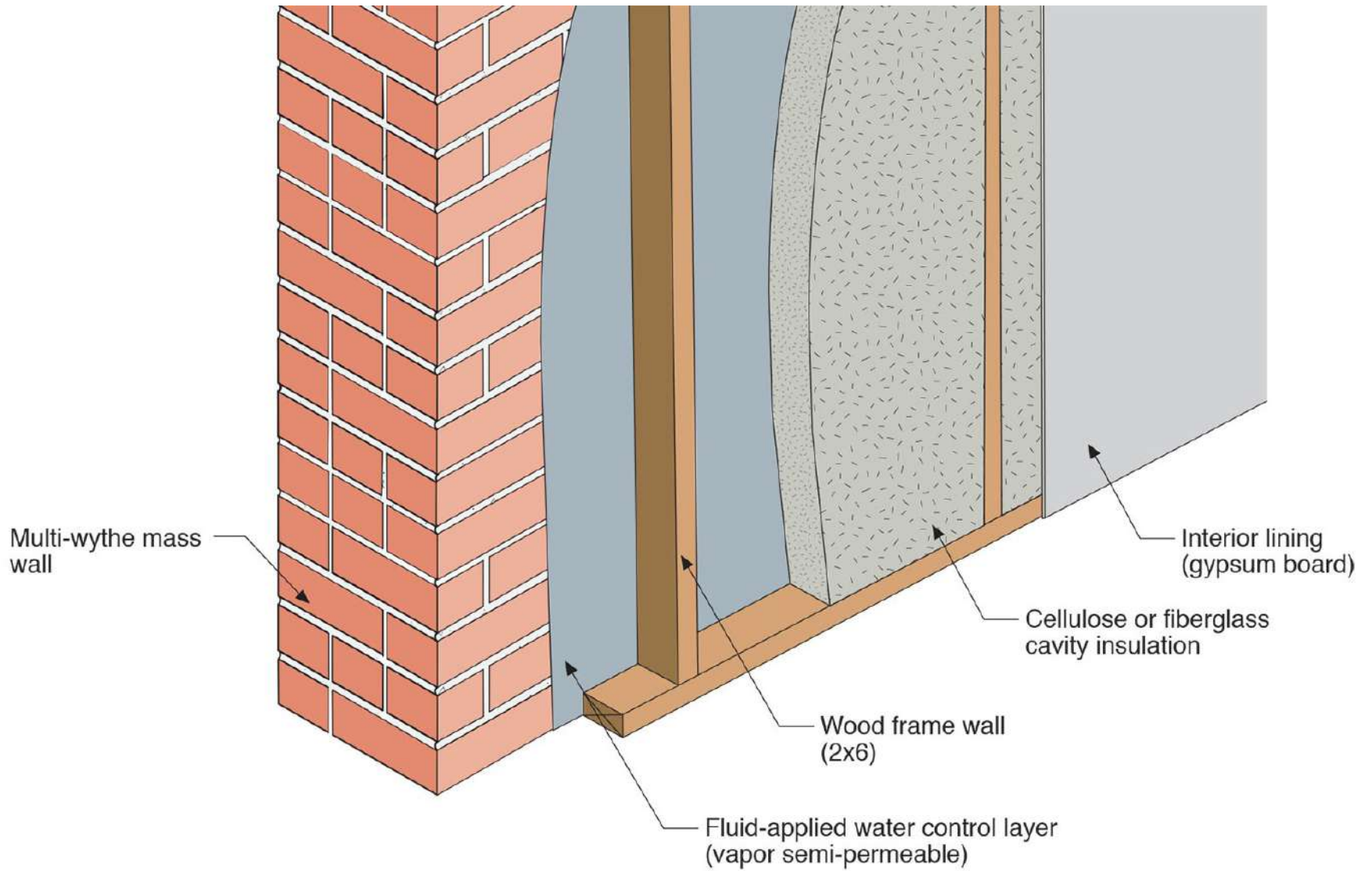


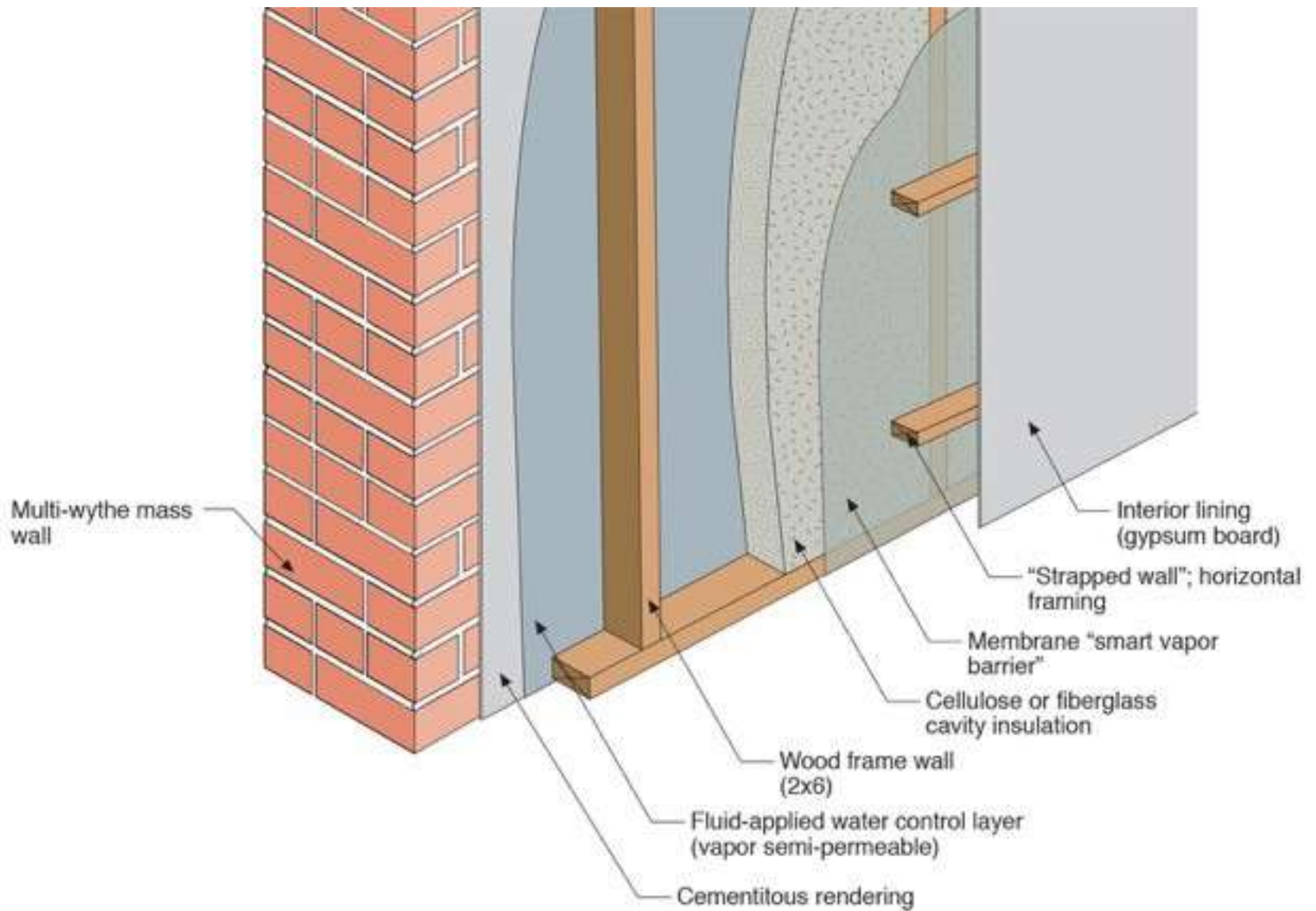


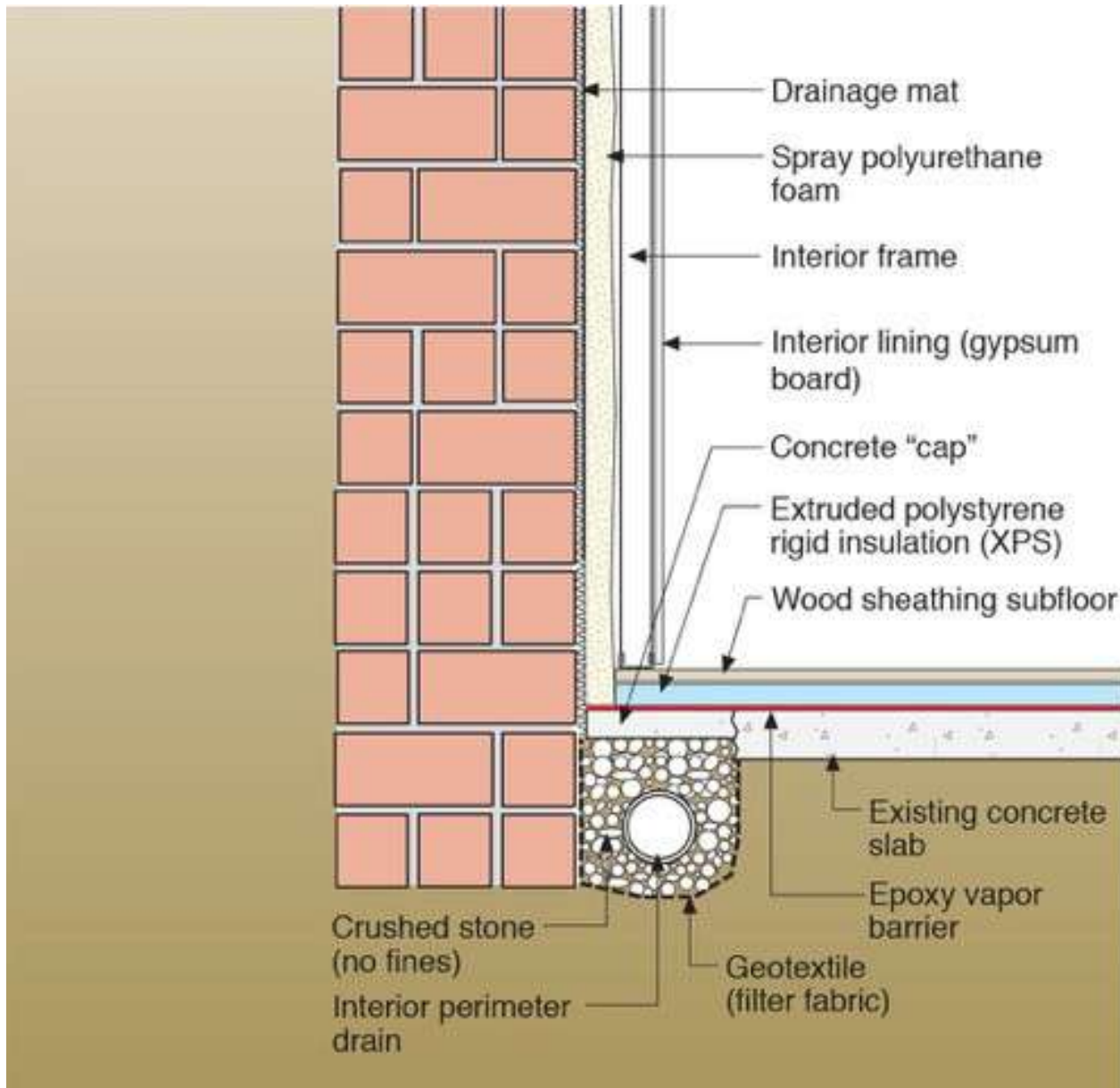


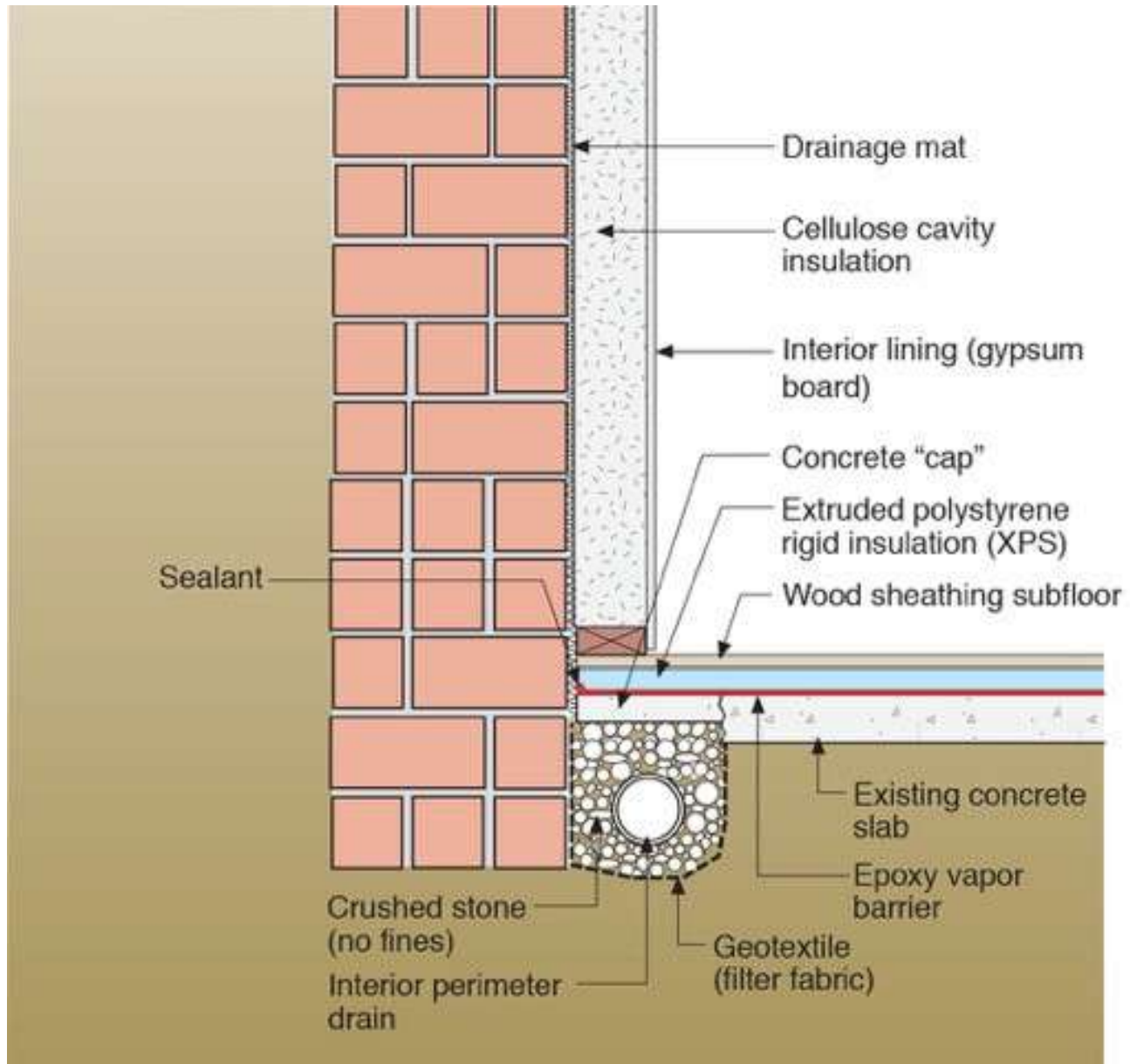


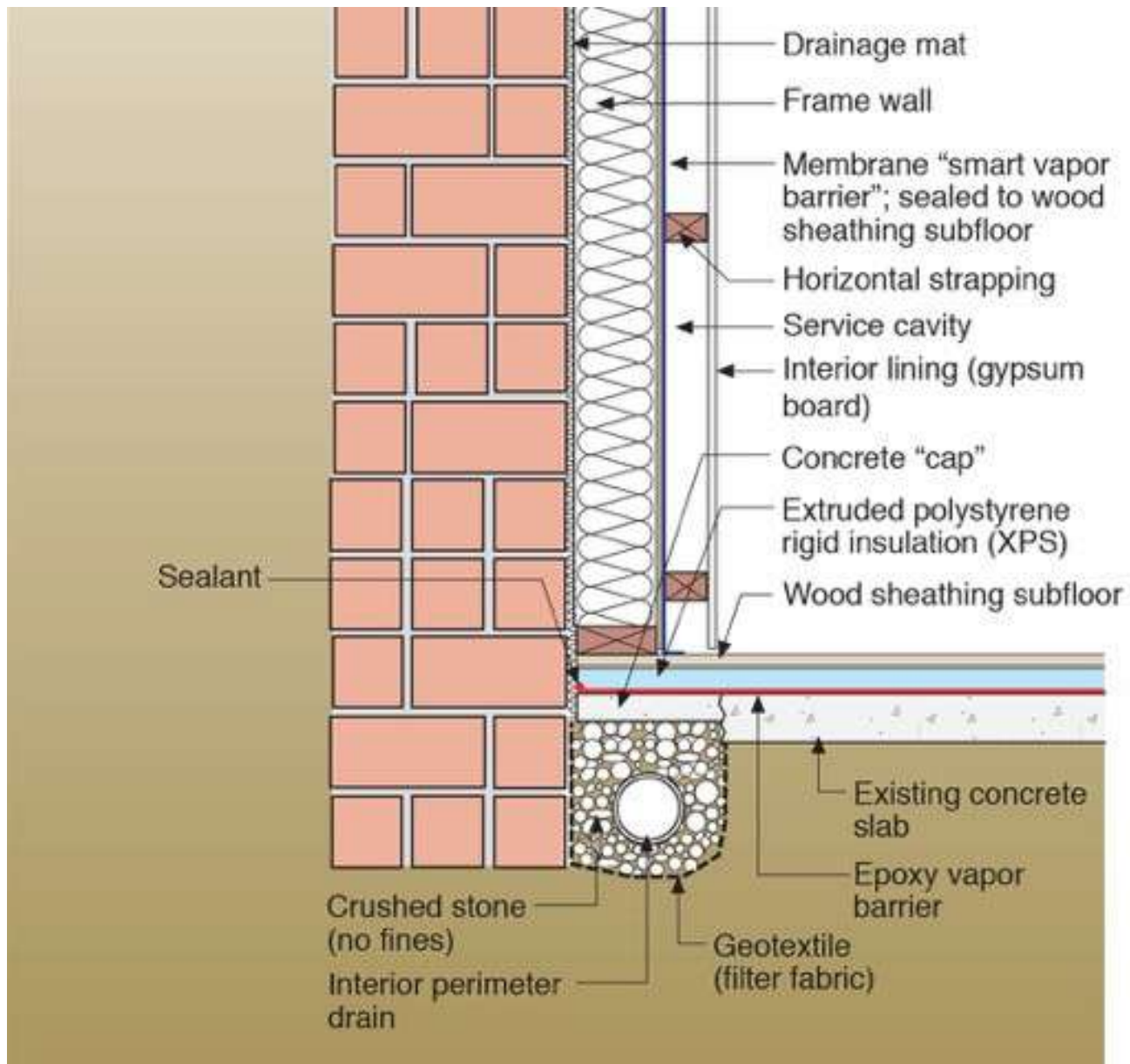




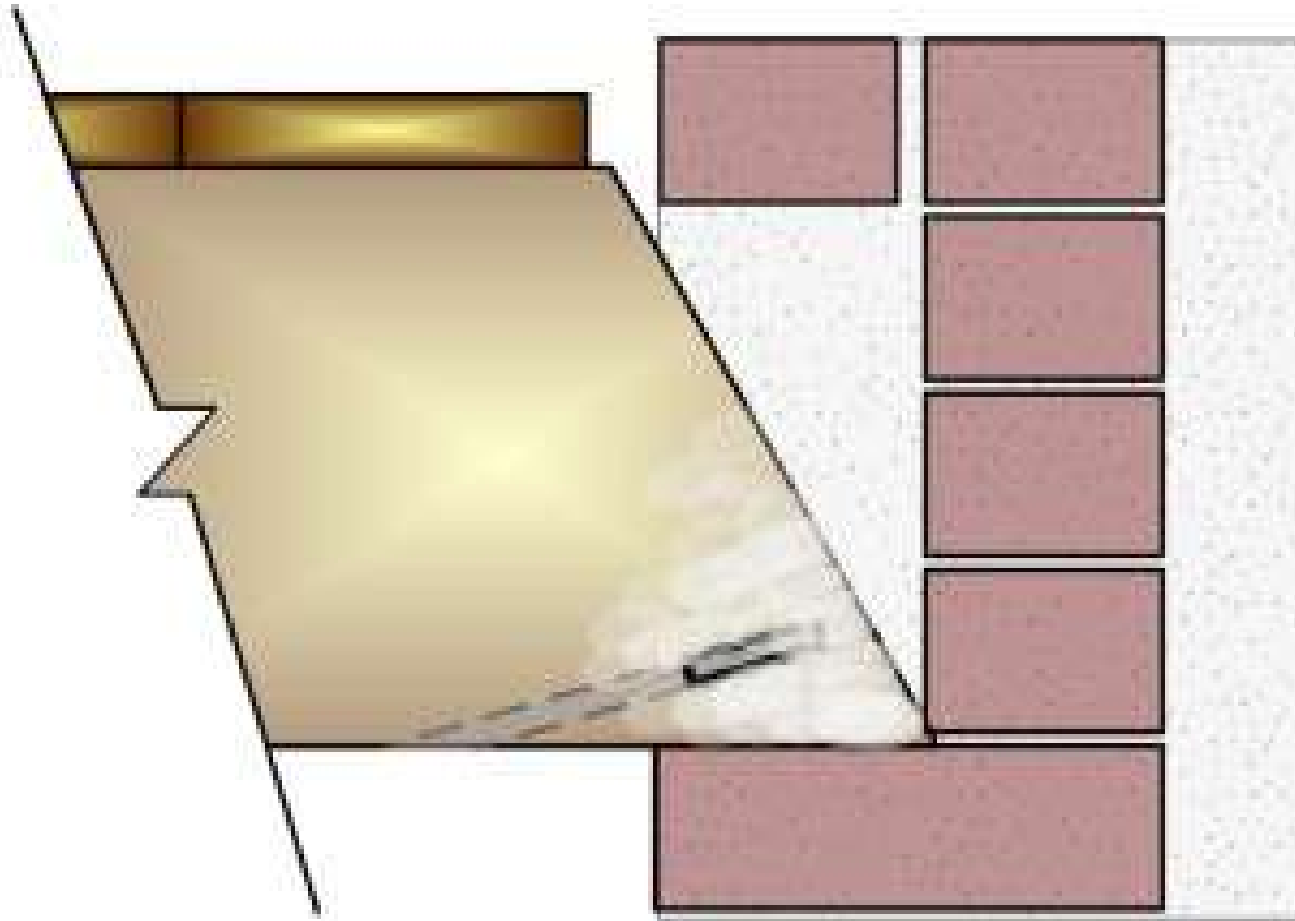






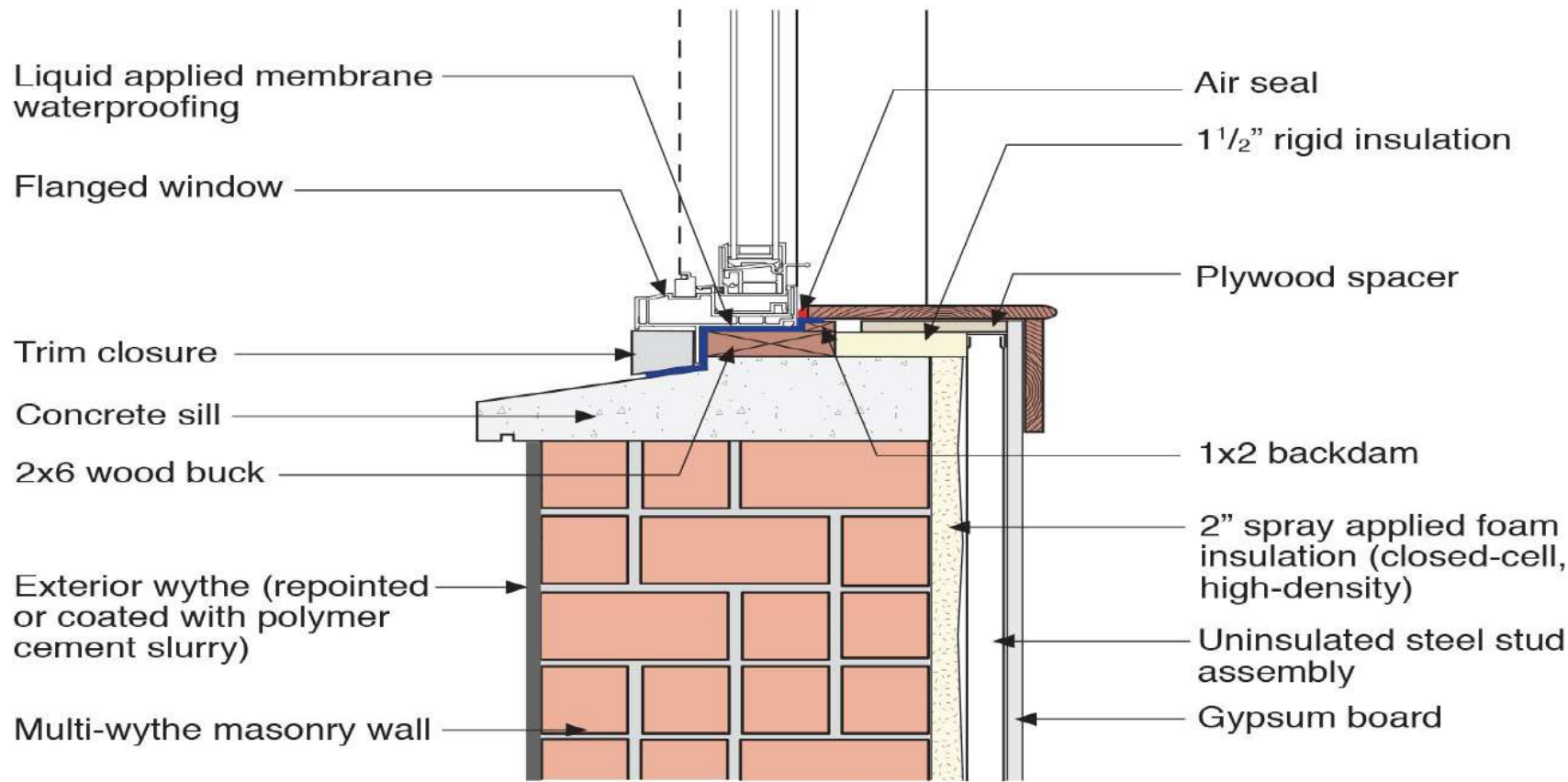




































Stucco

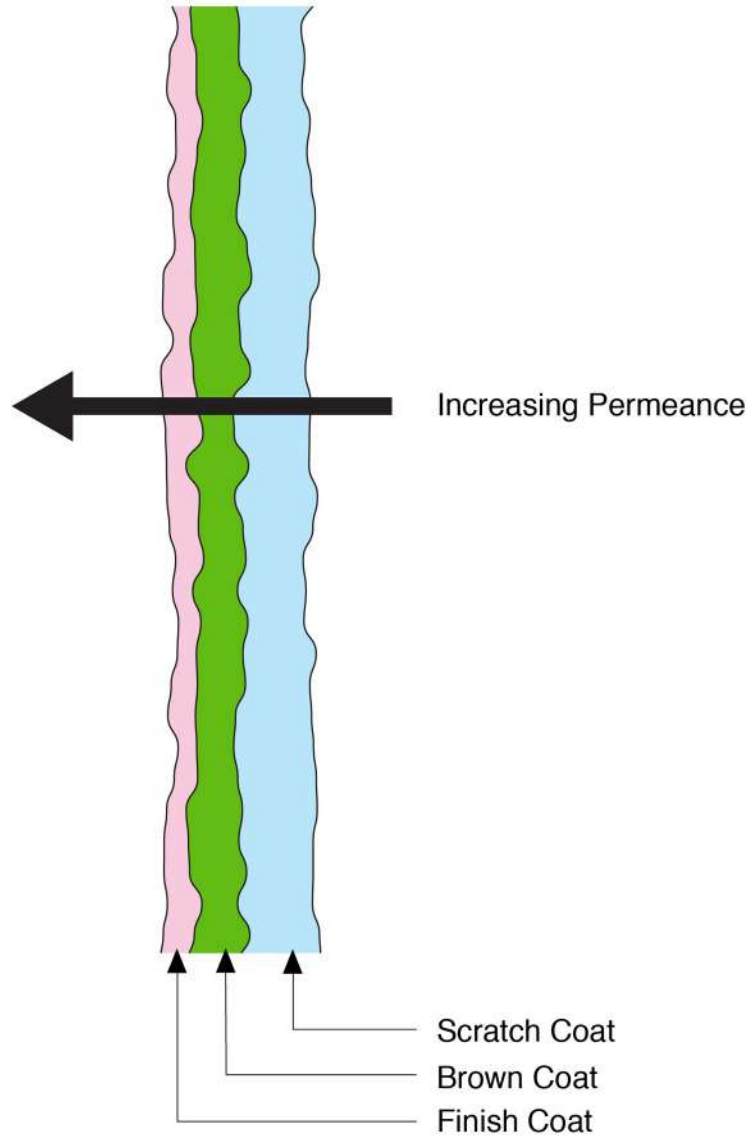




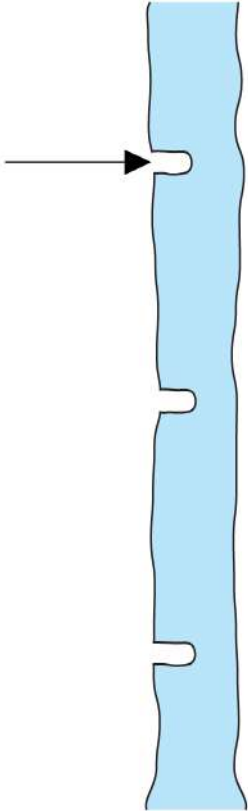




Traditional Lime Stucco	Greater than 20 perms
Lime/Portland Cement Stucco	5 to 10 perms
Portland Cement Stucco	1 to 5 perms
Polymer Modification	Less than 1



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



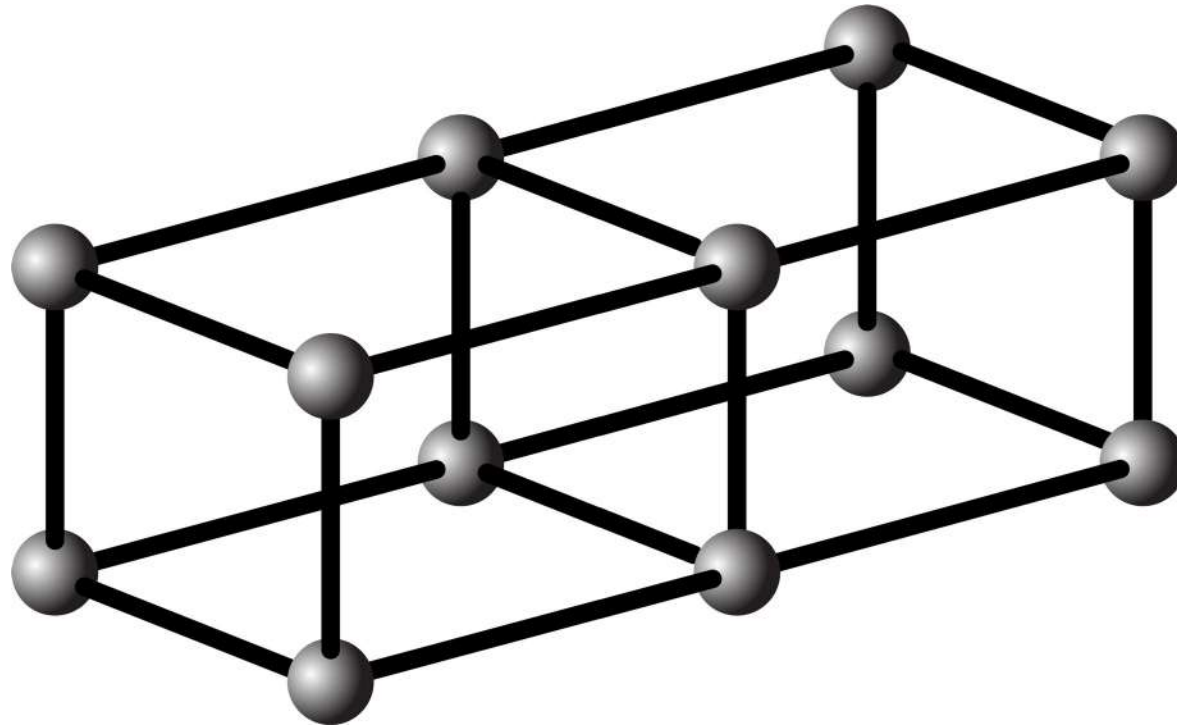




Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

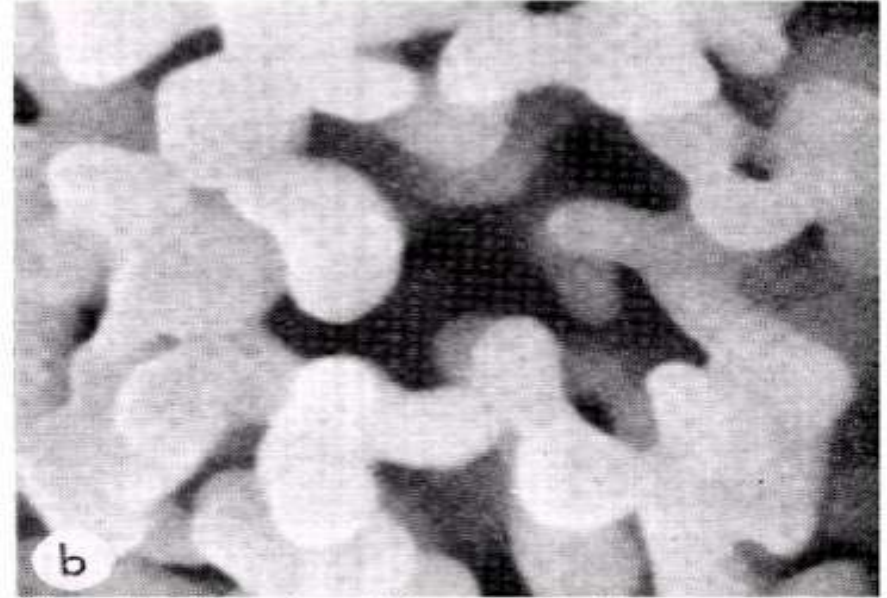
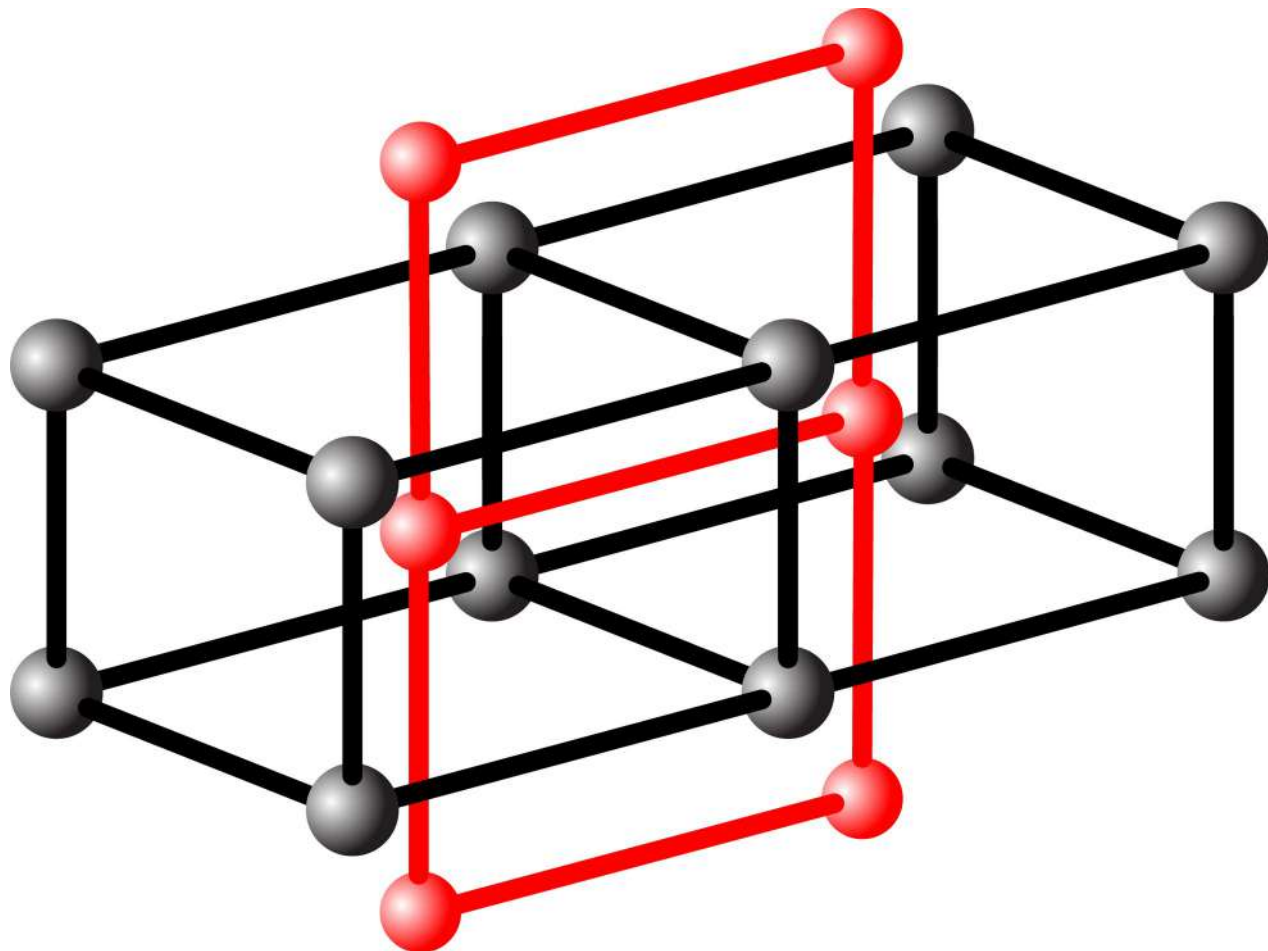


Figure 1b. Brick, sintered clay, porosity 40 per cent.



Ancient Modification Additives

Cow Dung

Egg Whites

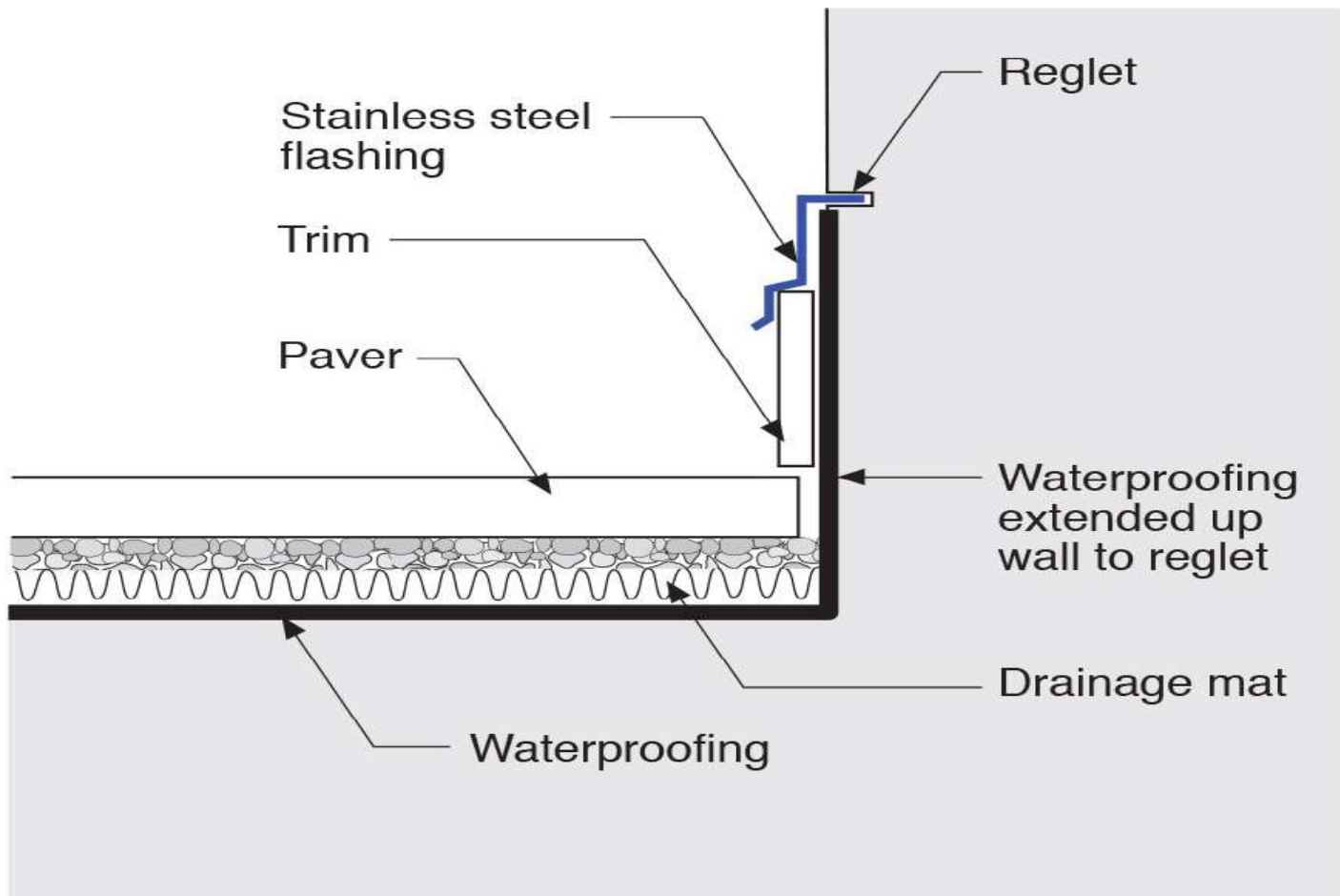
Pig Blood





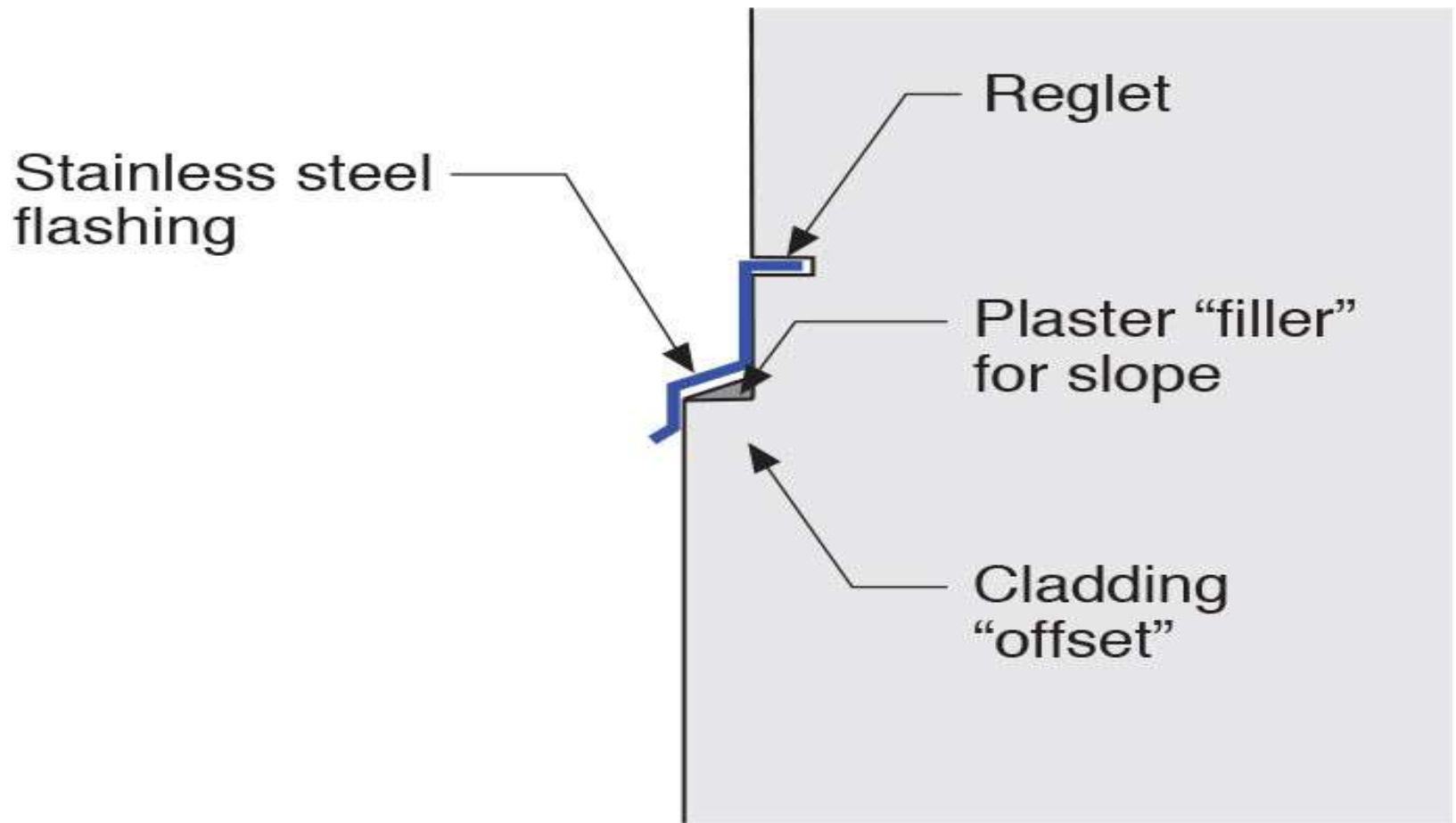




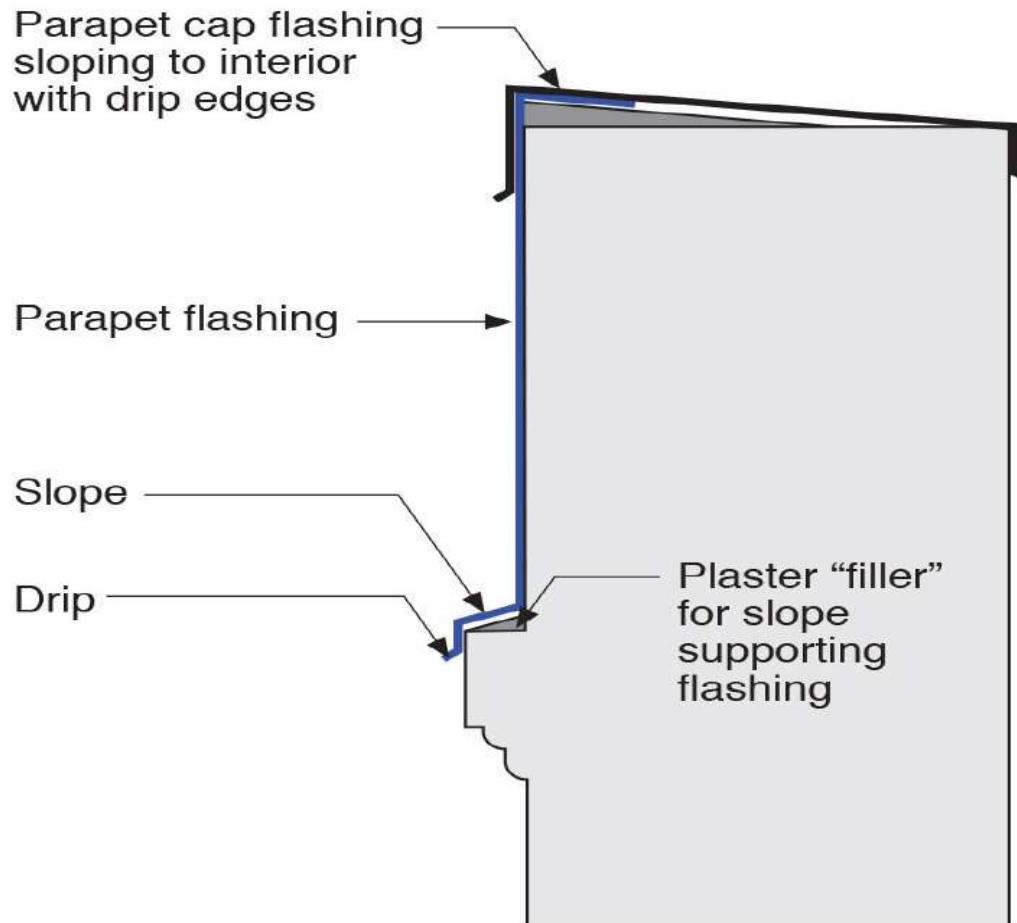


















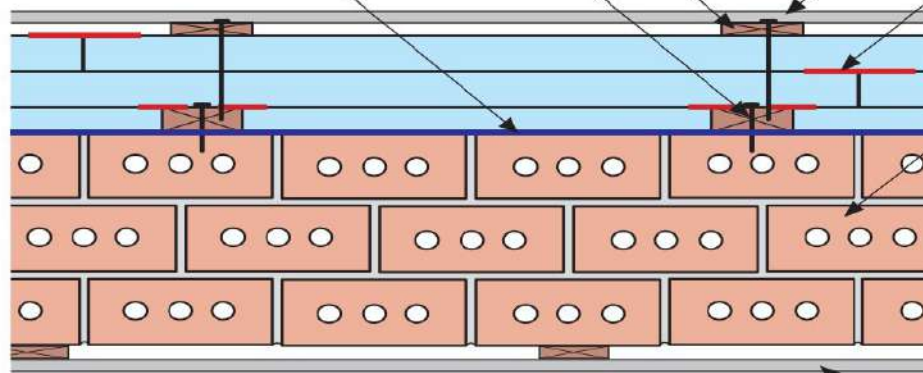




1x4 wood furring attached through rigid insulation to 2x4 wood furring

2x4 wood furring mechanically attached to masonry wall

Fluid-applied water control layer and air control layer



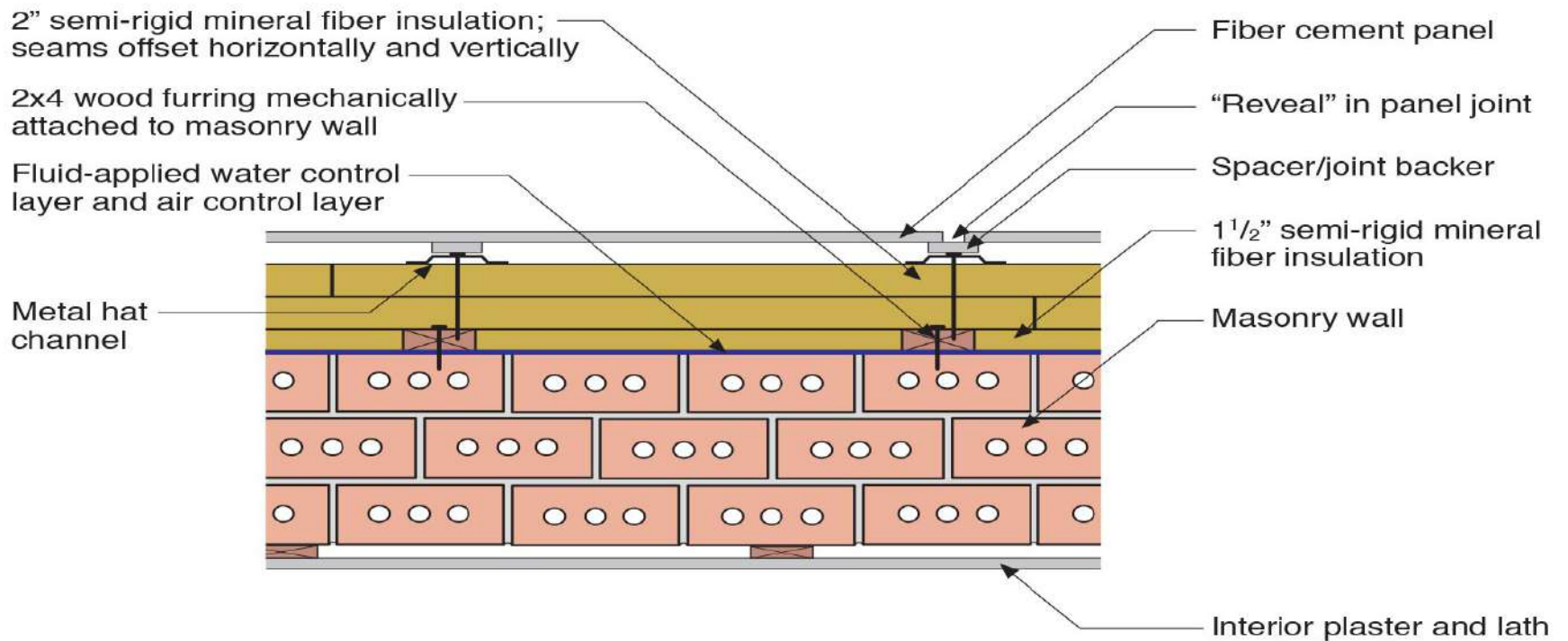
Cladding

Joints offset horizontally and vertically with each layer taped

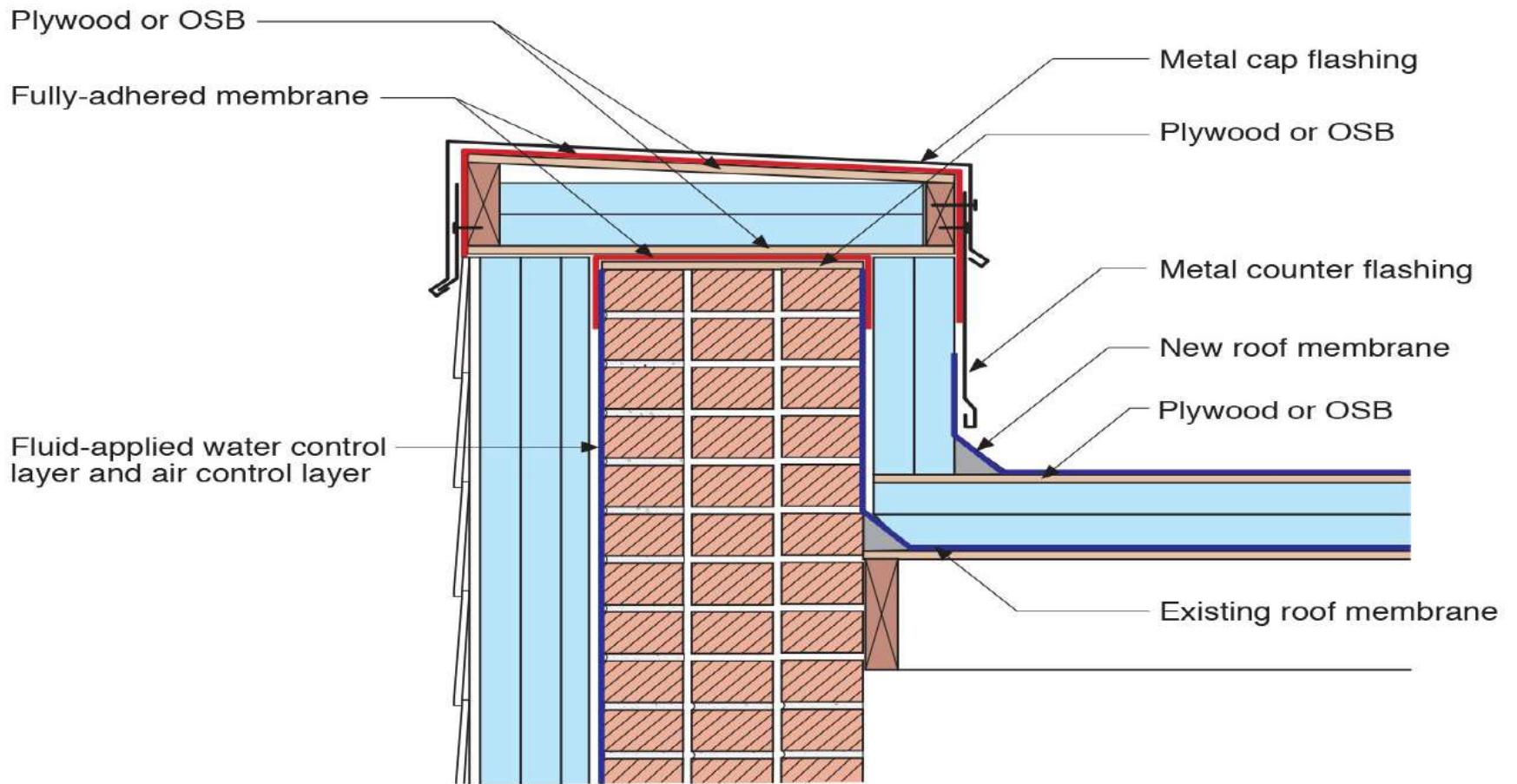
Masonry wall

Interior plaster and lath













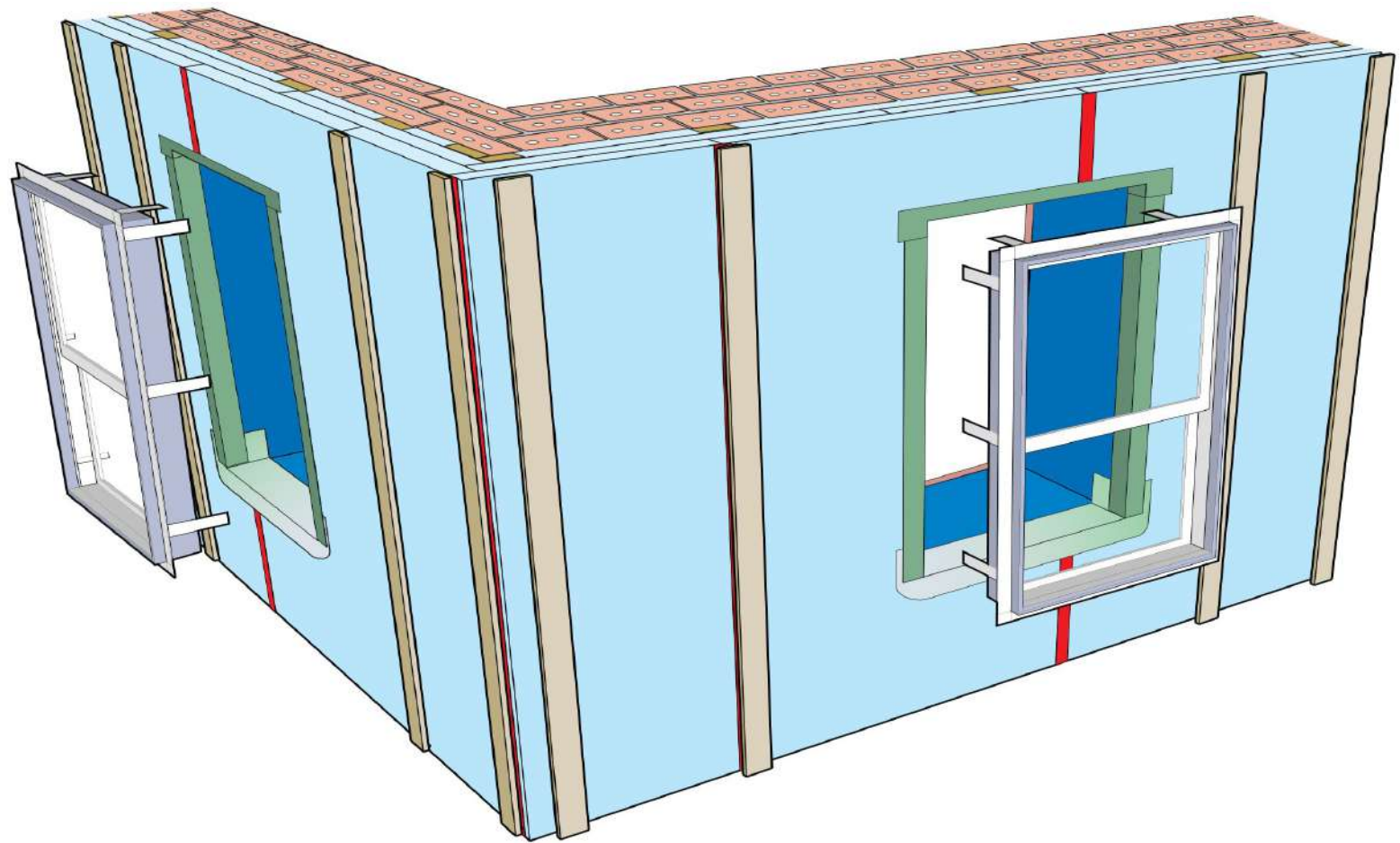






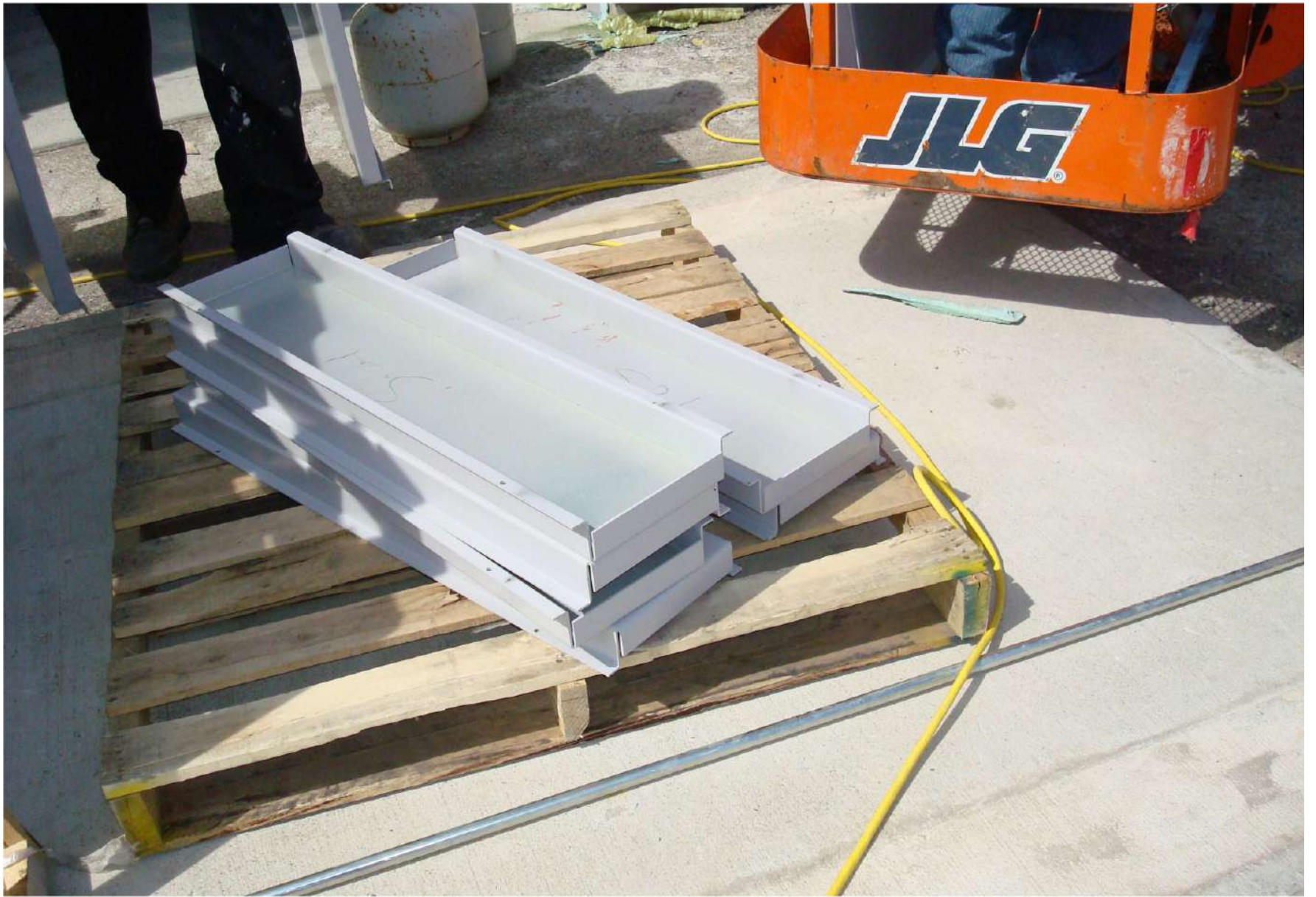






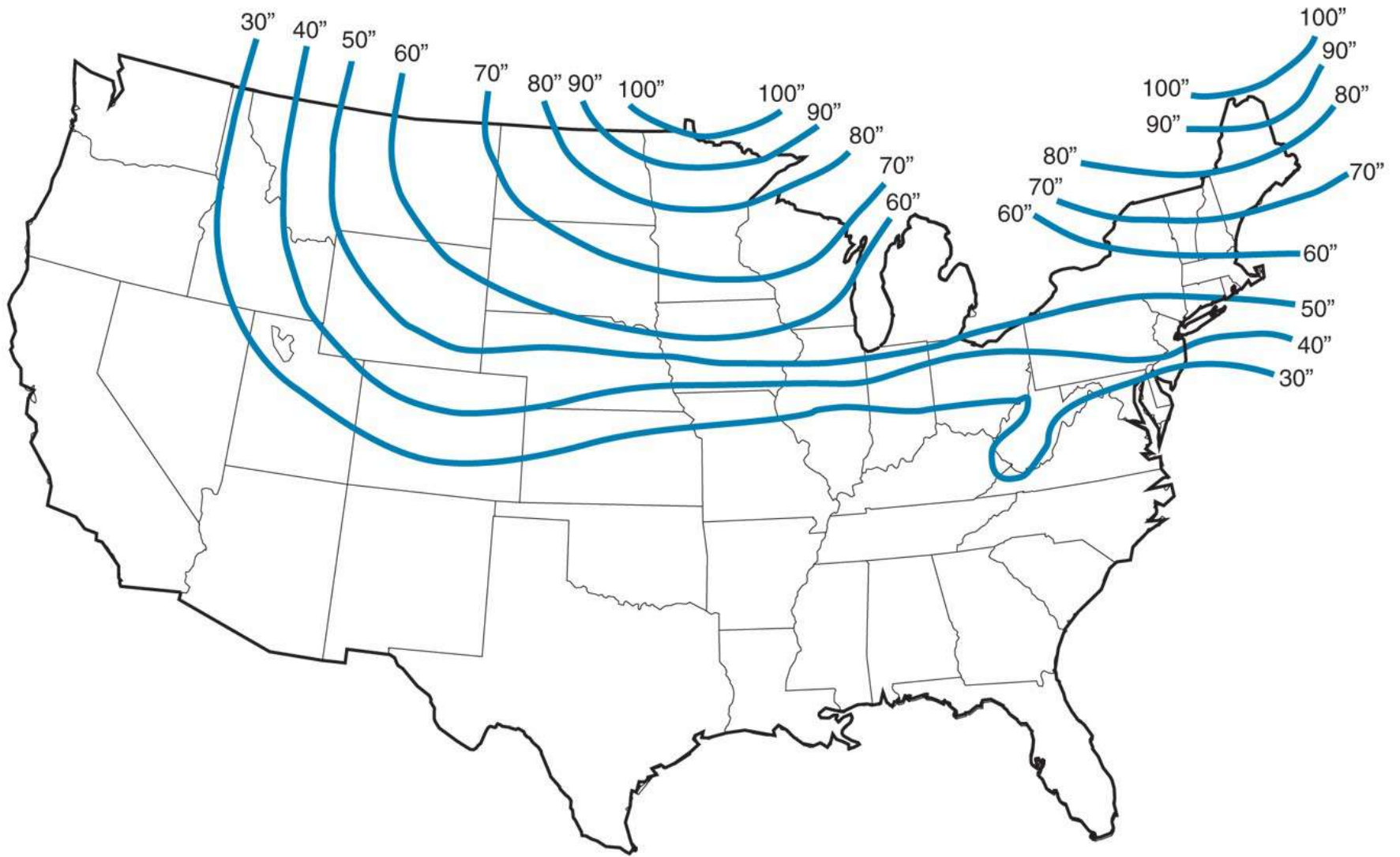




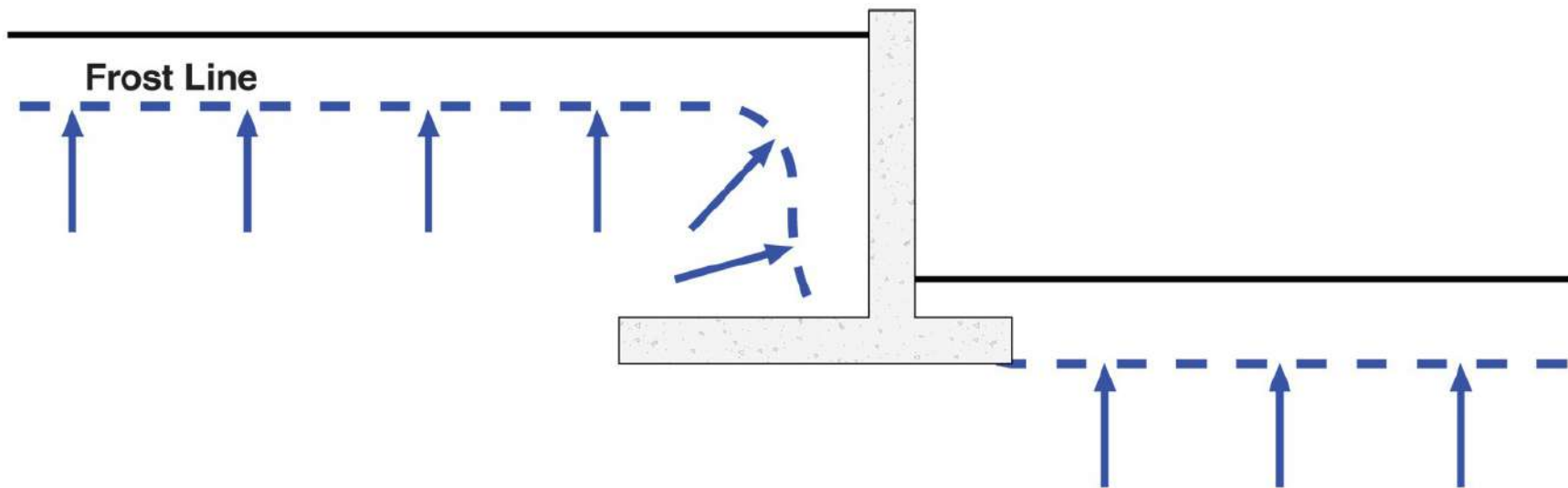


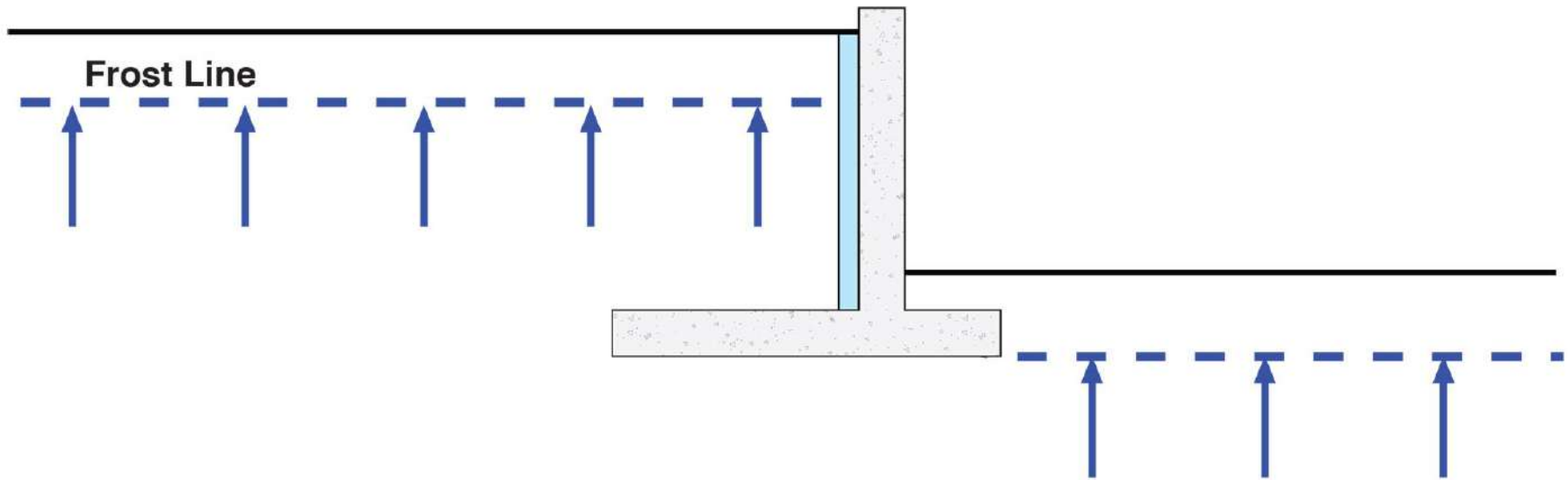




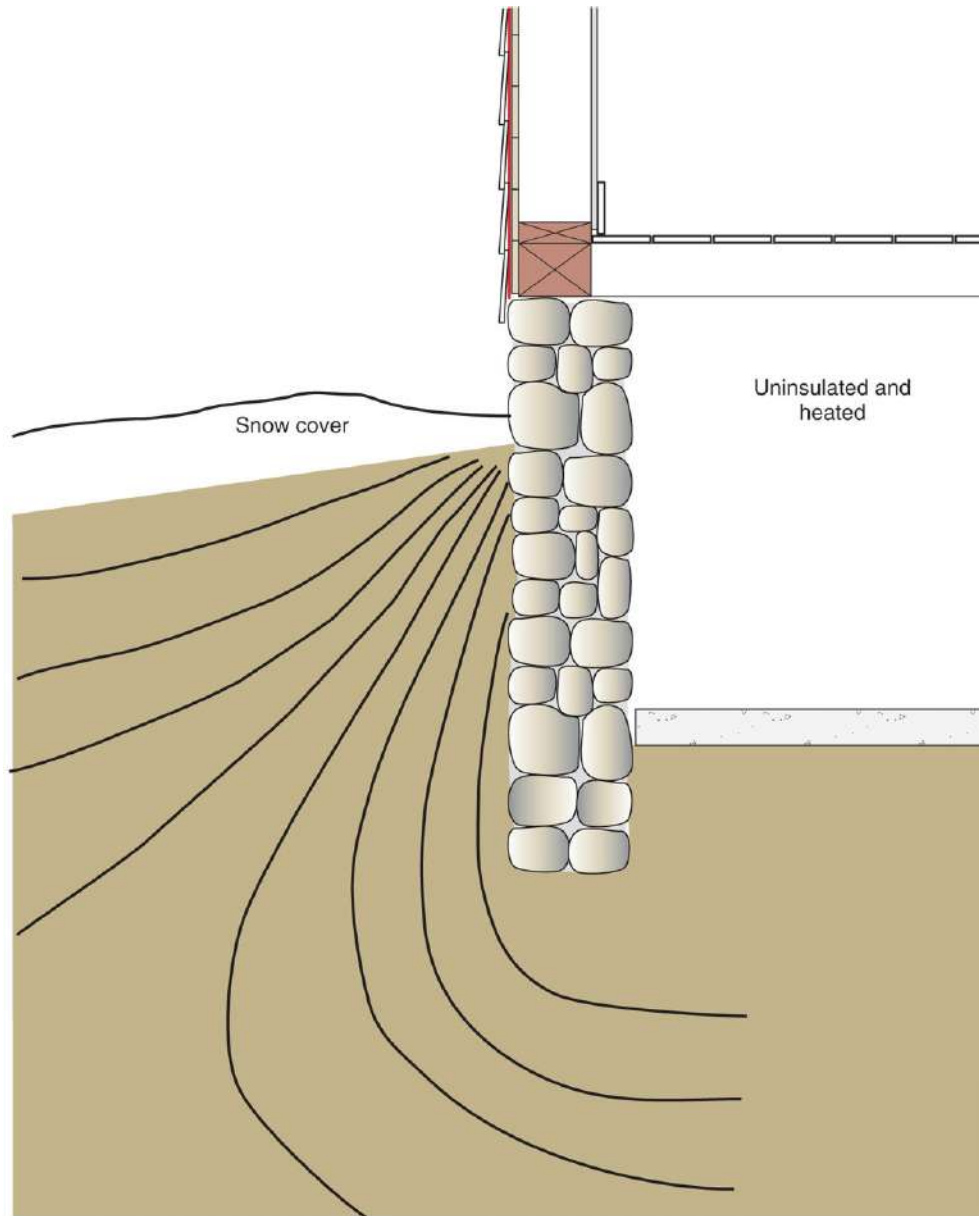


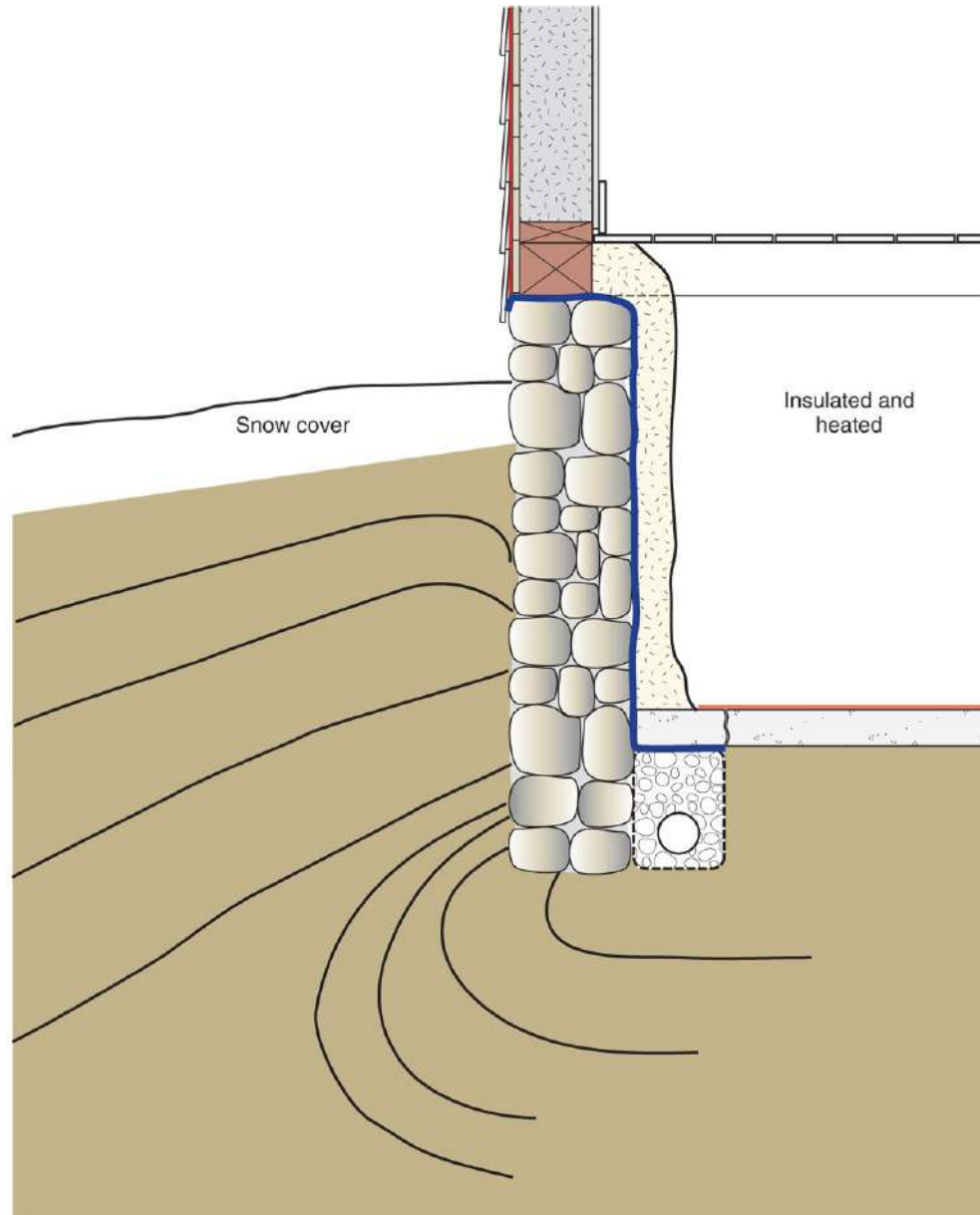
From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.

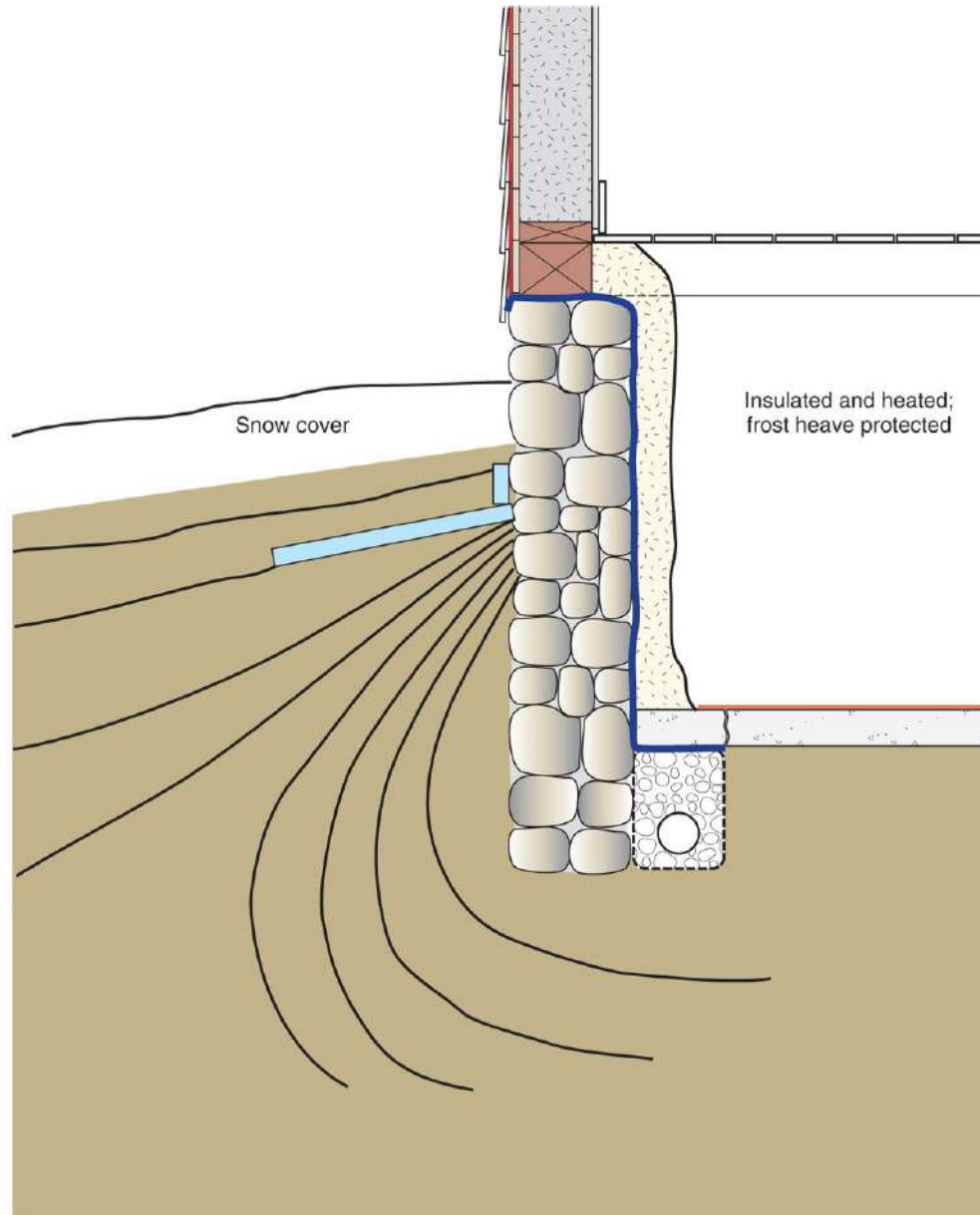


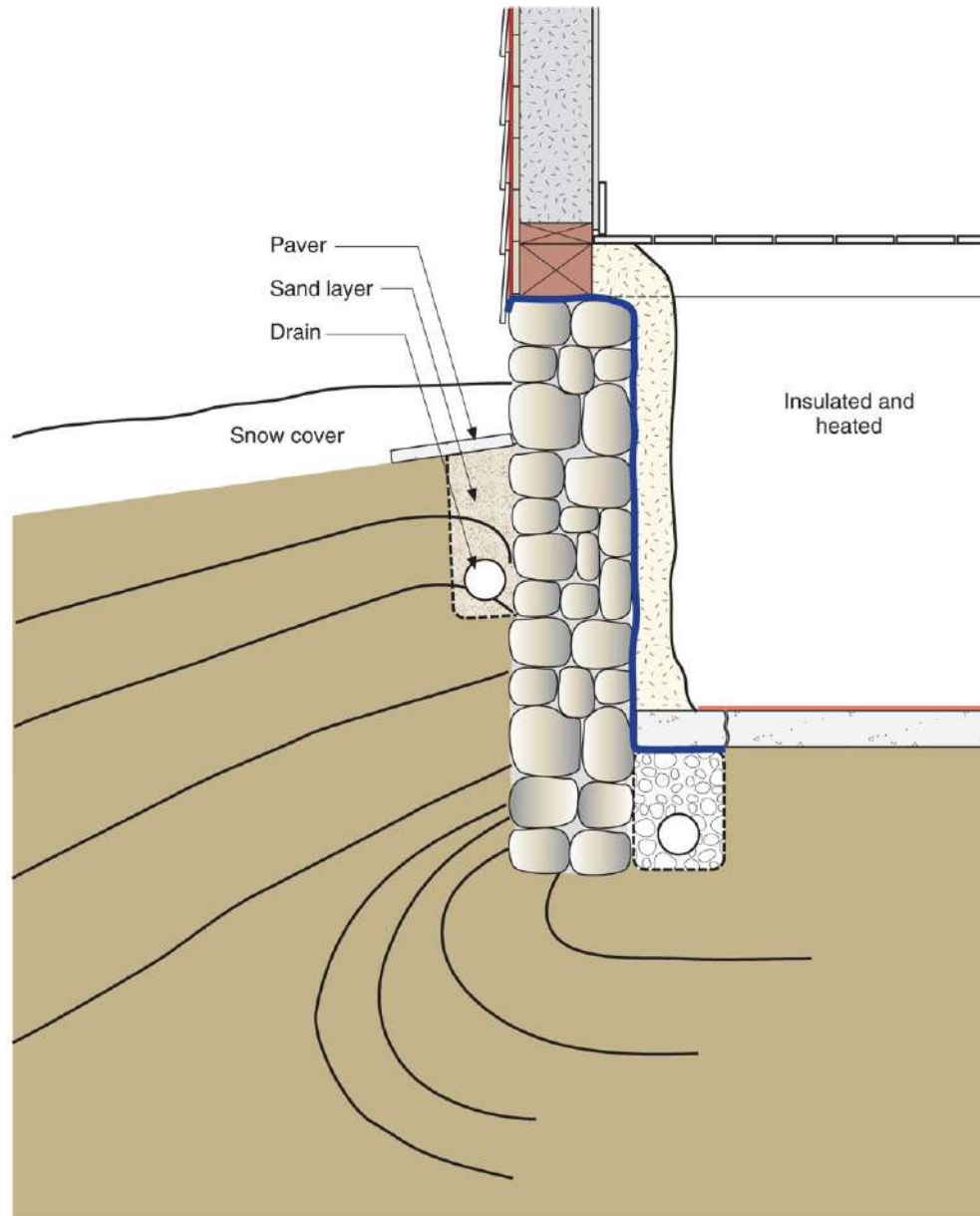


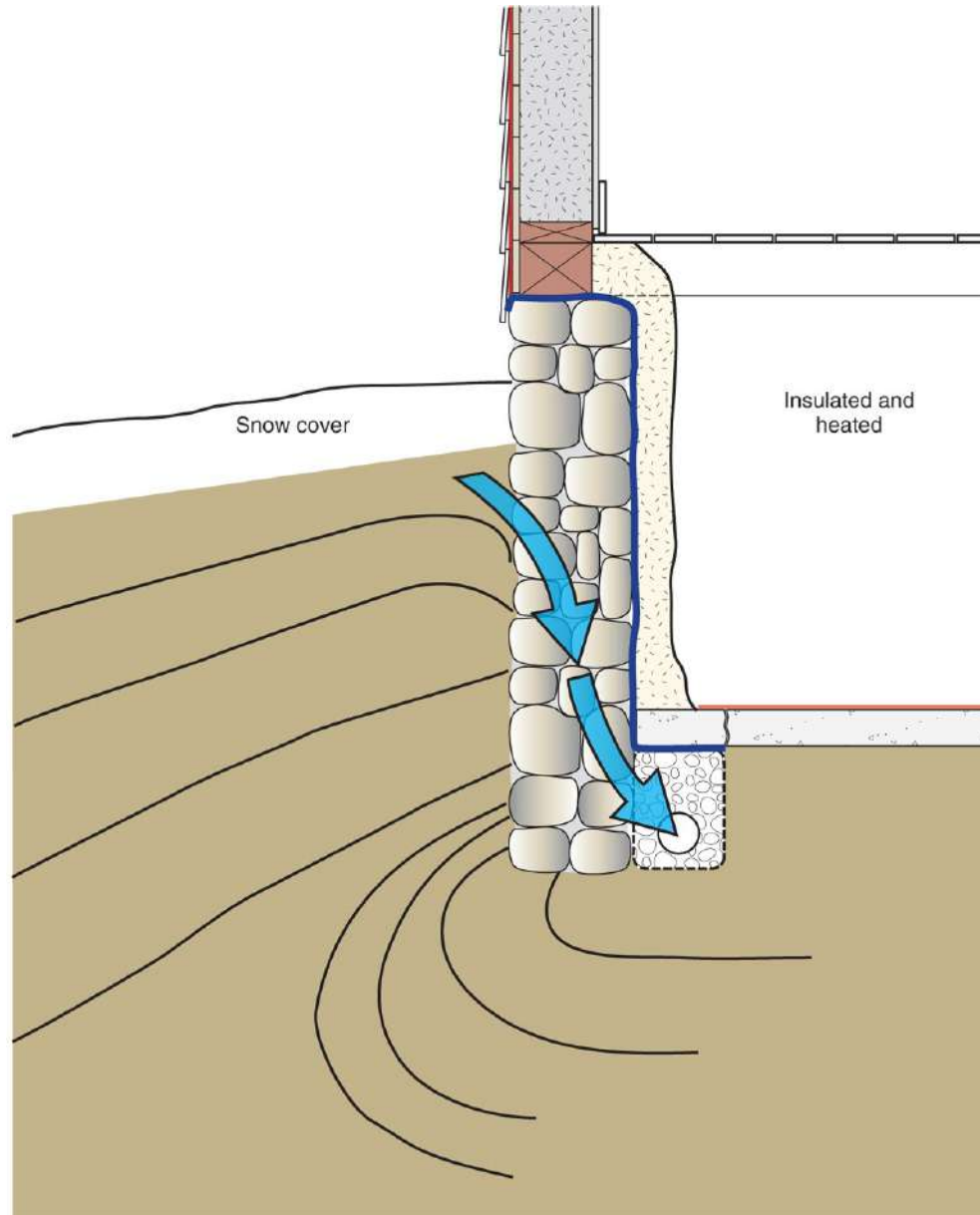












Retrofits – Frame Buildings







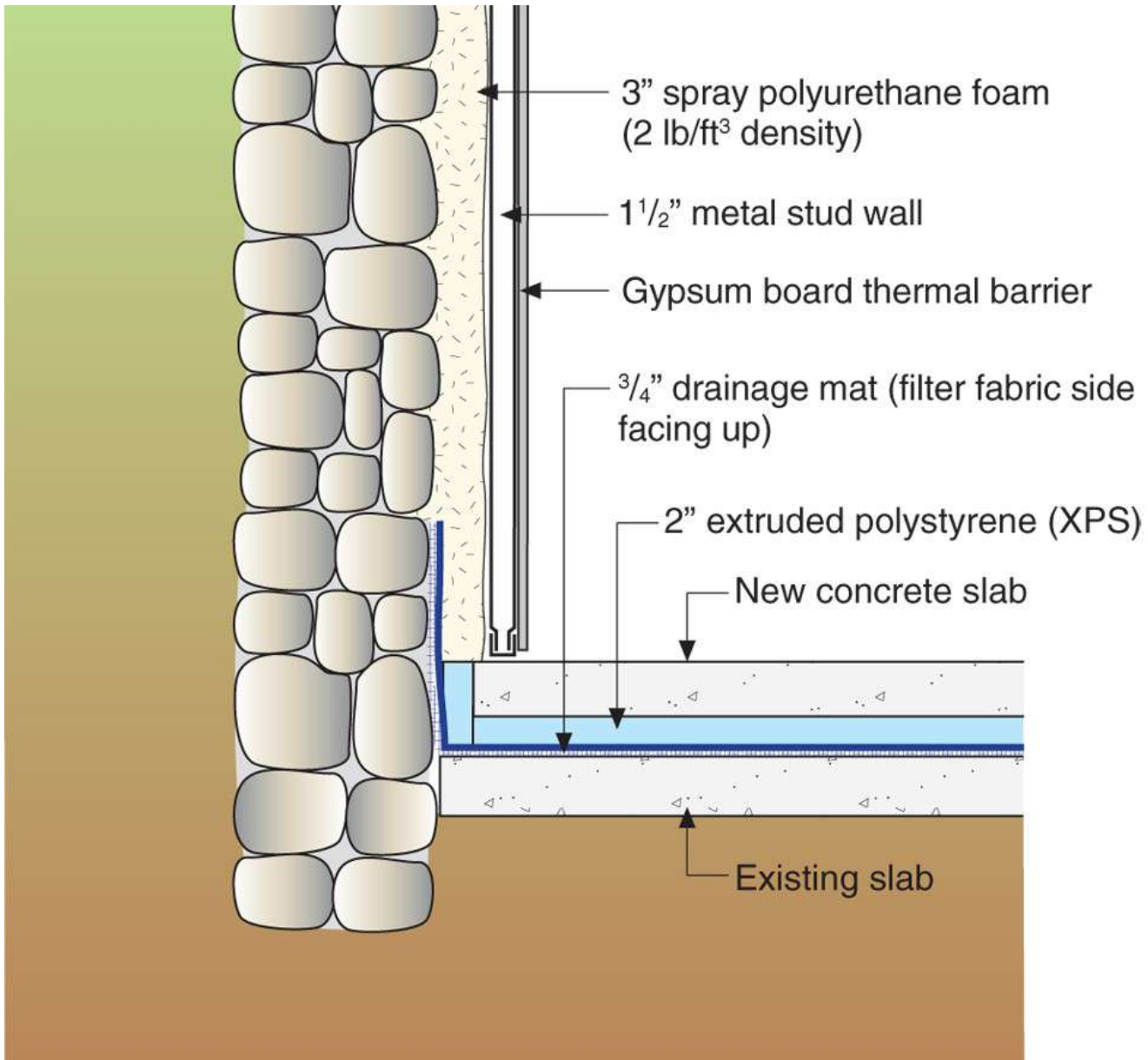


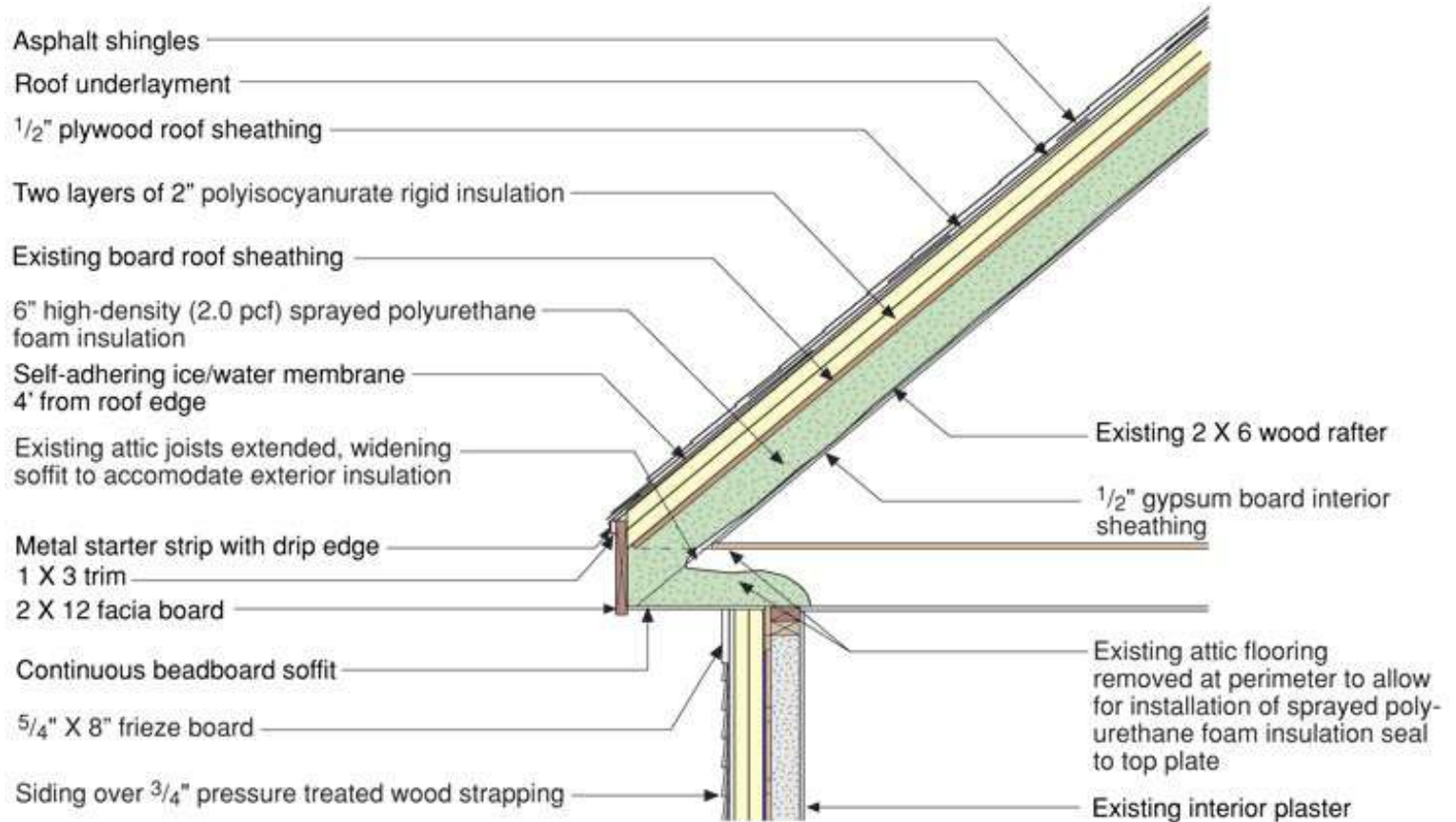






































































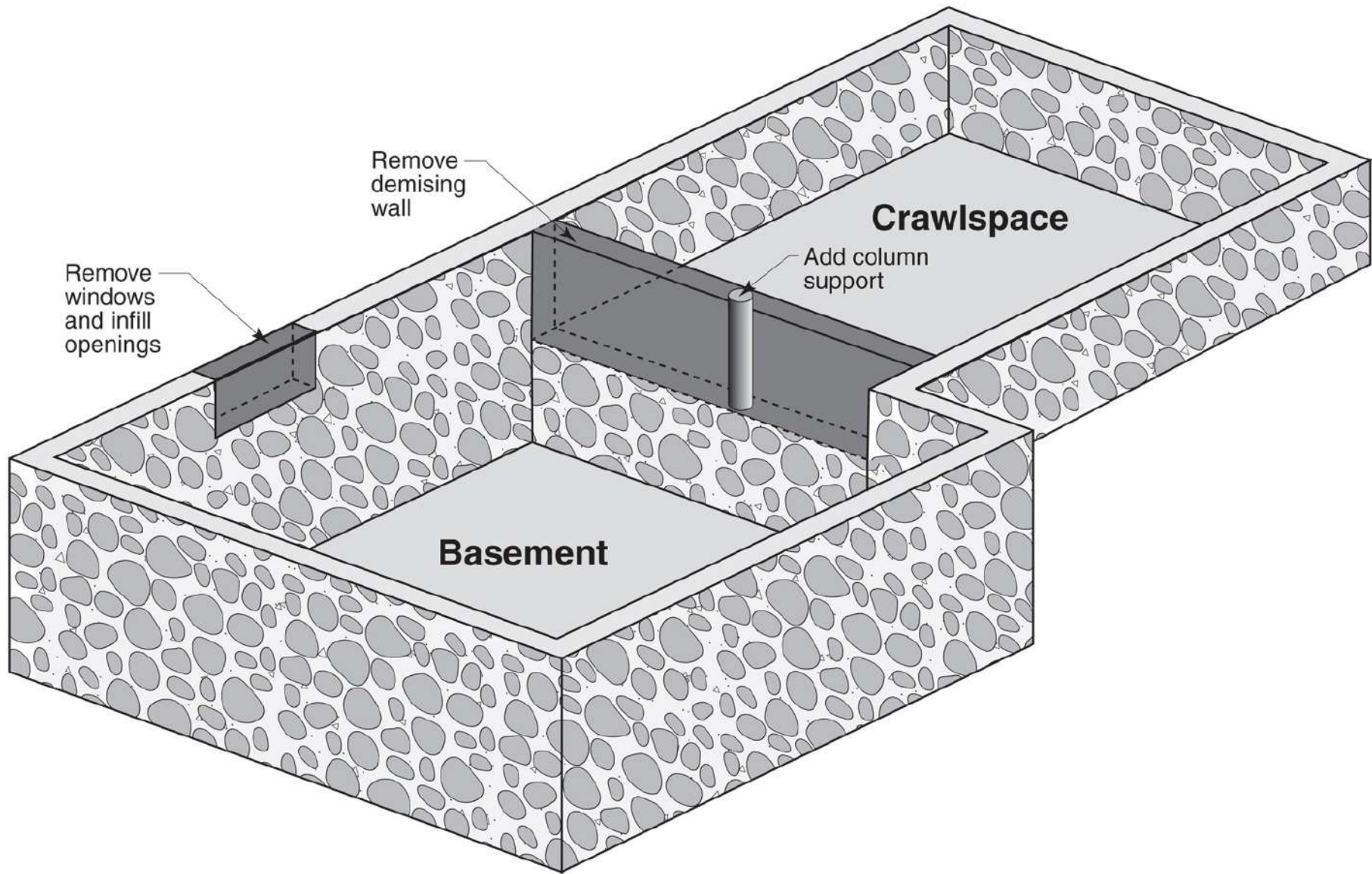




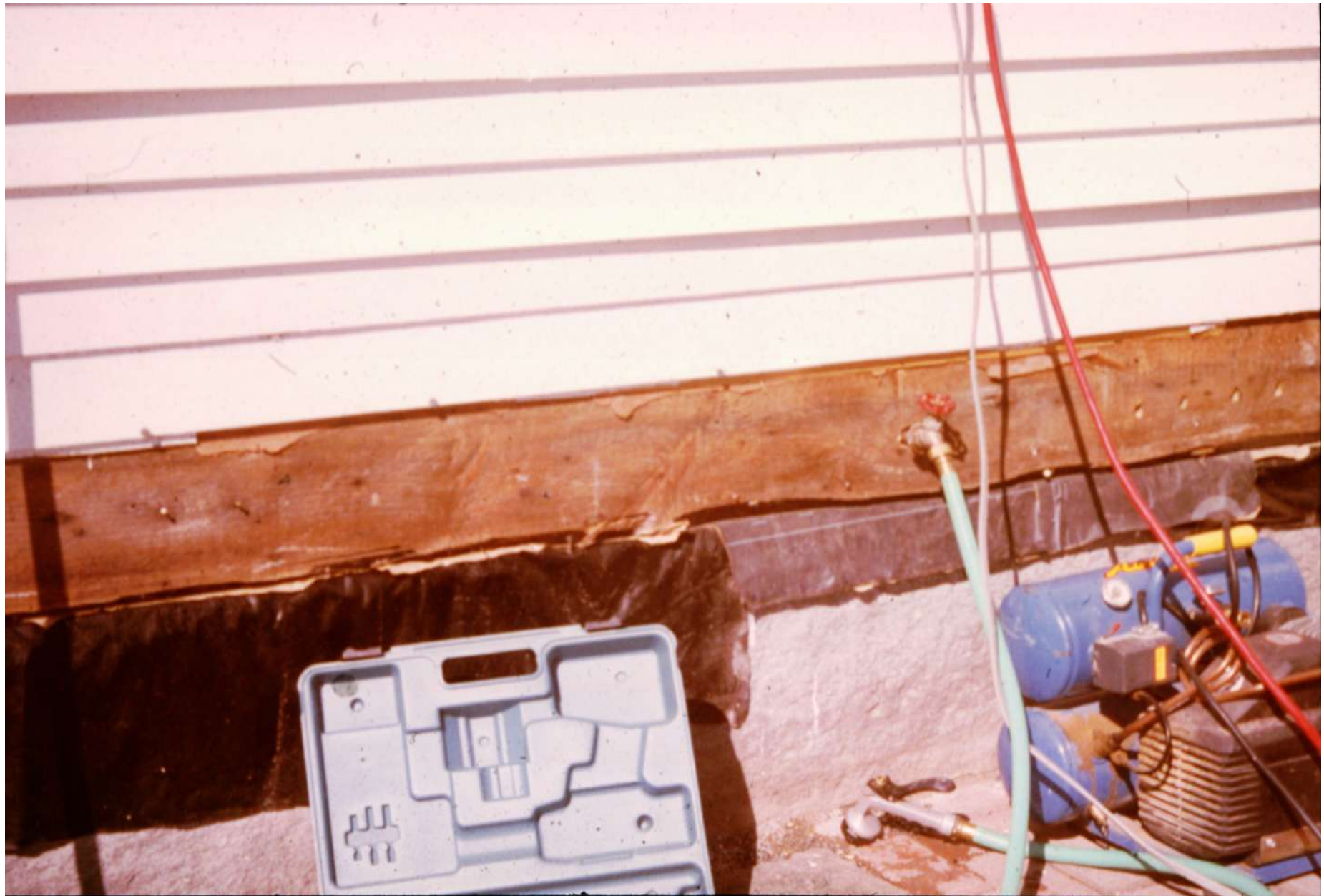










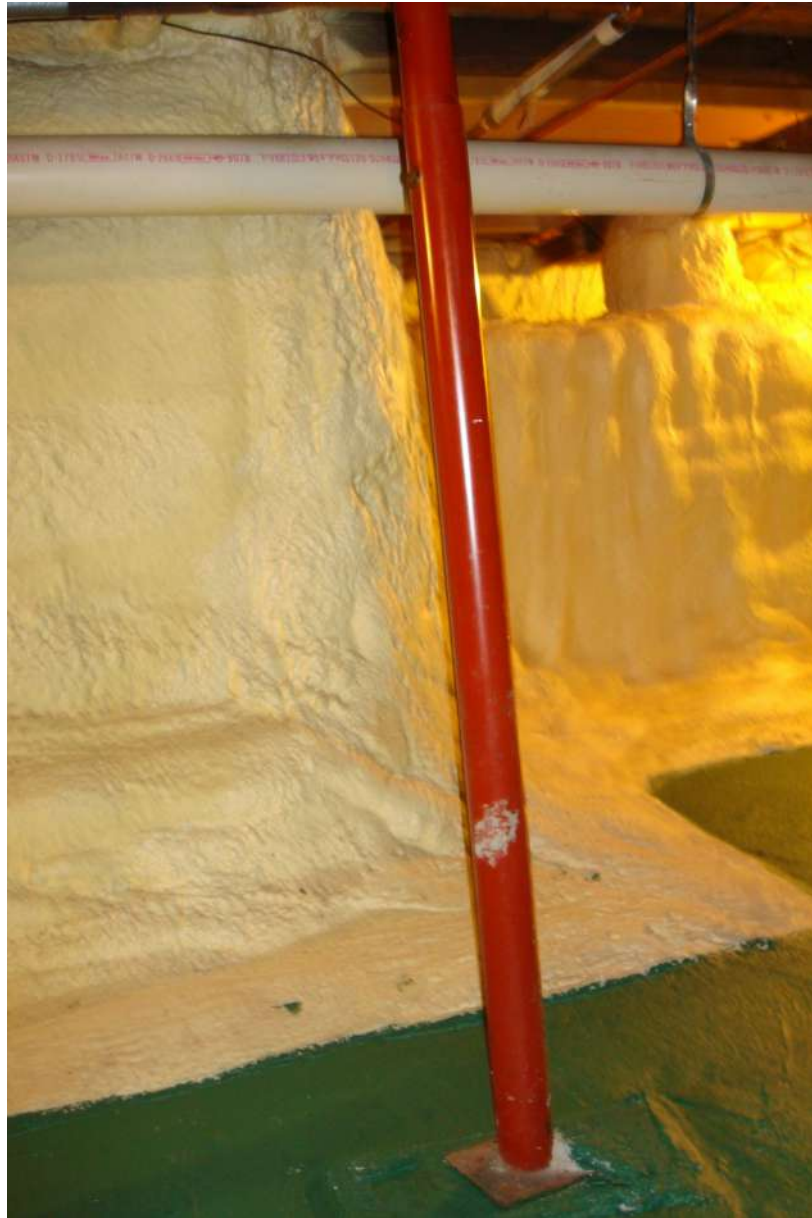










































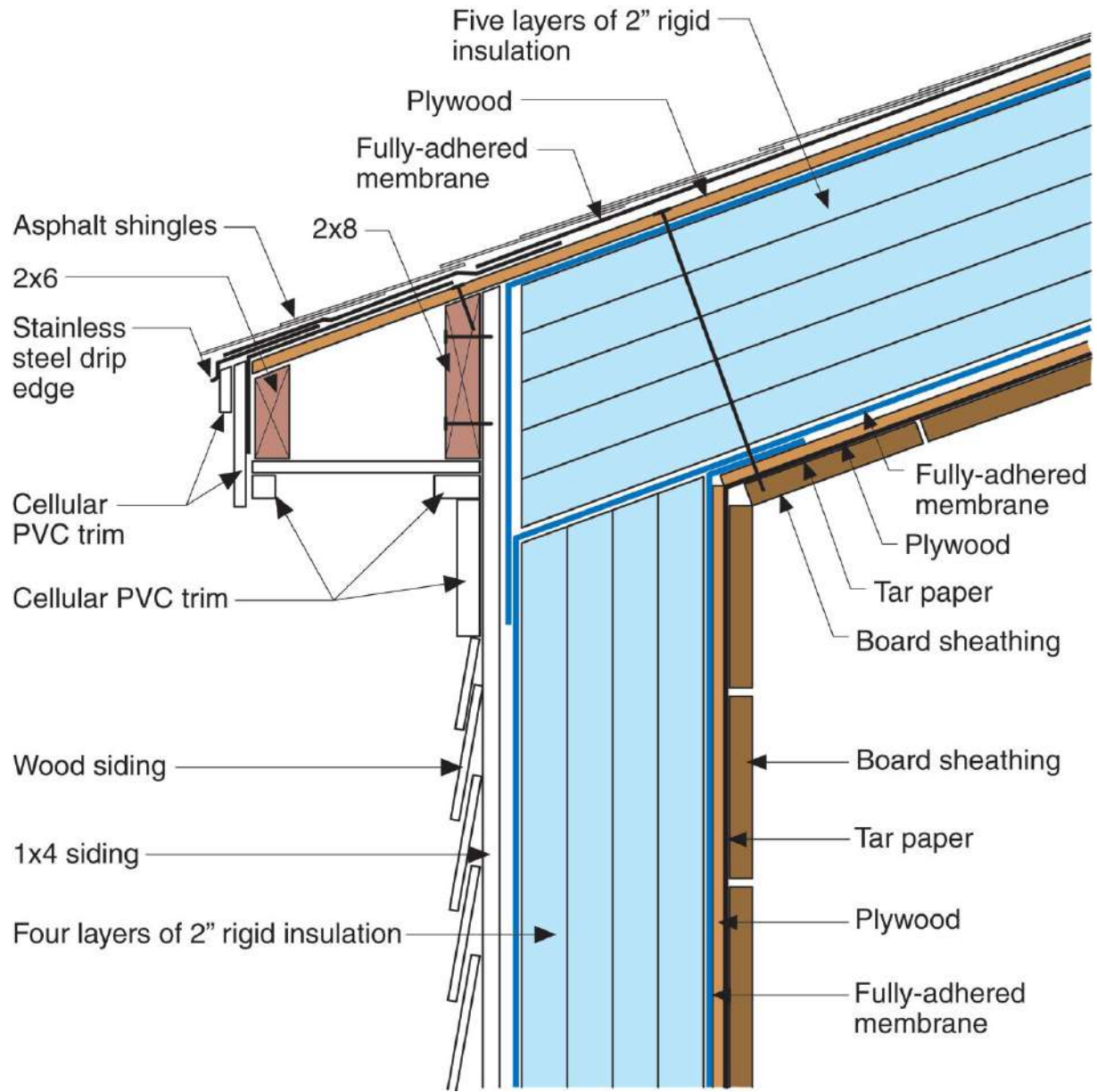


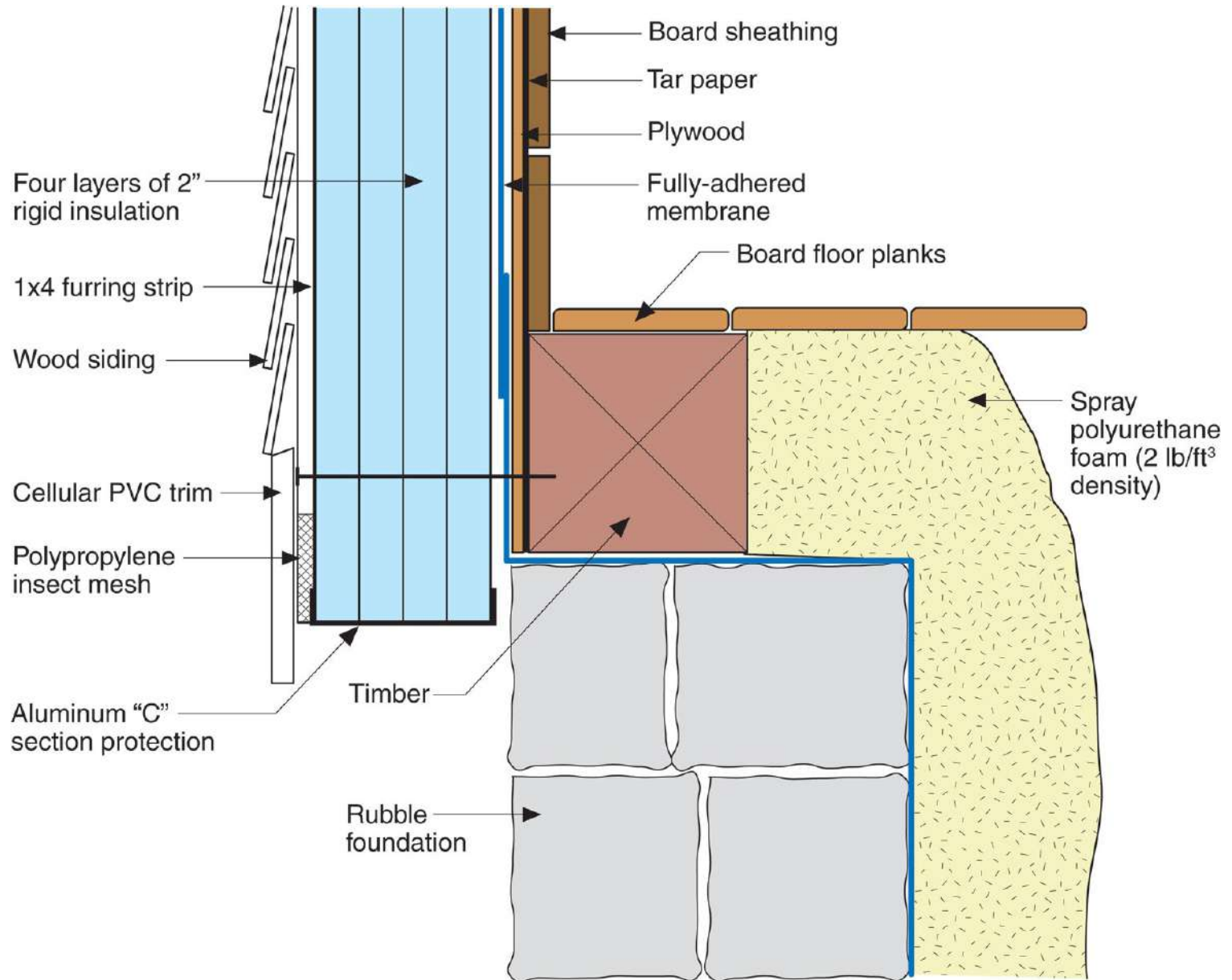


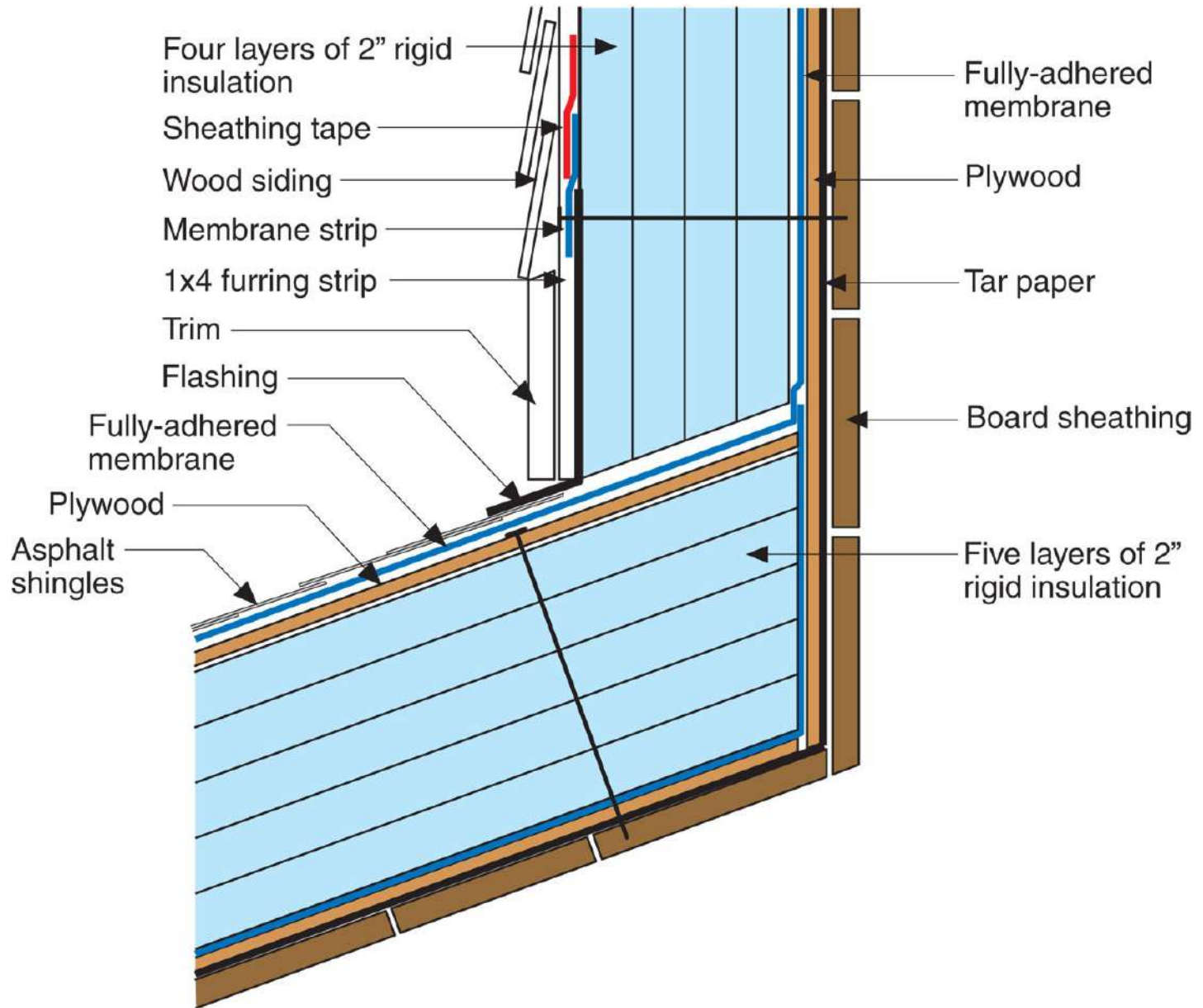












Four layers of 2" rigid insulation

Sheathing tape

Wood siding

Membrane strip

1x4 furring strip

Trim

Flashing

Fully-adhered membrane

Plywood

Asphalt shingles

Fully-adhered membrane

Plywood

Tar paper

Board sheathing

Five layers of 2" rigid insulation









Normal Guard Thickness

R-VALUE	1"	1 1/2"	2"
	0.5	0.6	0.8

IT IS THE BUYER'S RESPONSIBILITY TO CONTACT THE LOCAL BUILDING DEPARTMENT FOR MORE INFORMATION.
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