

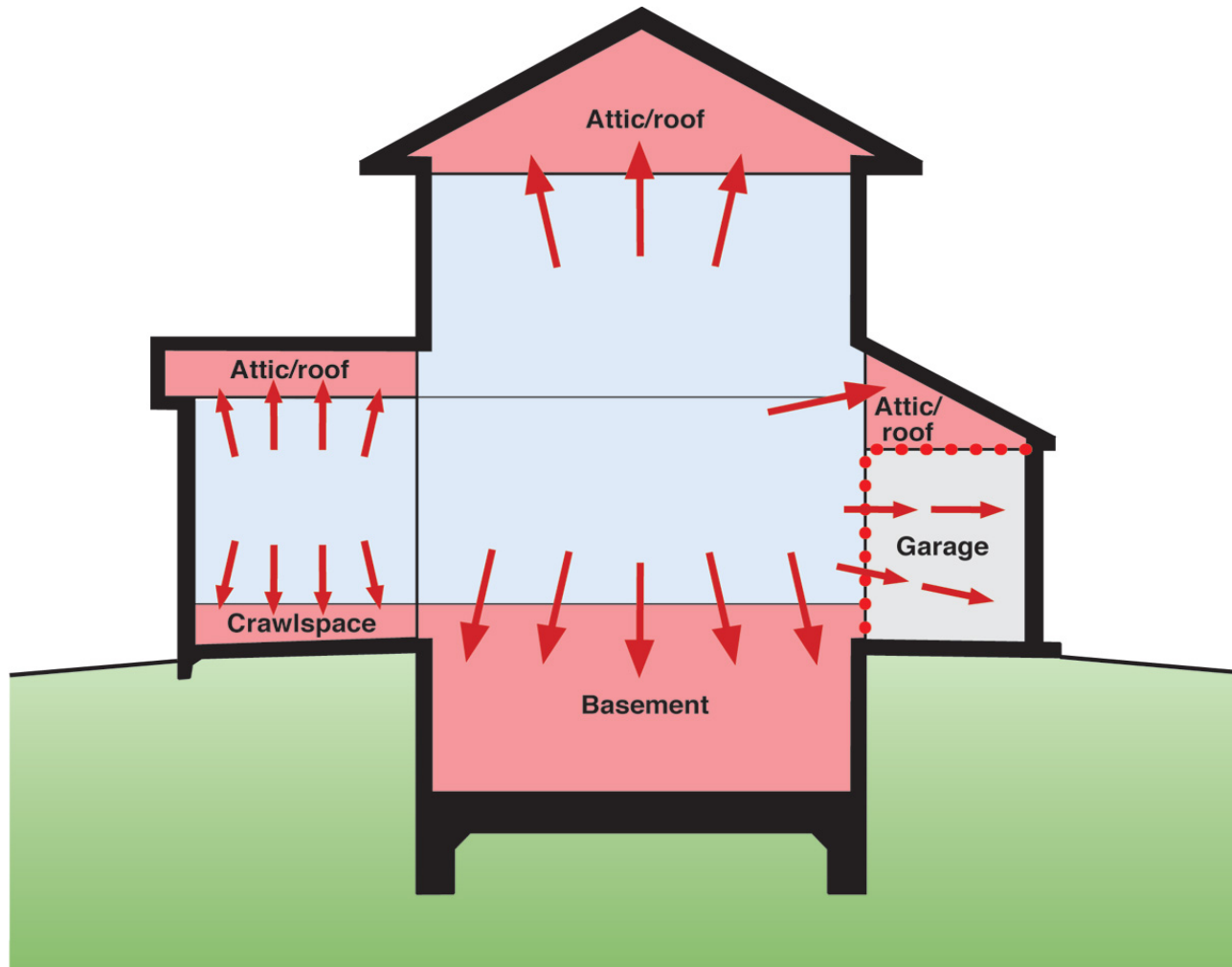
Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

# Building Science

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## Foundations

presented by [www.buildingscience.com](http://www.buildingscience.com)

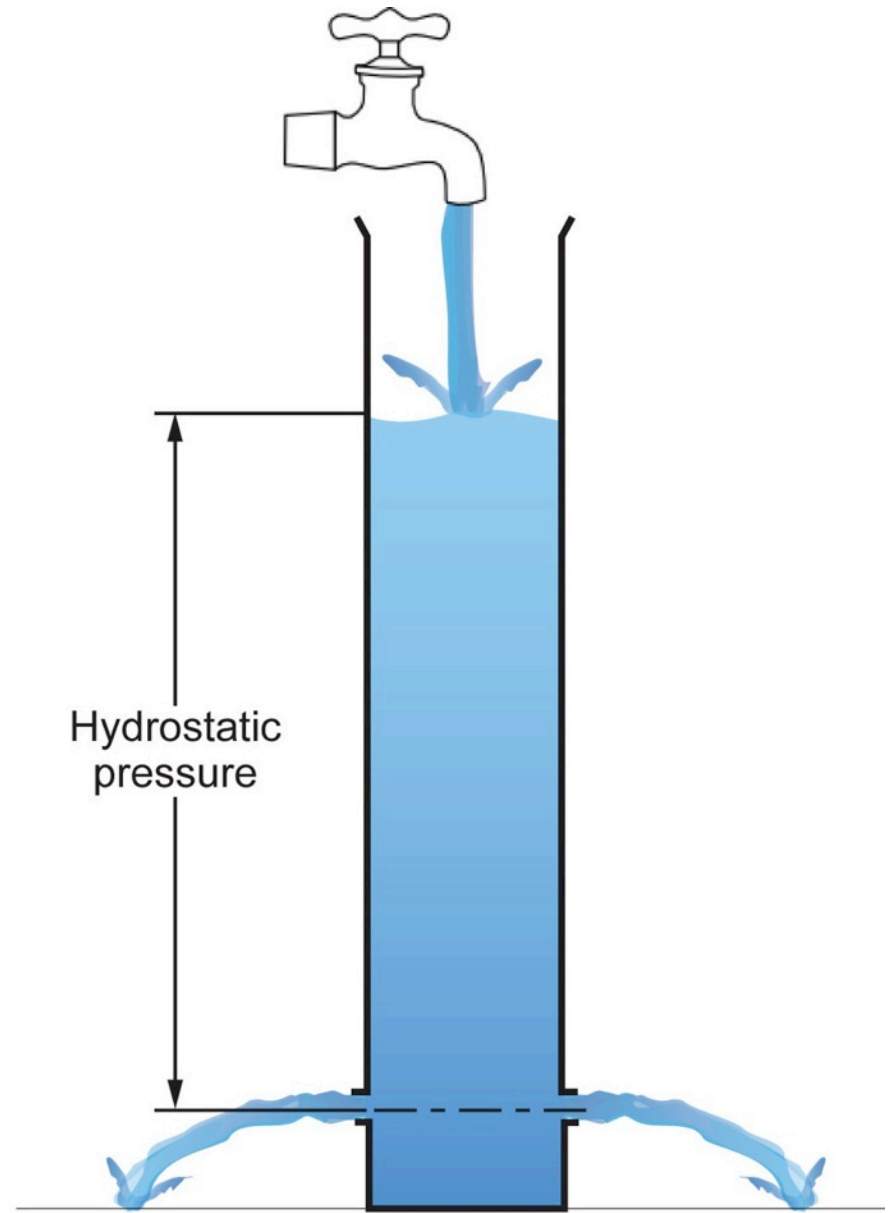
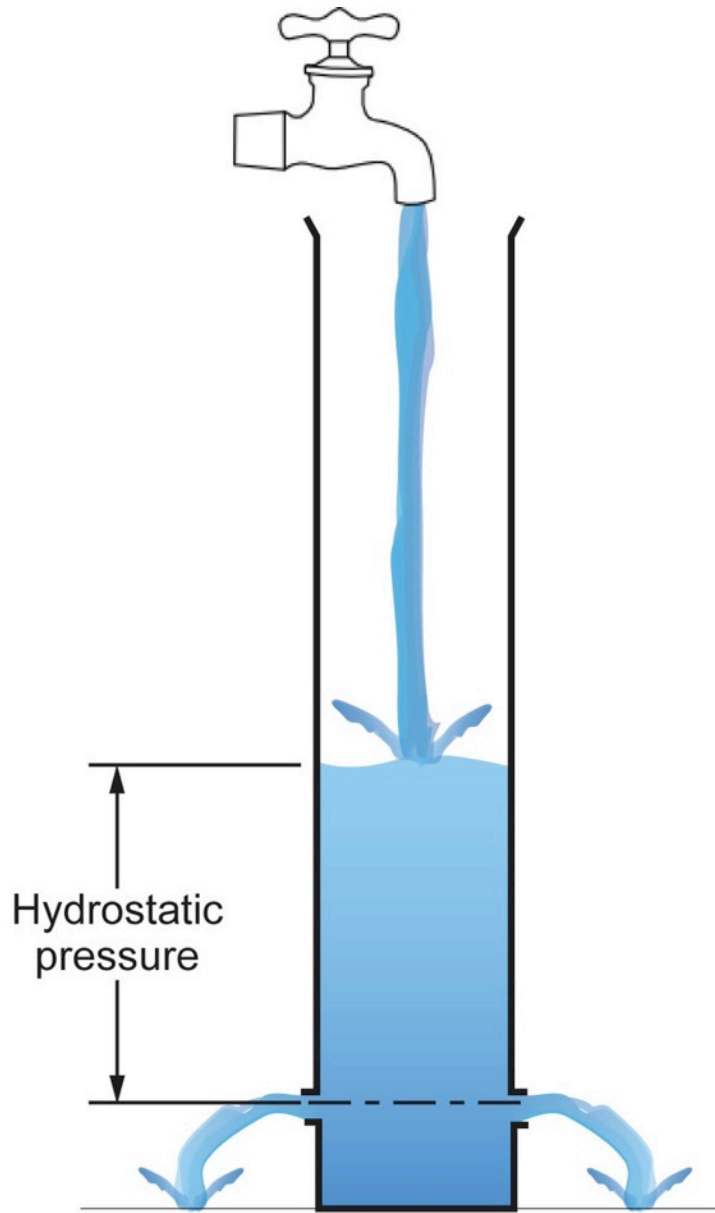


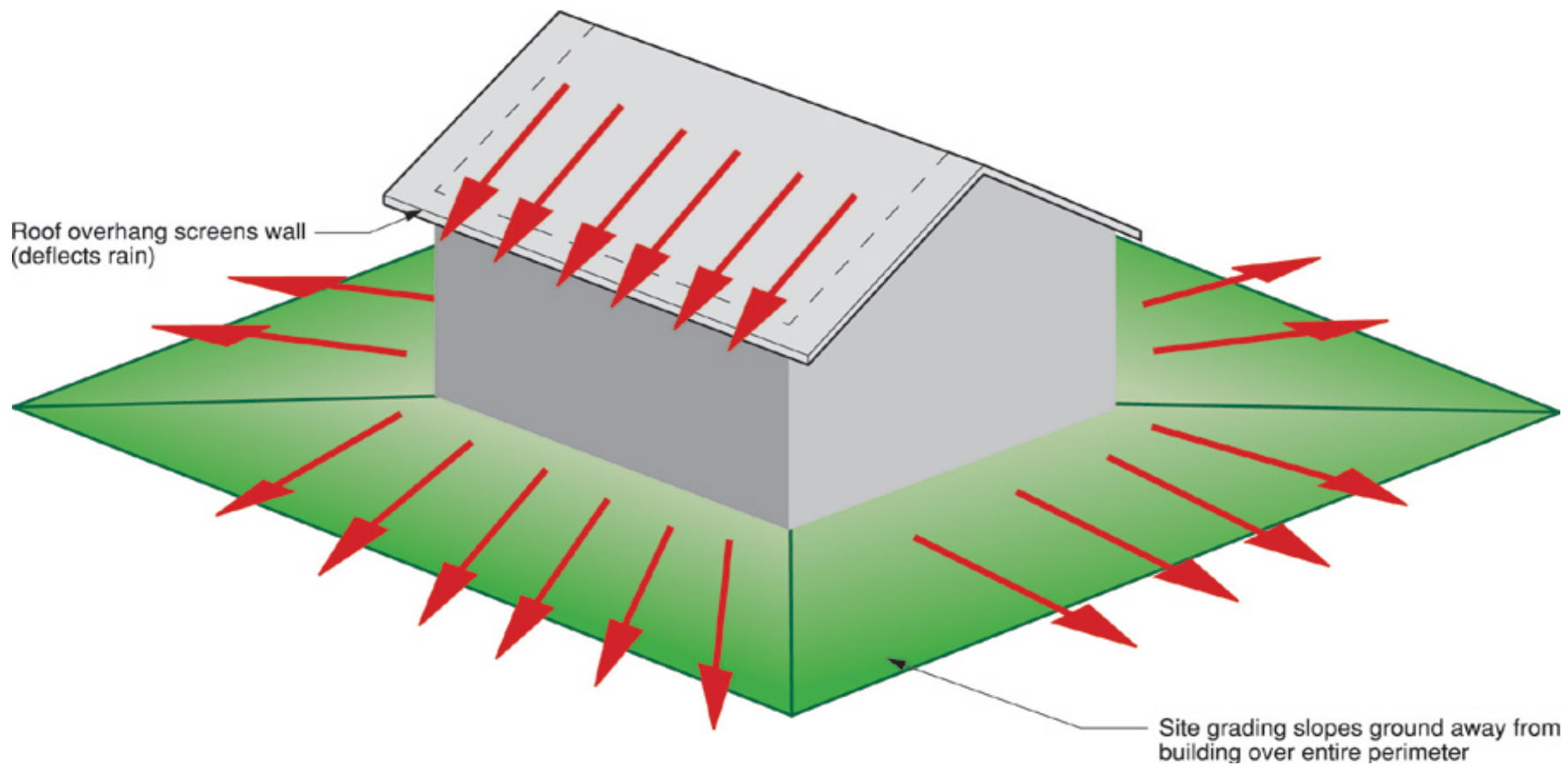
### Expansion of Conditioned Space

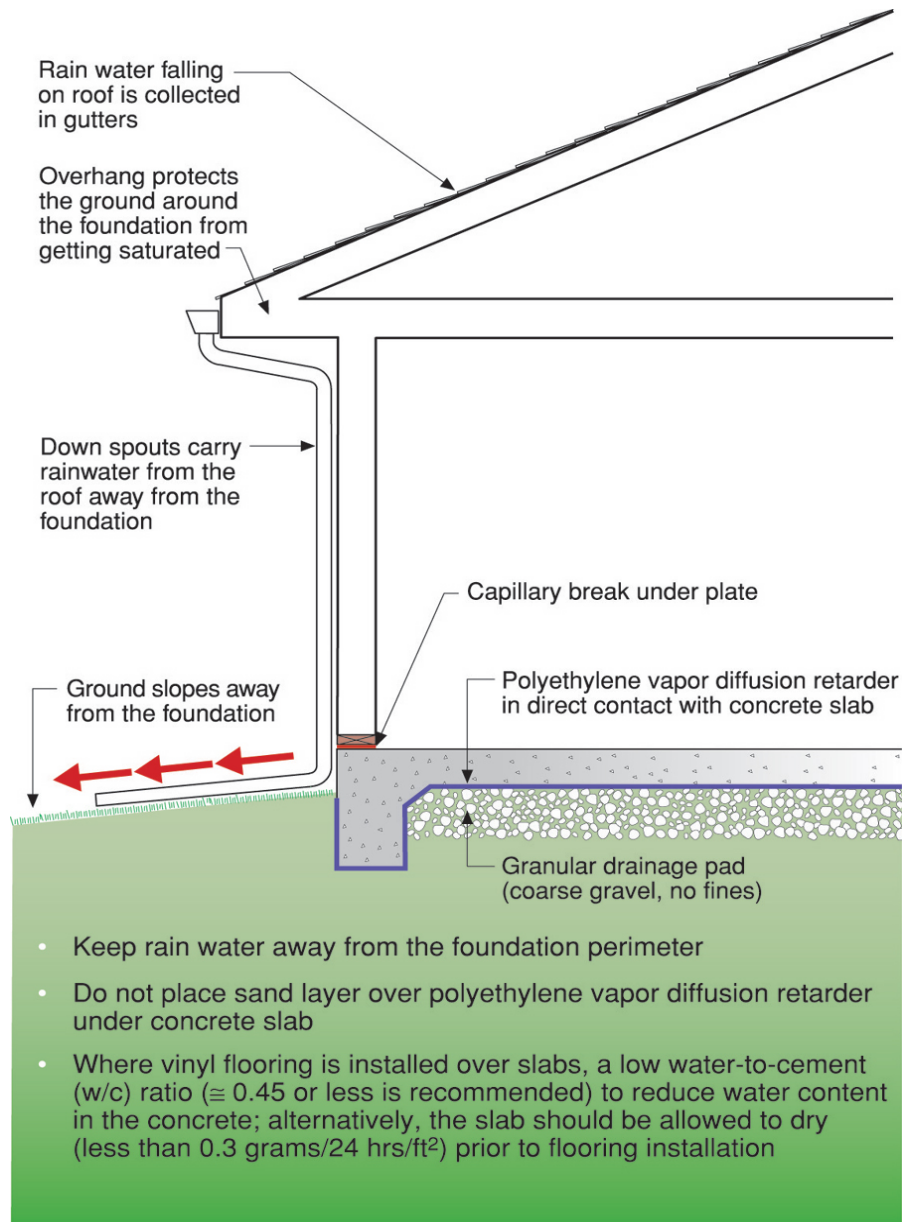
- Conditioned space boundaries moving towards exterior surfaces of building
- Garage isolated from house by air barrier/pressure boundary
- Garage ventilated and conditioned independently of rest of conditioned spaces

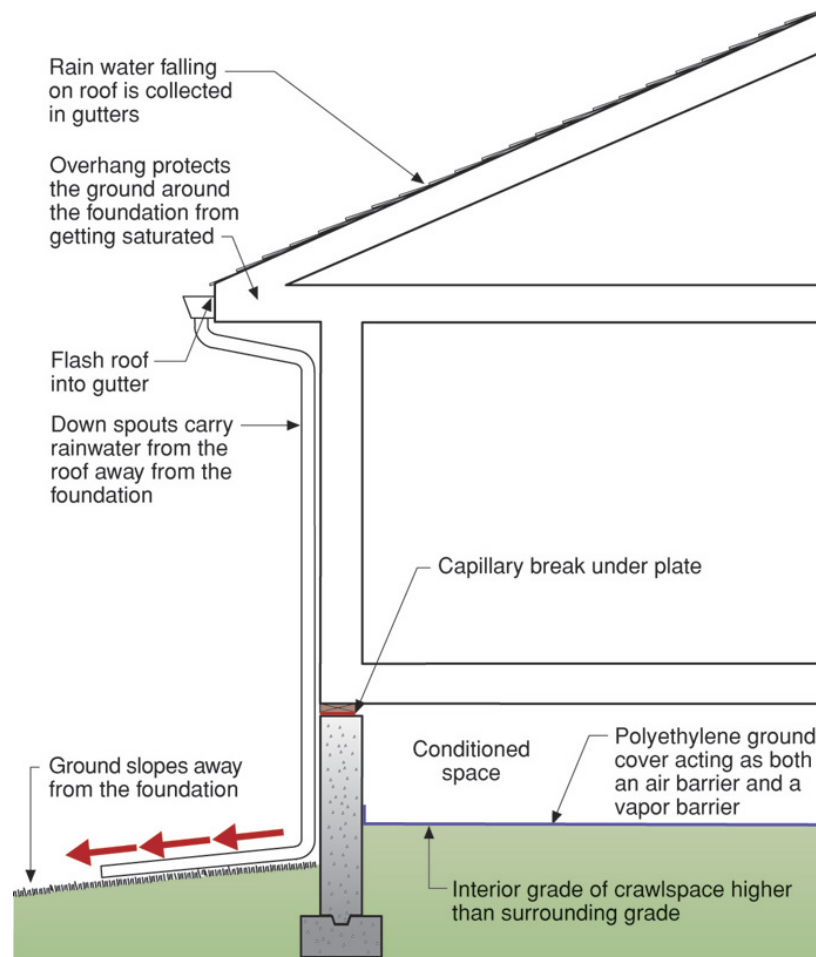
# Mechanisms of Flow

- Liquid            Gravitational            Hydrostatic Pressure  
                         Capillary                    Suction Pressure  
                         Osmosis                      Solute Concentration
- Vapor              Diffusion                  Vapor Pressure  
                         Convective                Air Pressure

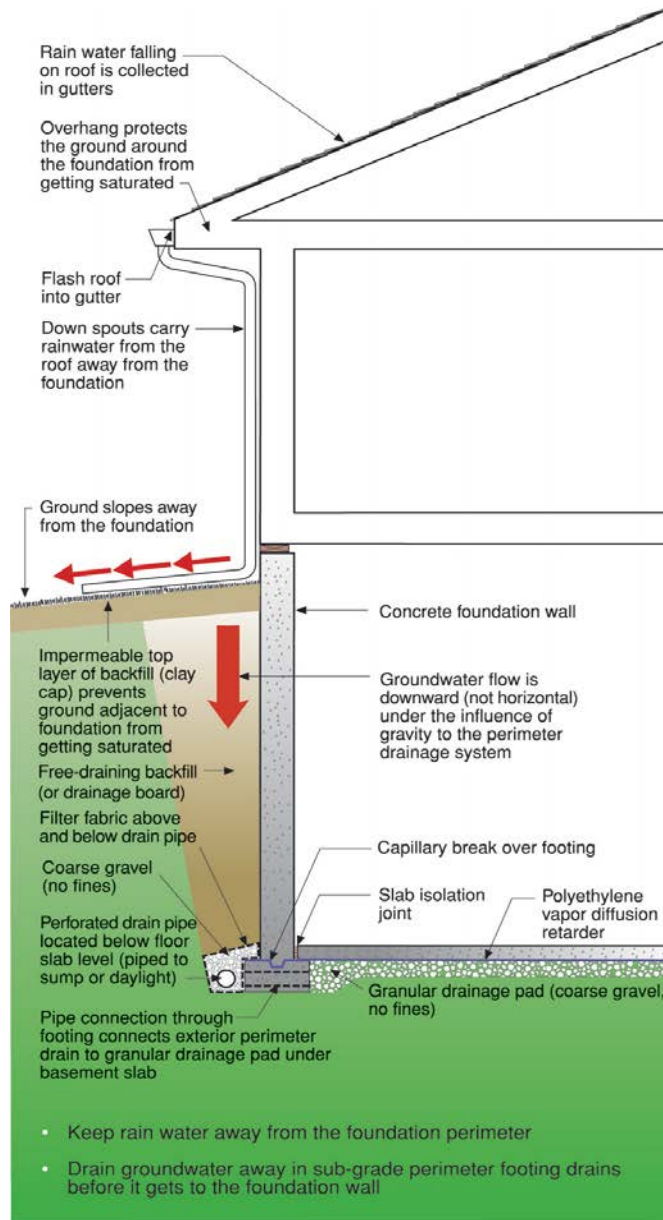








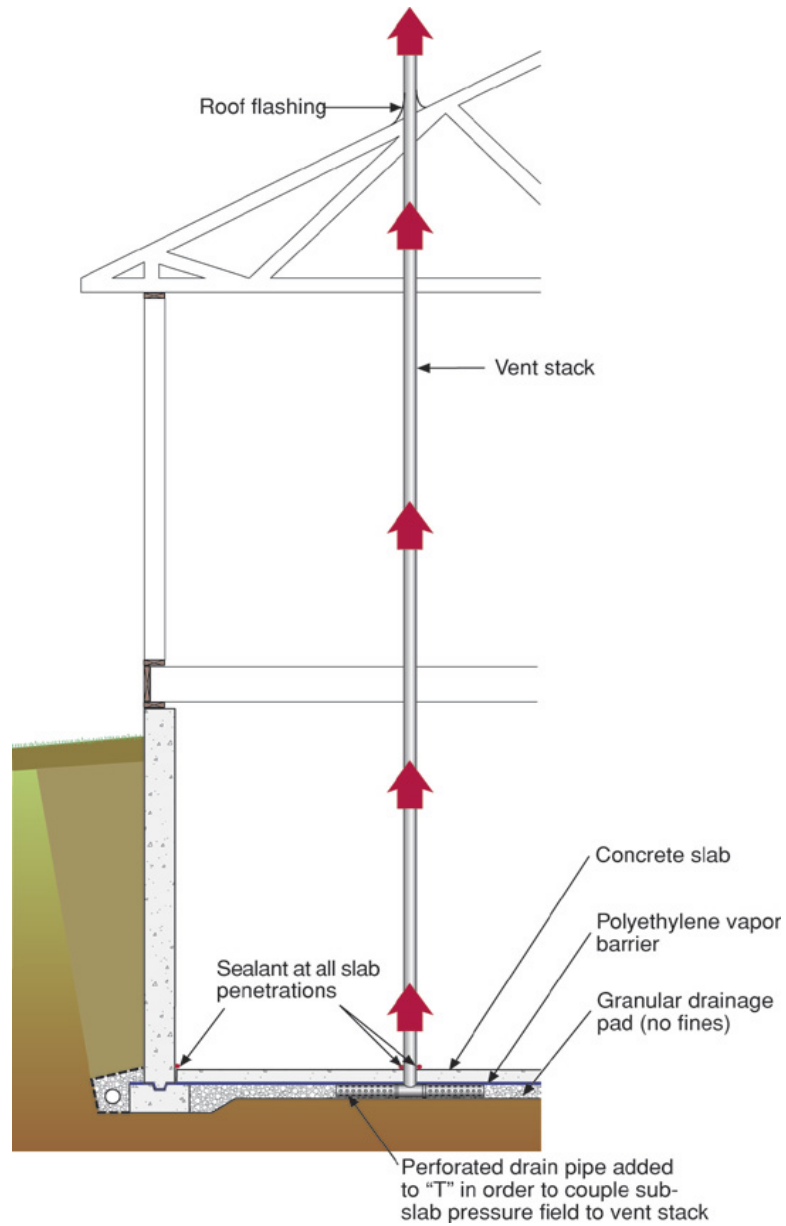
- Keep rain water away from the foundation perimeter
- If the interior crawlspace is lower than the exterior grade, a sub-grade perimeter footing drain is necessary as in a basement foundation
- The crawlspace is conditioned space; it is part of the "interior" of the building and should be heated, cooled and ventilated as part of the building's heating, cooling and ventilating strategy

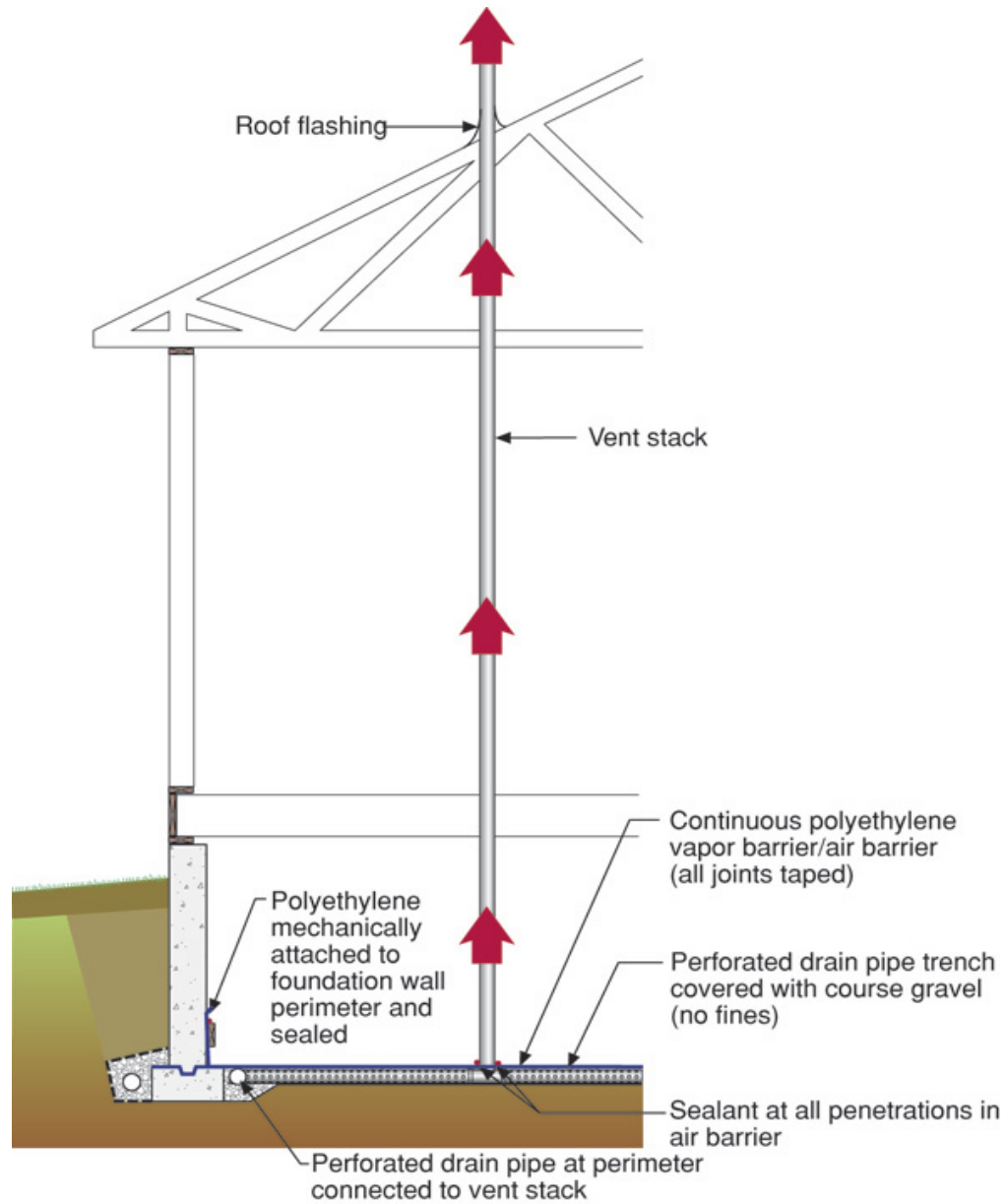


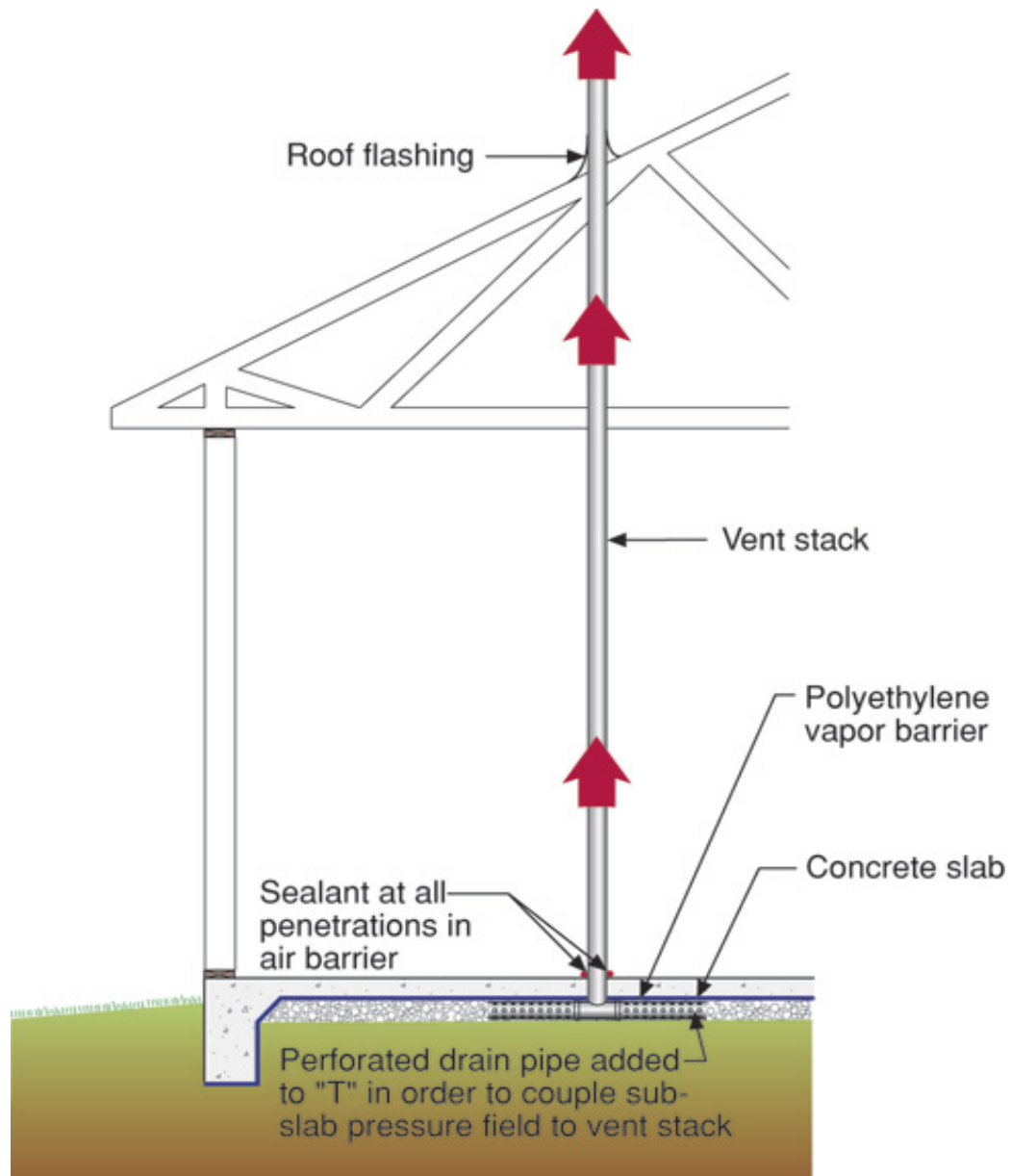




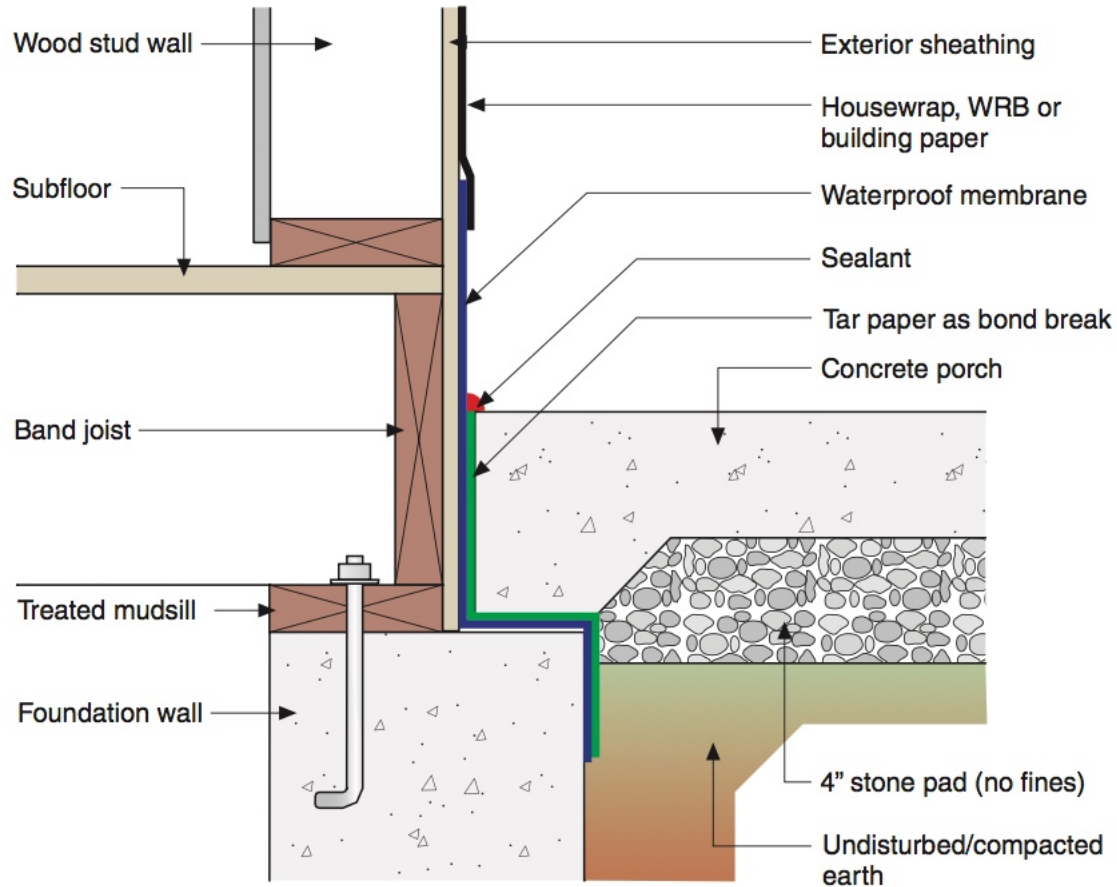




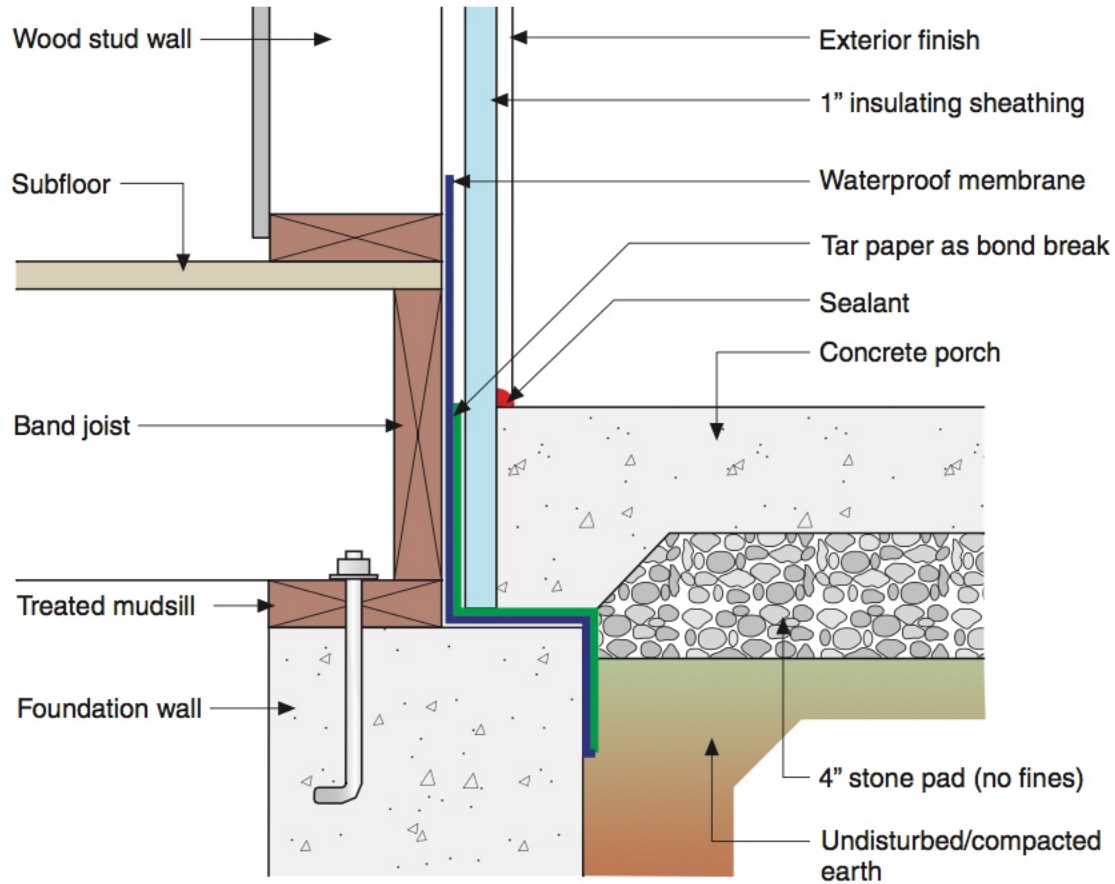




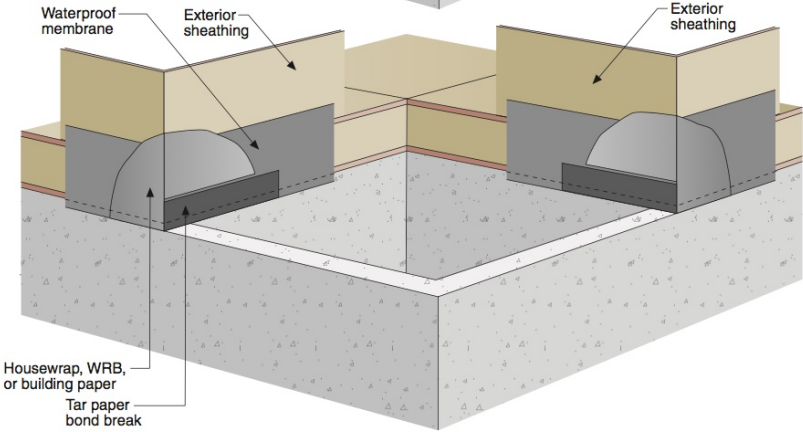
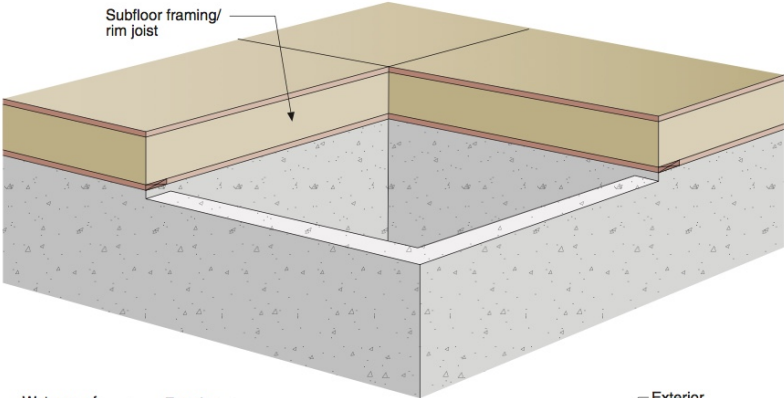
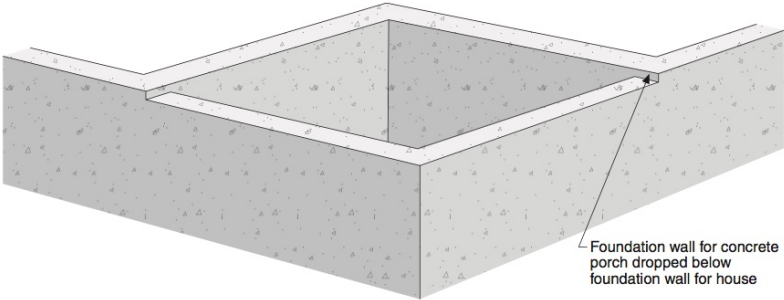
## CONCRETE PORCH SLAB WITH HOUSEWRAP



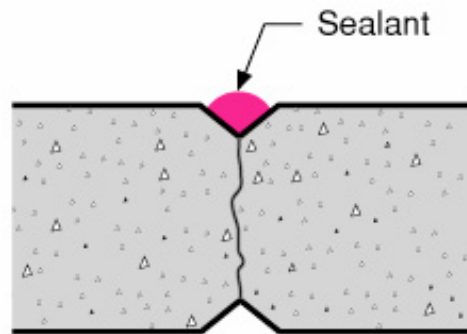
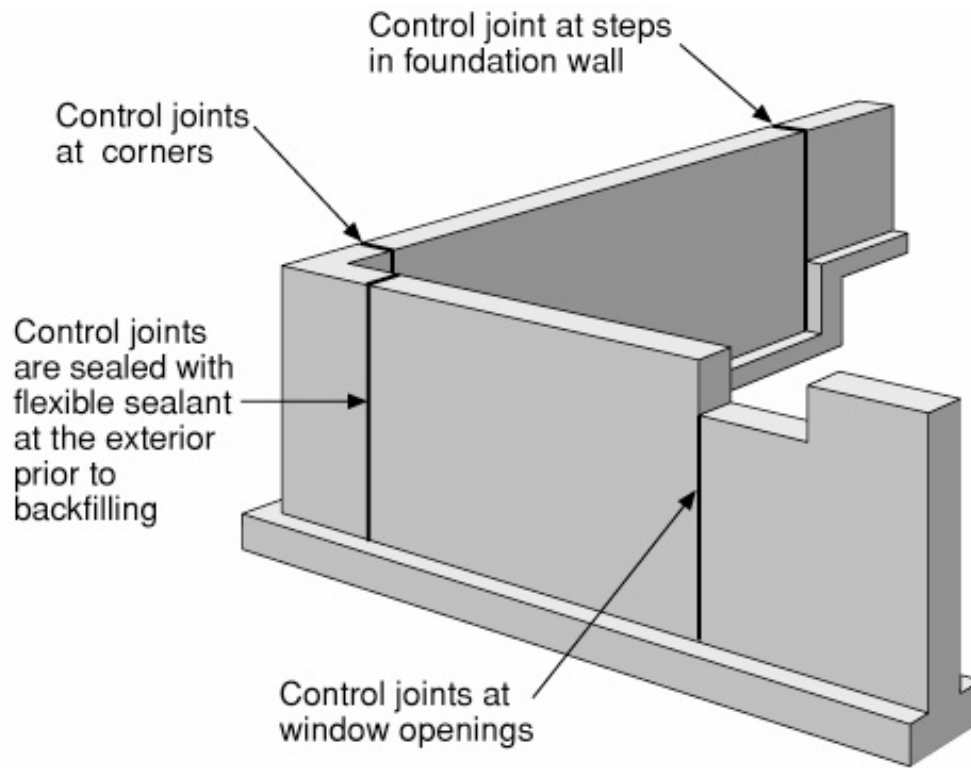
## CONCRETE PORCH SLAB WITH INSULATING SHEATHING



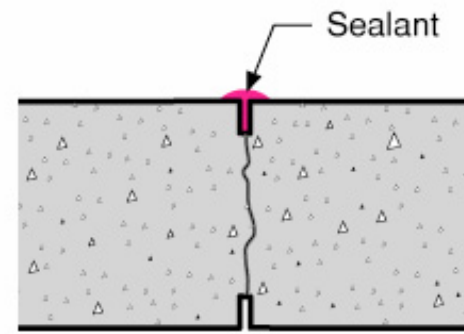
**CONCRETE PORCH/FOUNDATION INTERSECTION**







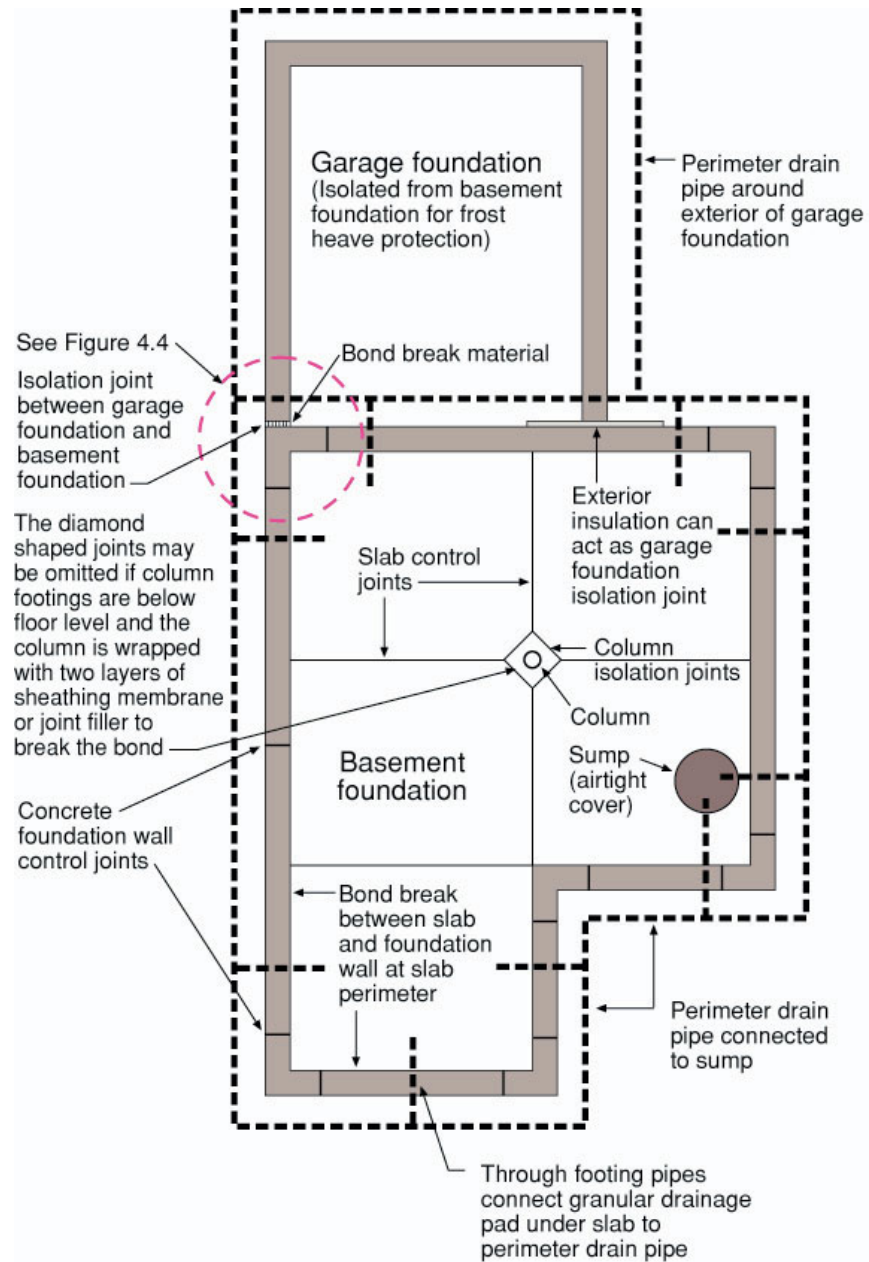
Diagonally cut 2 x 2's in forms provide goose neck joint



Saw cut joint



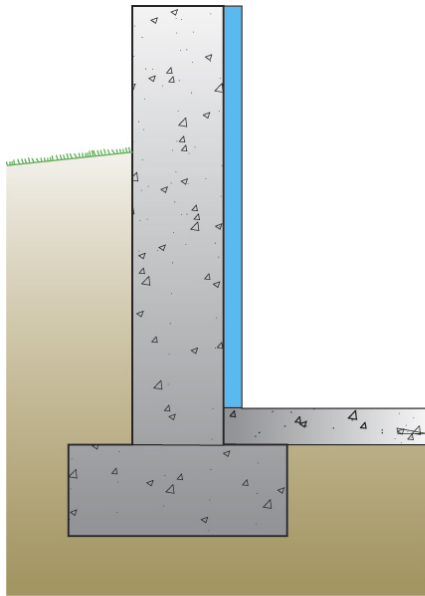




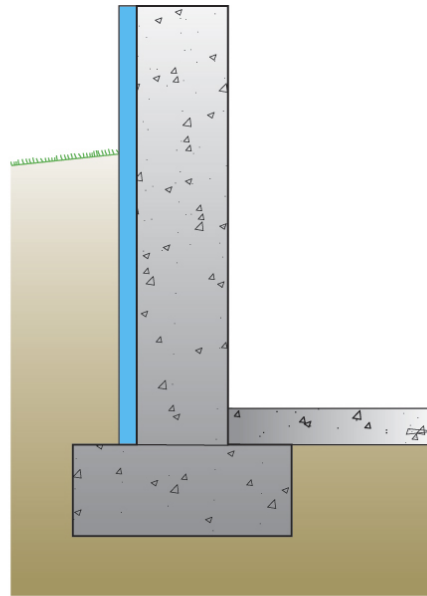




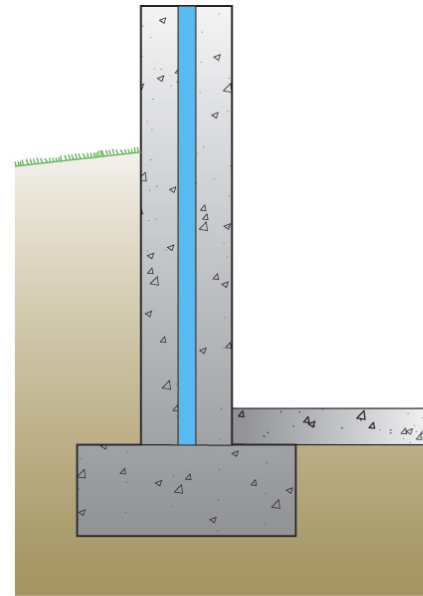




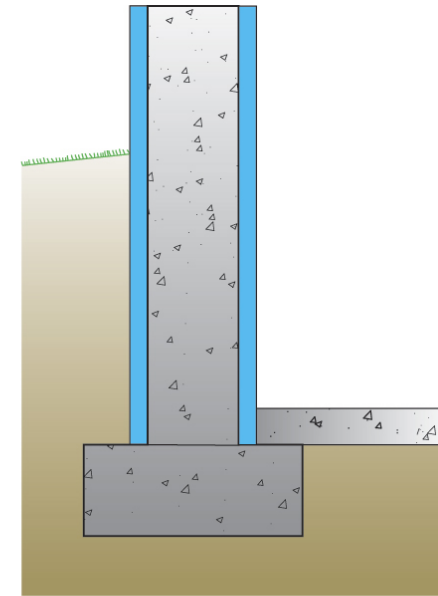
**Internally Insulated  
Basement**



**Externally Insulated  
Basement**



**Basement Insulated in the  
Middle**



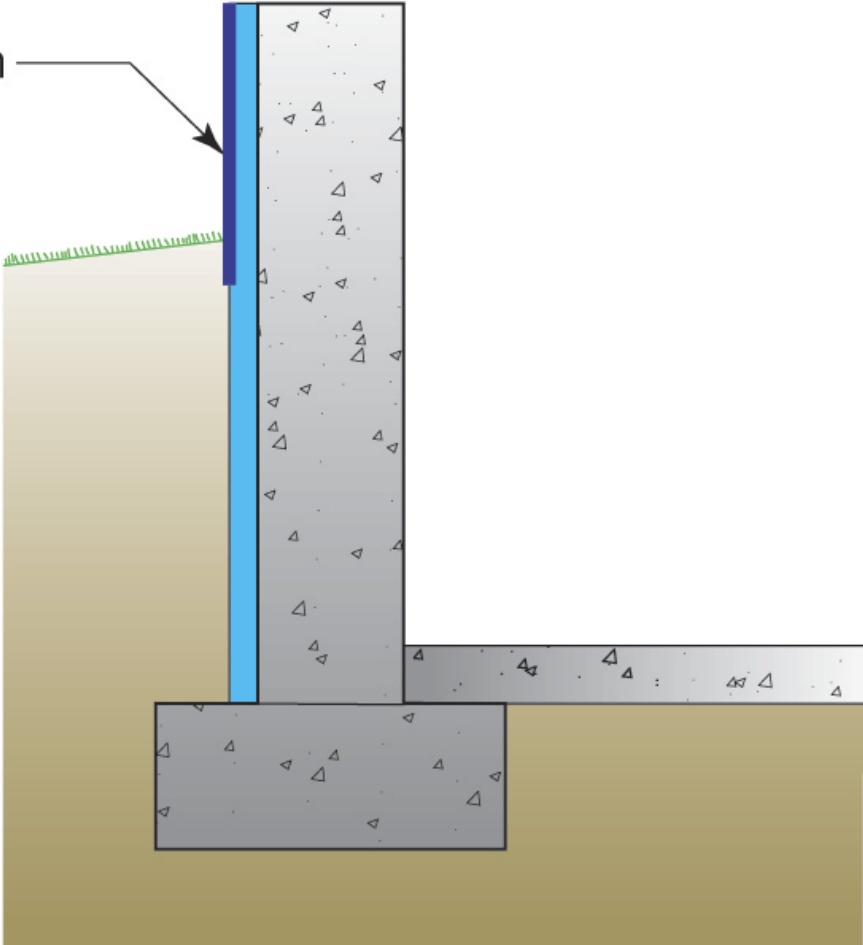
**Basement Insulated Both  
Externally and Internally**



Structure of house on foundation must be shifted outward to compensate for thickness of exterior insulation



Protection layer/system



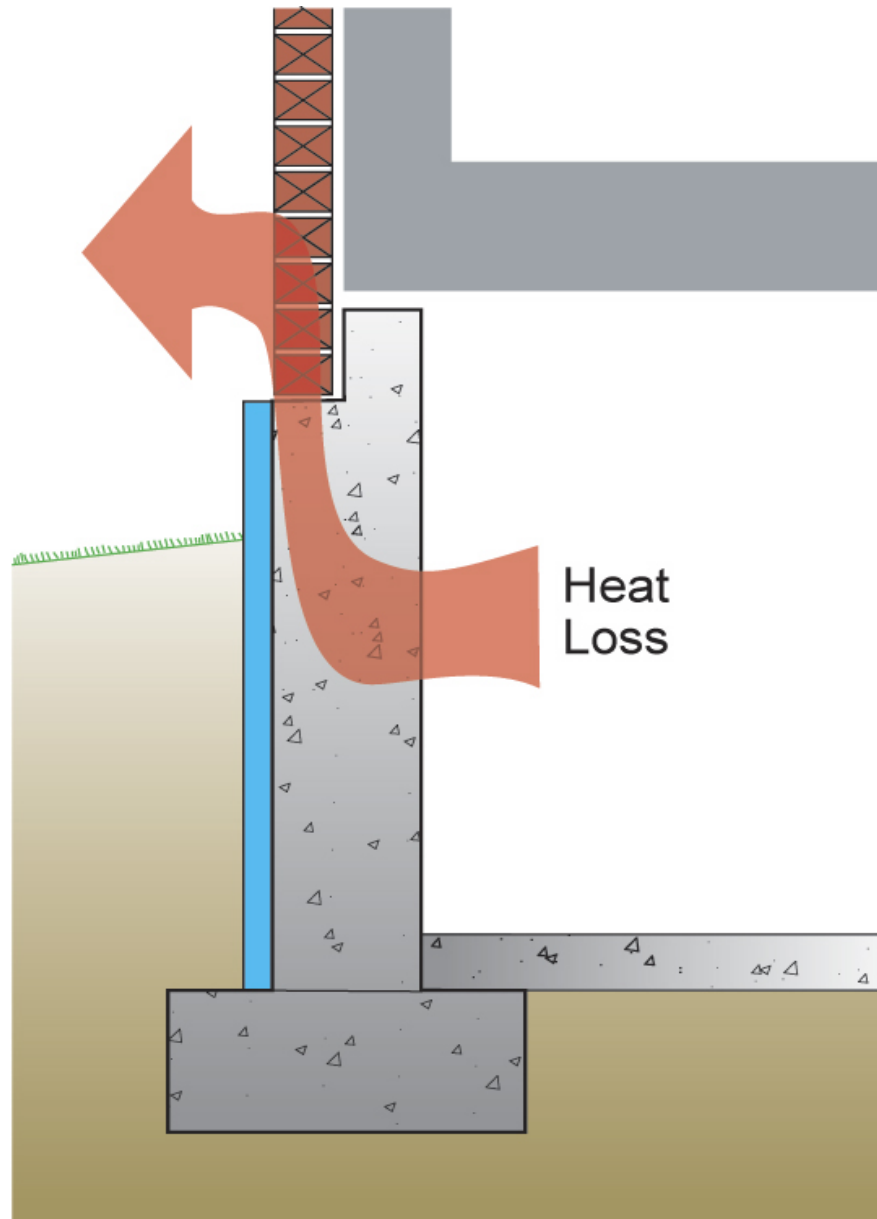


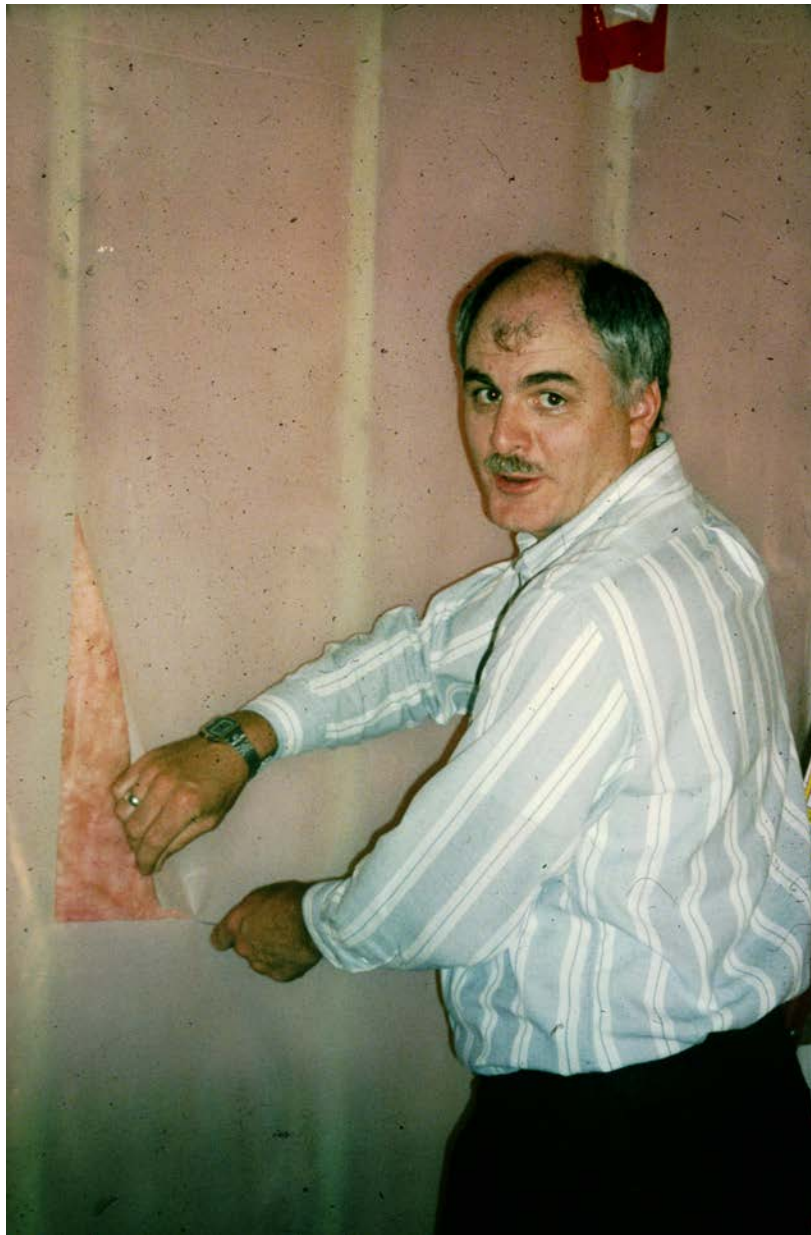






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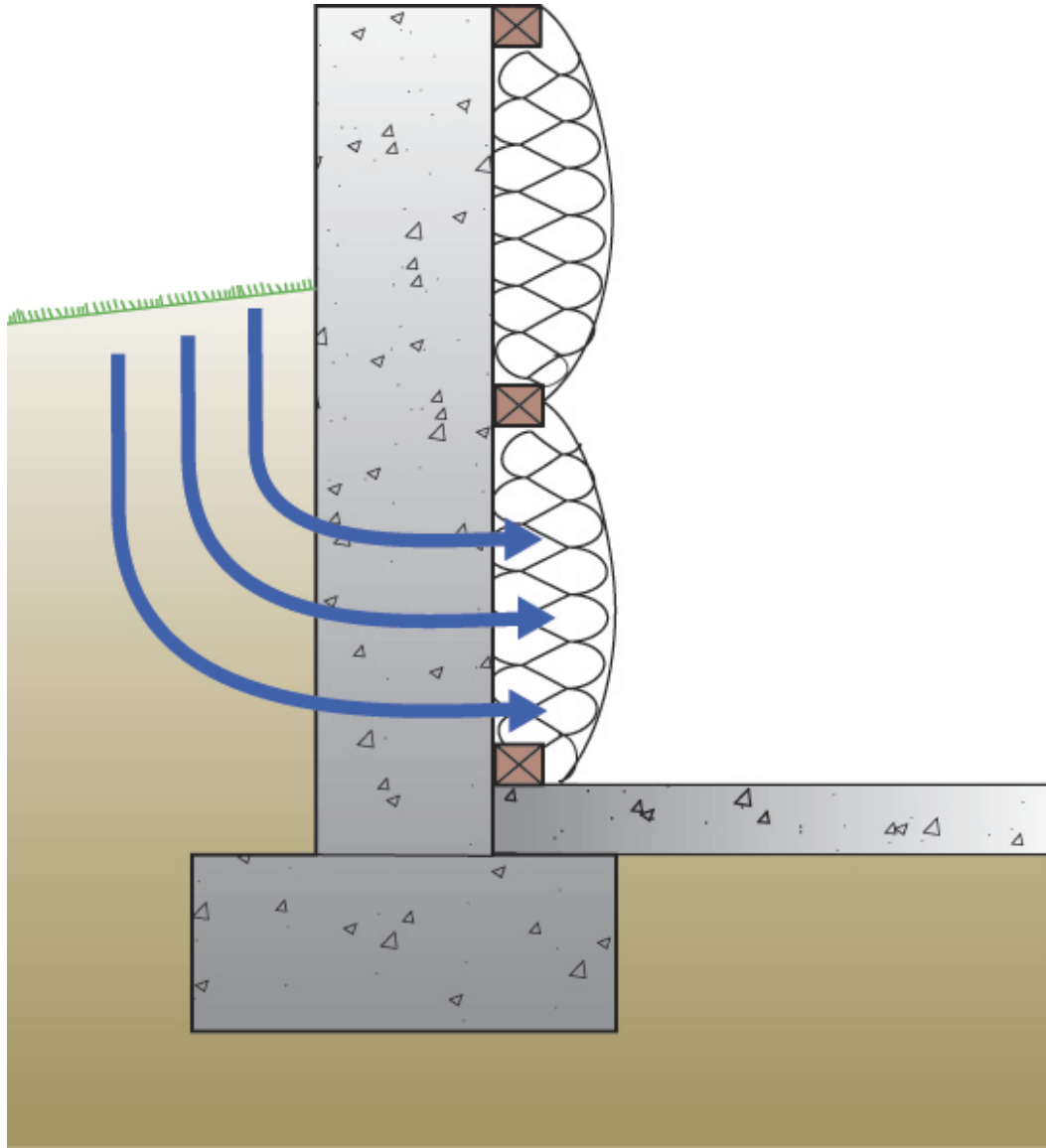


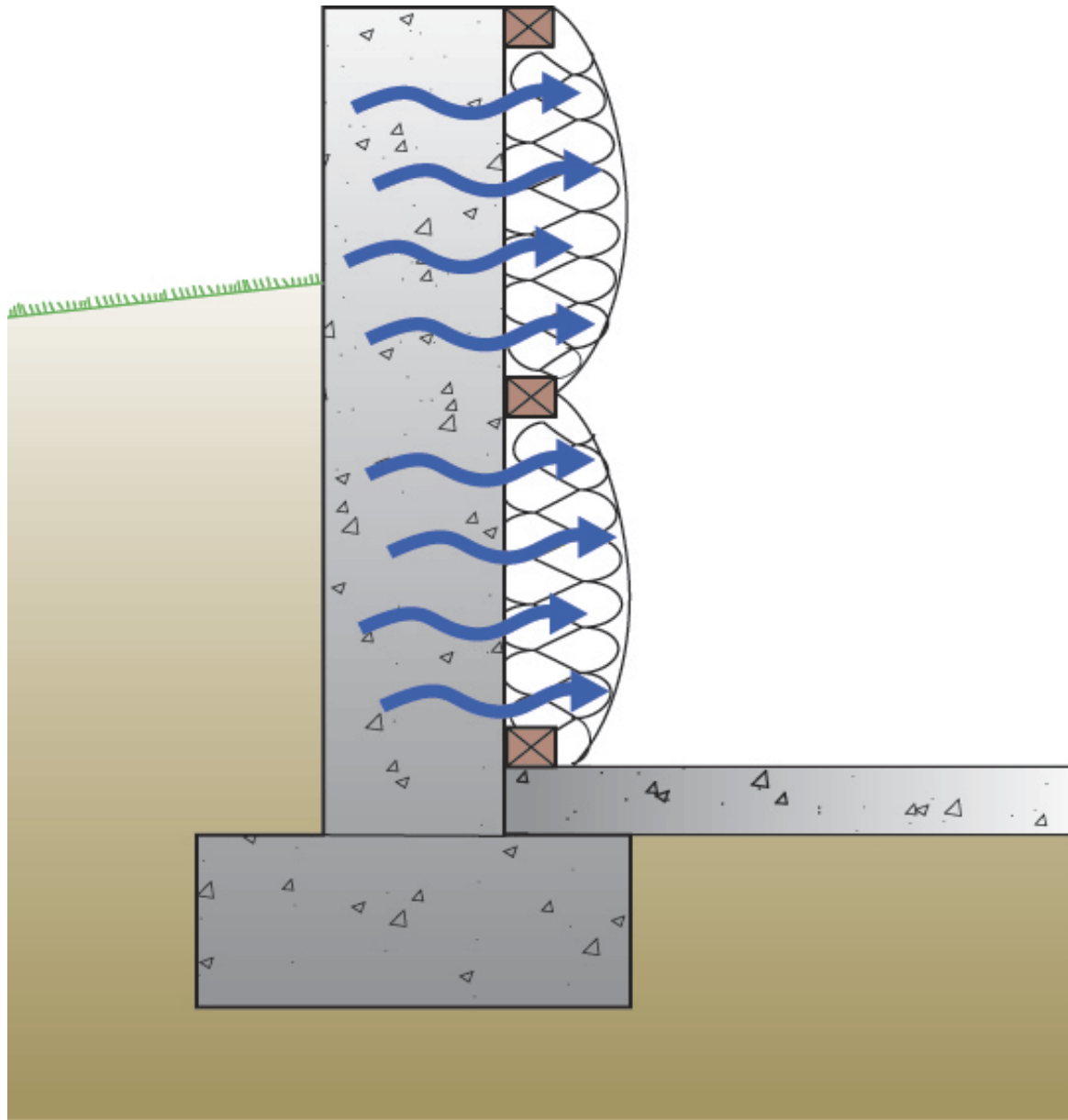


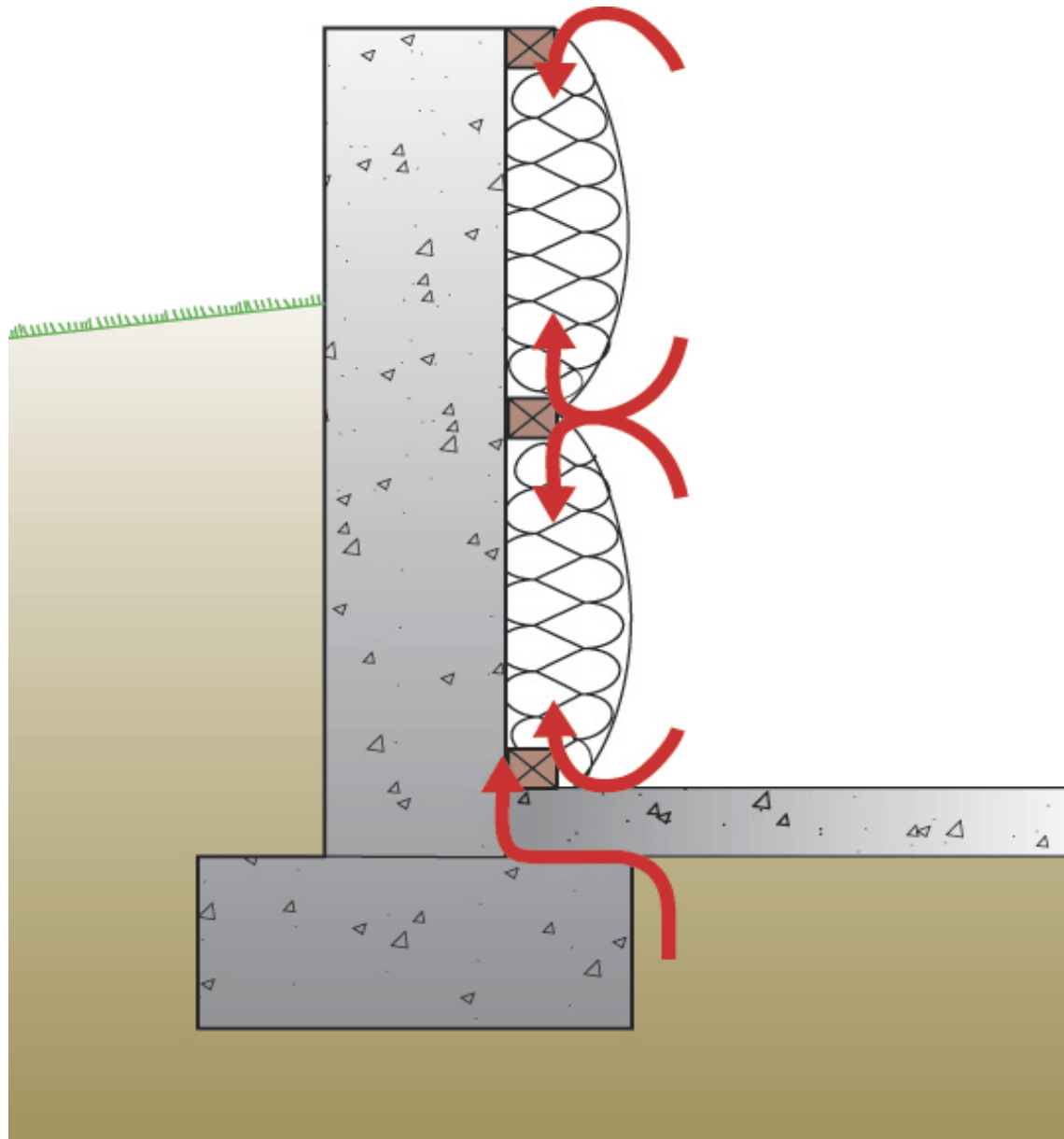


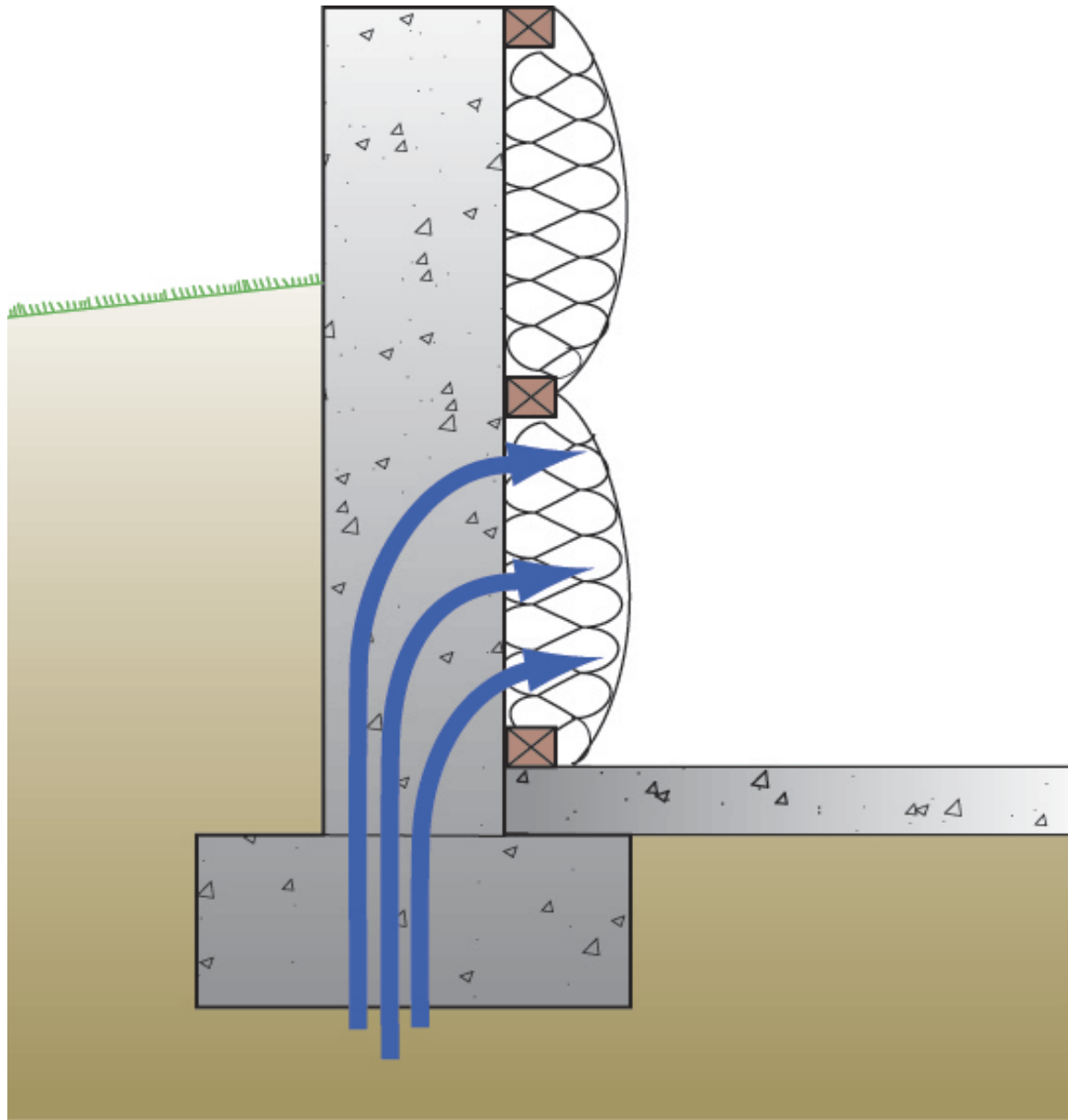






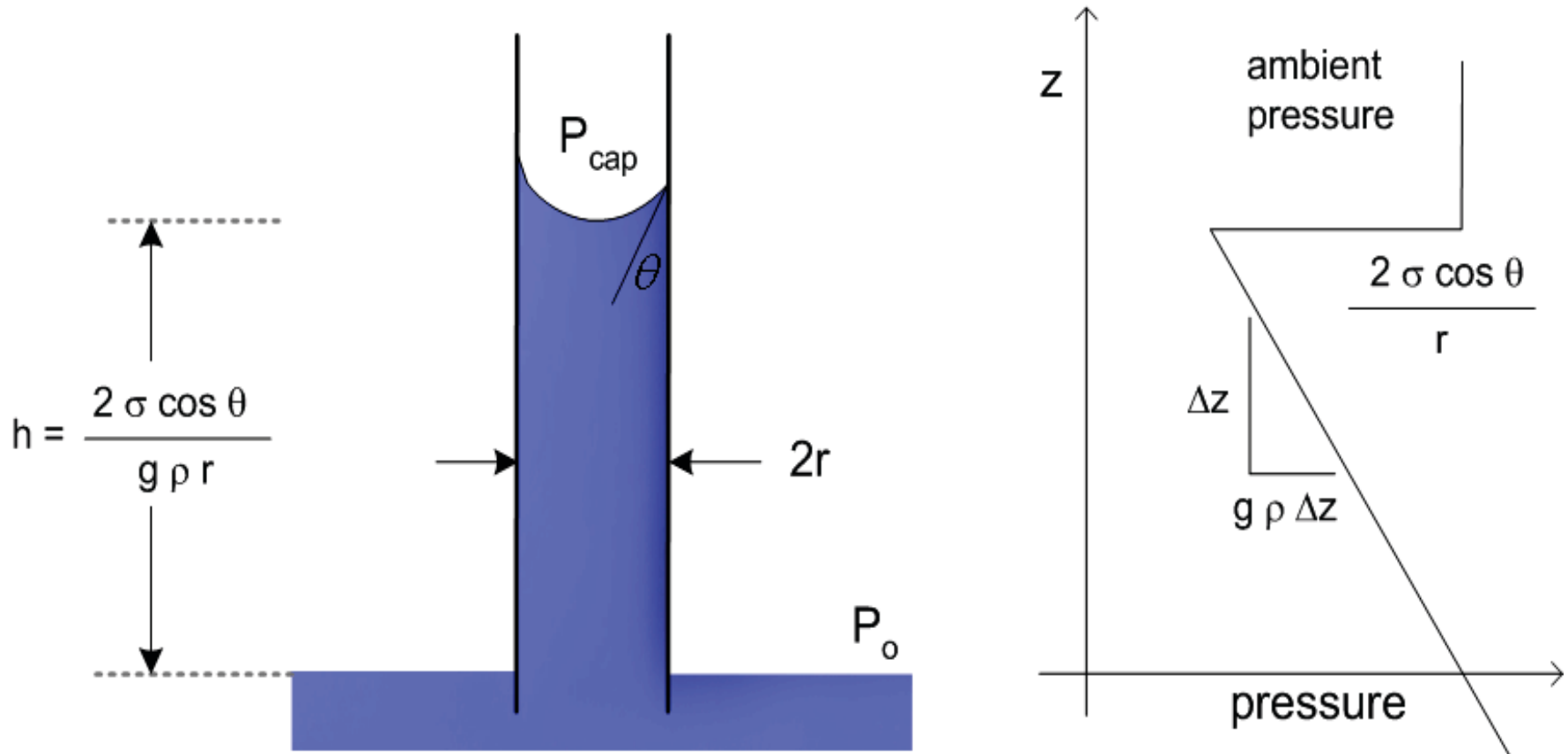




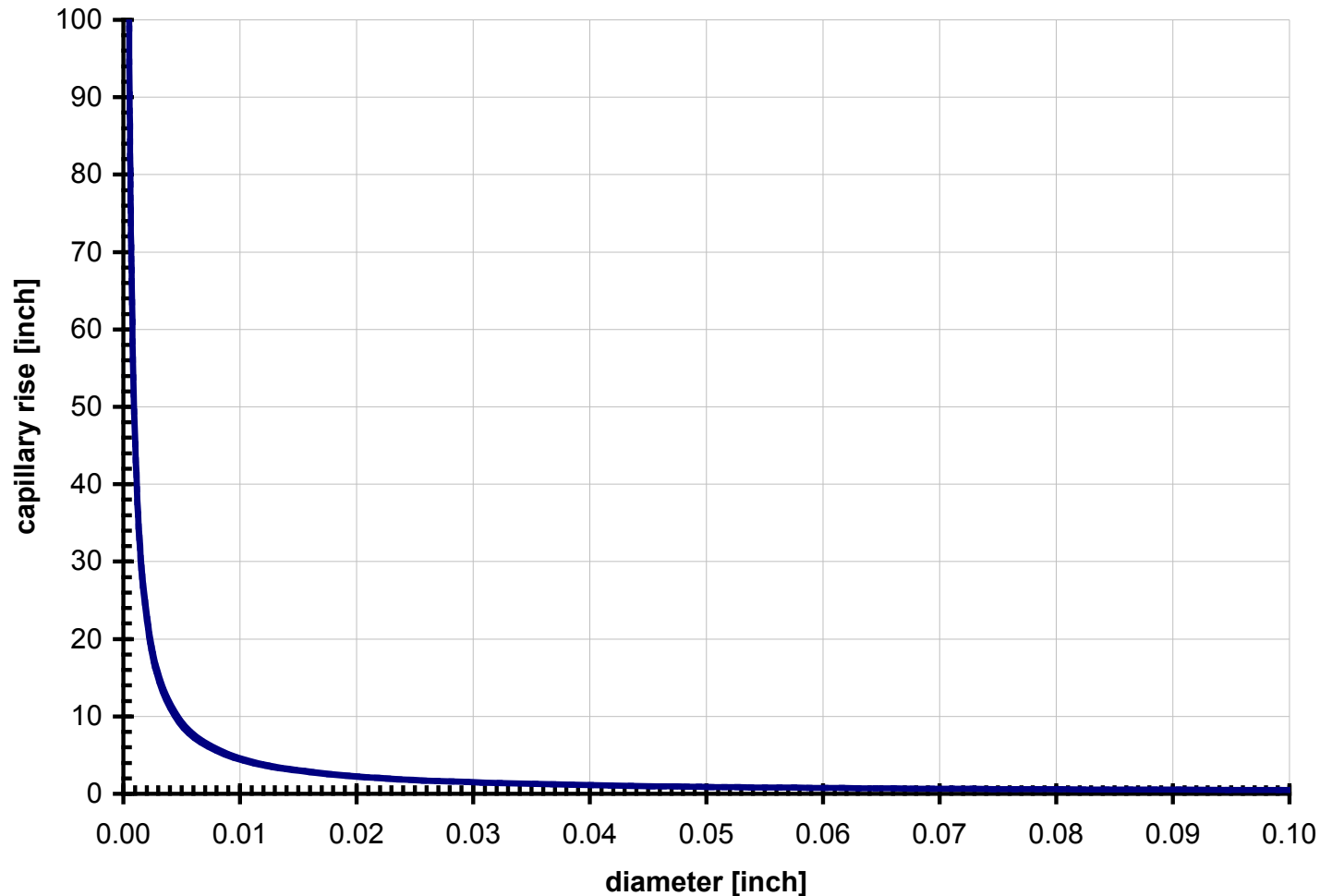




# Calculating capillary rise

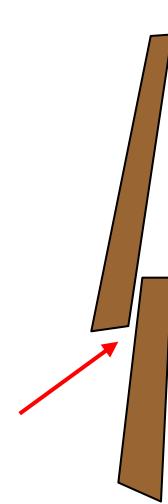


# Capillary rise versus diameter



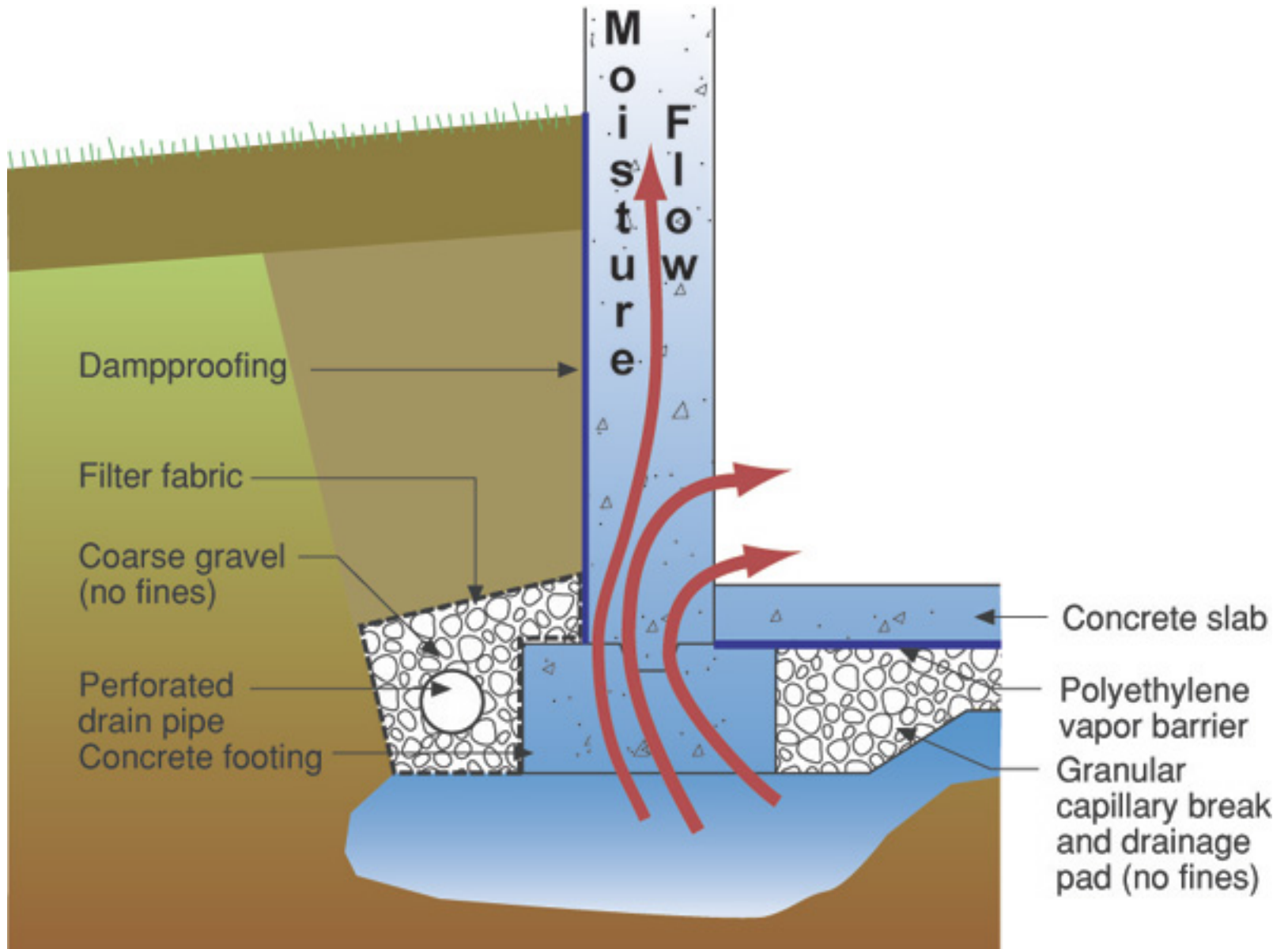
# Capillary Flow

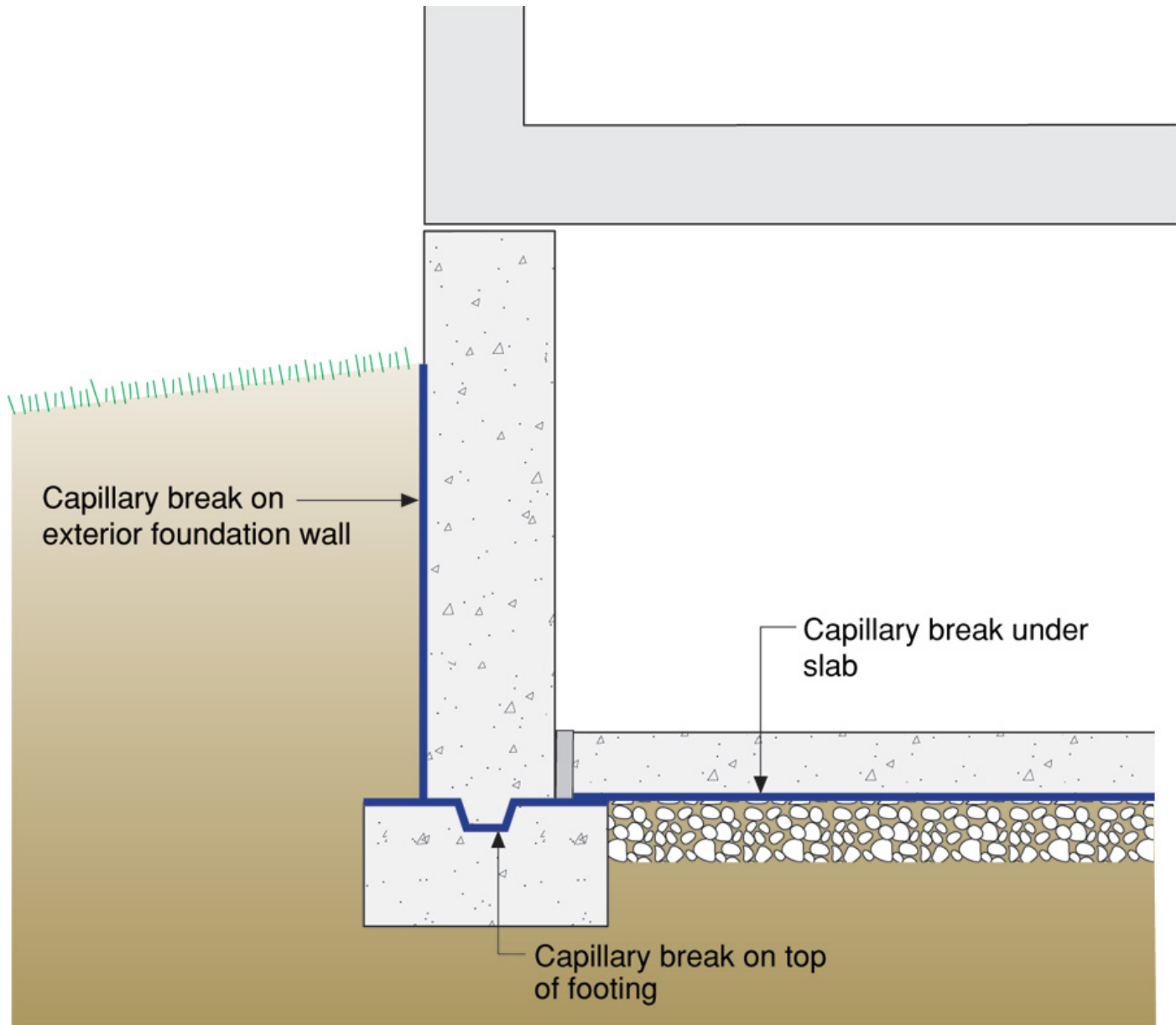
## Siding laps

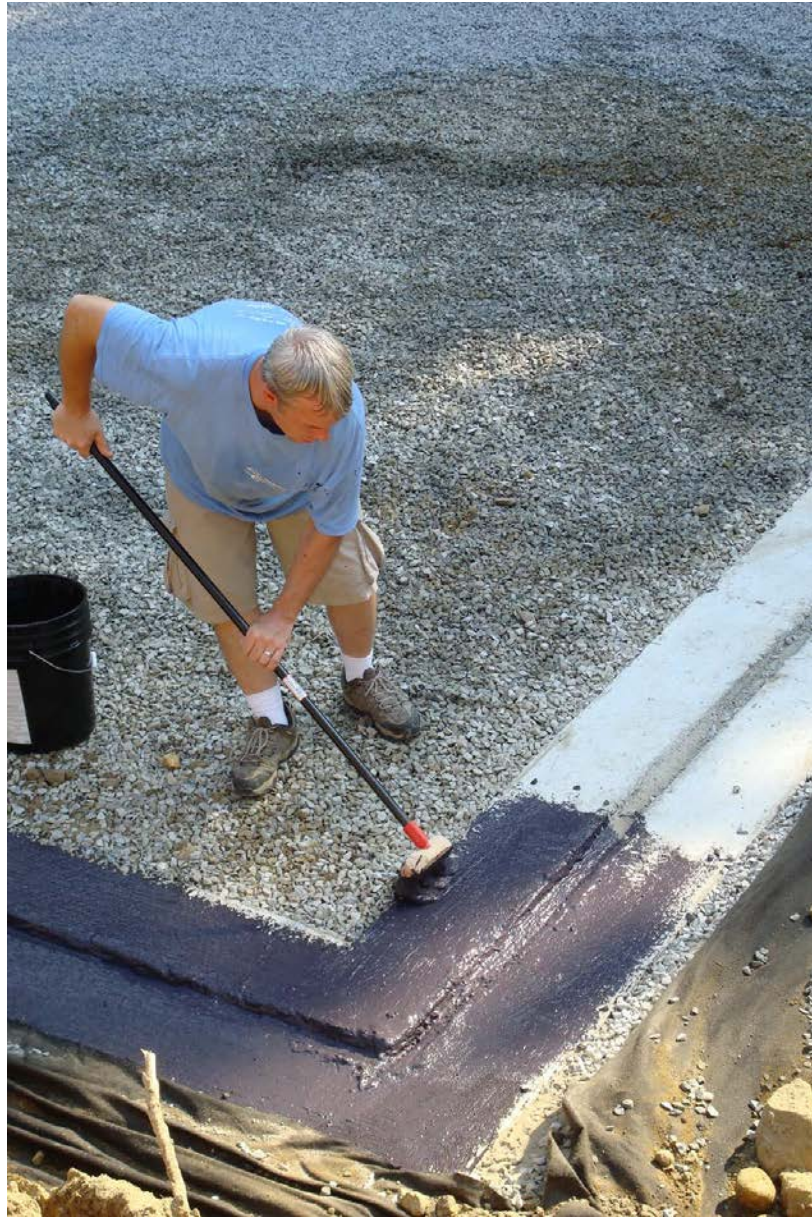




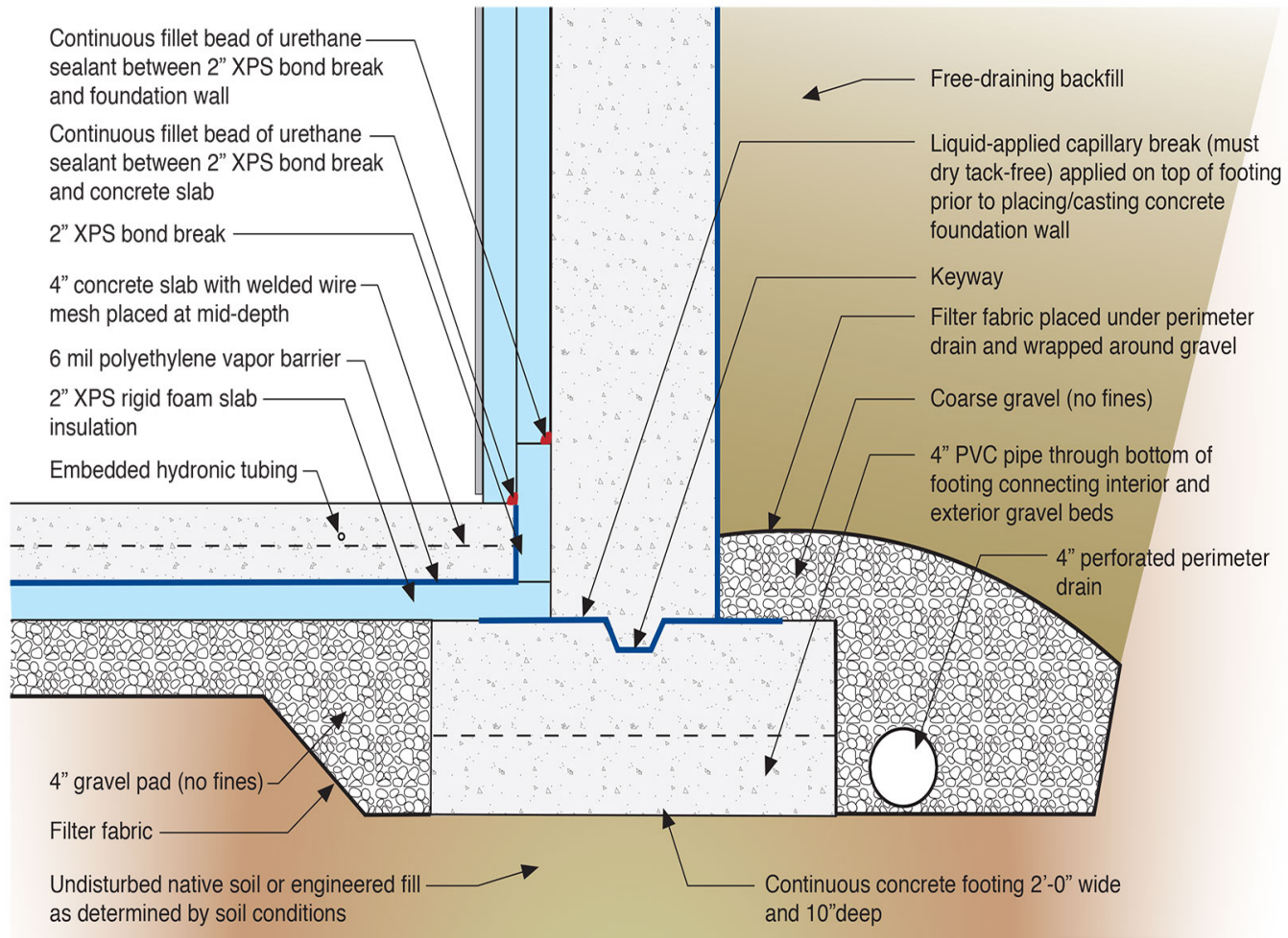










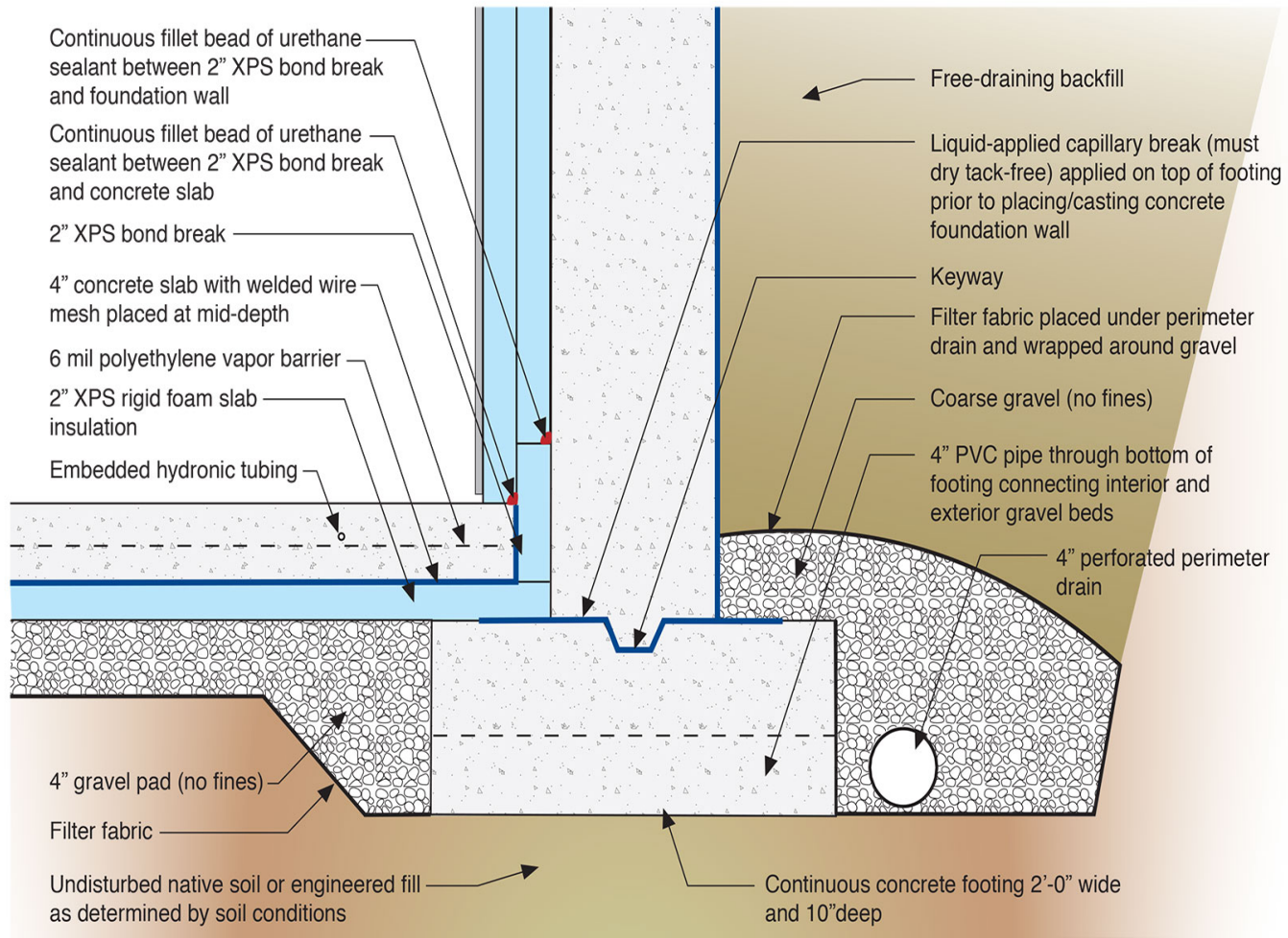




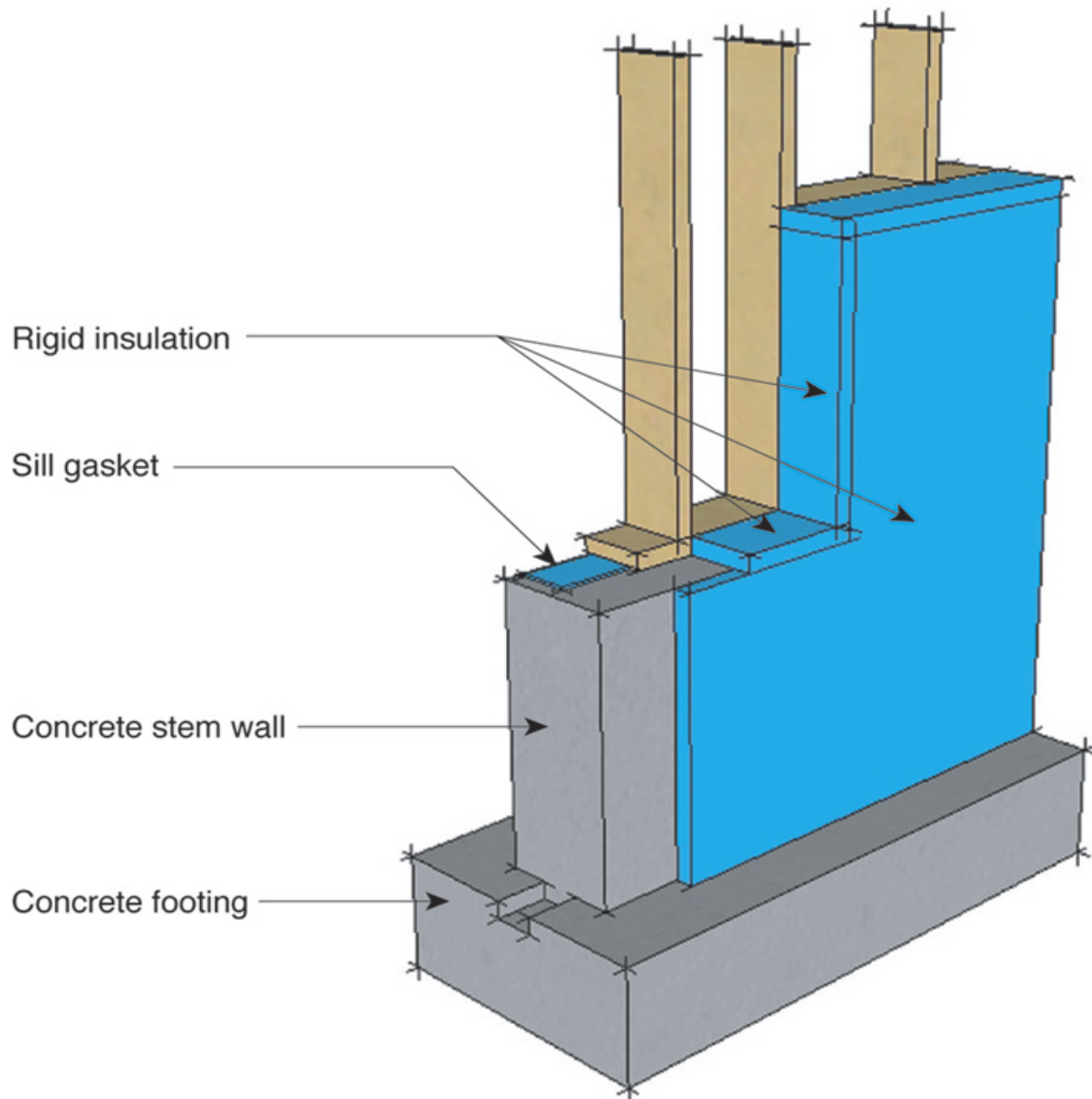




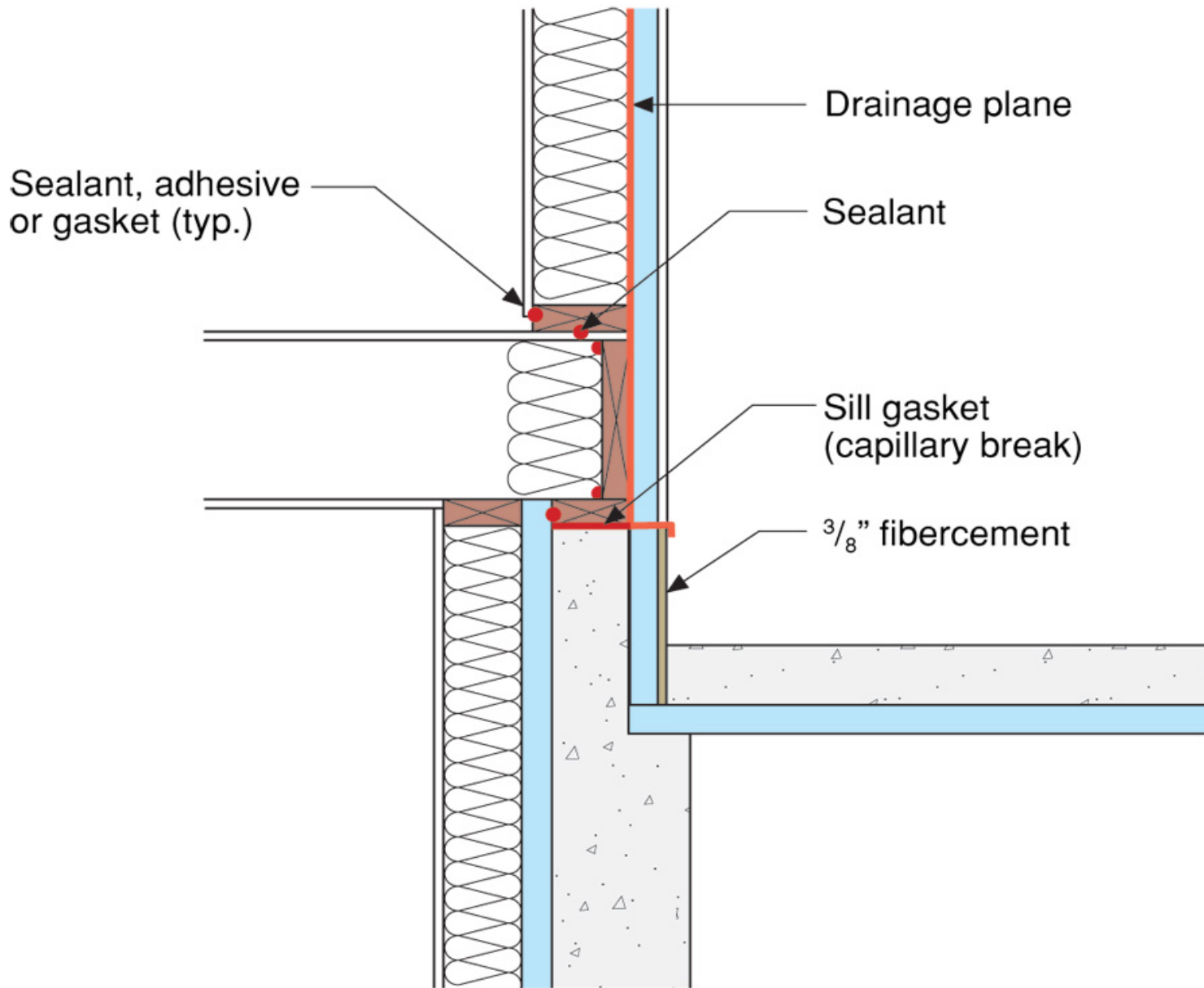


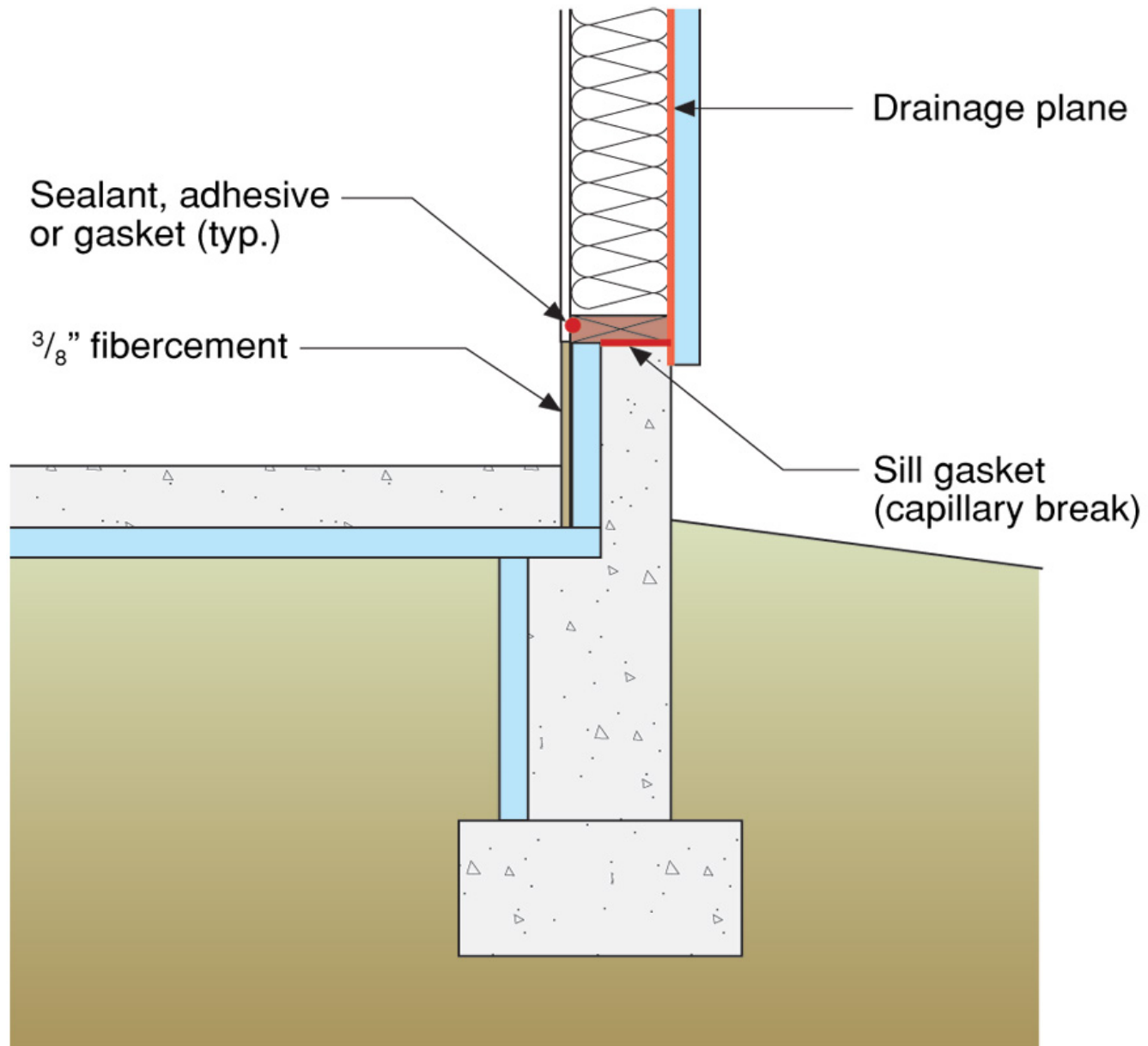


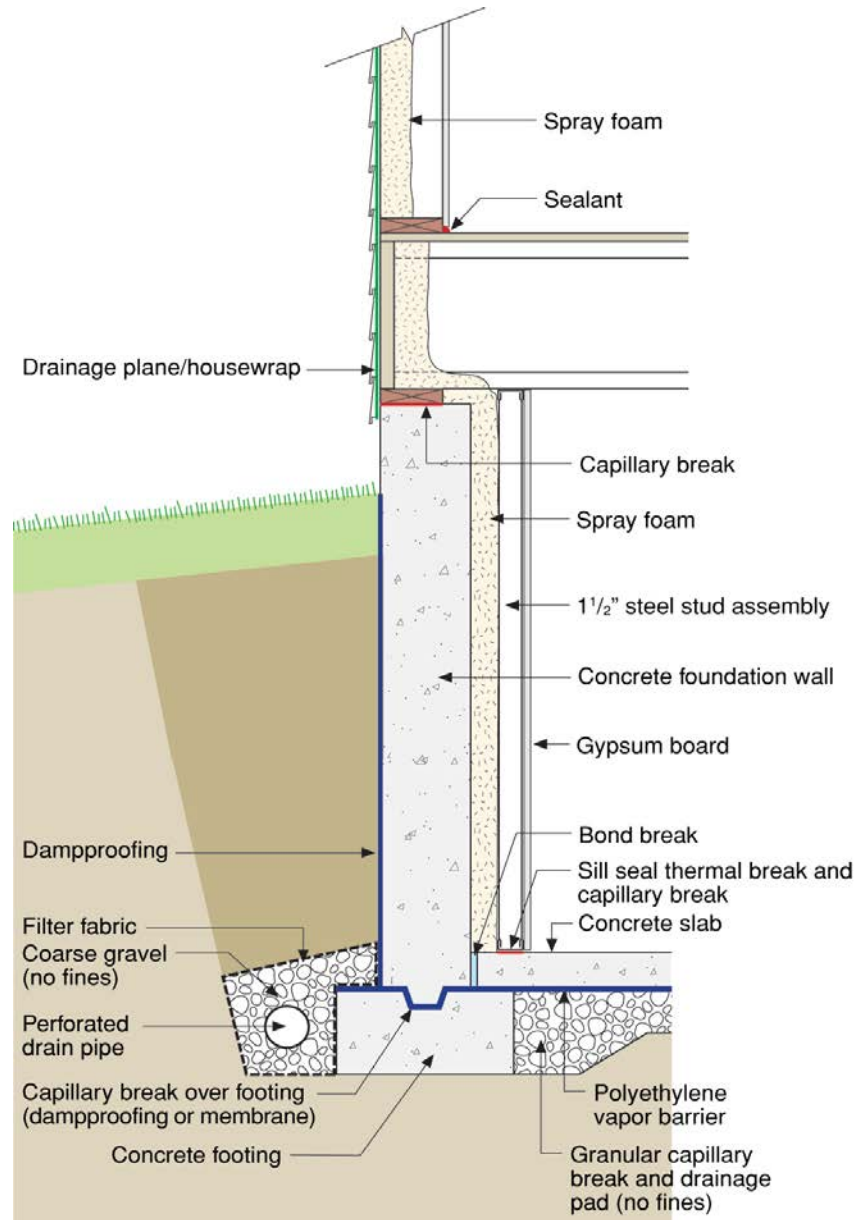






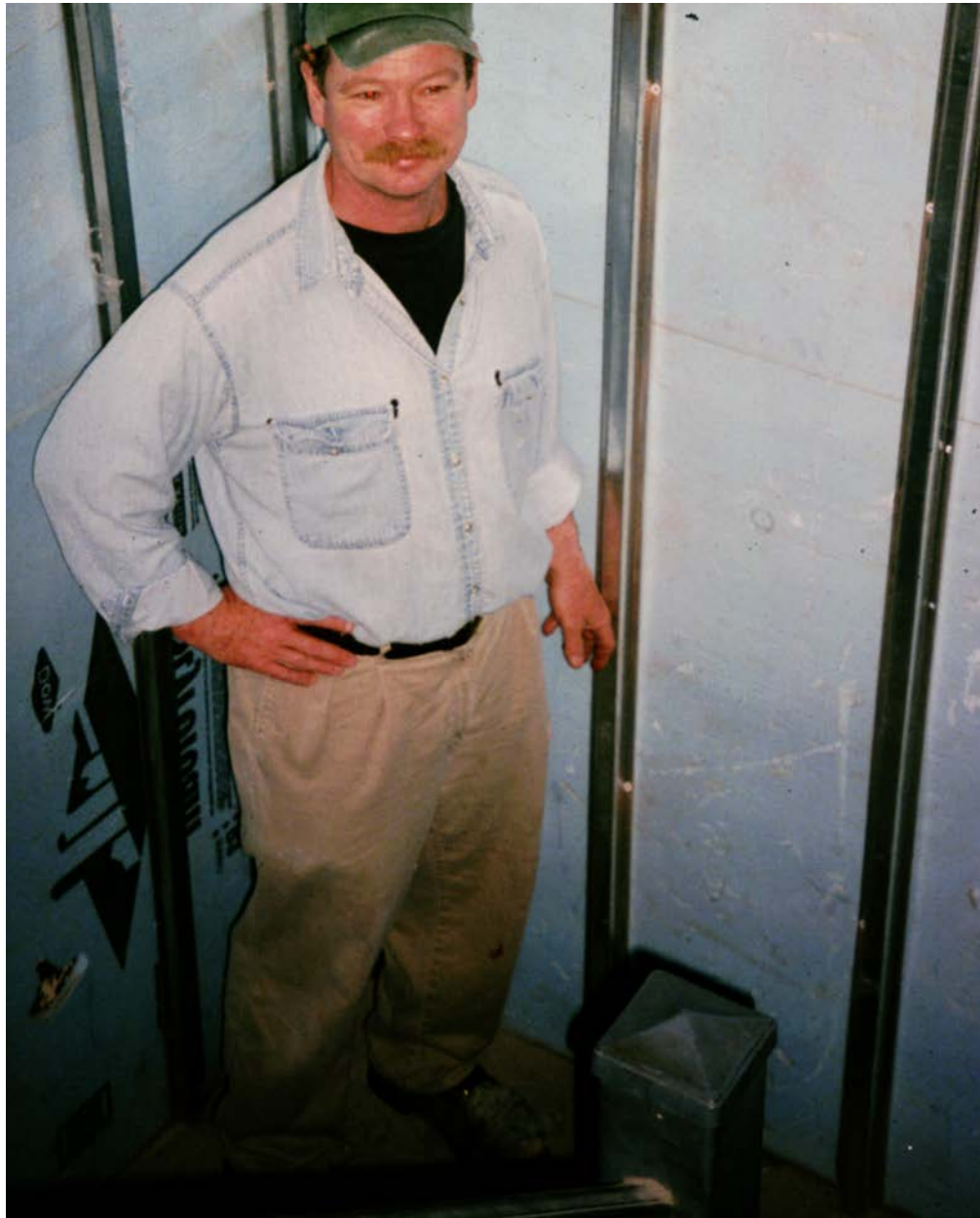








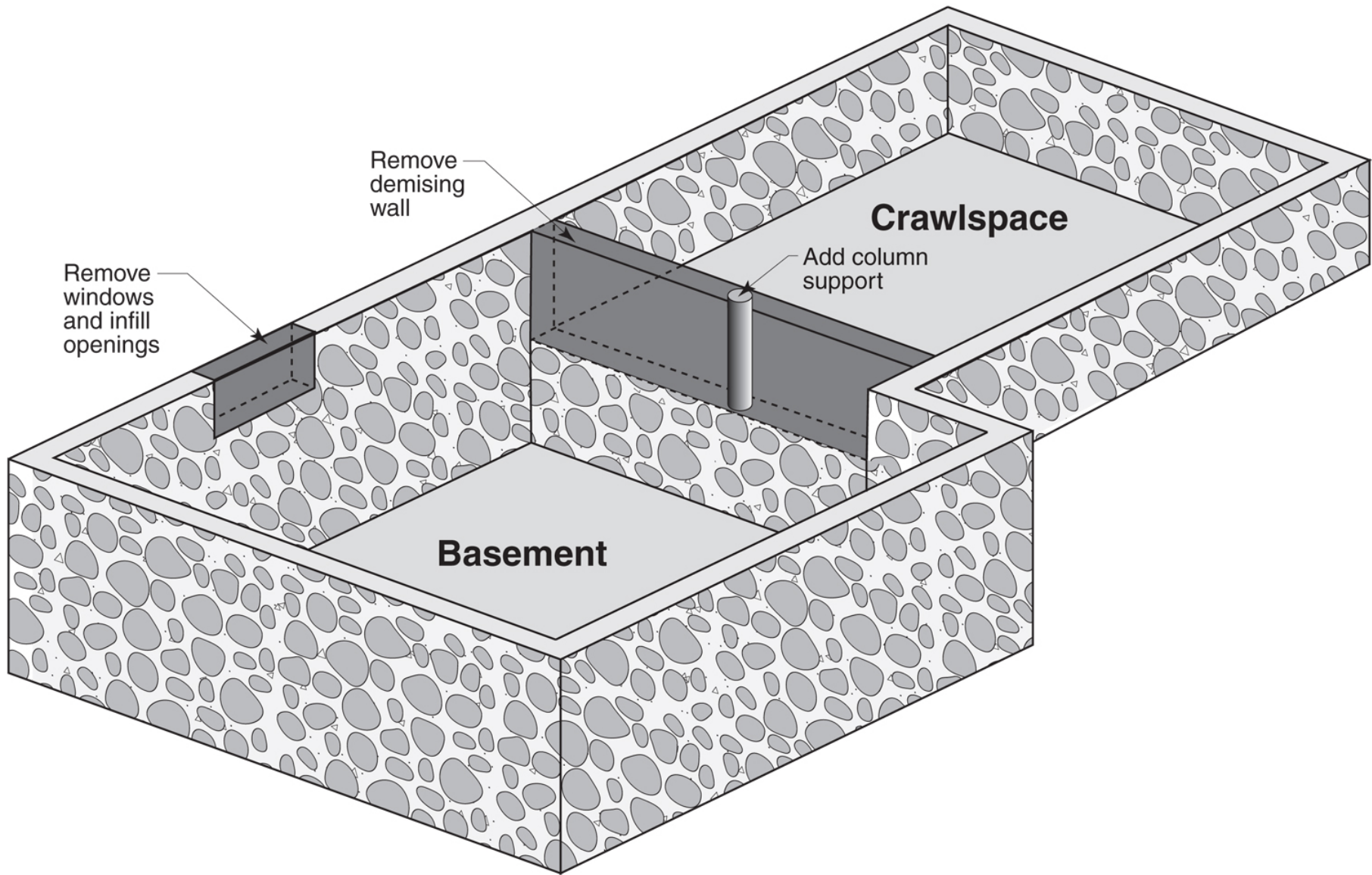




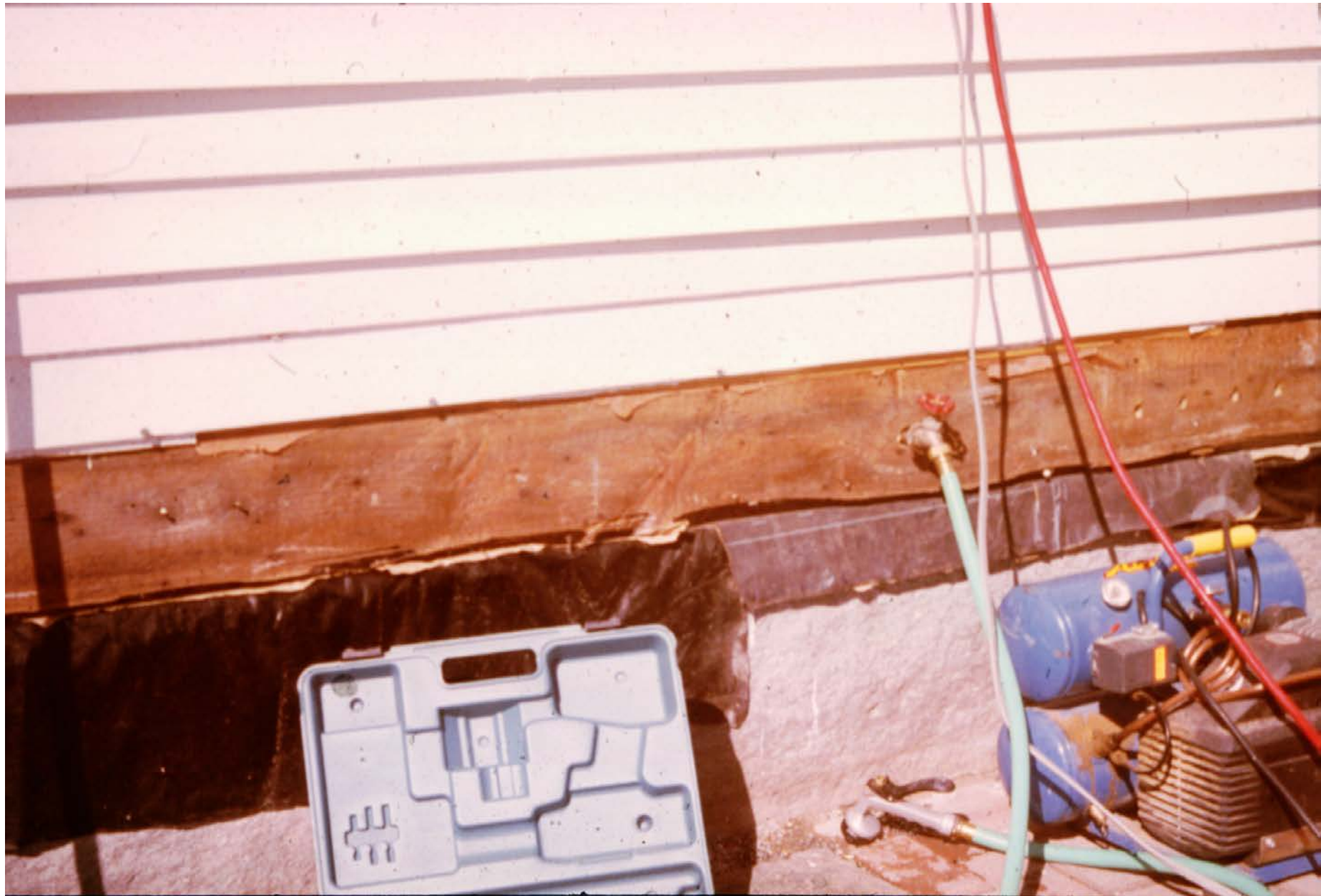




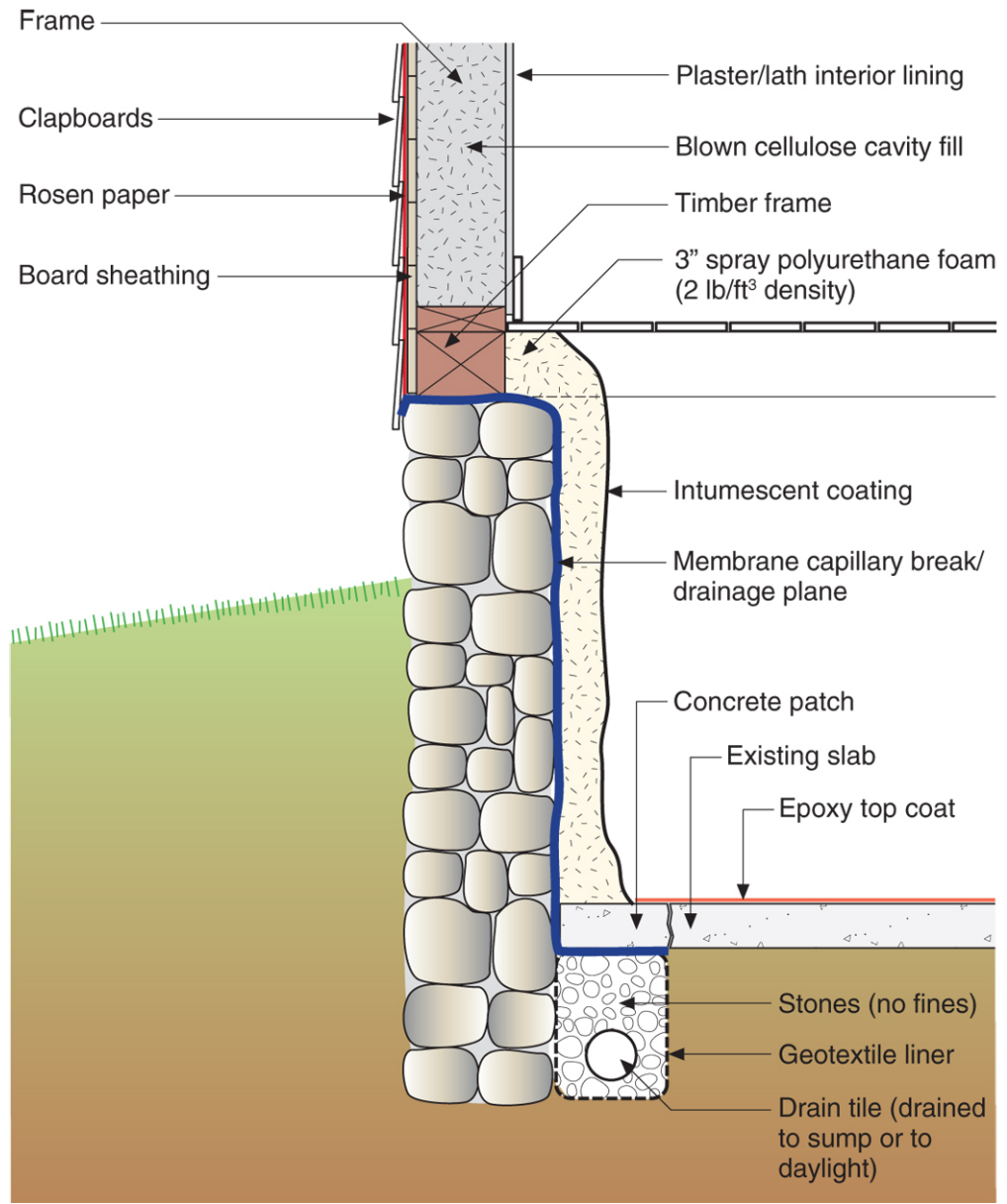










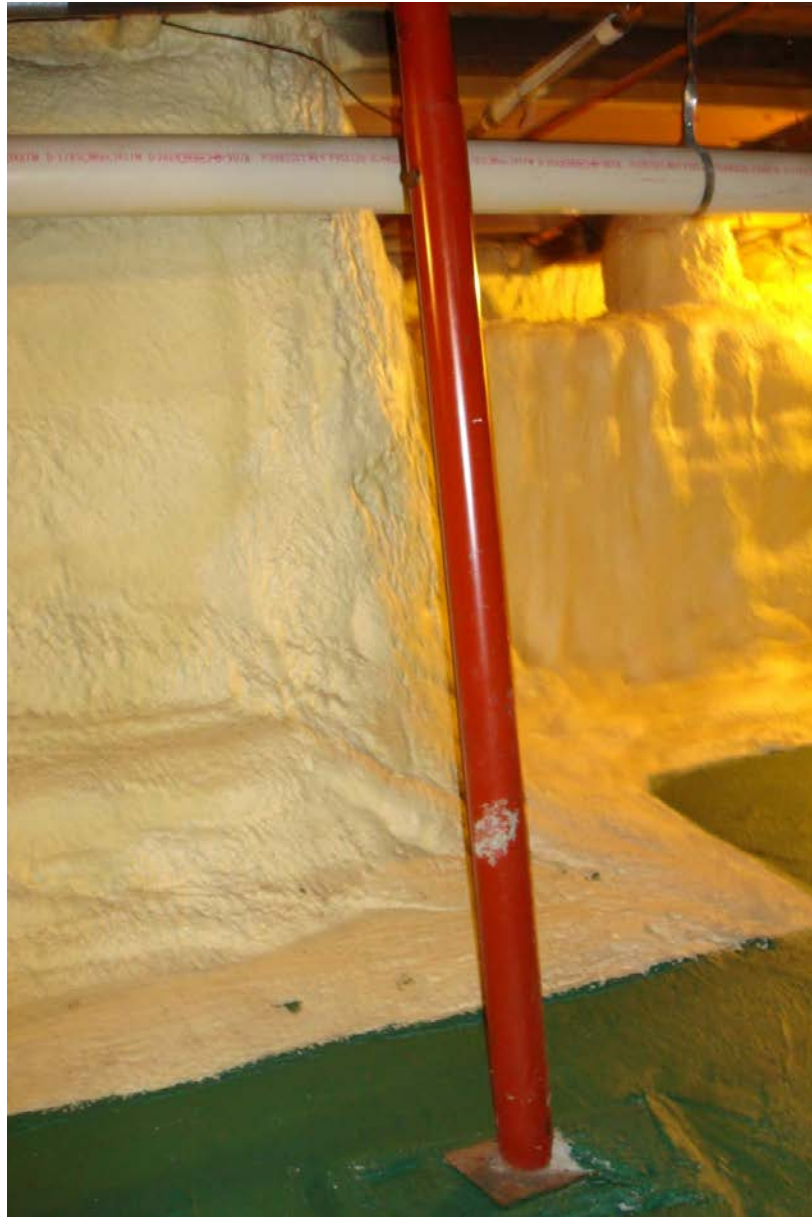




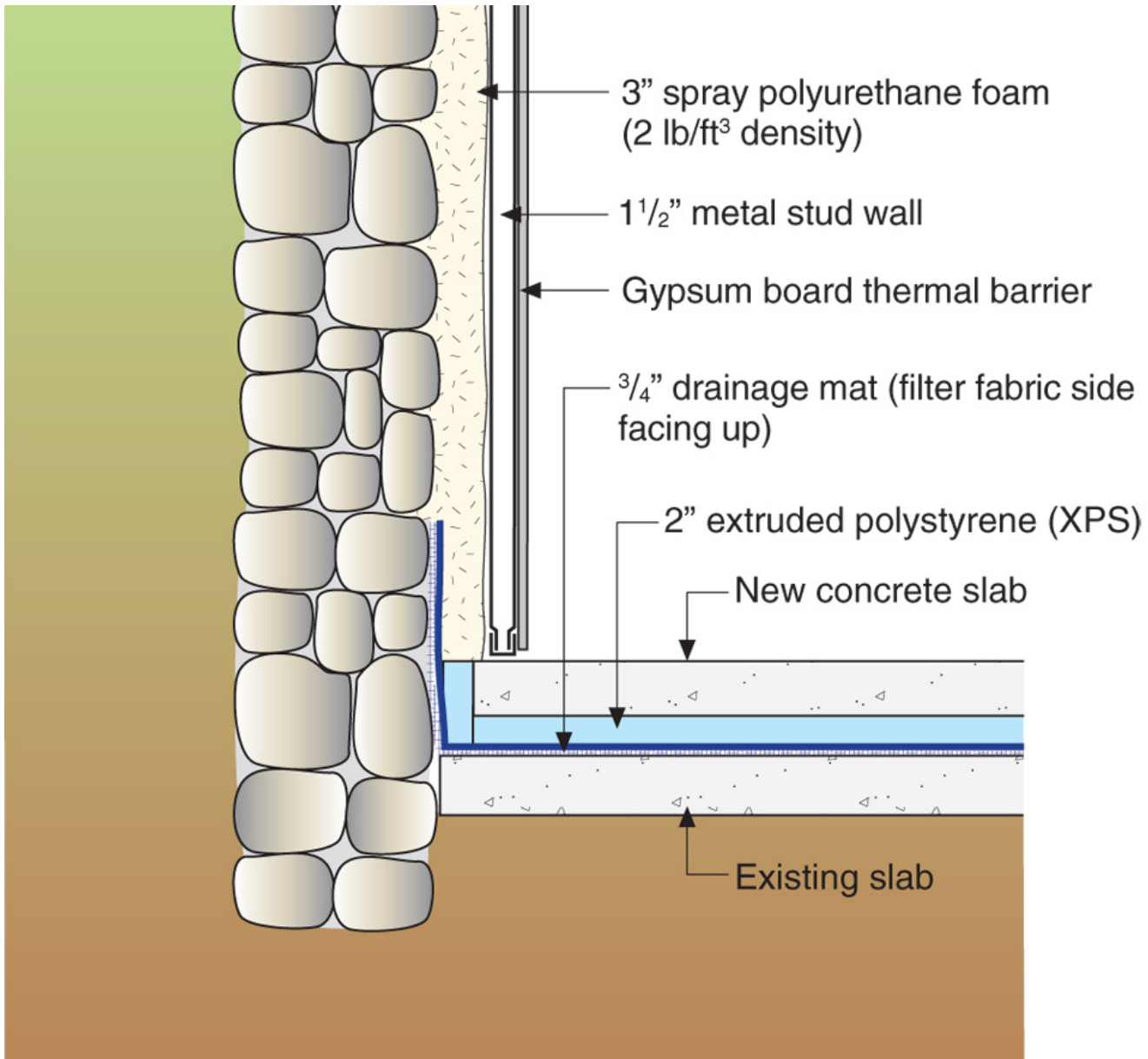


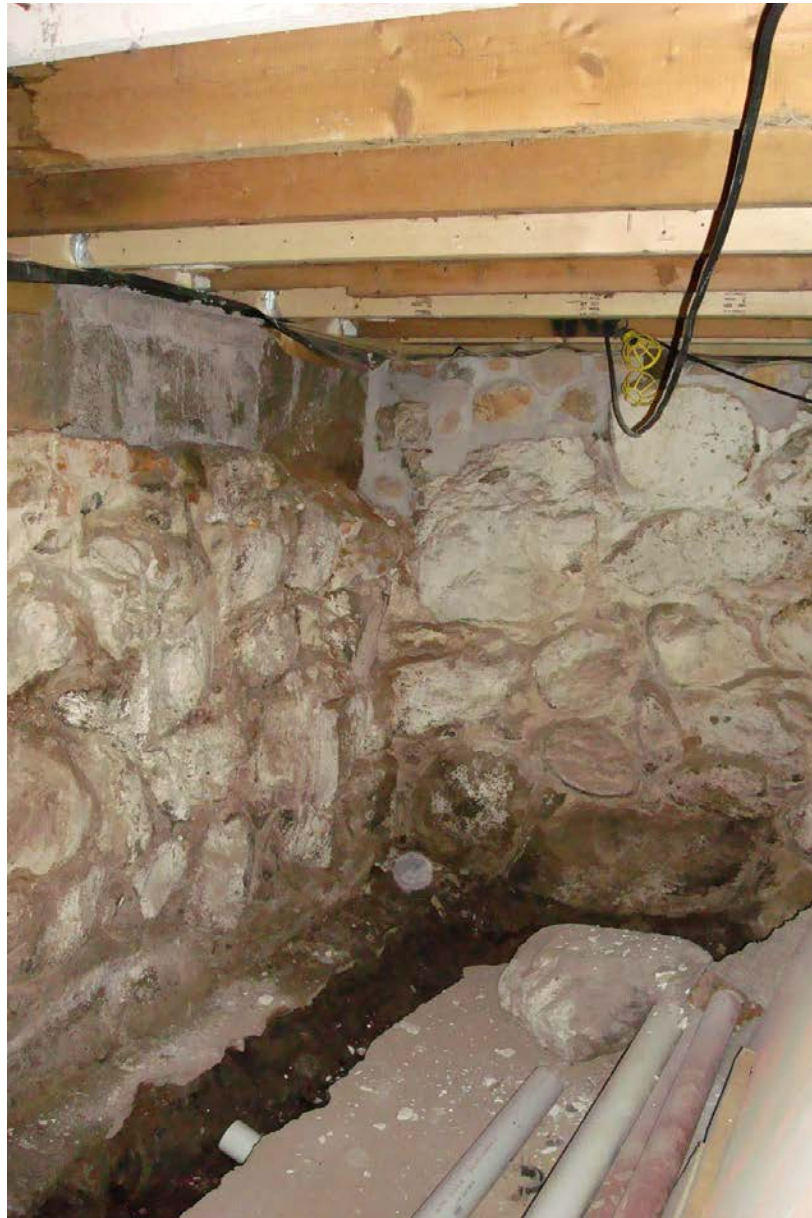






















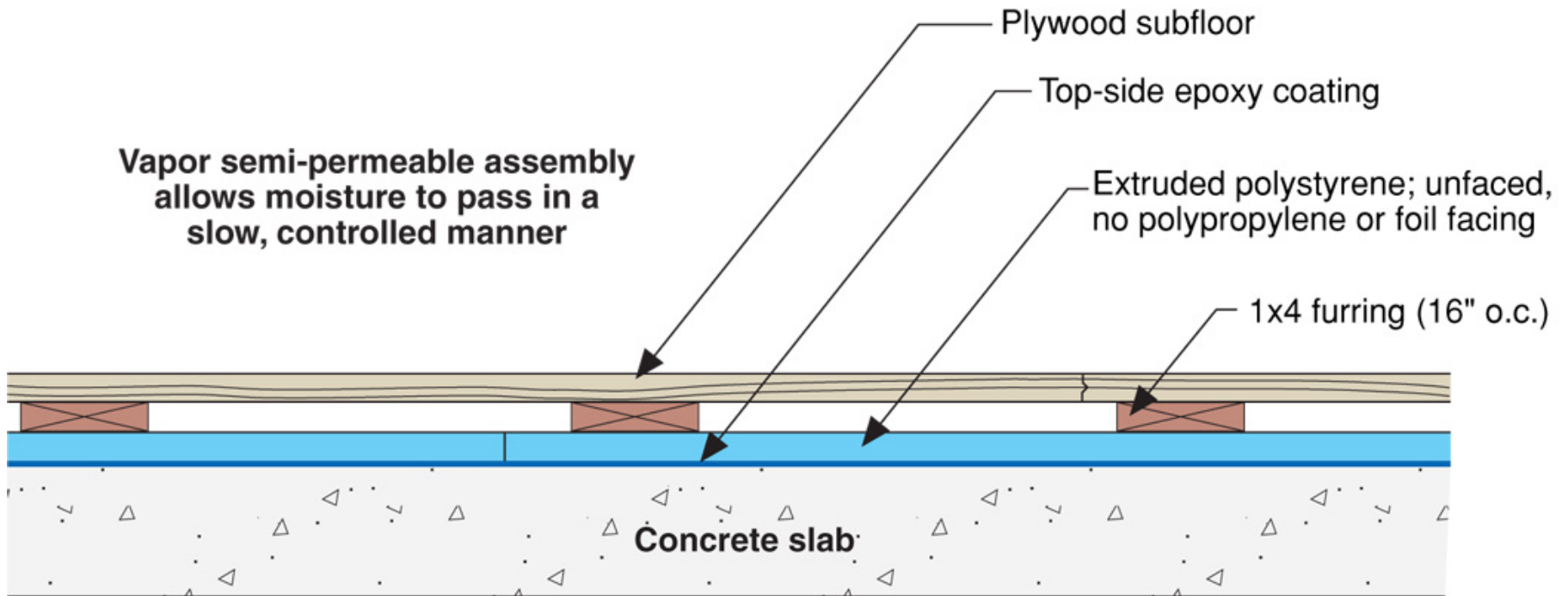








**Vapor semi-permeable assembly  
allows moisture to pass in a  
slow, controlled manner**

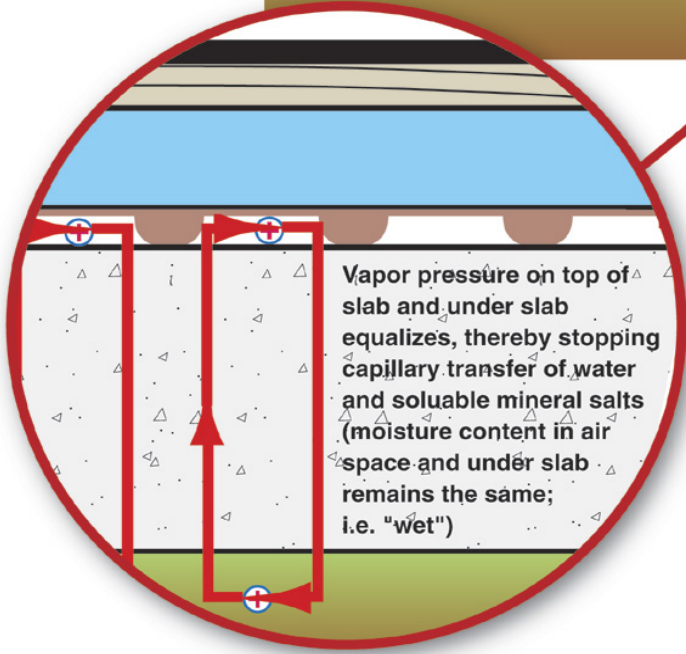
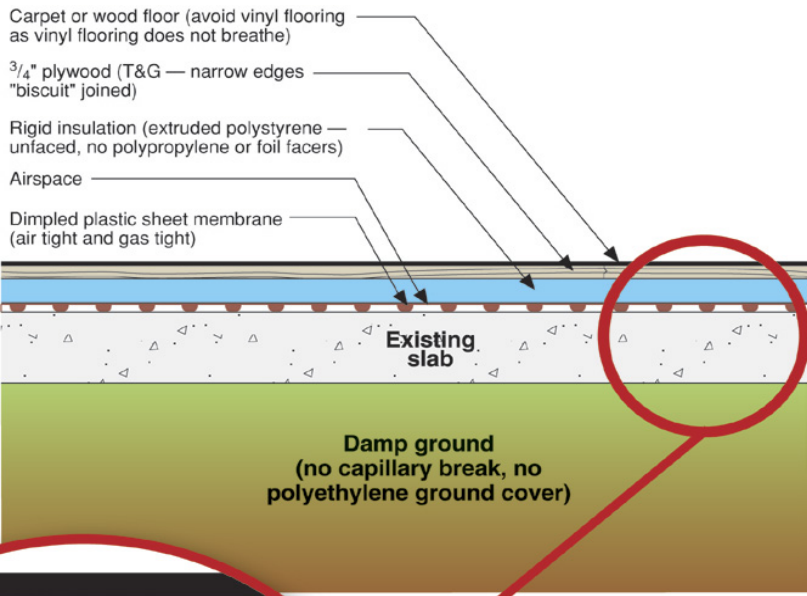




























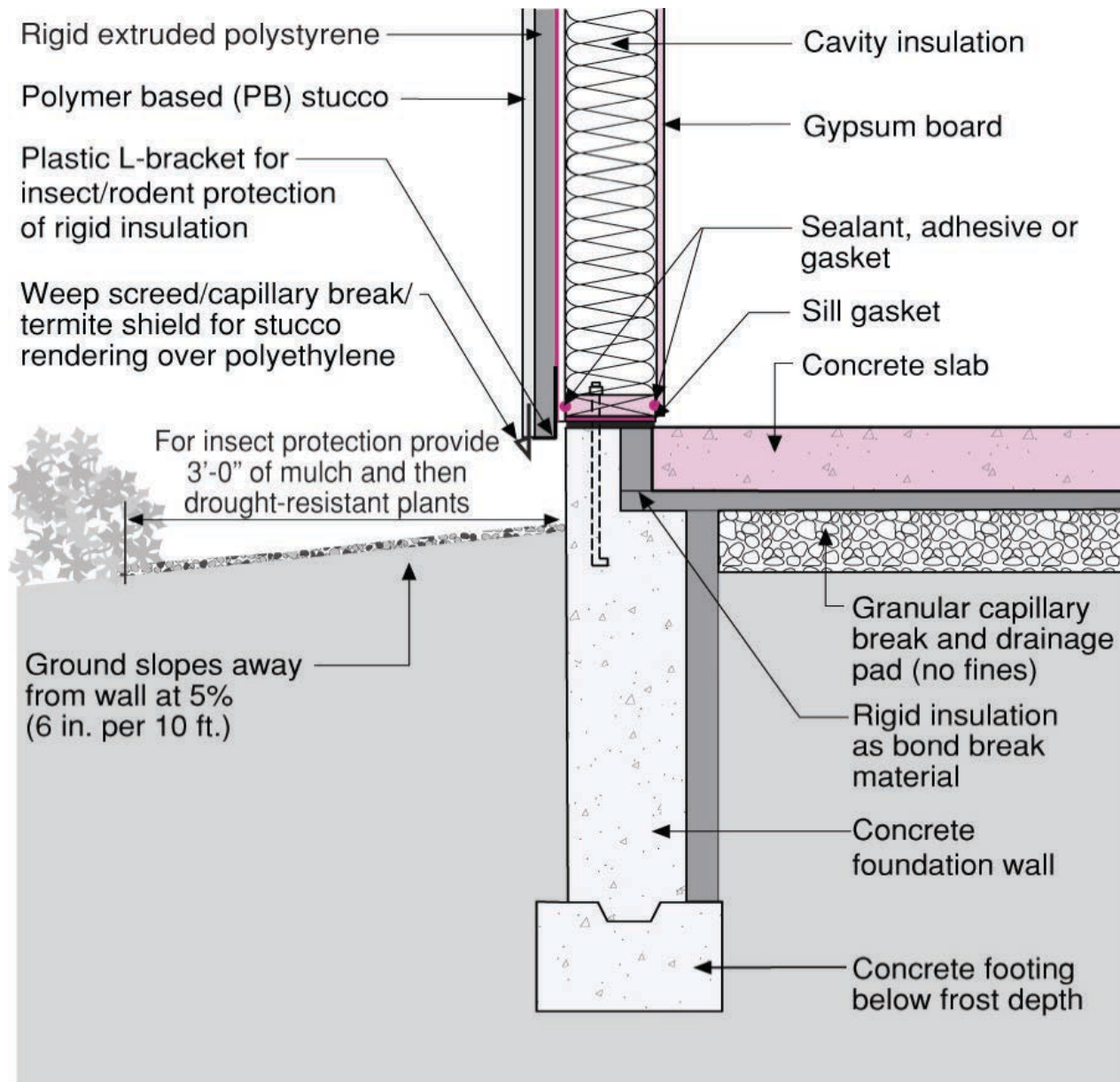
















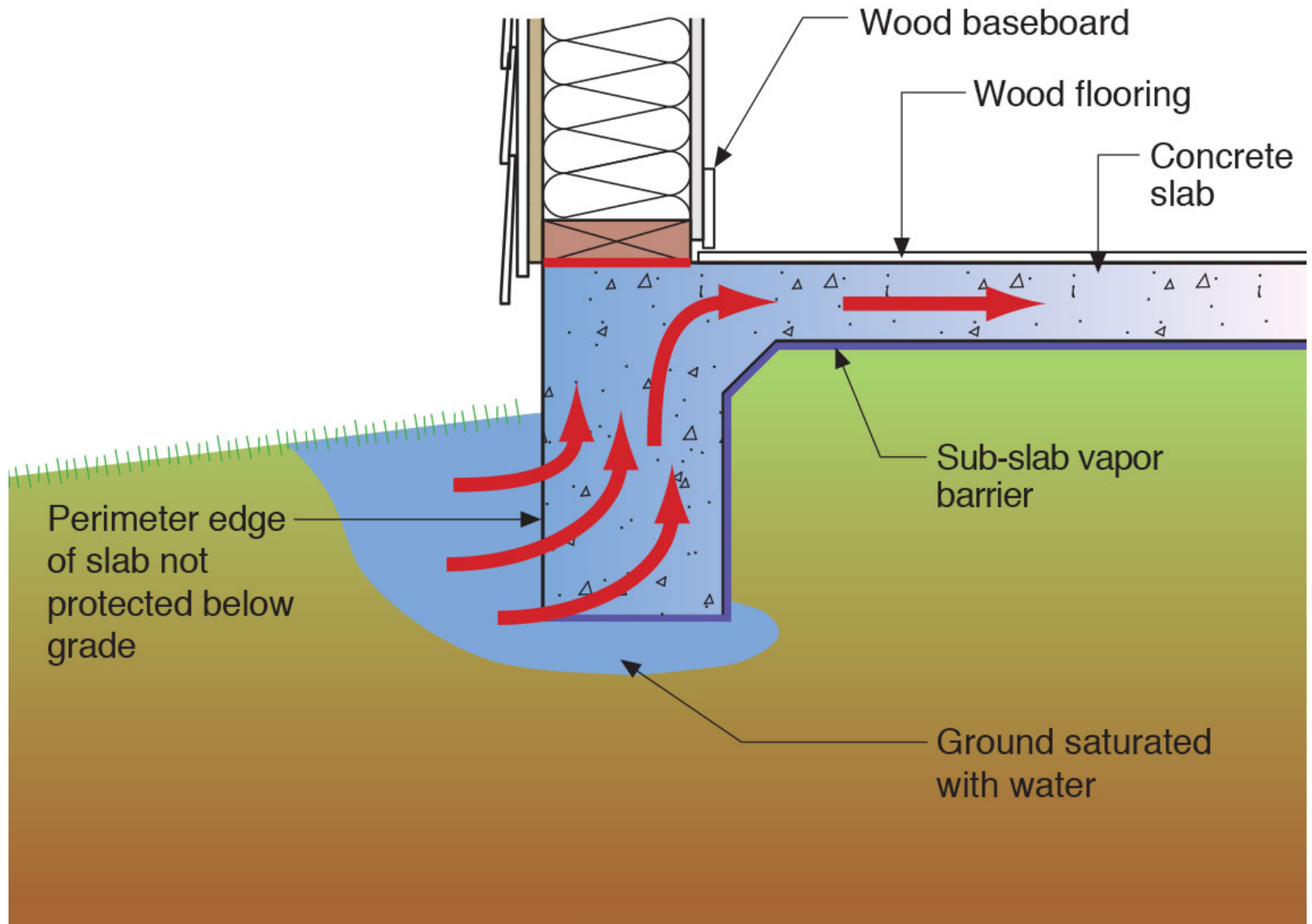










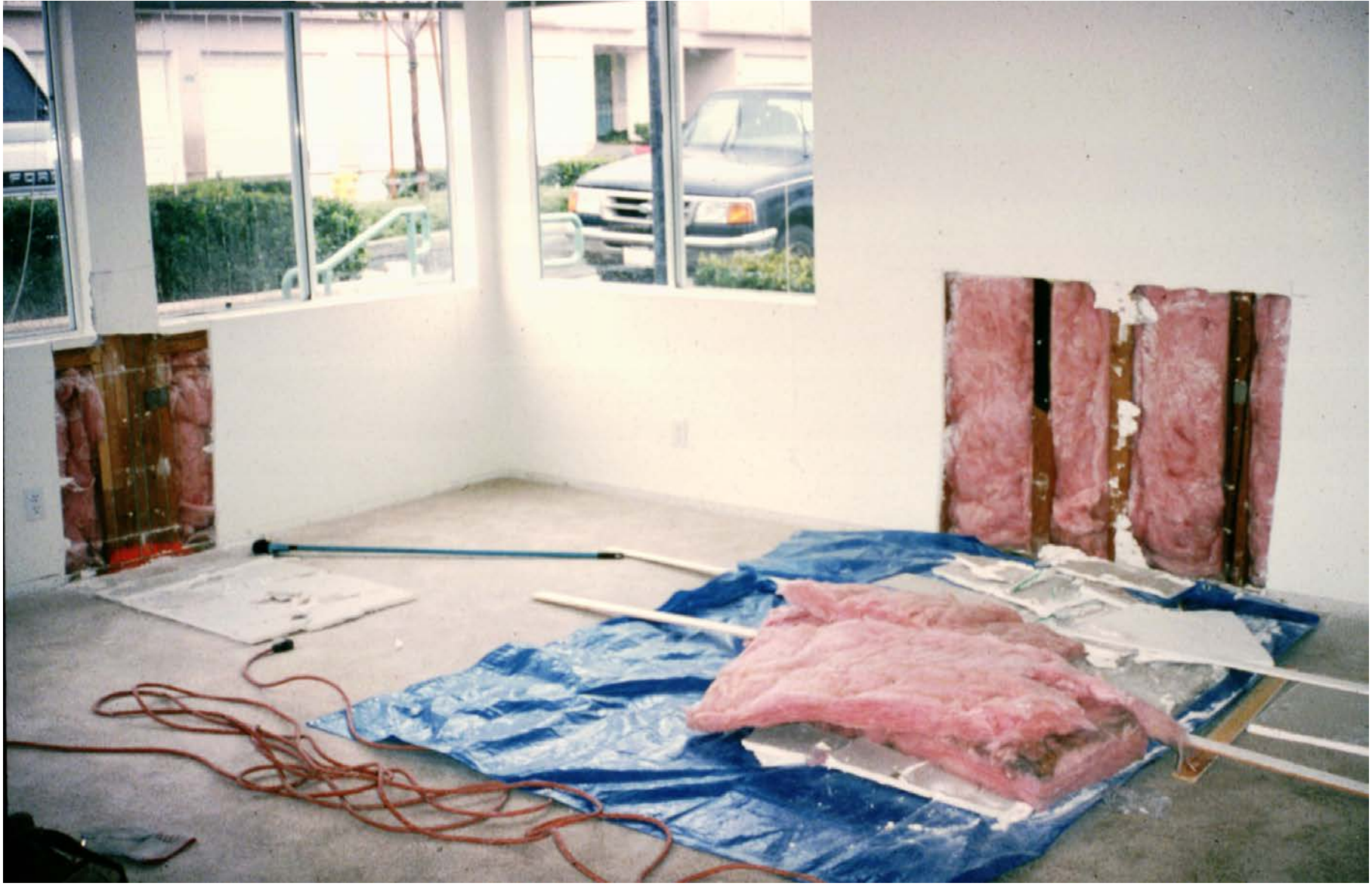














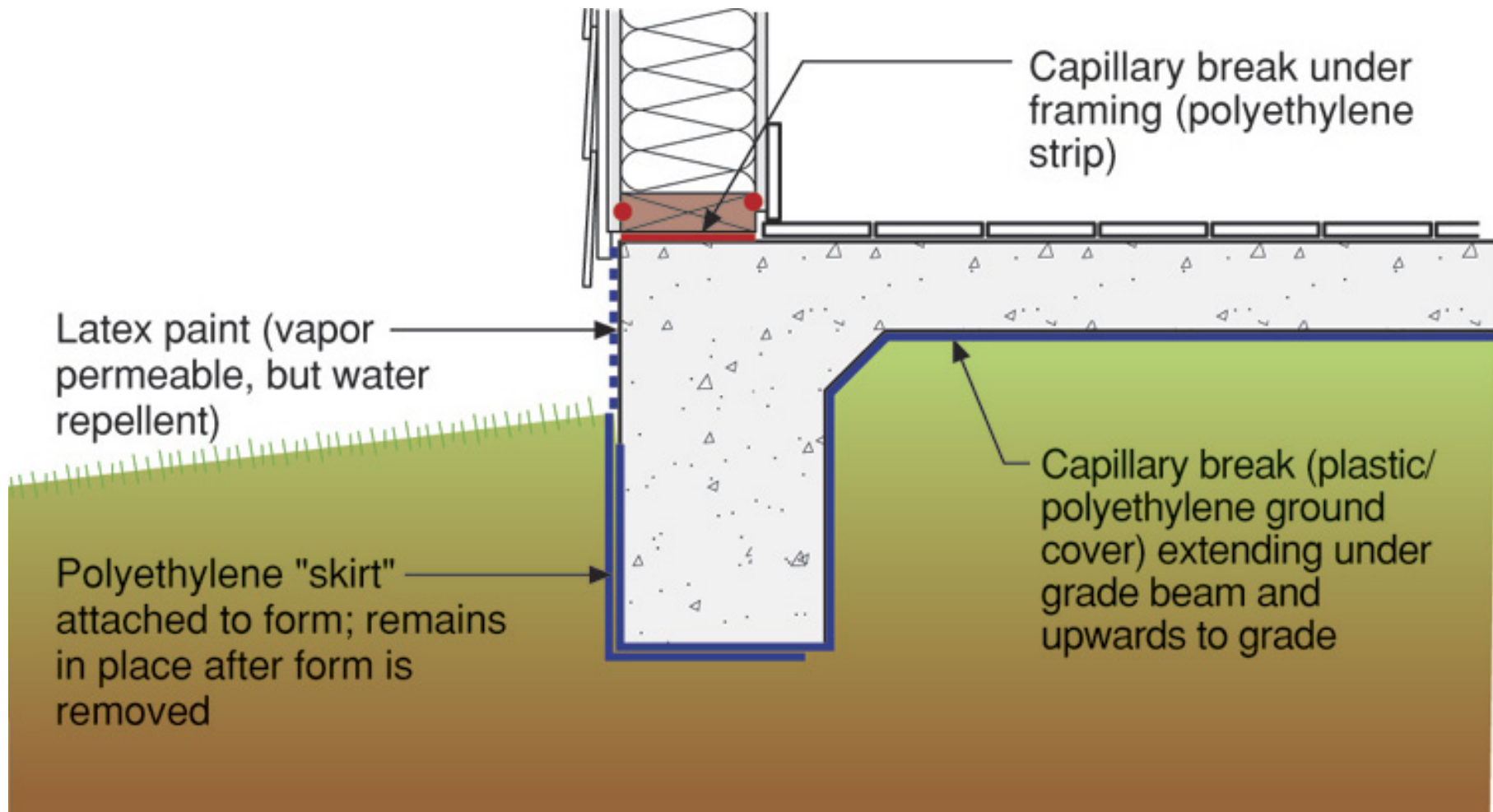








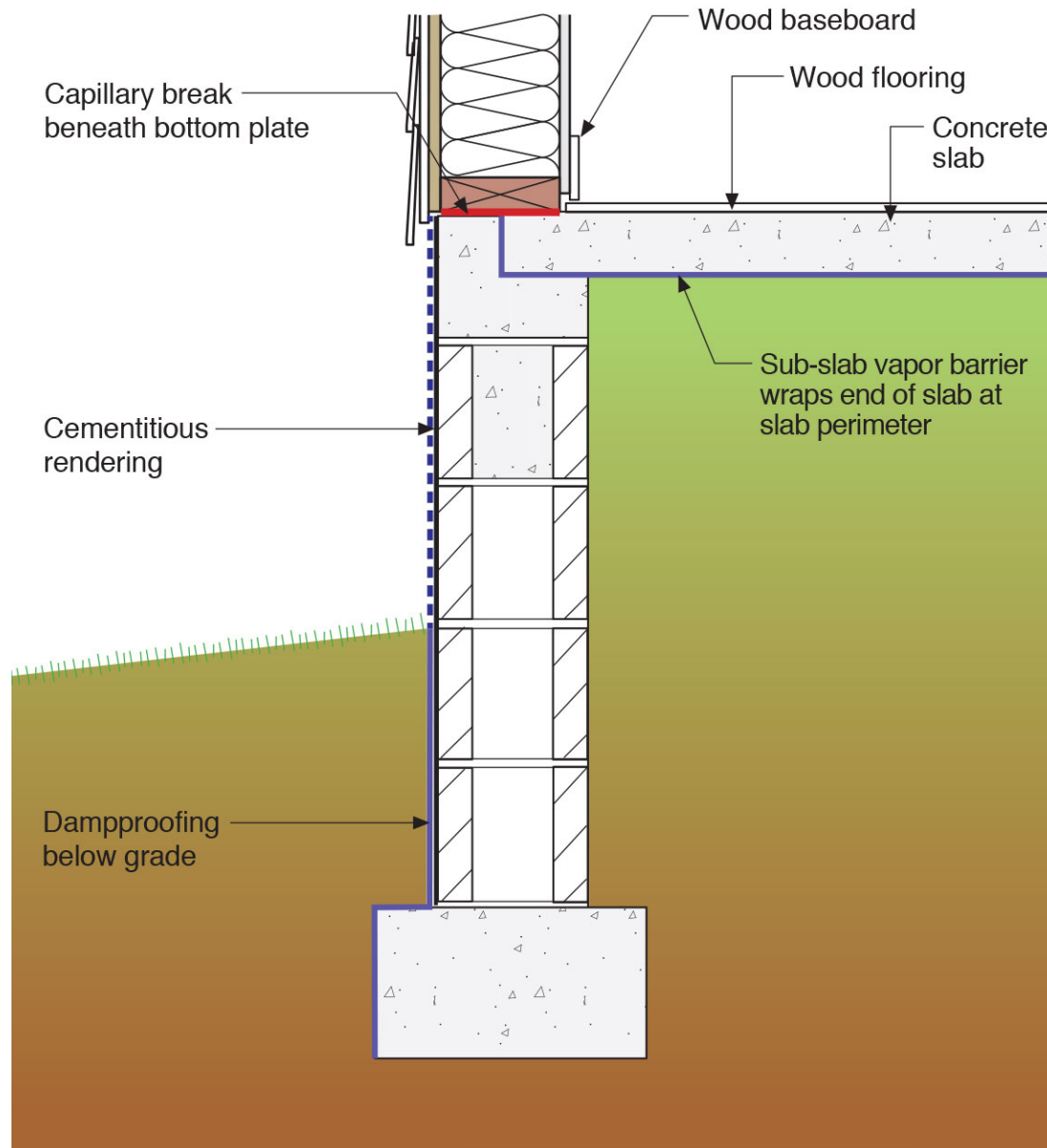






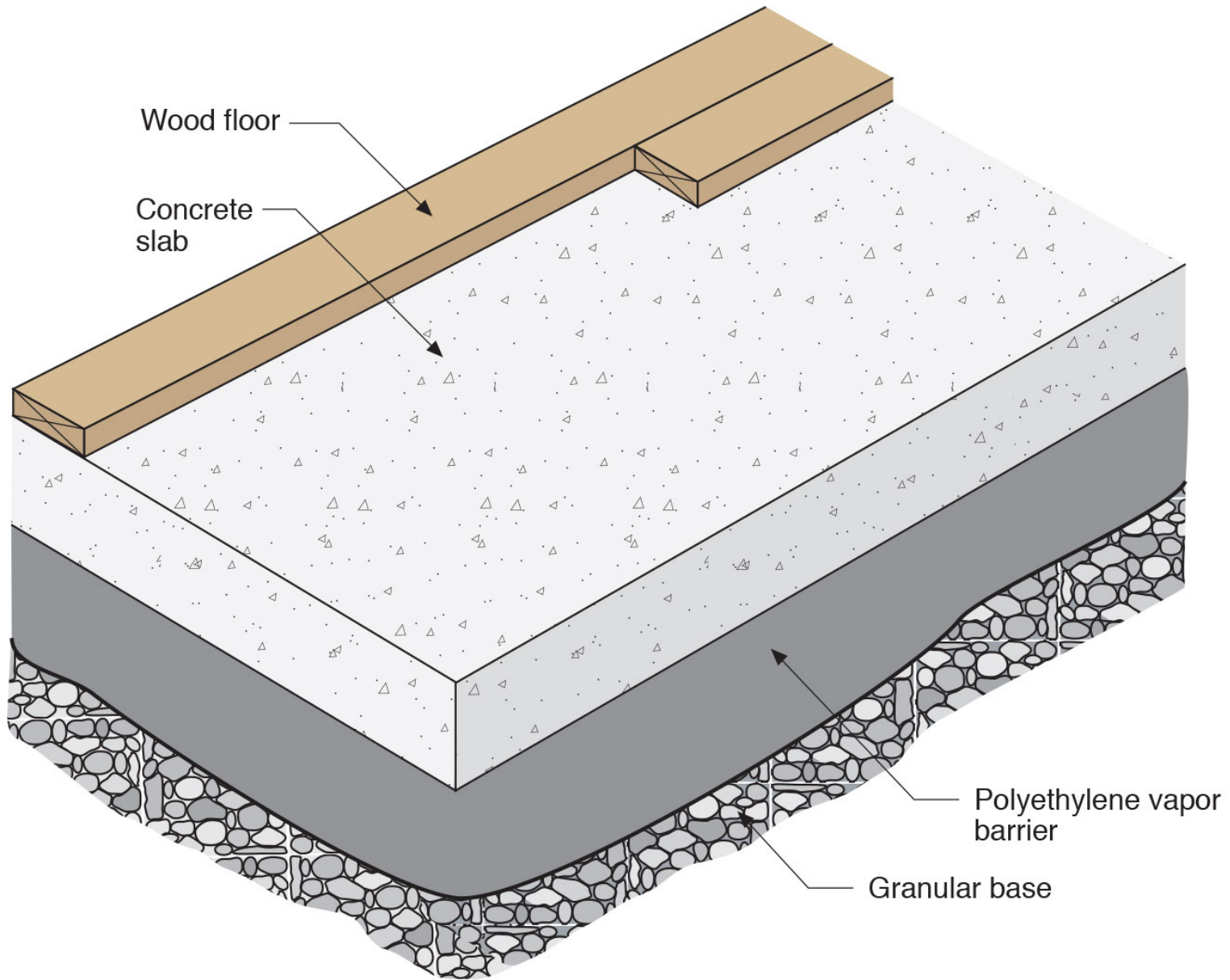


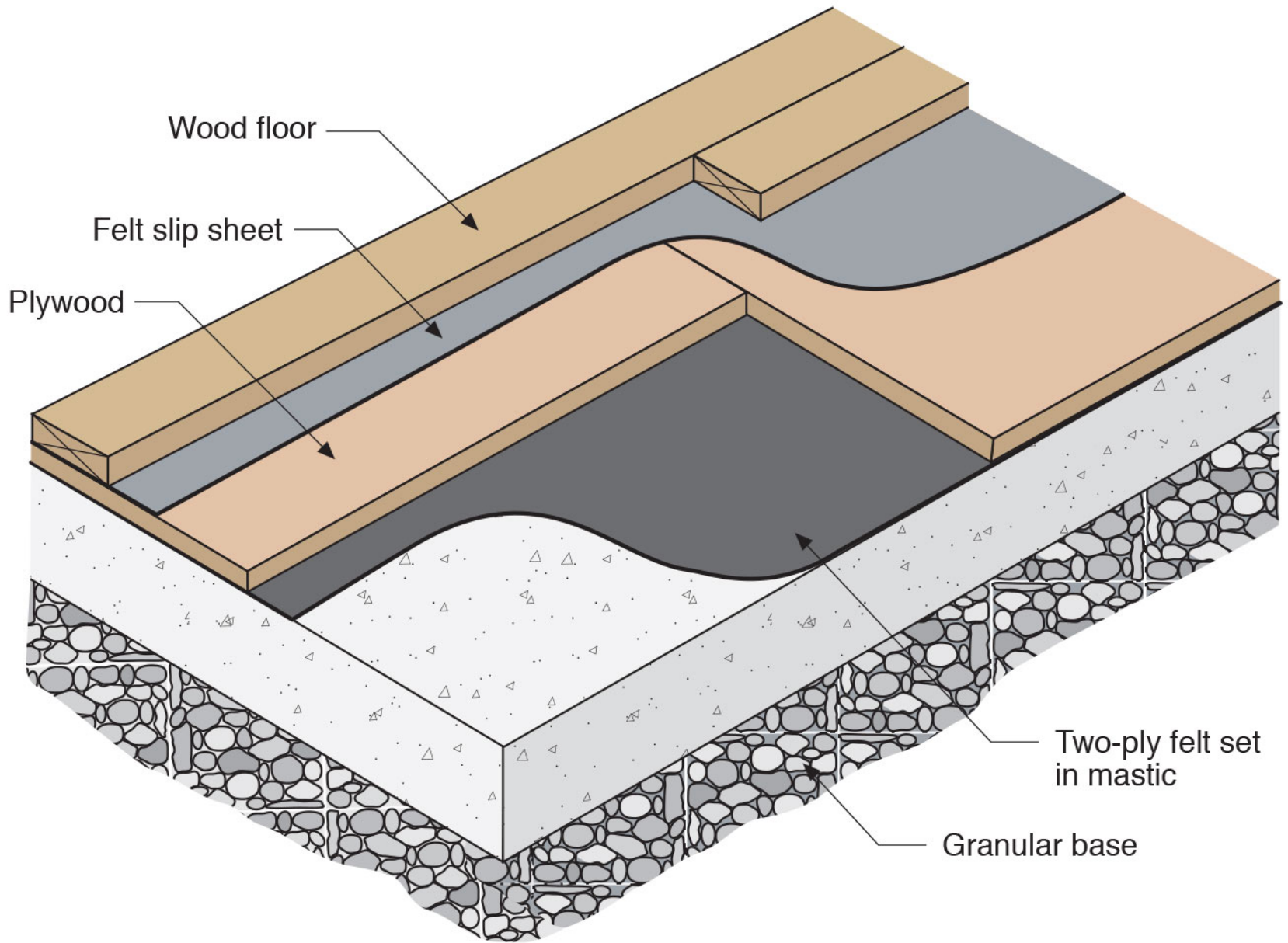






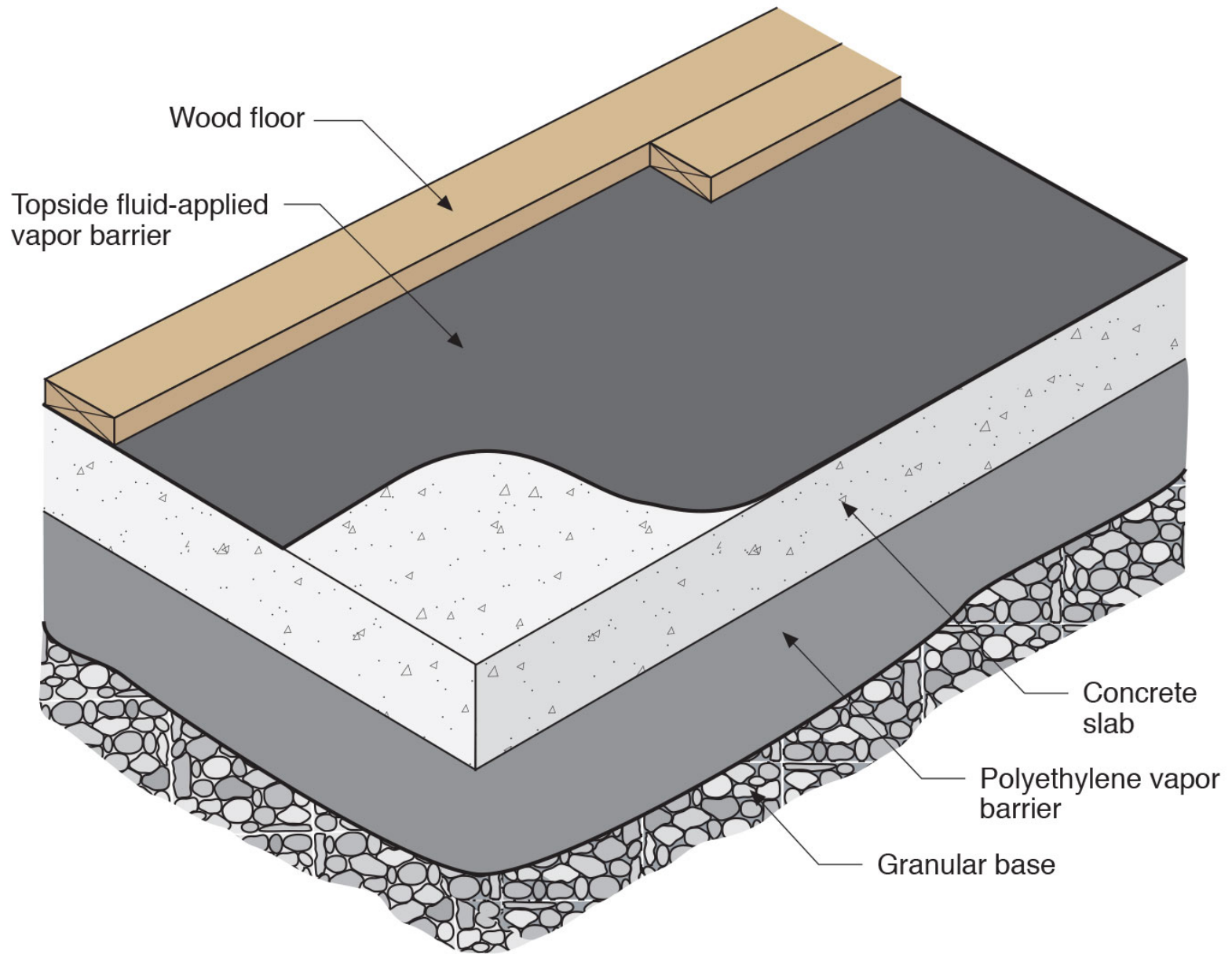






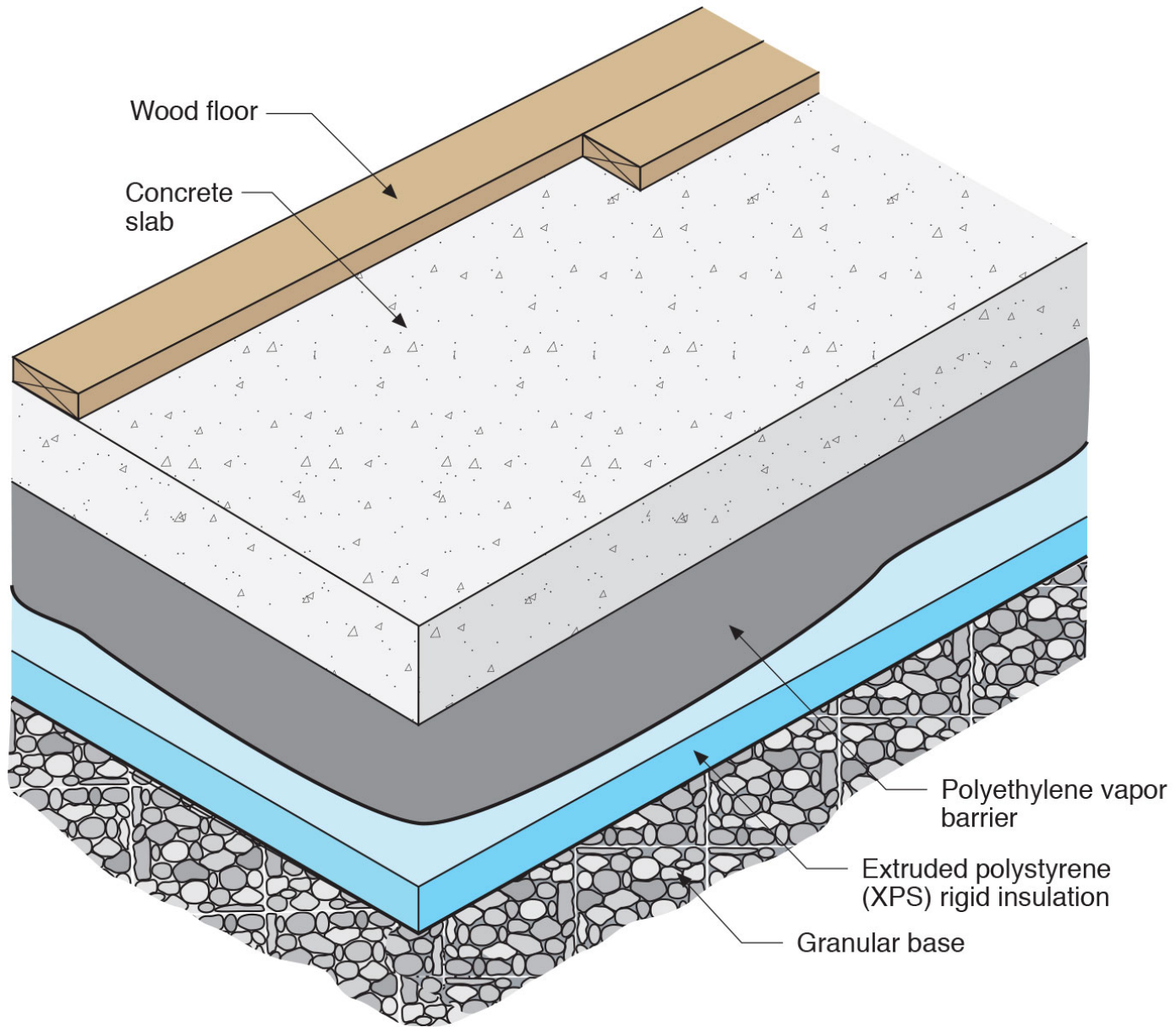








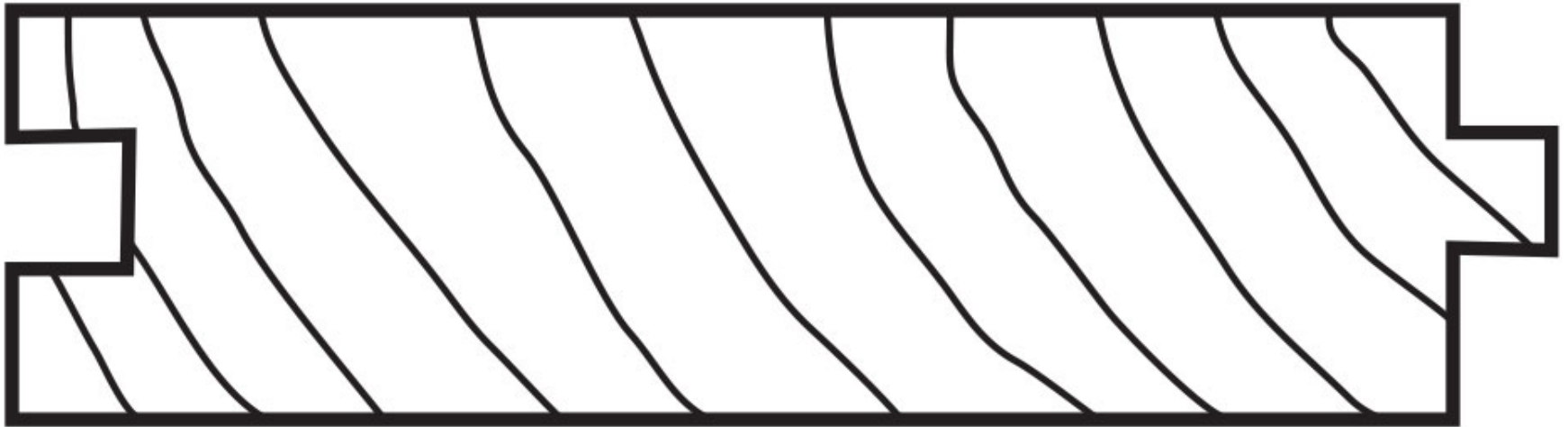






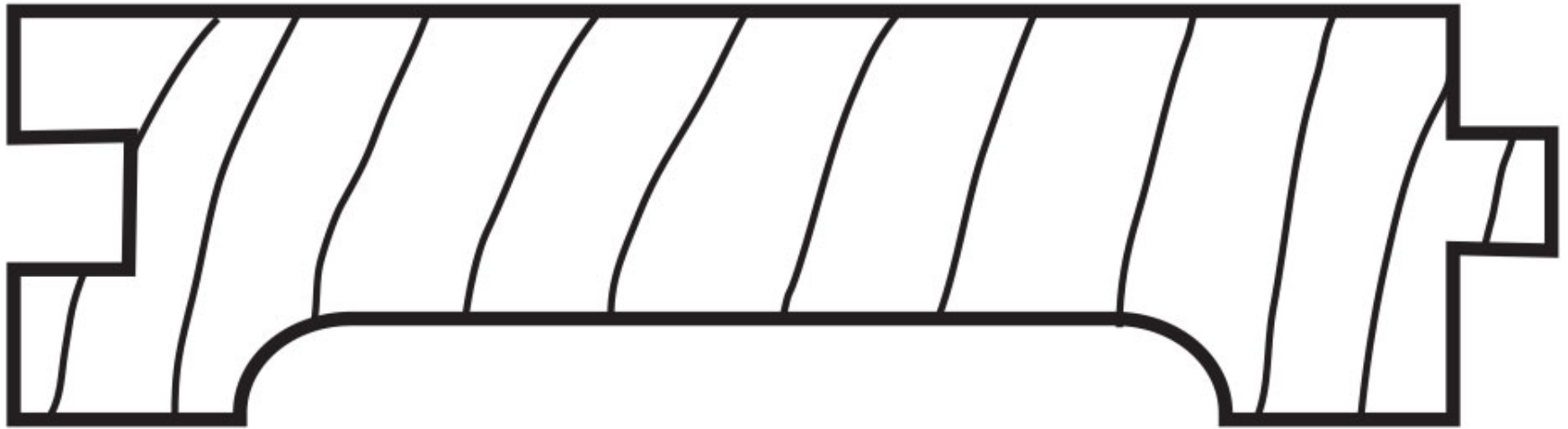




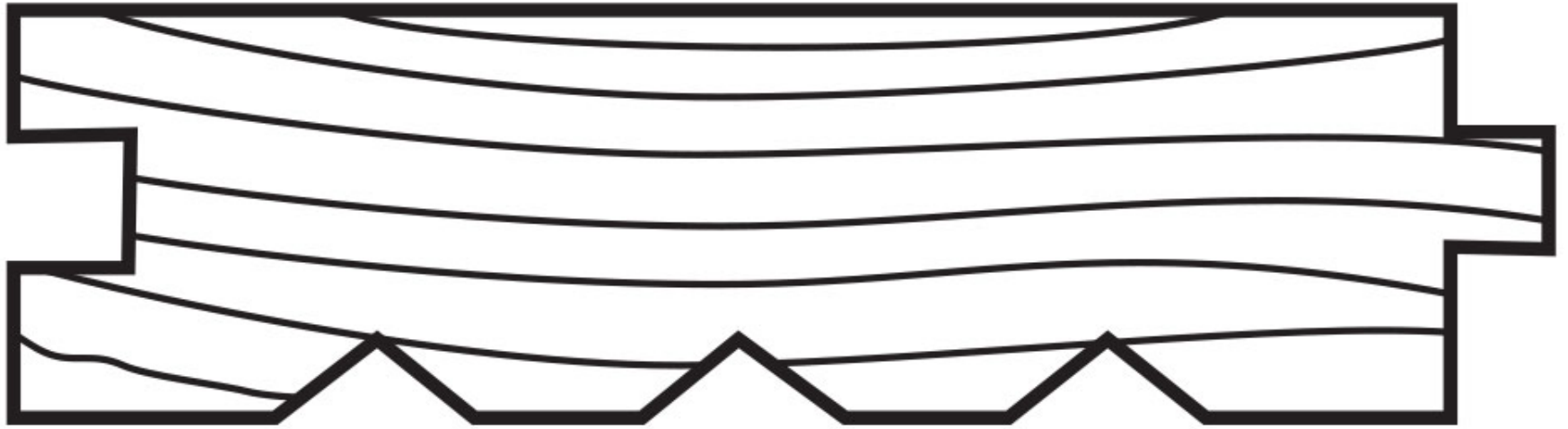


**Plain**

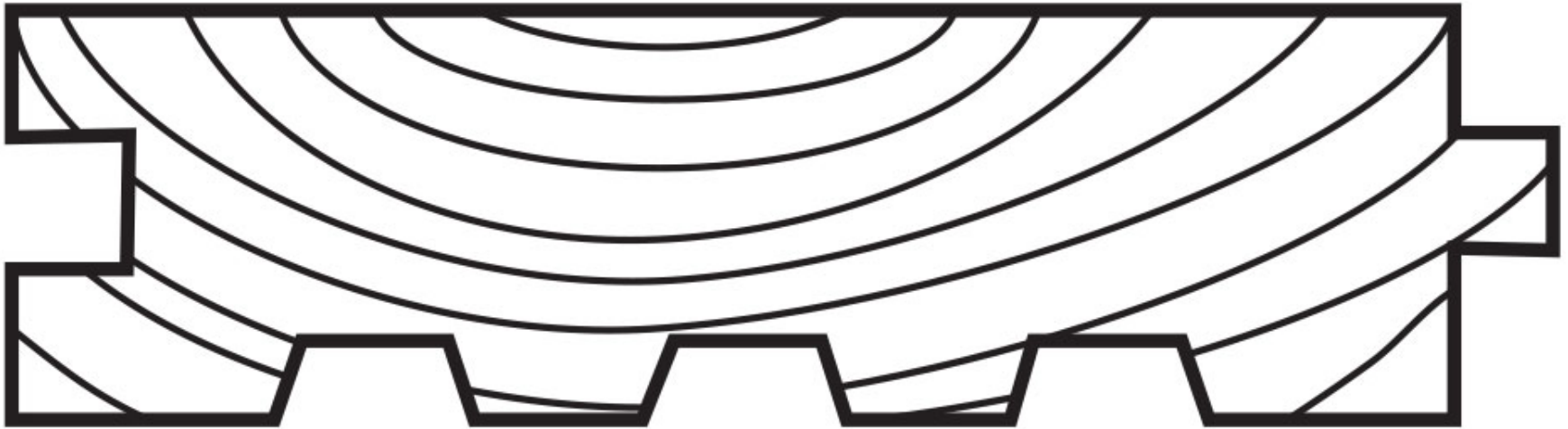




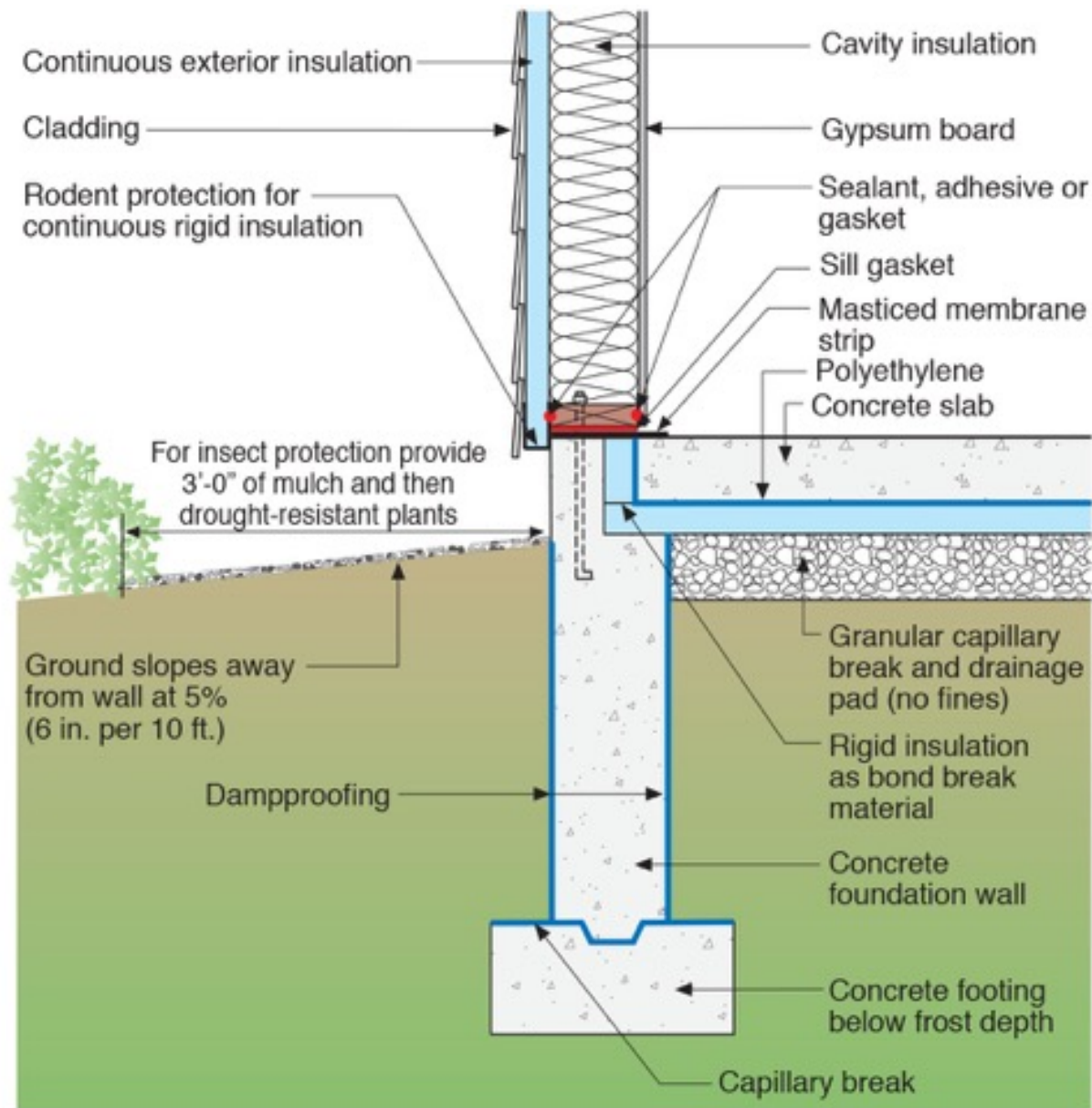
# Hollow Back

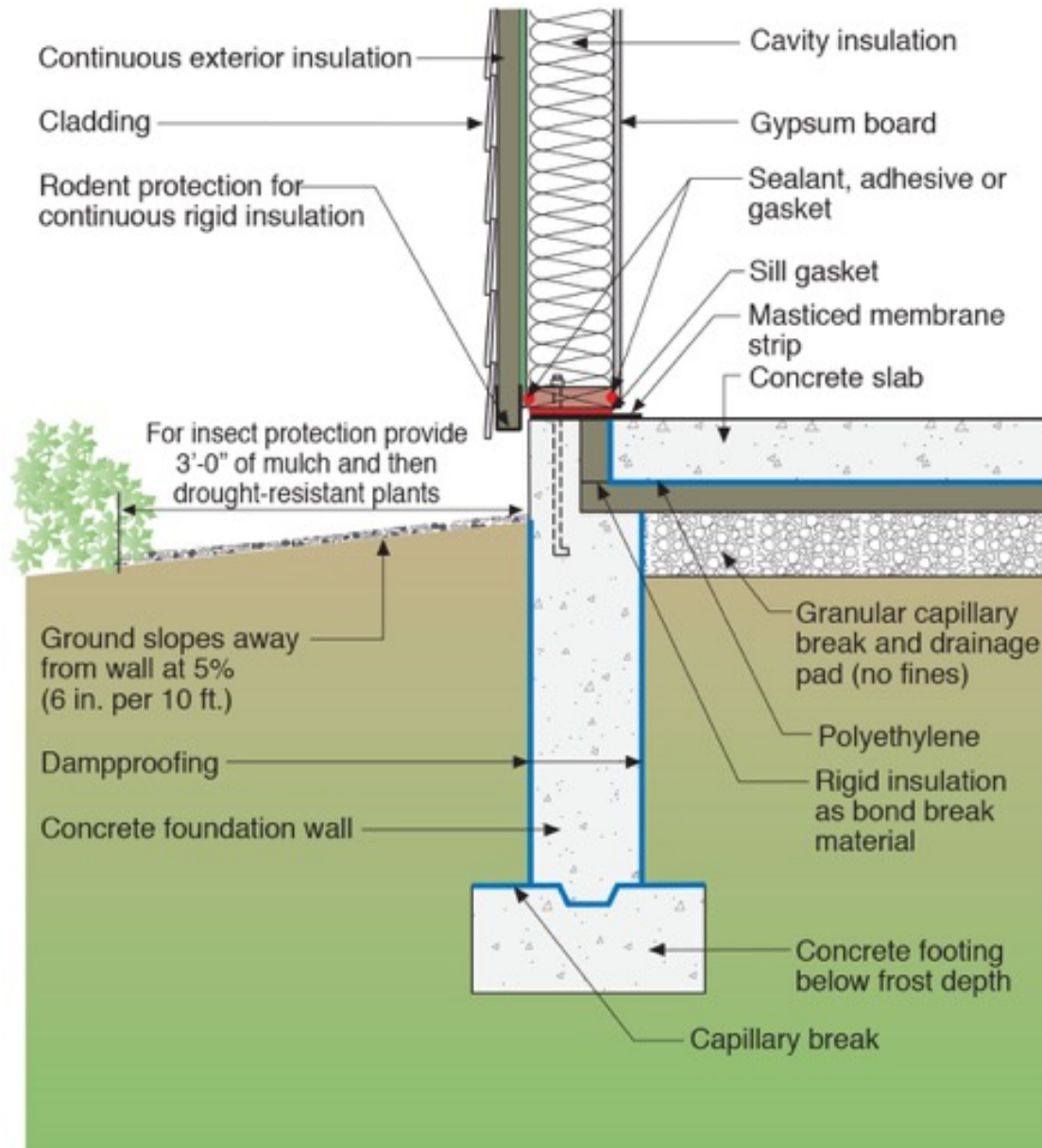


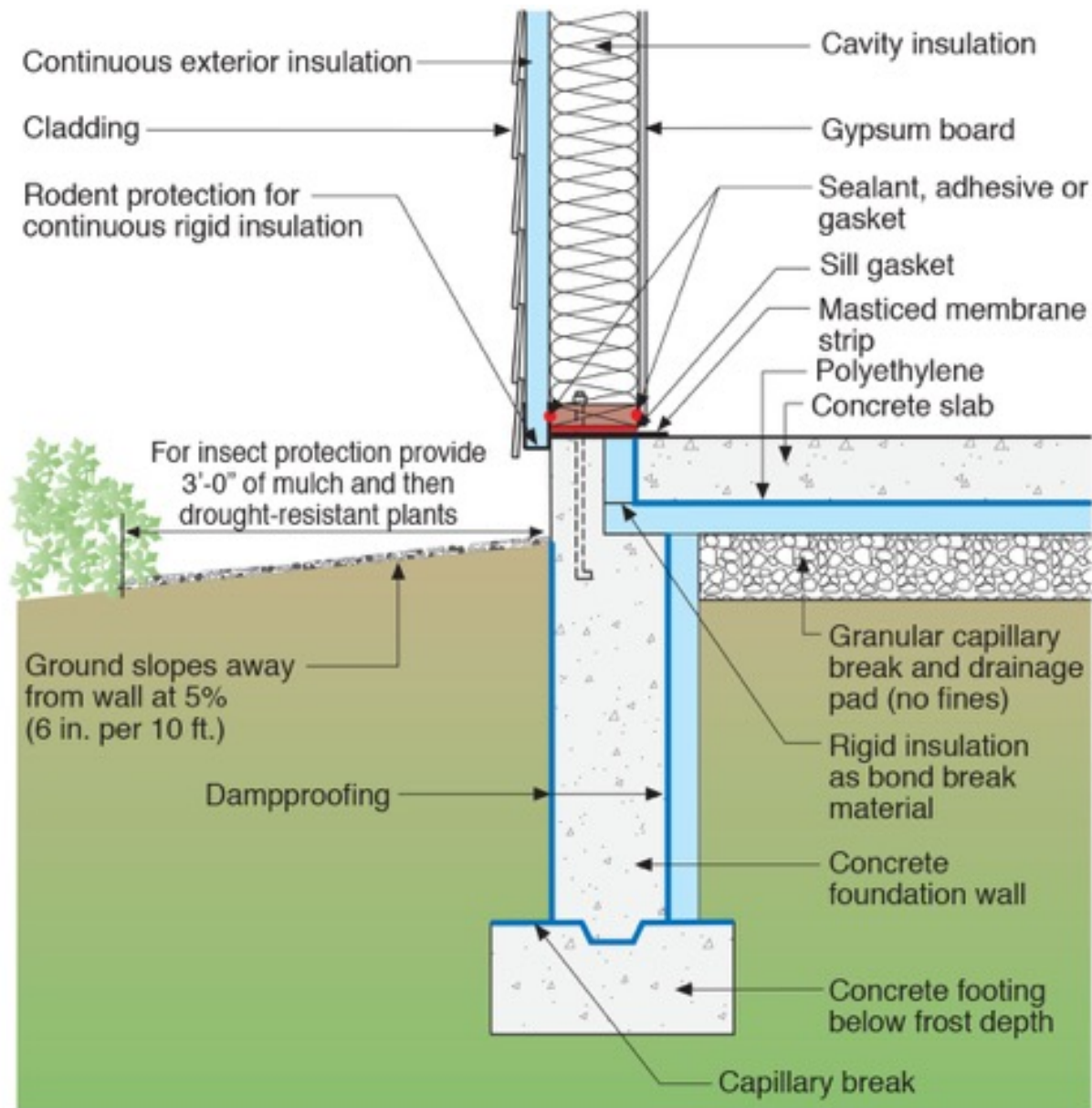
# Scratch Back

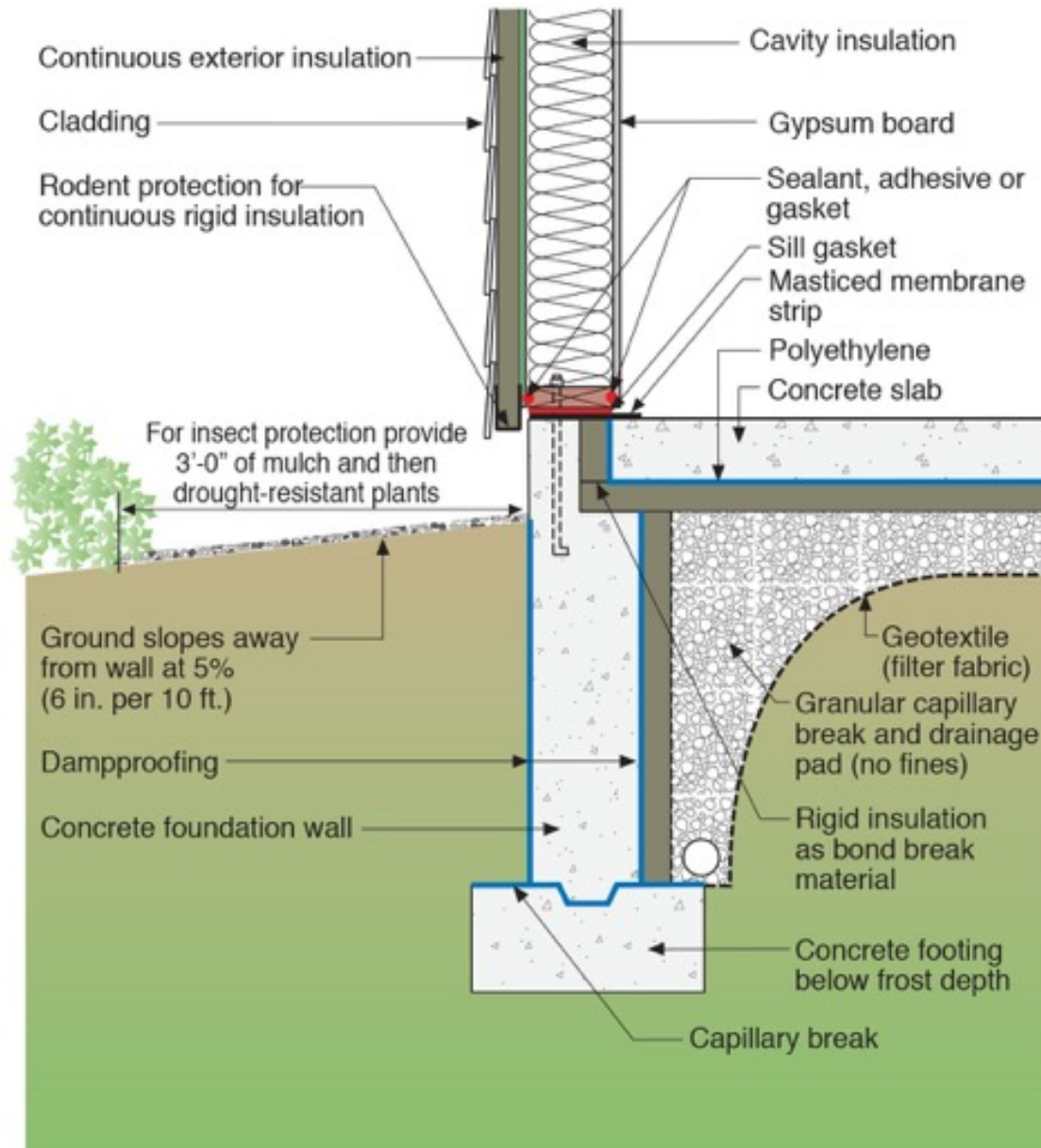


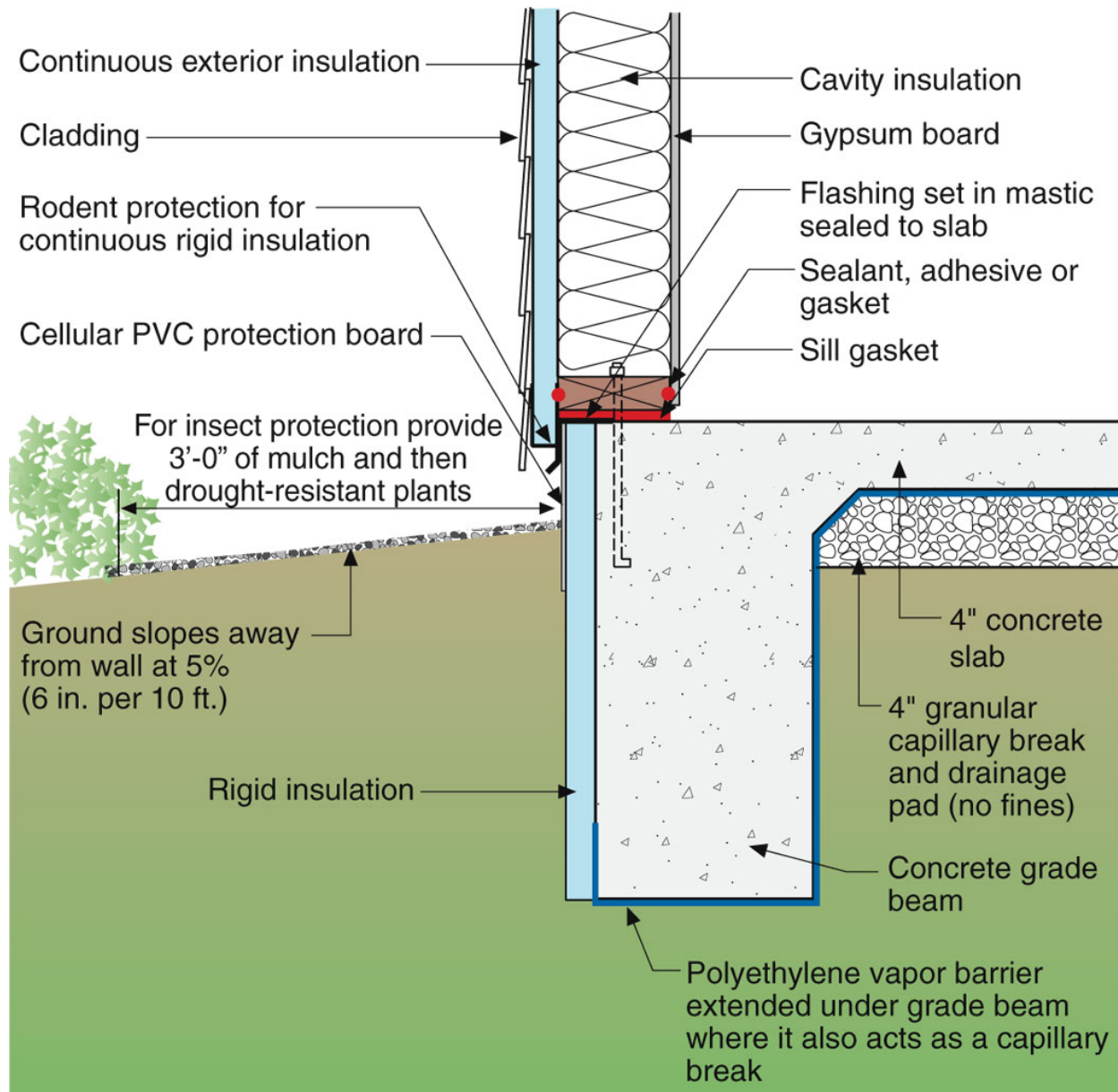
# Hollow or Scratch Back



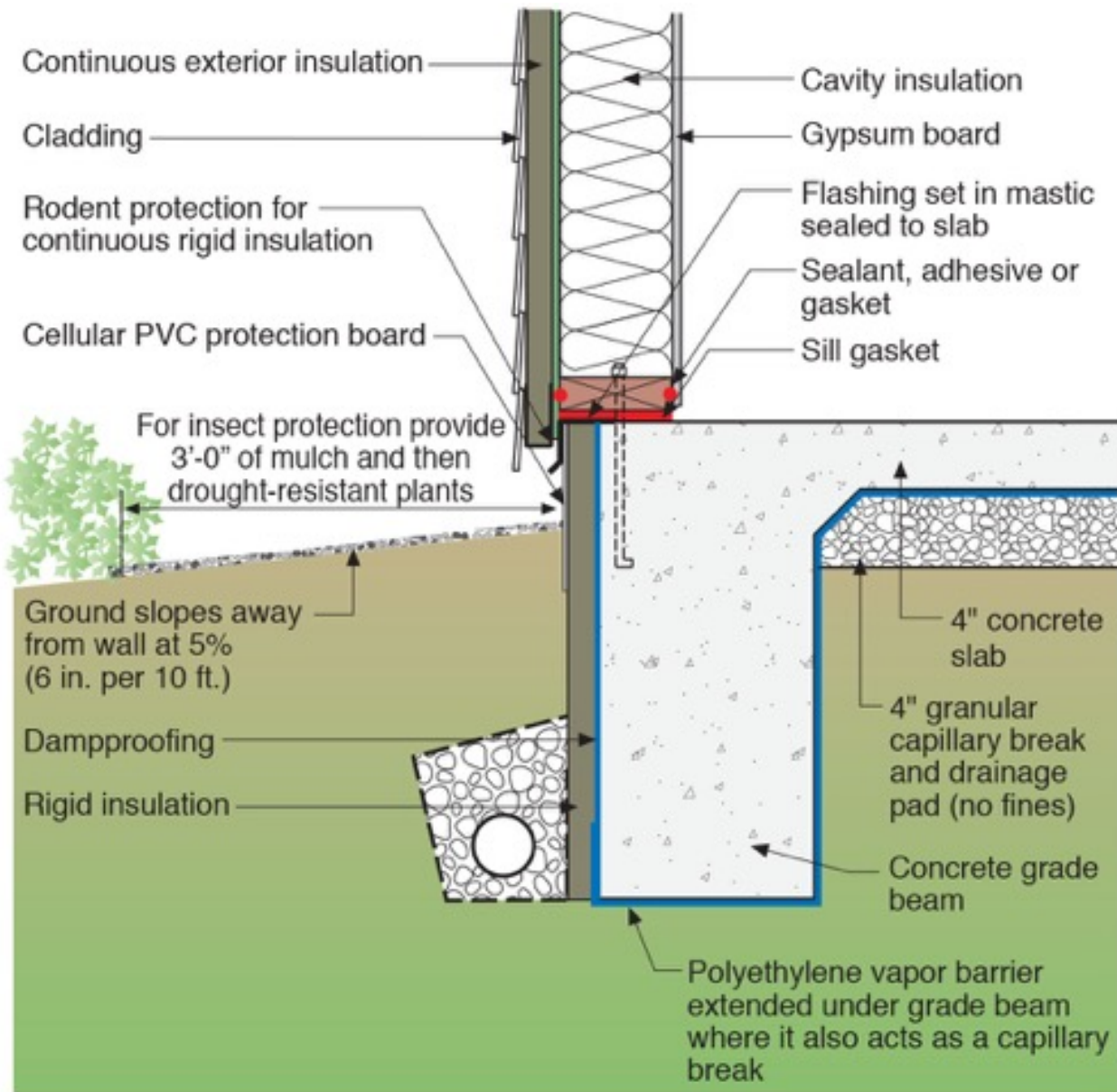


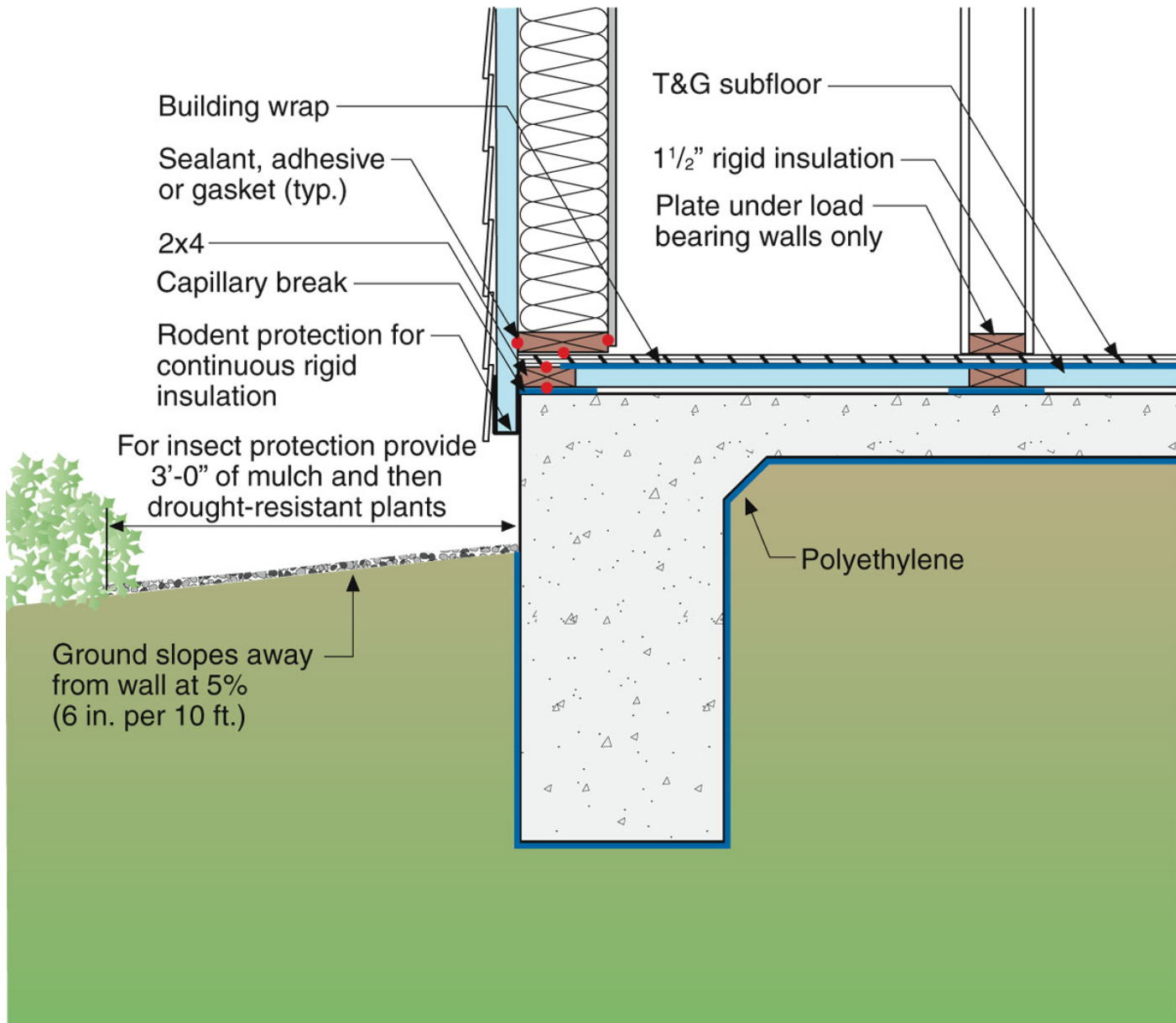


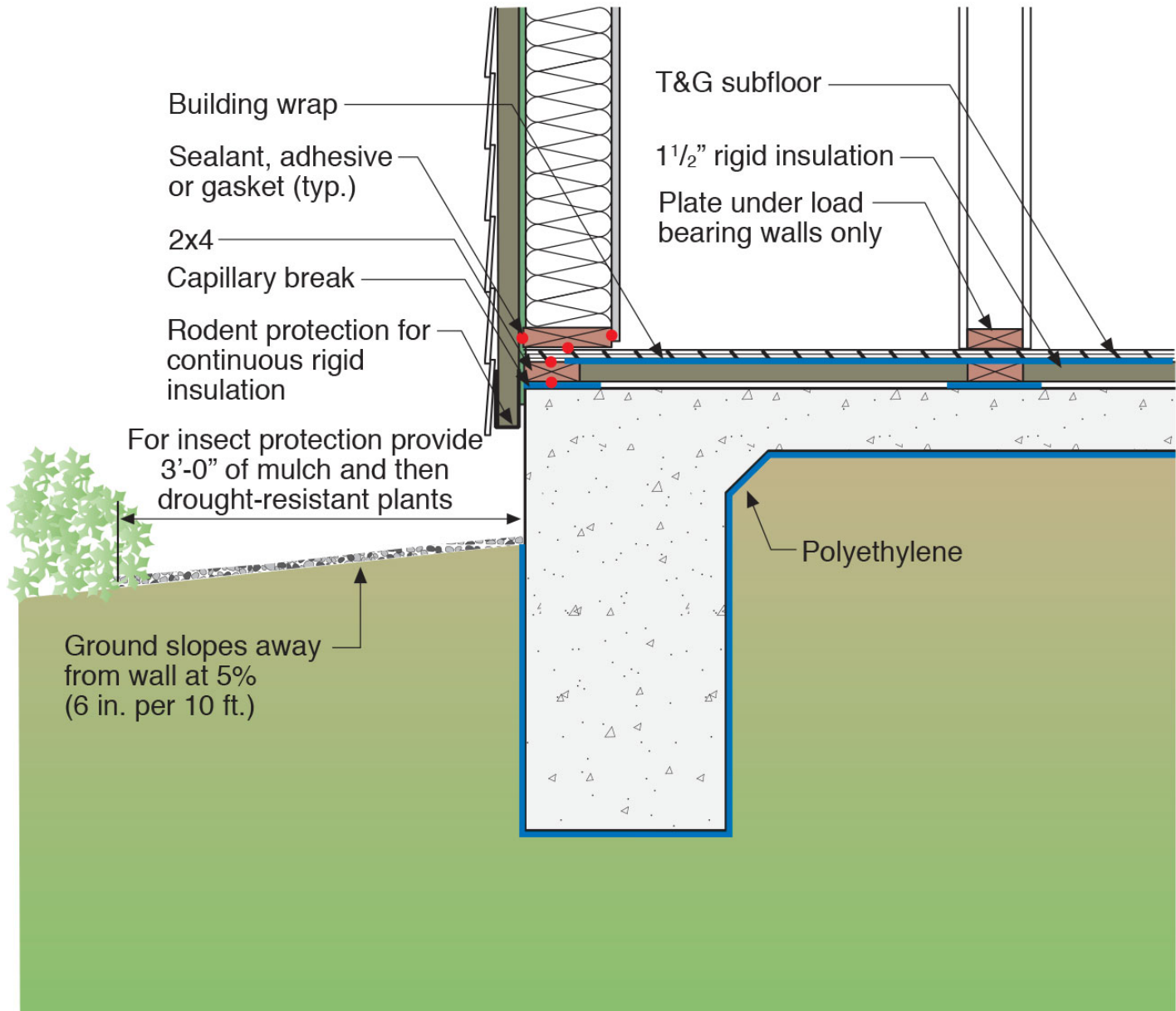


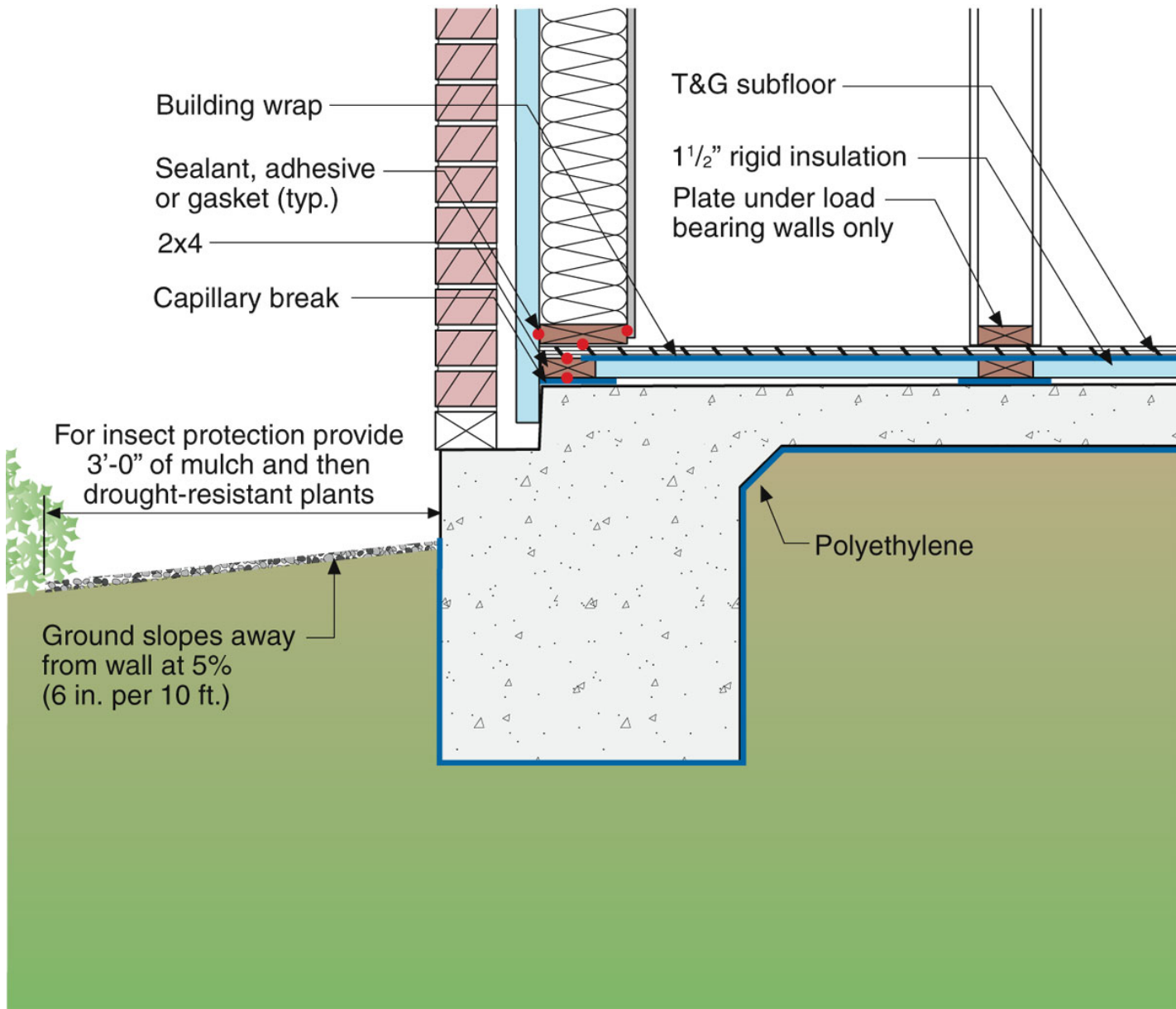


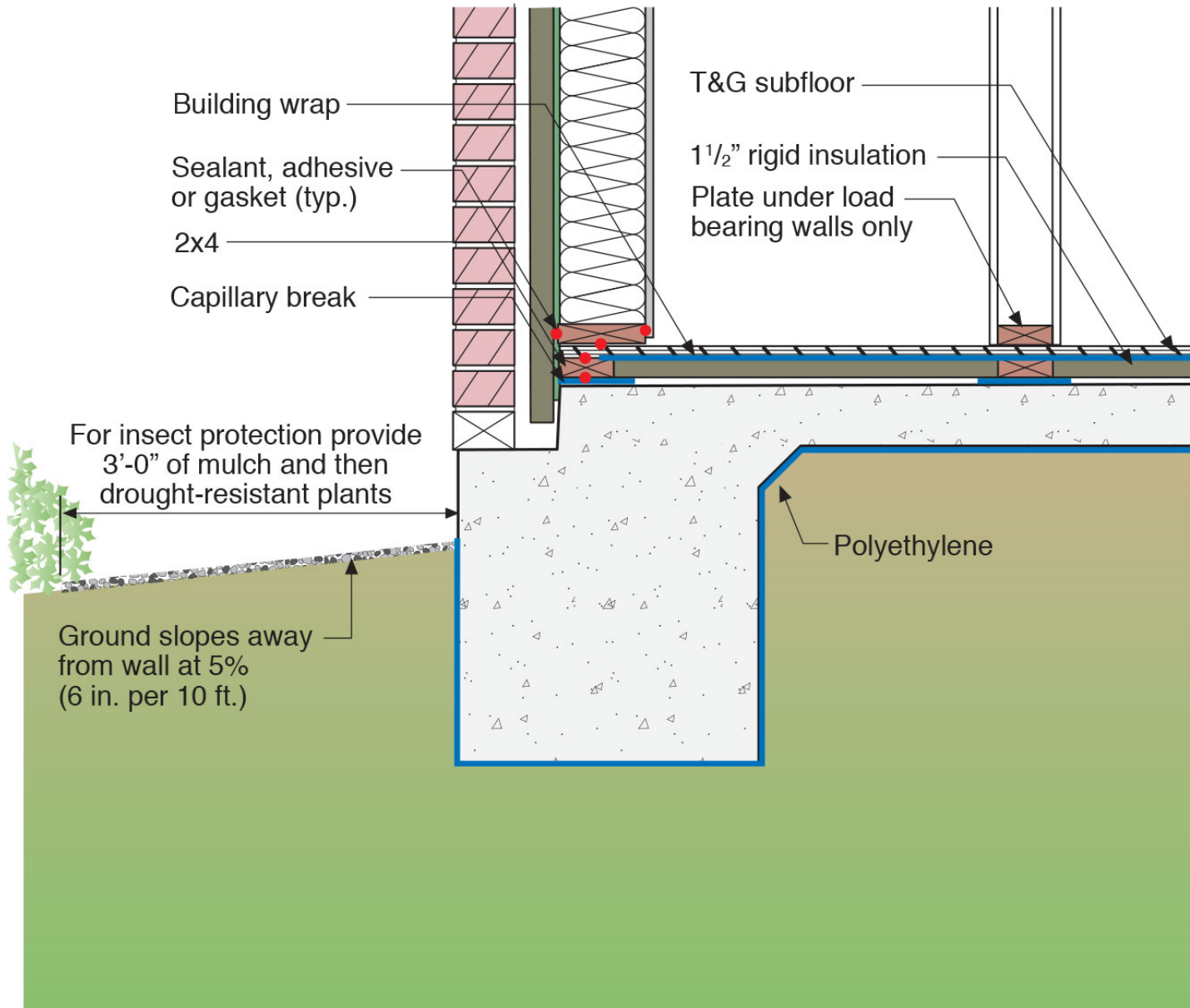


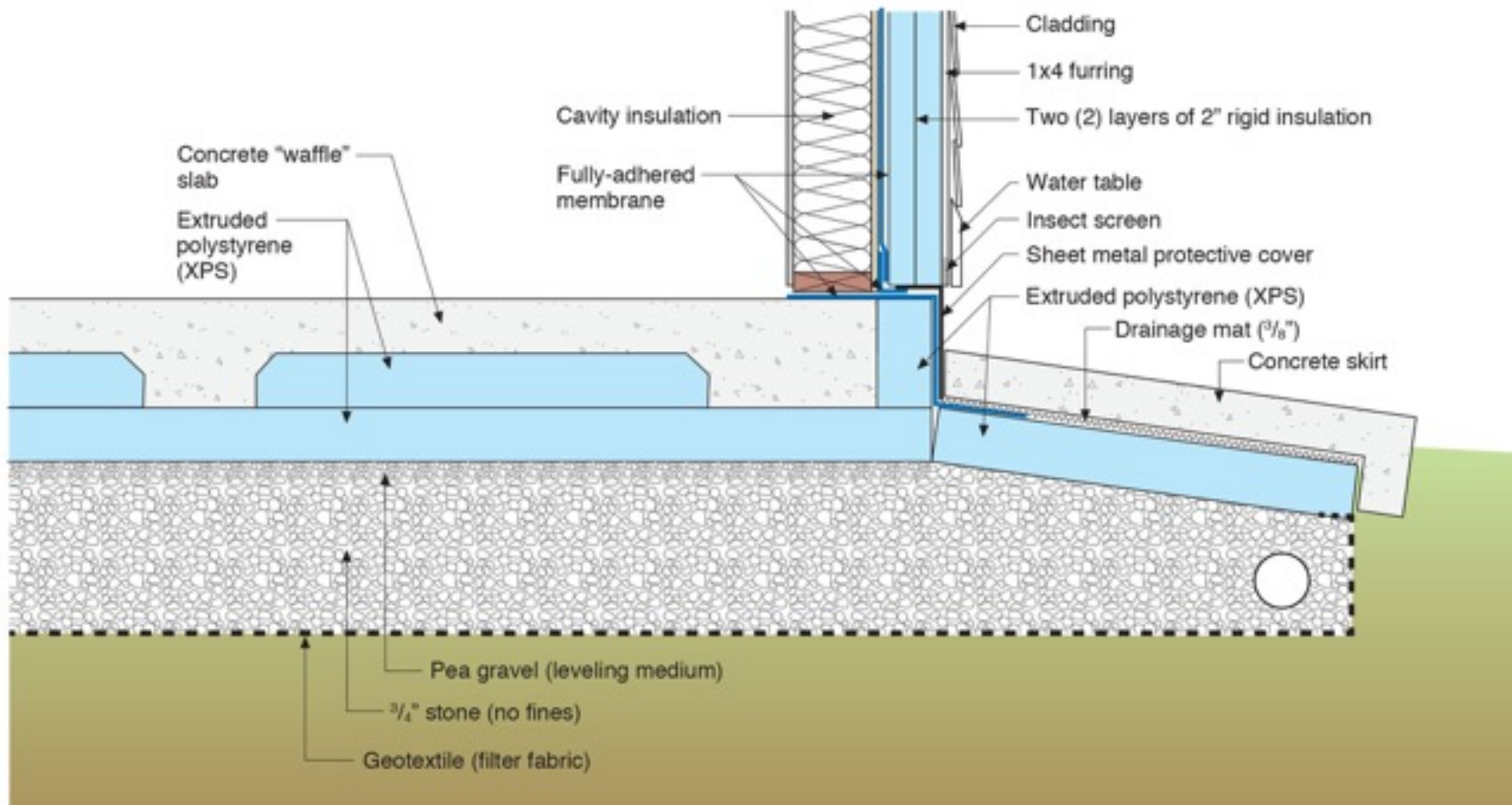


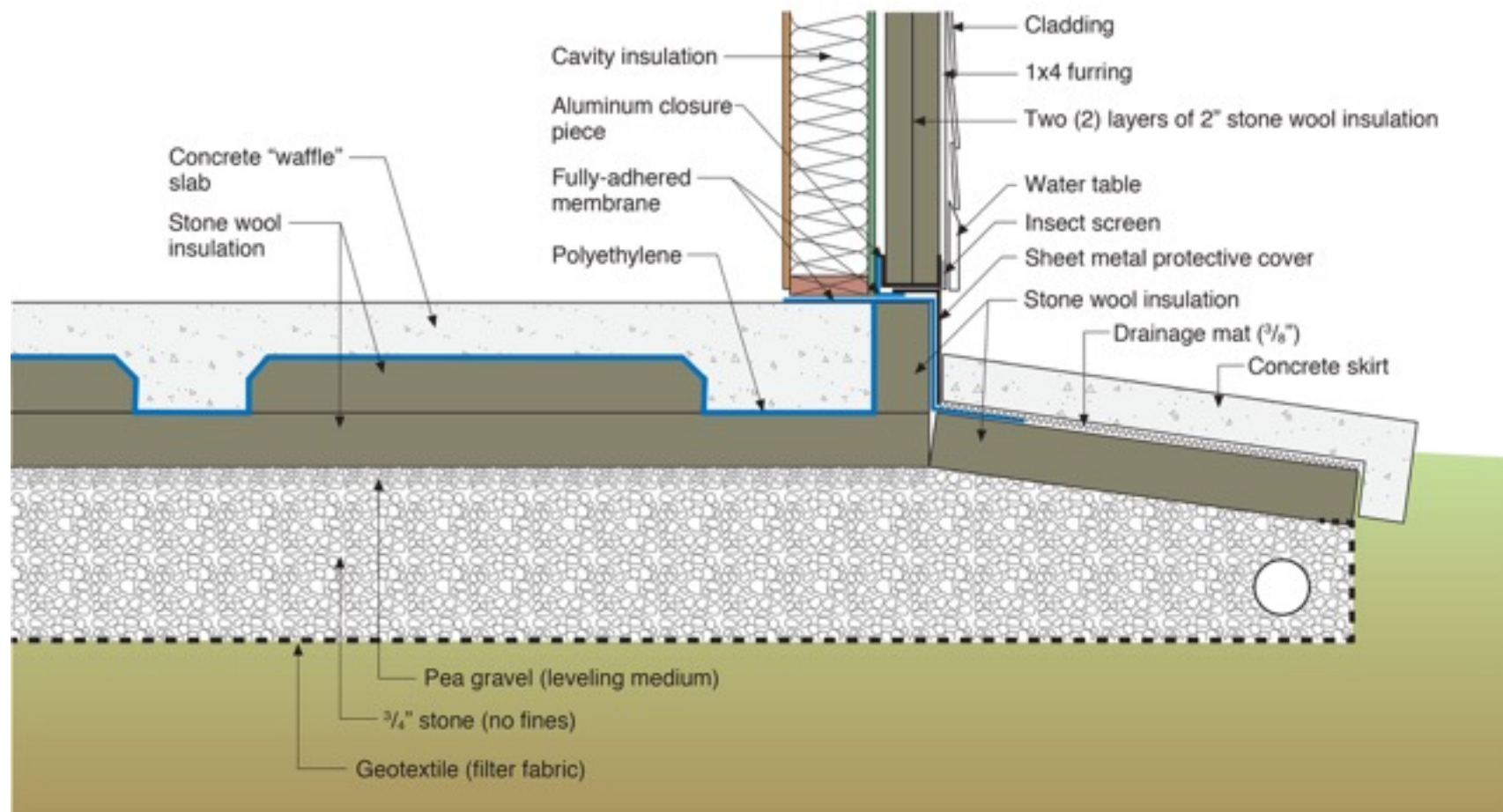














































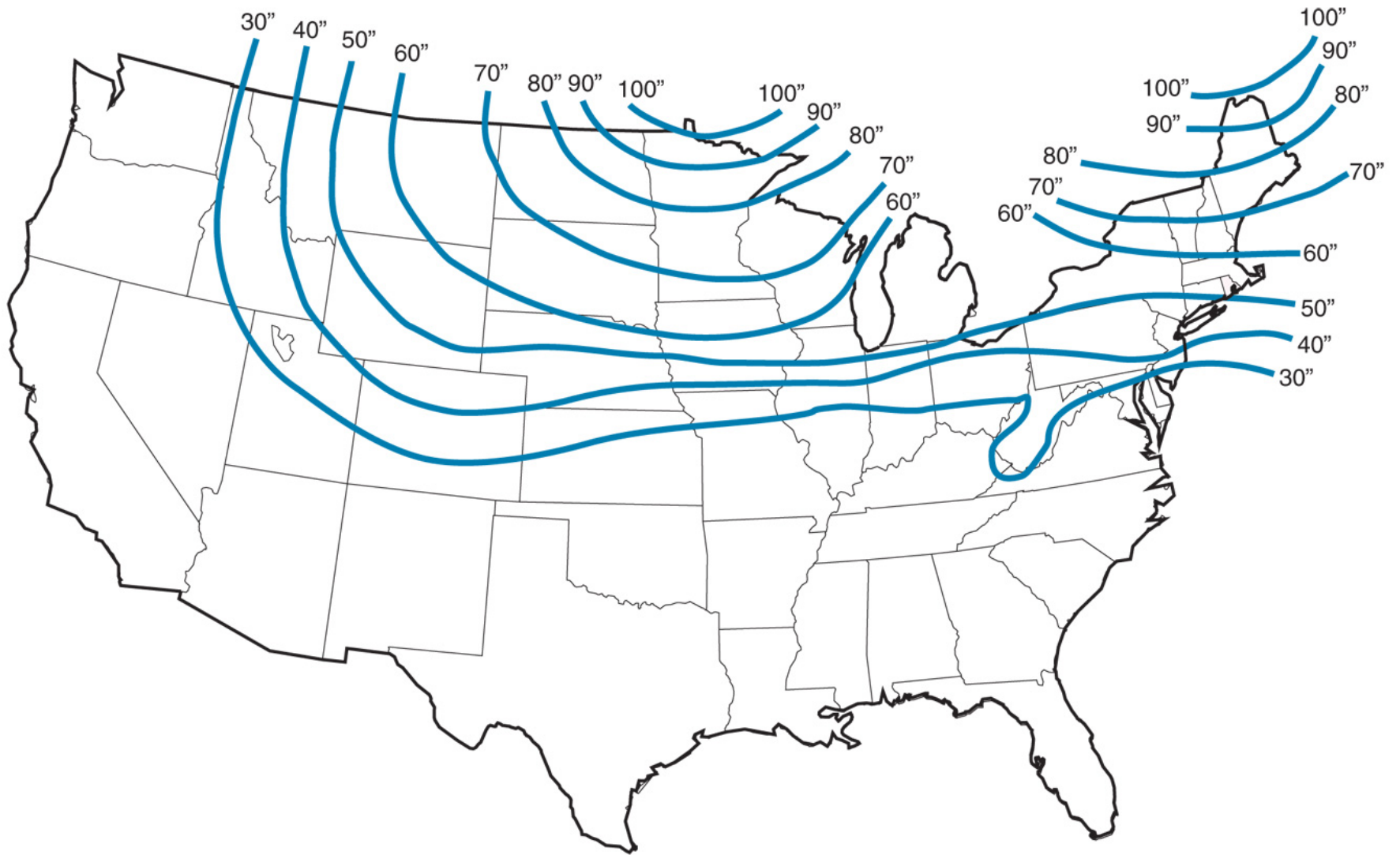




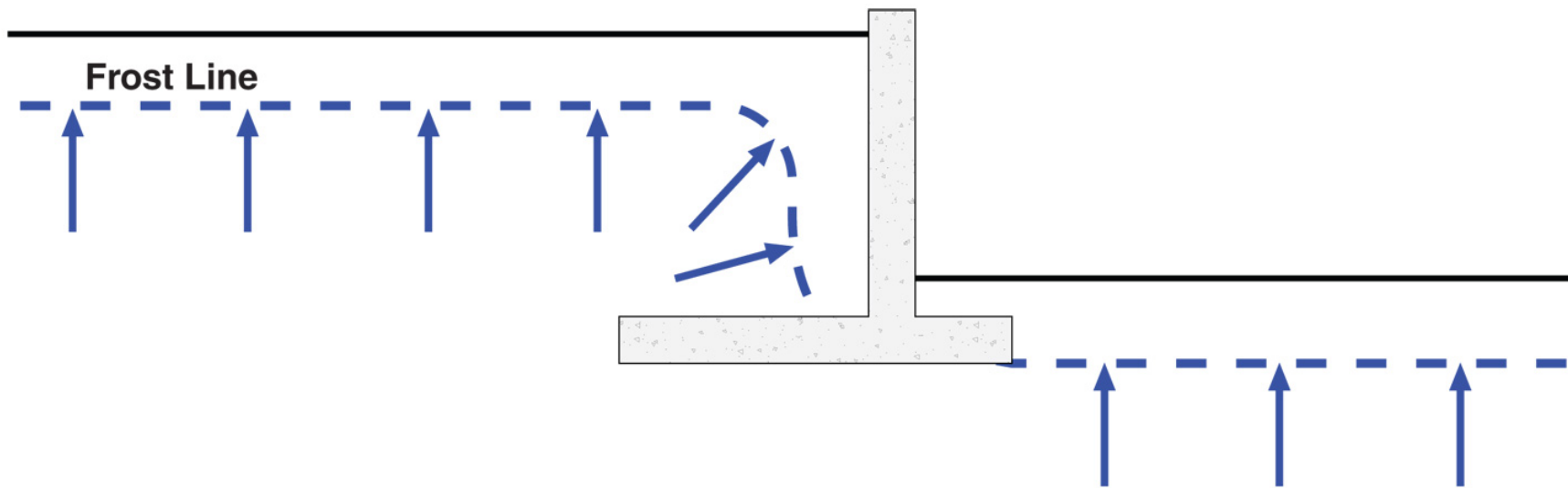


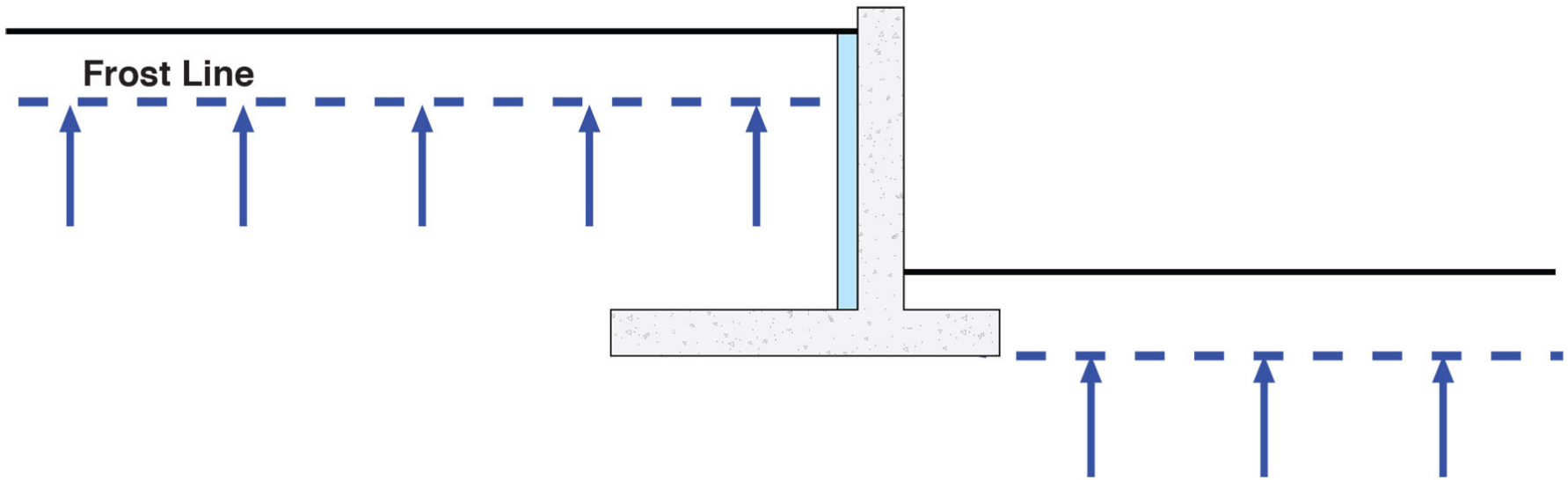




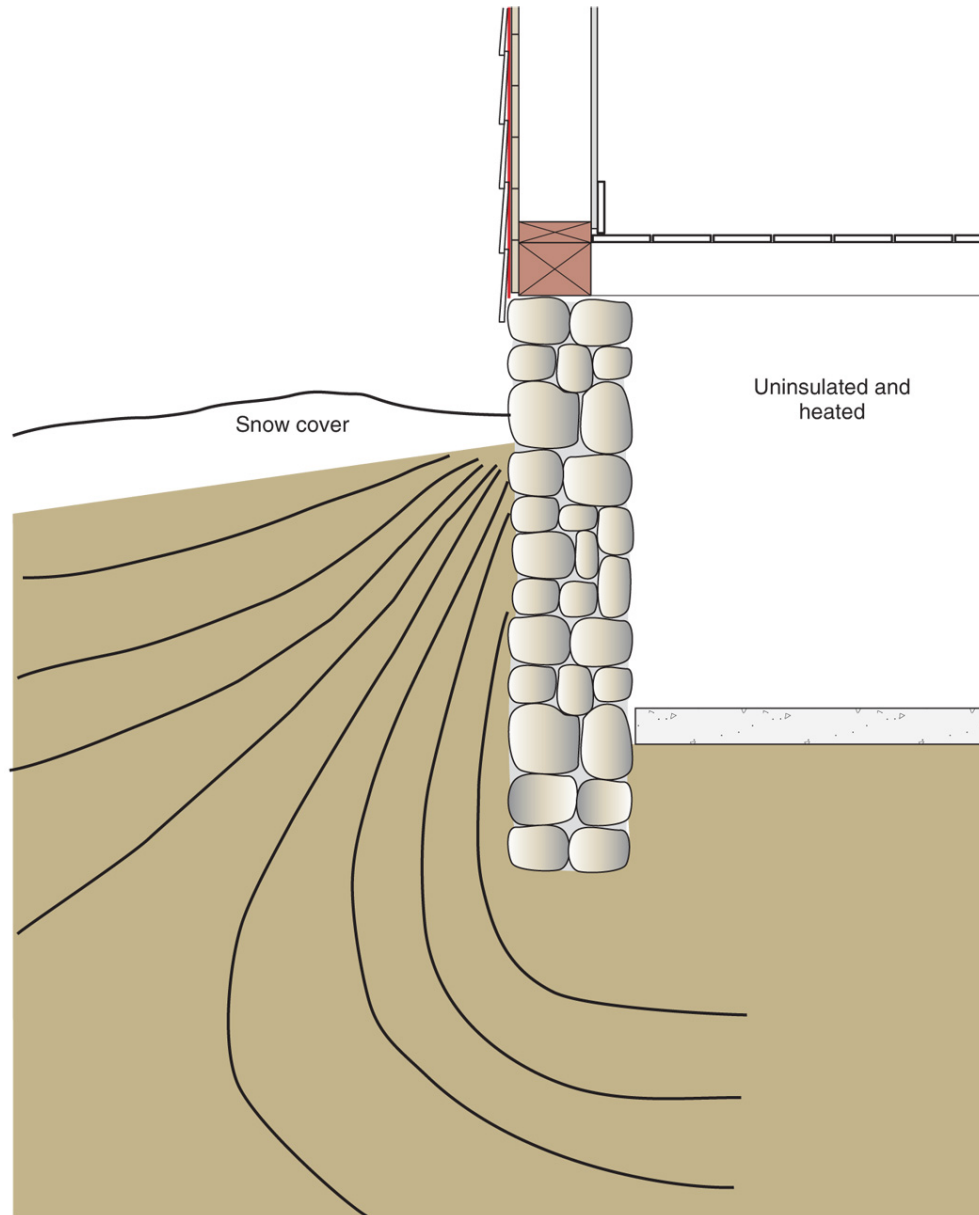


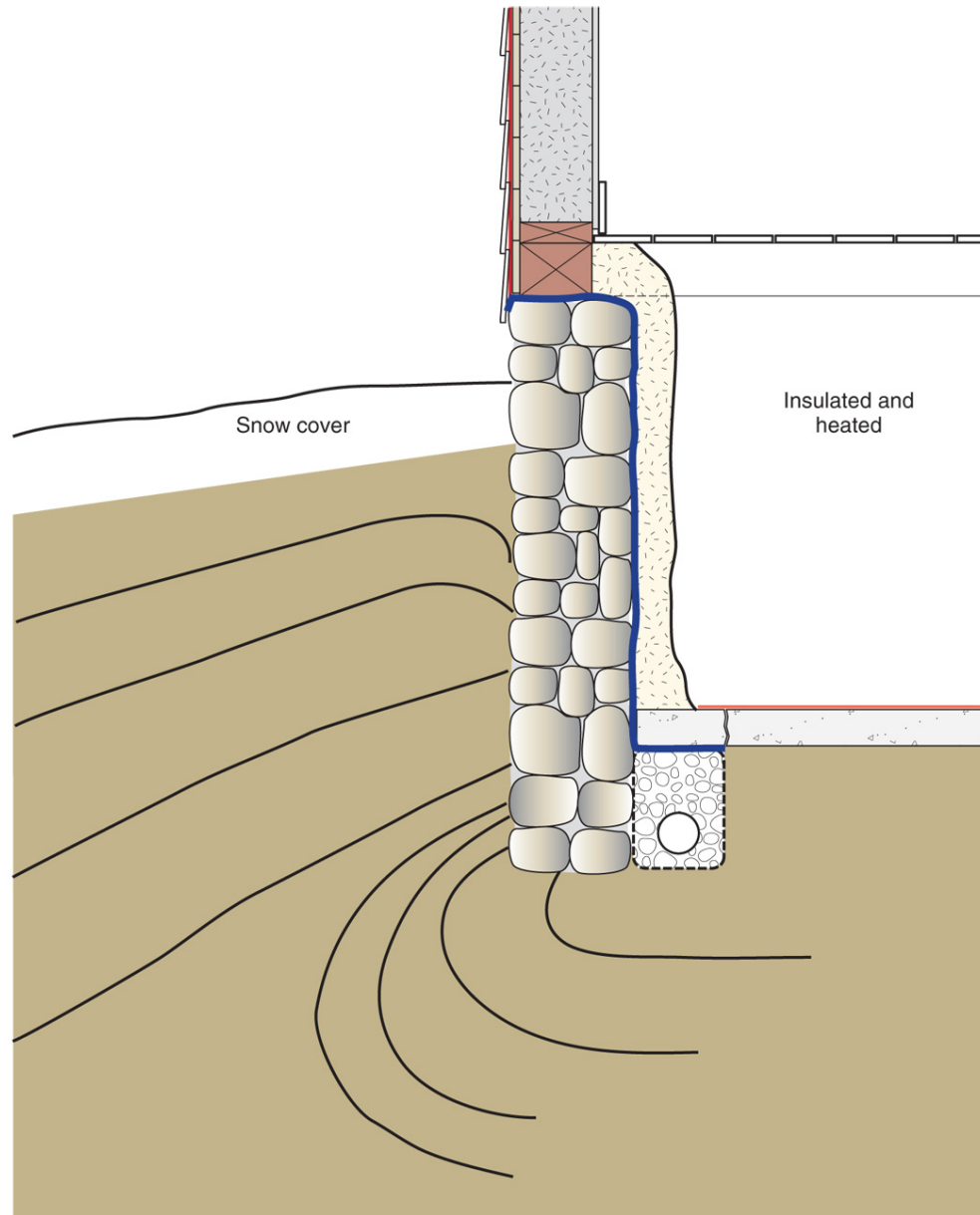
From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.



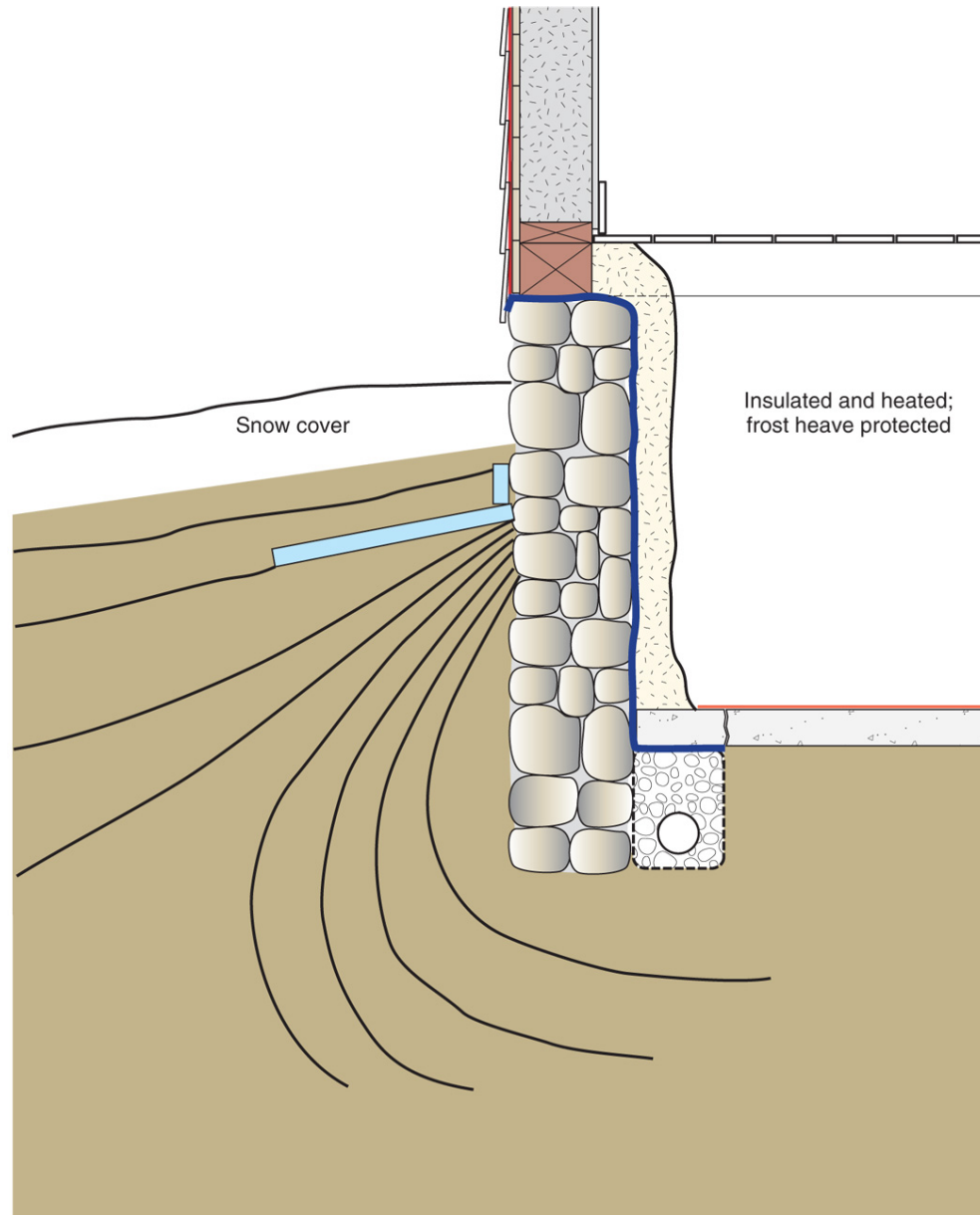


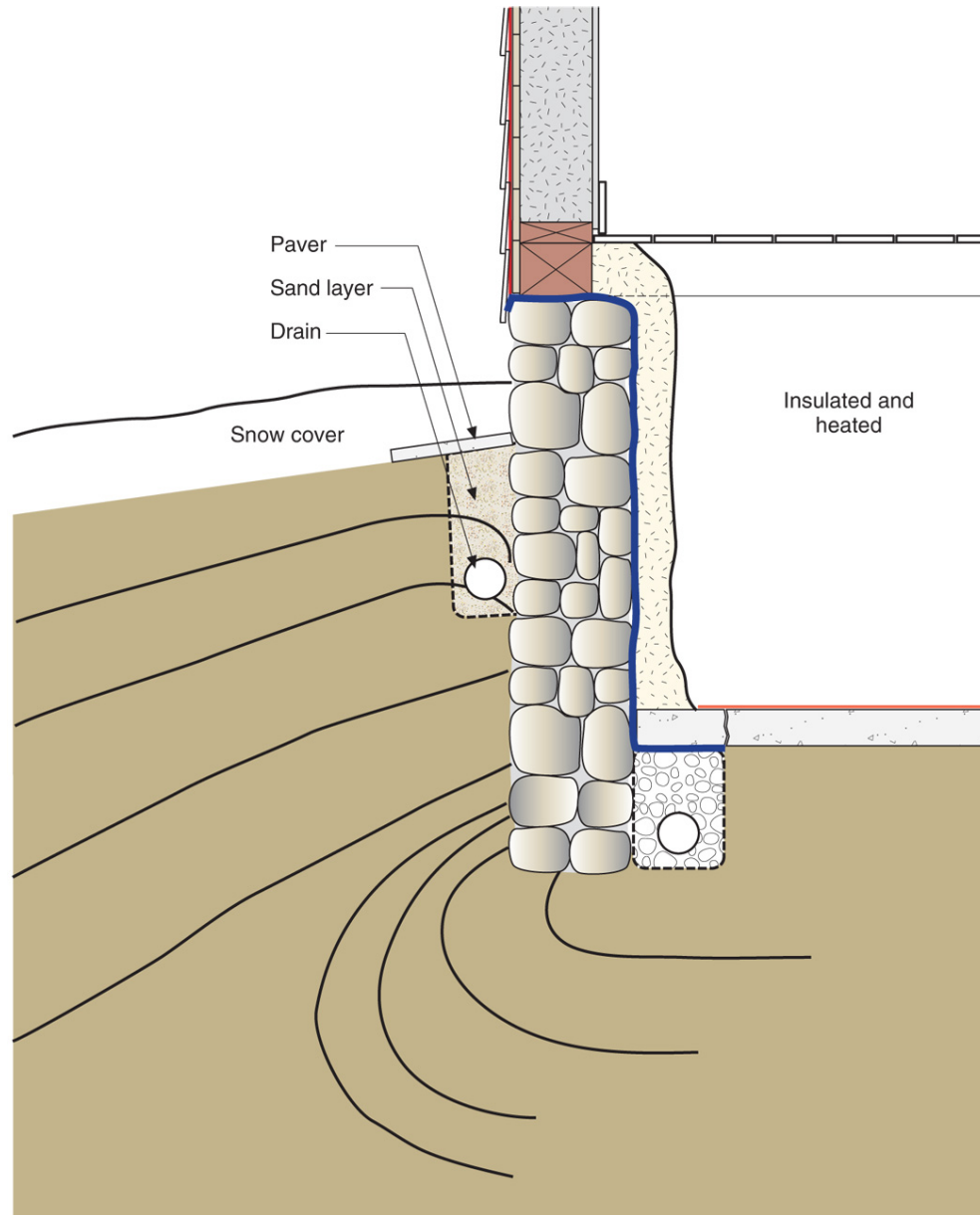


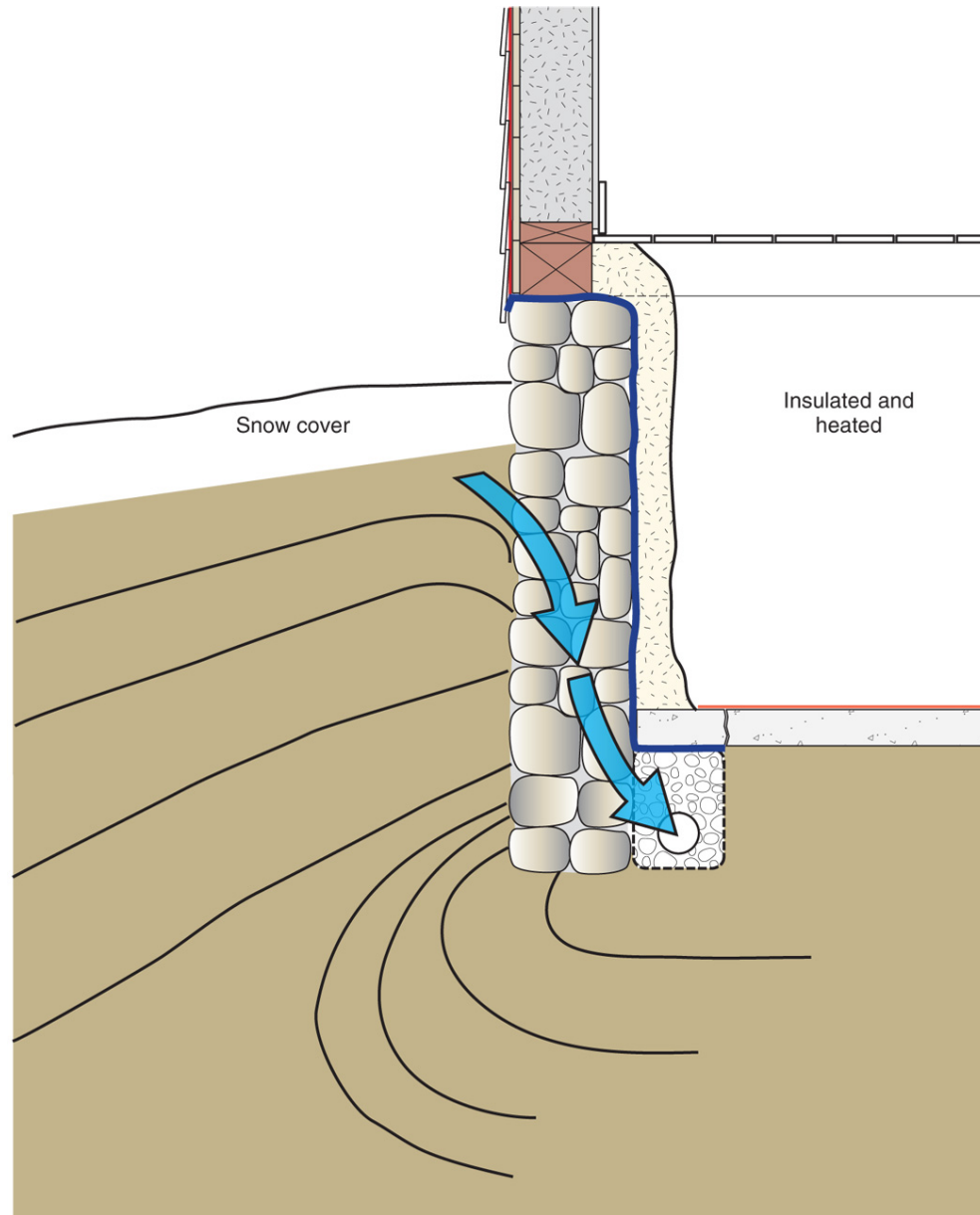






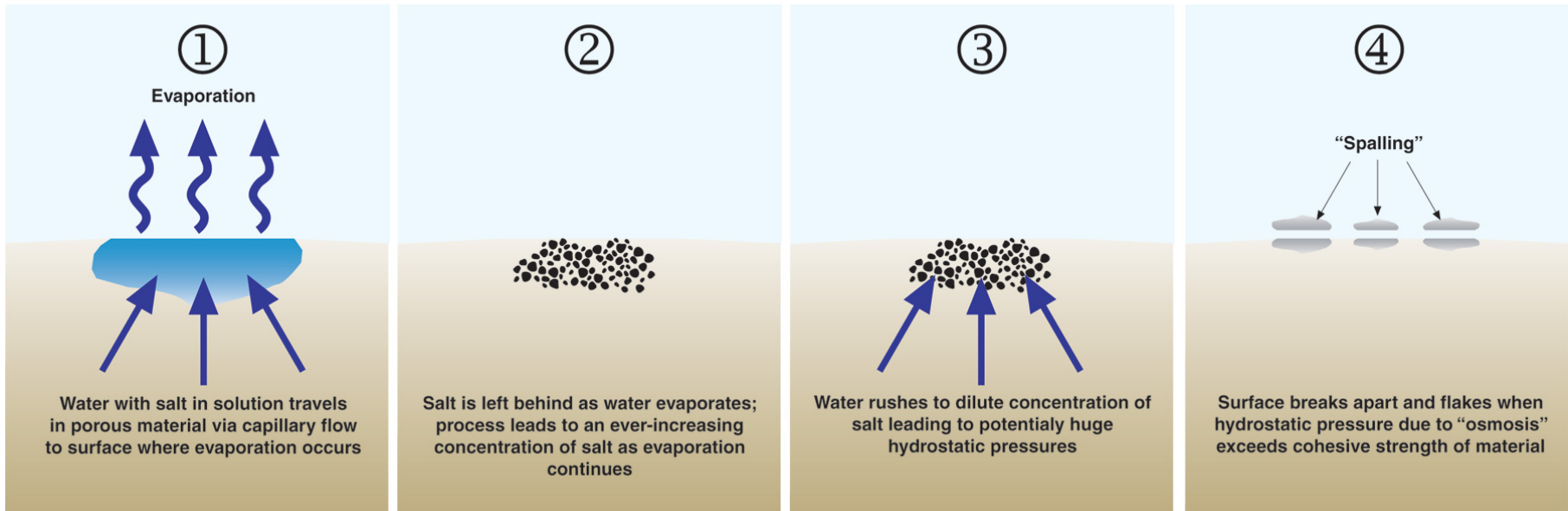






# Capillarity + Salt = Osmosis

- Mineral salts carried in solution by capillary water
- When water evaporates from a surface the salts left behind form crystals in process called efflorescence
- When water evaporated beneath a surface the salts crystallize within the pore structure of the material in called sub-efflorescence
- The salt crystallization causes expansive forces that can exceed the cohesive strength of the material leading to spalling



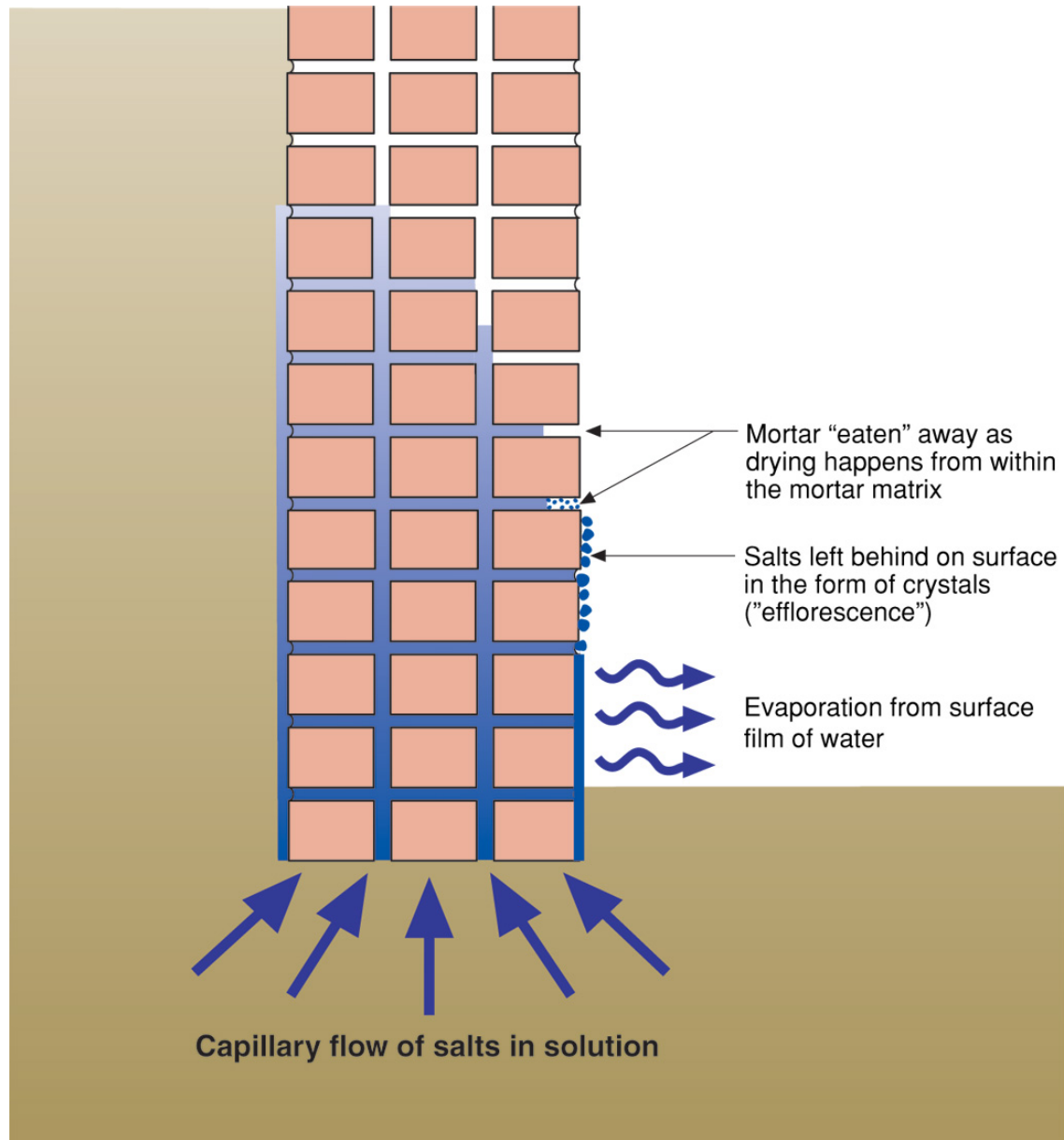
# Diffusion + Capillarity + Osmosis = Problem

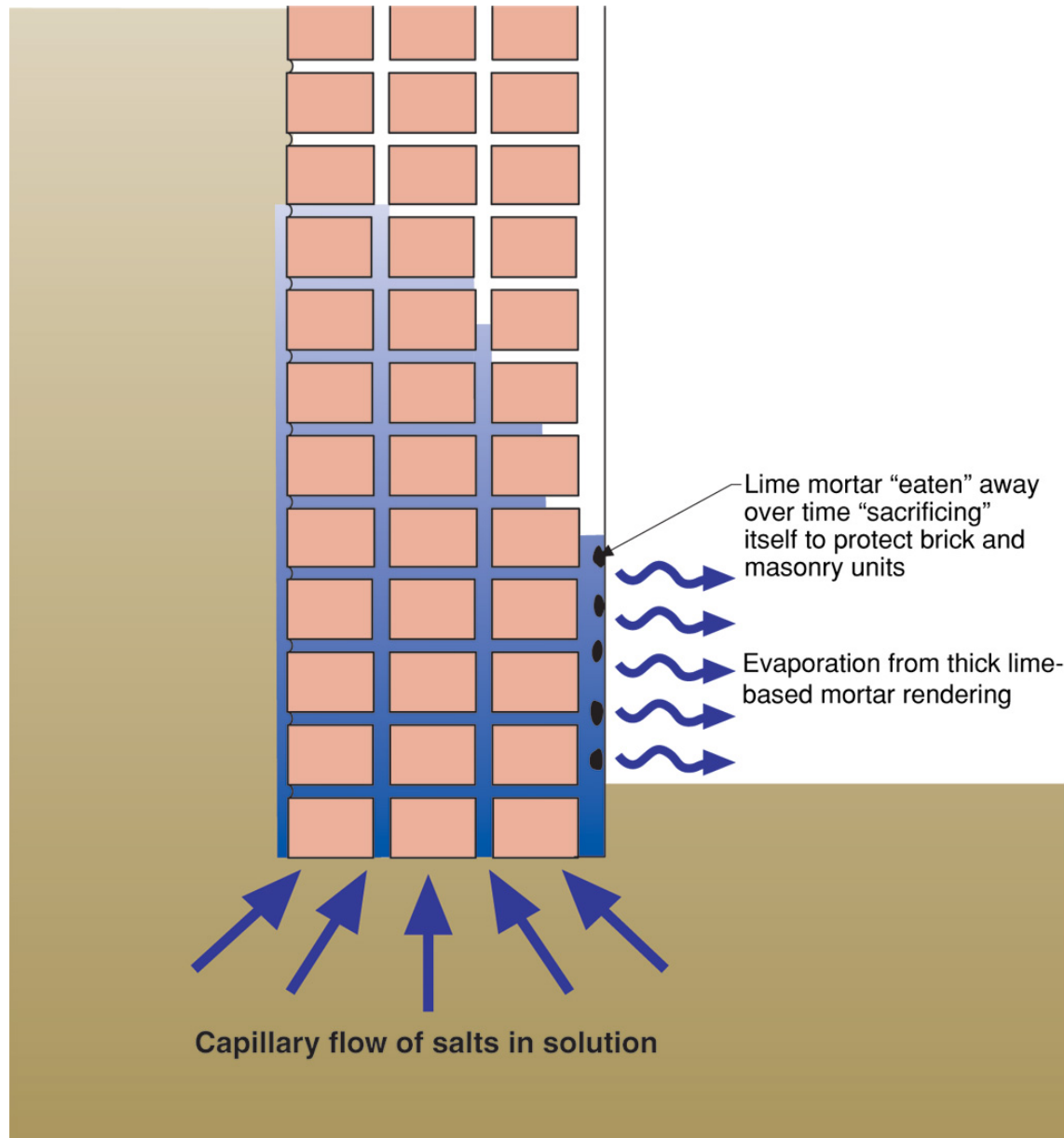
- Diffusion Vapor Pressure 3 to 5 psi
- Capillary Pressure 300 to 500 psi
- Osmosis Pressure 3,000 to 5,000 psi





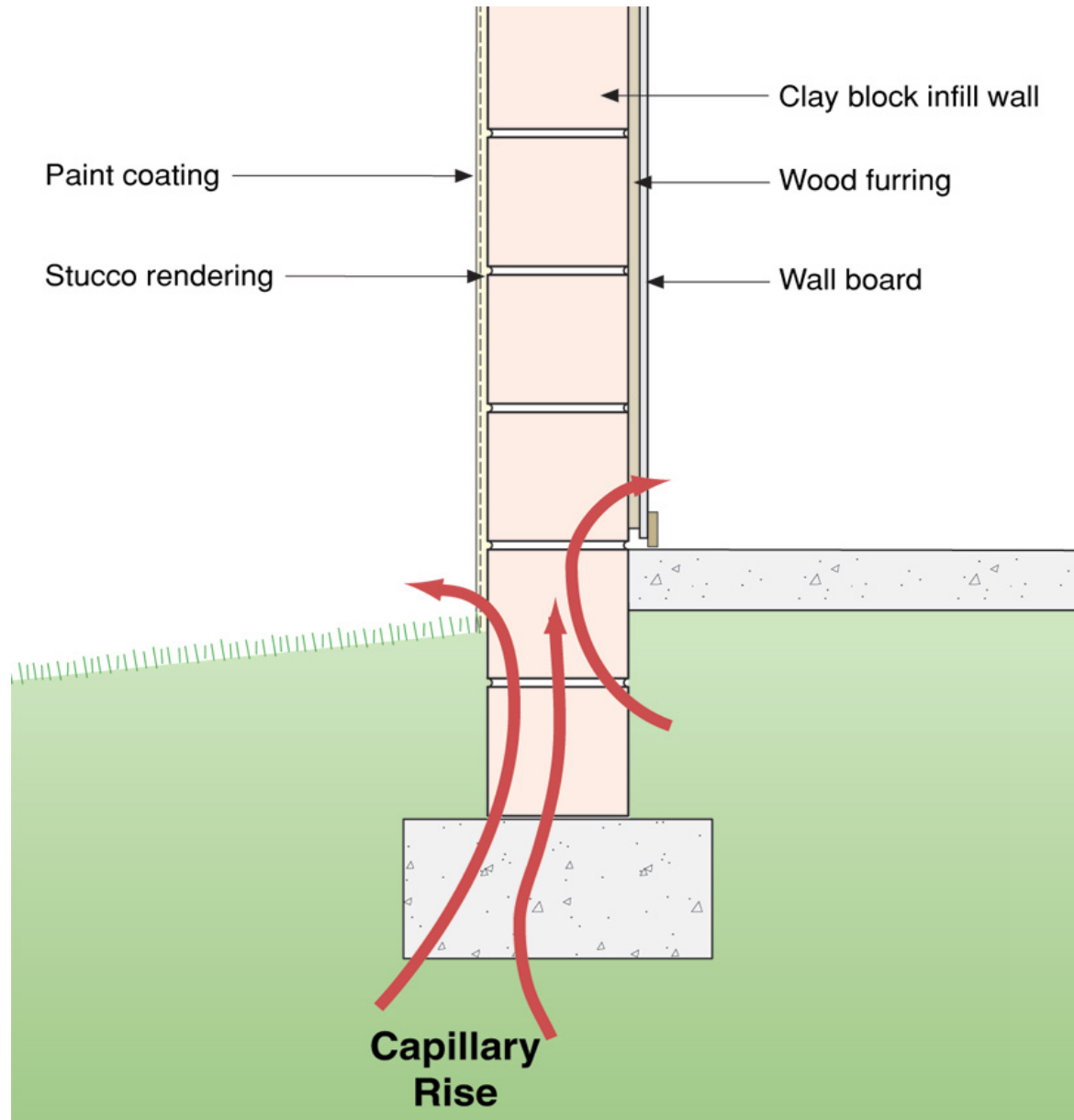


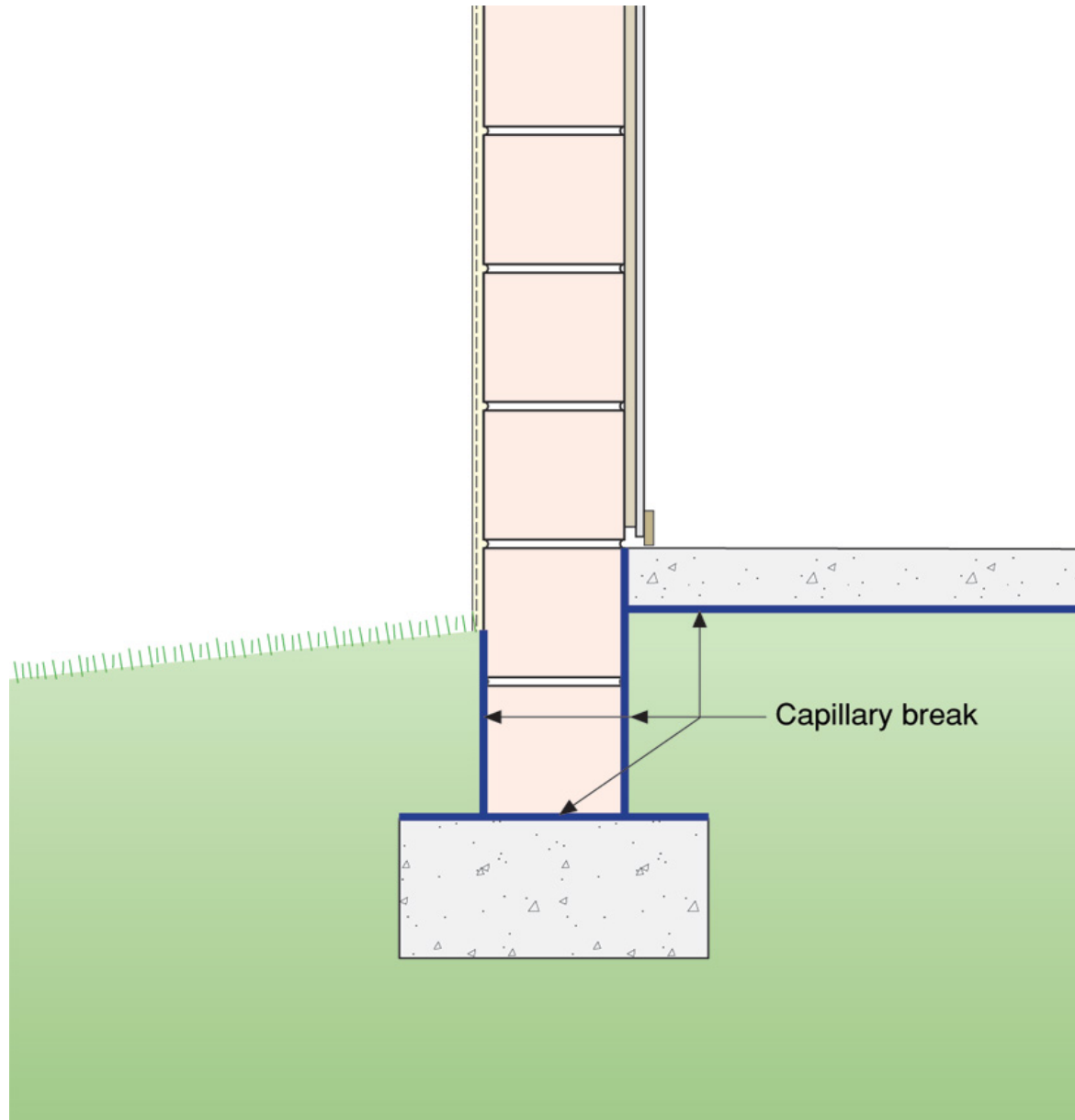


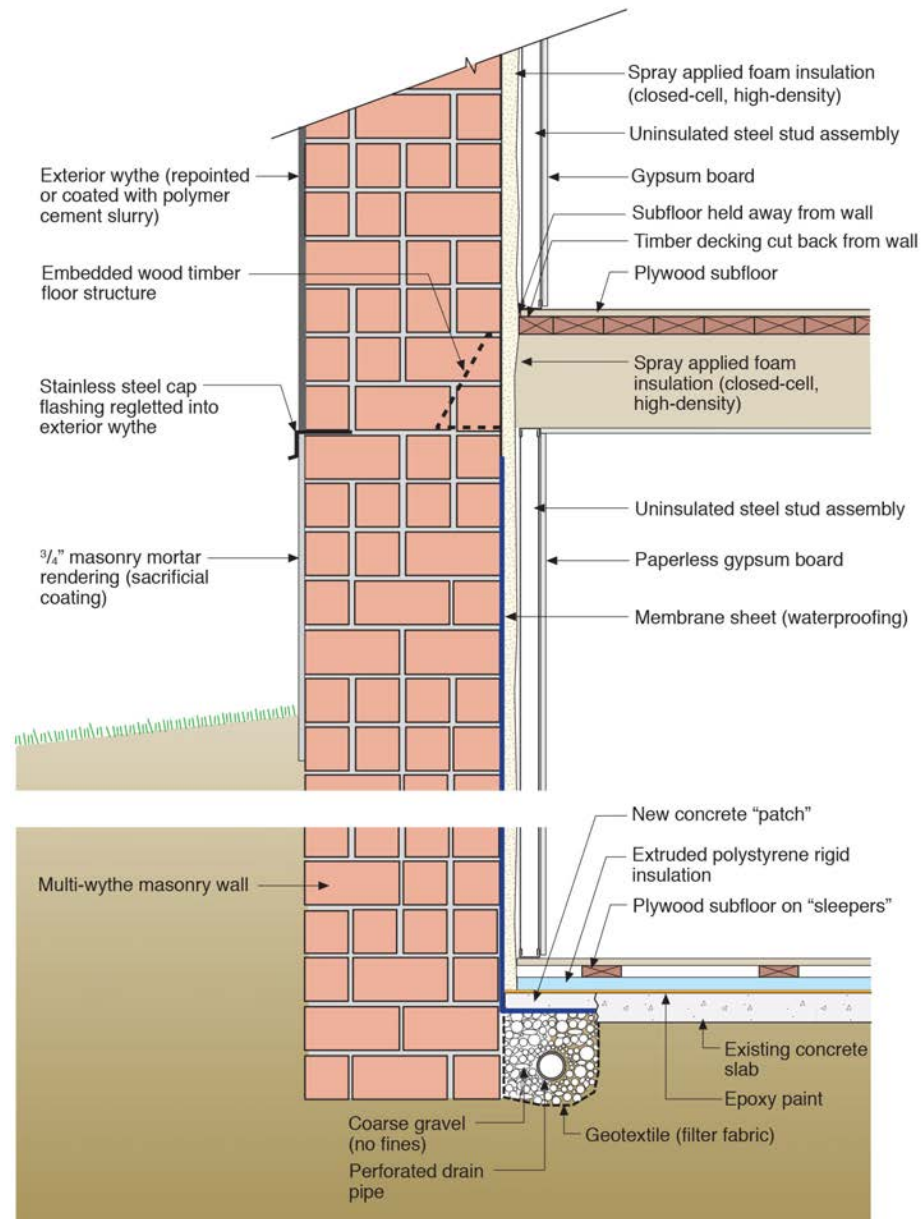


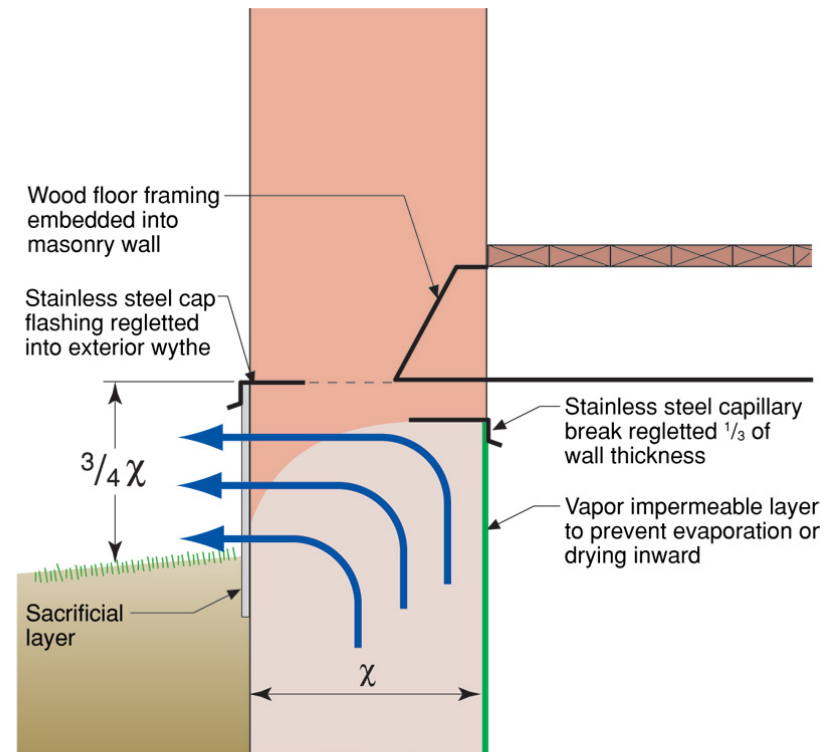
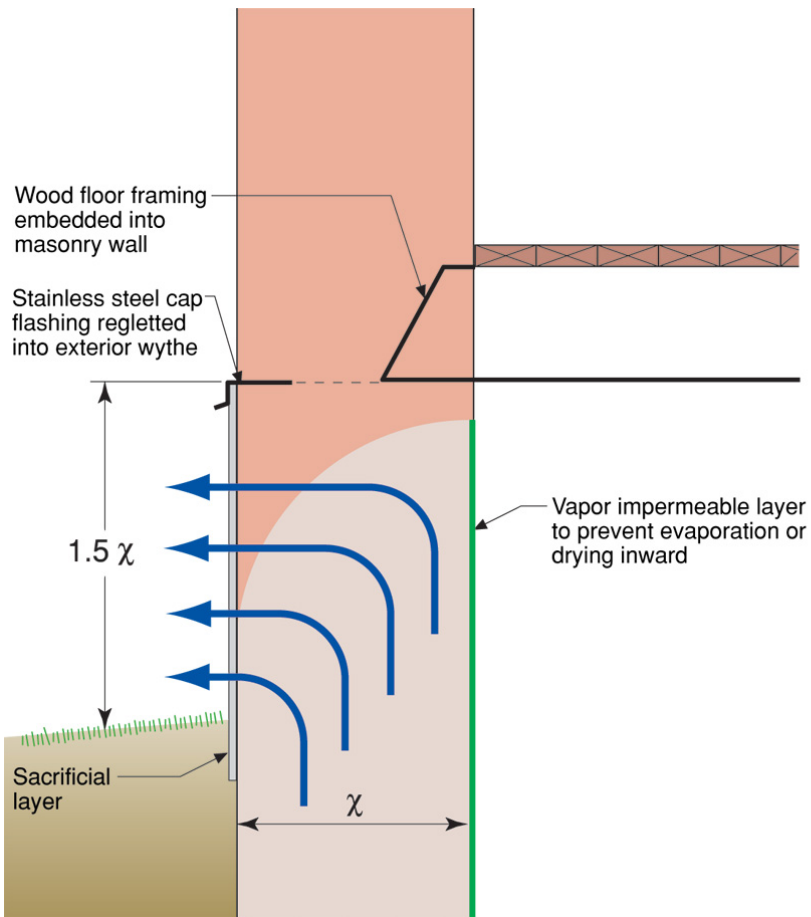






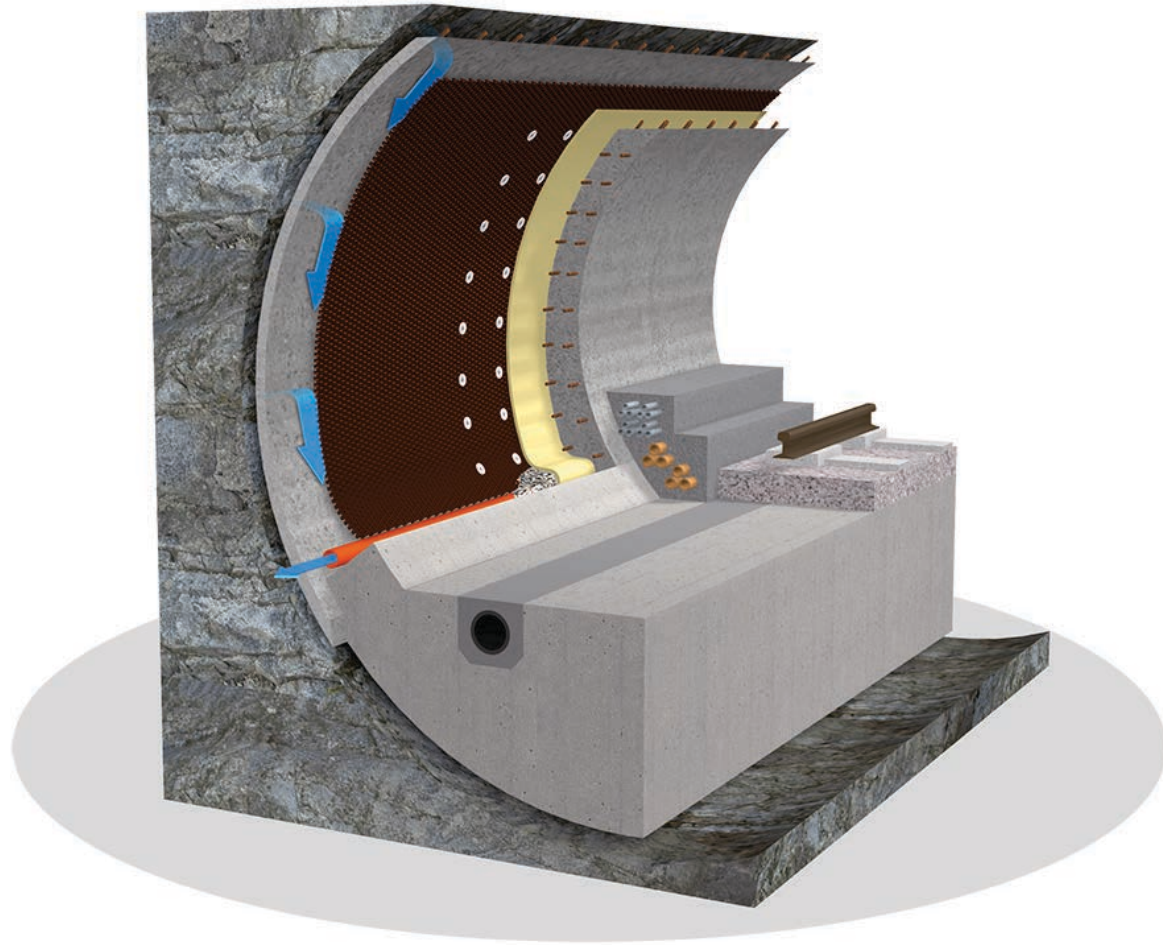




























16 Million Gallons are Pumped Out of the  
Tunnels Each Year....