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

Building Science

Adventures In Building Science

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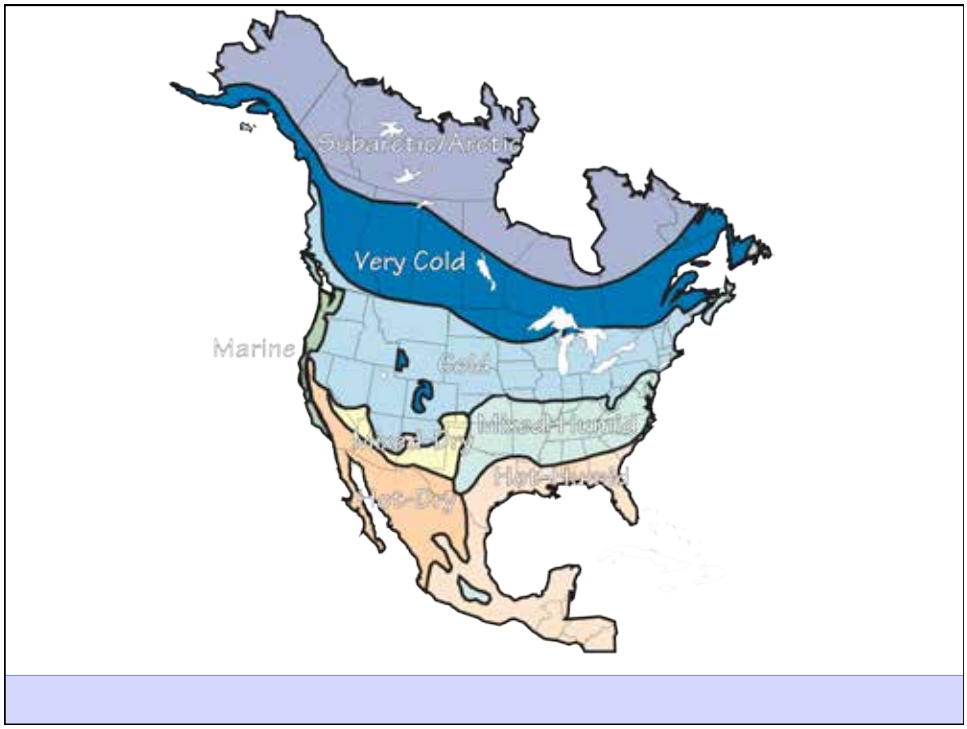
Freeze-Thaw Damage

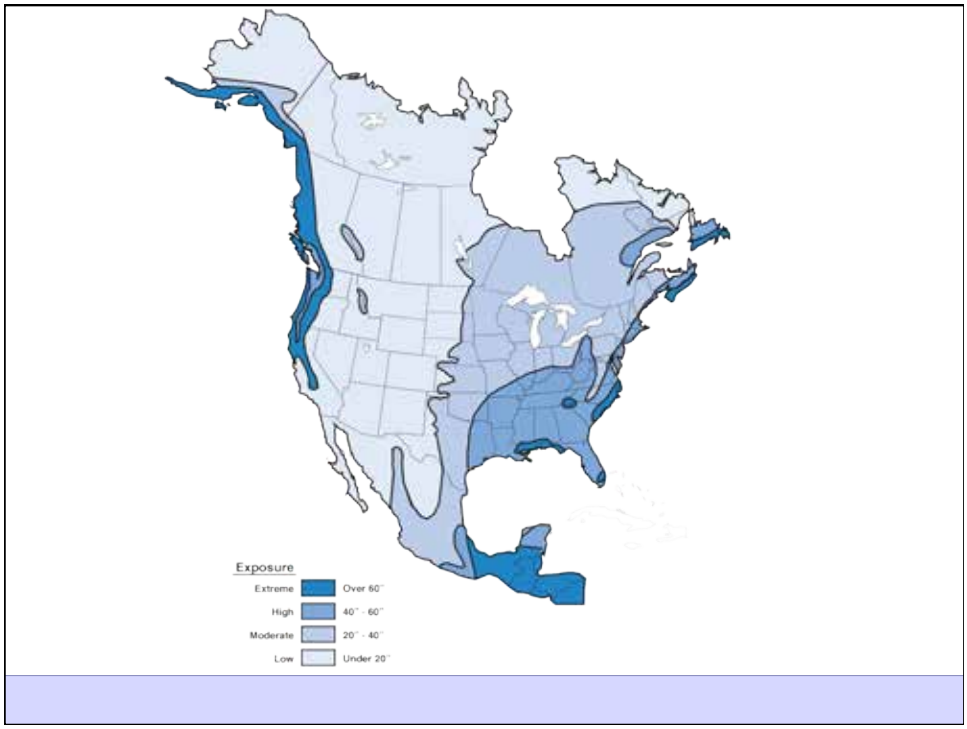
Freeze-Thaw Damage

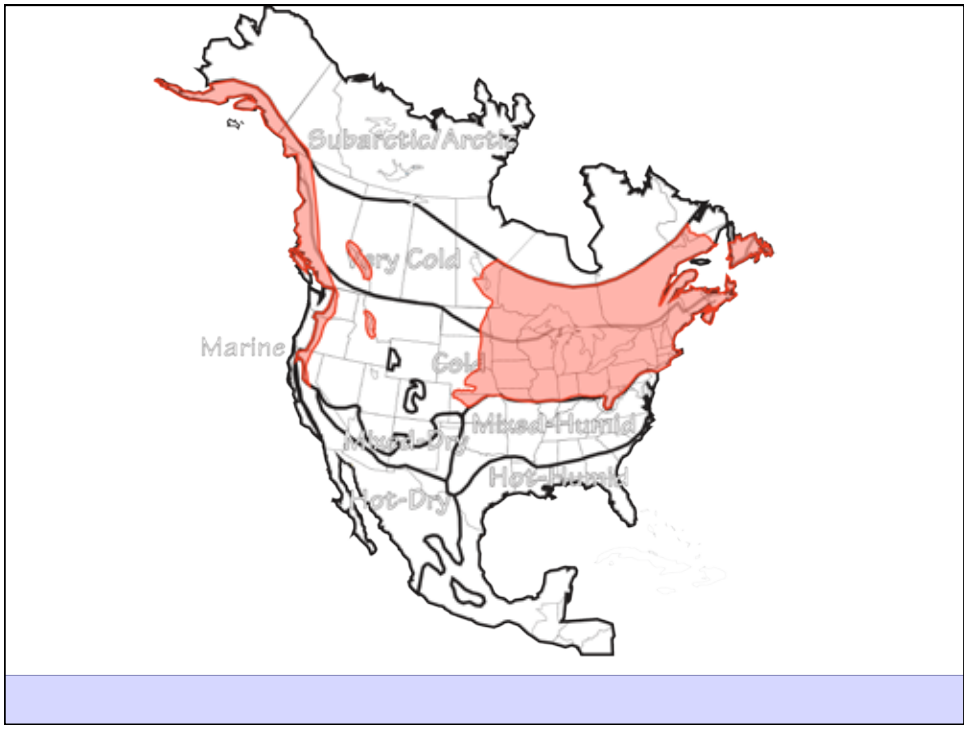
Freezing Temperatures

Water

Susceptible Brick


Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Hot-Humid
Hot-Dry


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



Susceptible Brick
Firing Temperature
Vitrification

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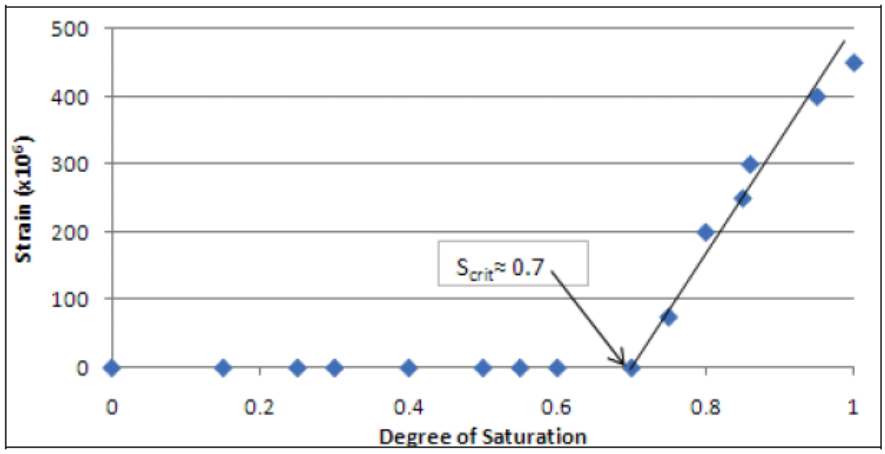

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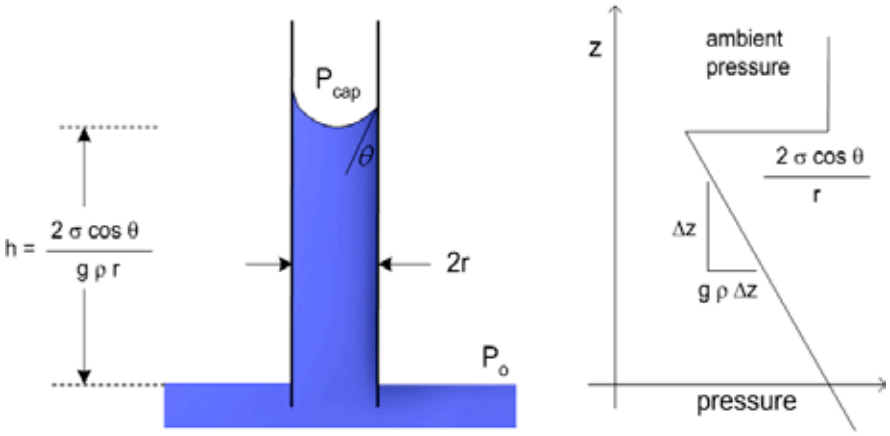
Calculating capillary rise



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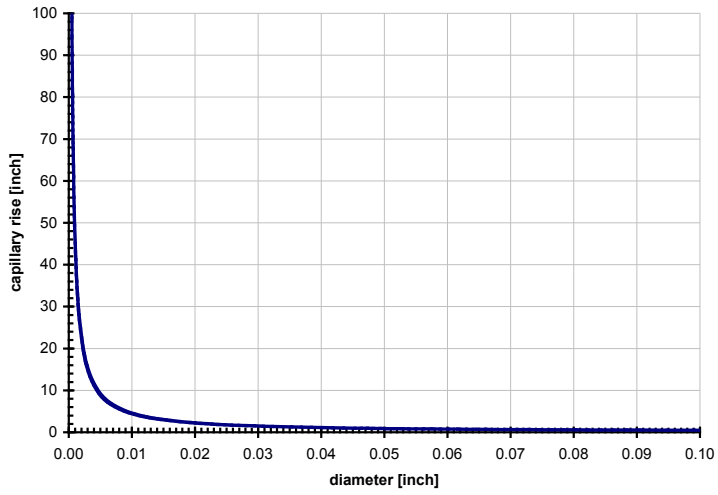
Capillary rise versus diameter



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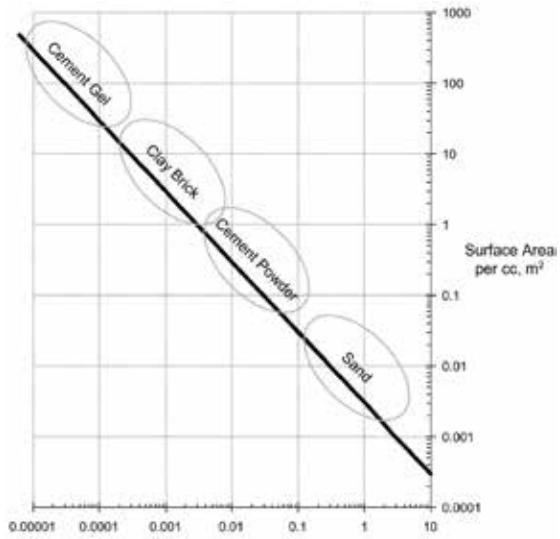

Surface area vs. particle size
From Straube & Burnett, 2005

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

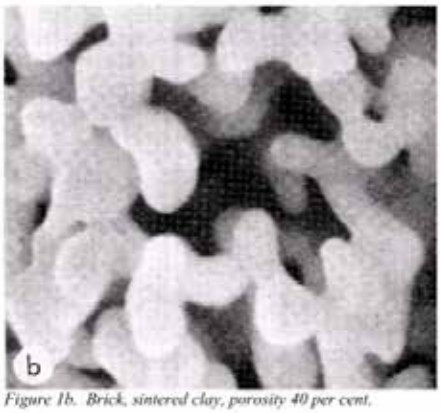

Figure 1b. Brick, sintered clay, porosity 40 per cent.

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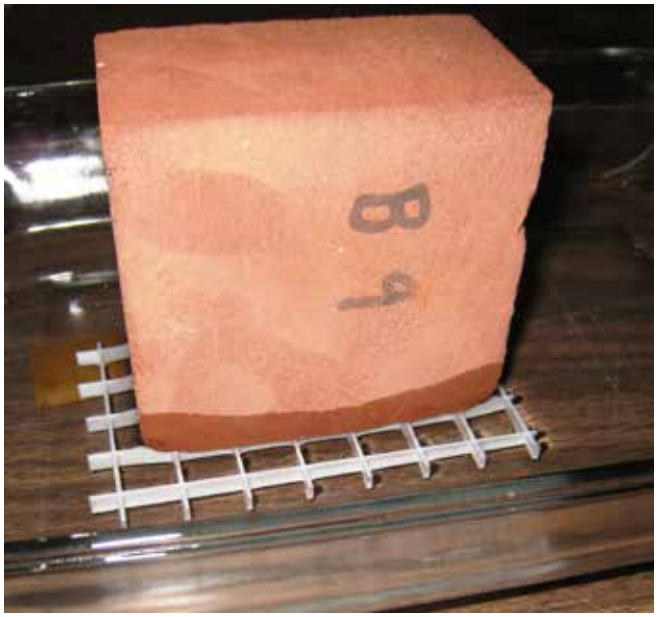

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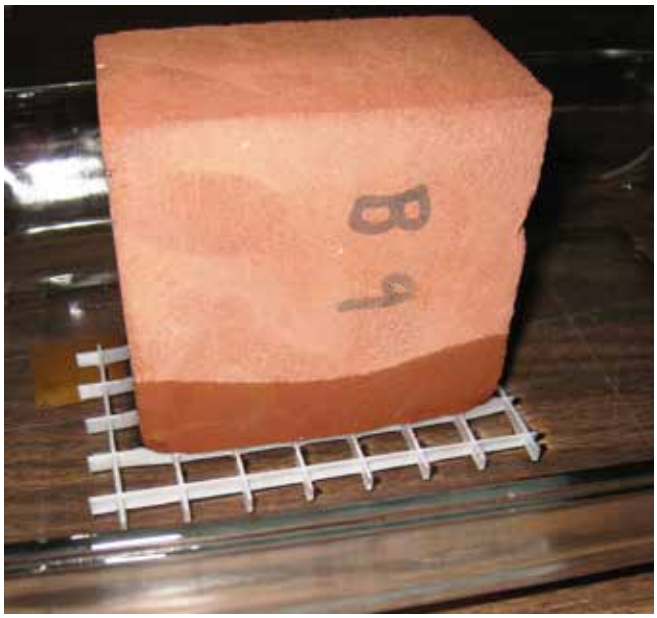

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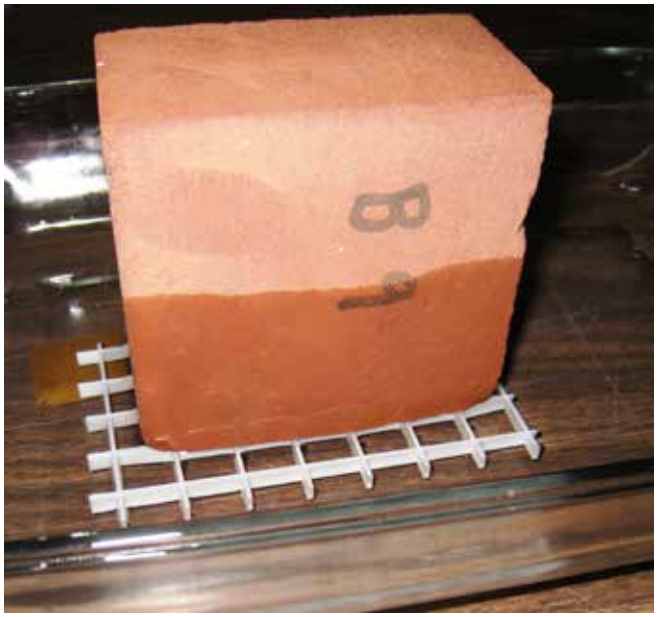

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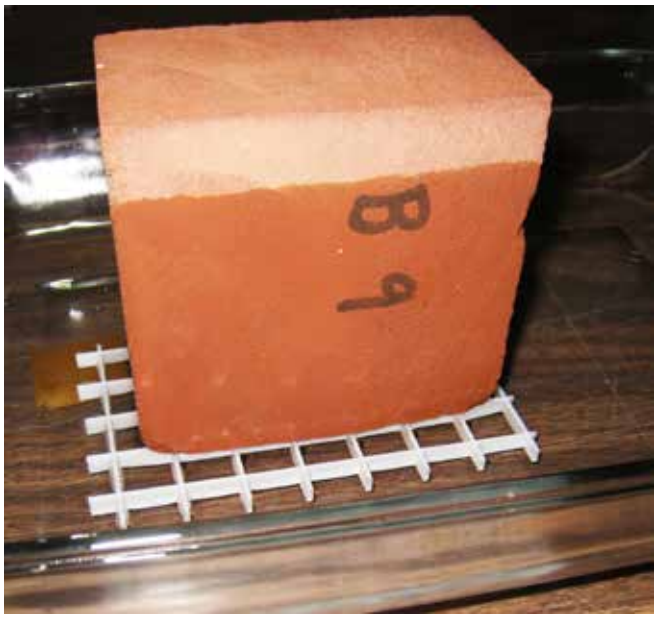

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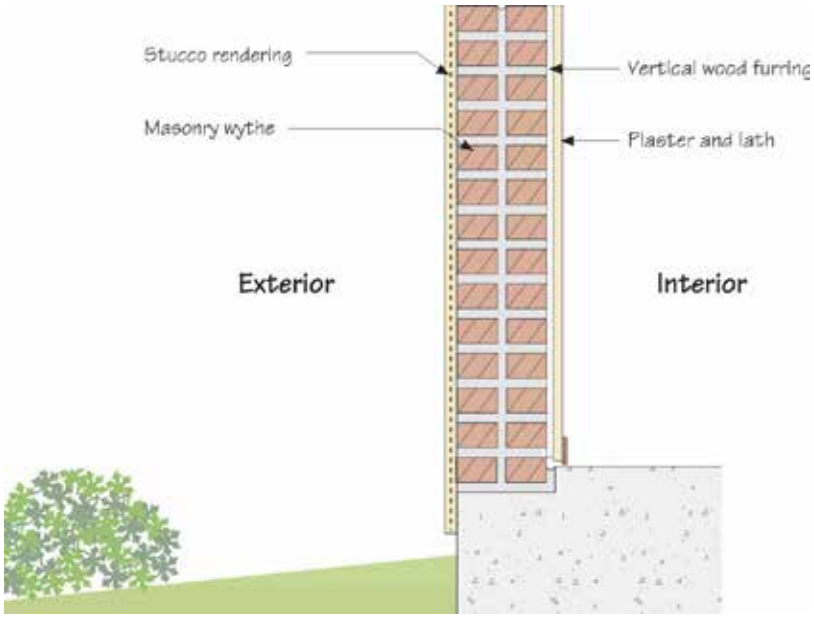

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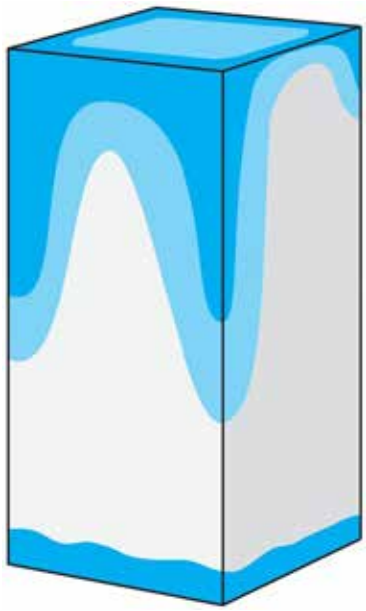

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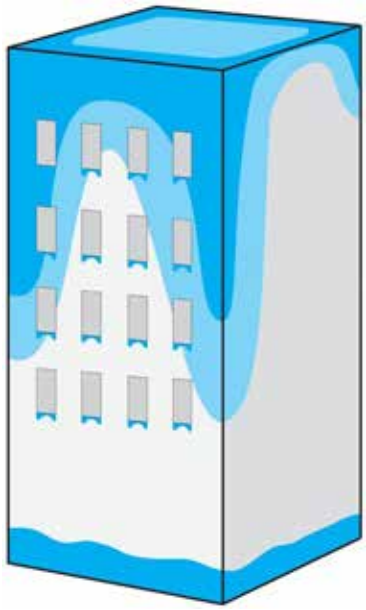

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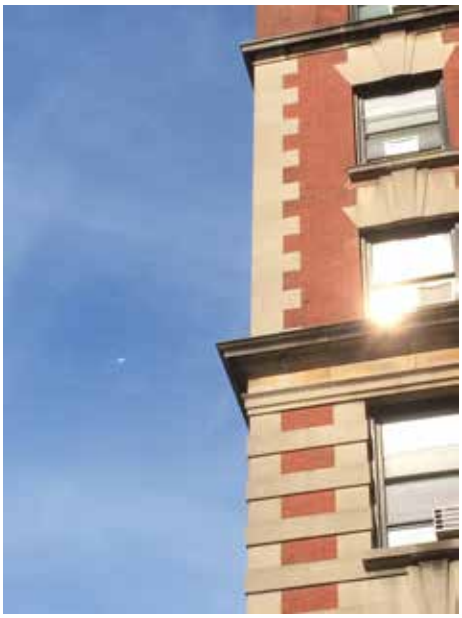

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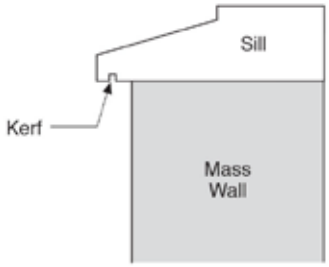

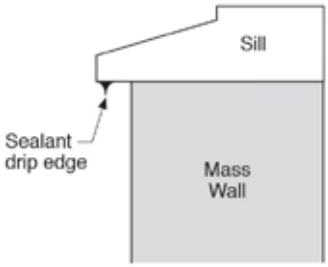

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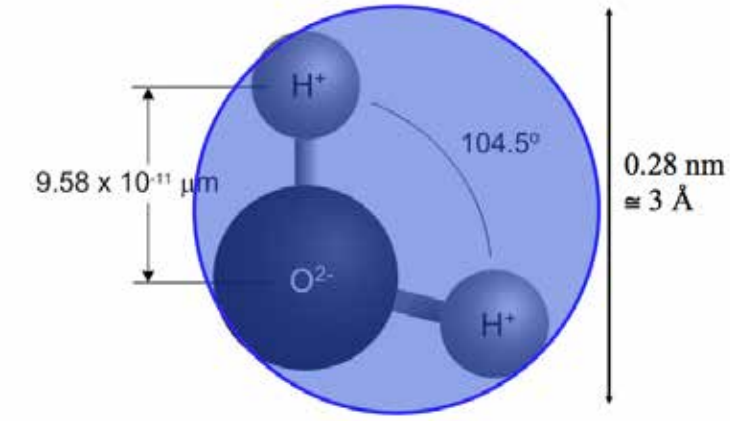

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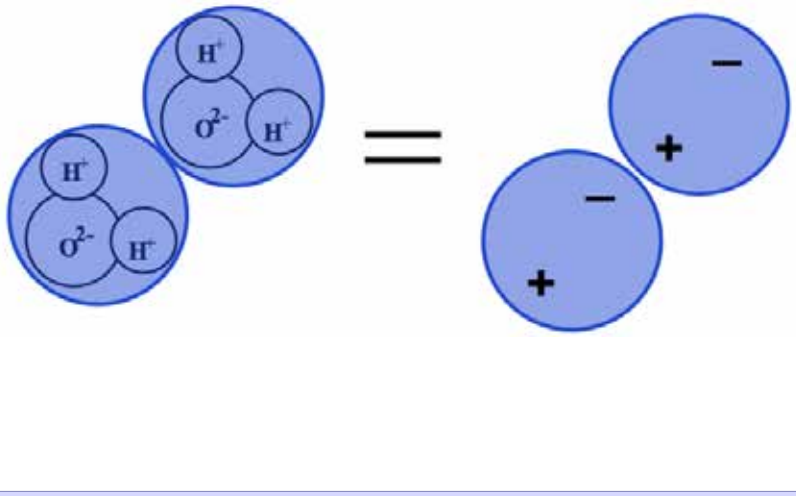

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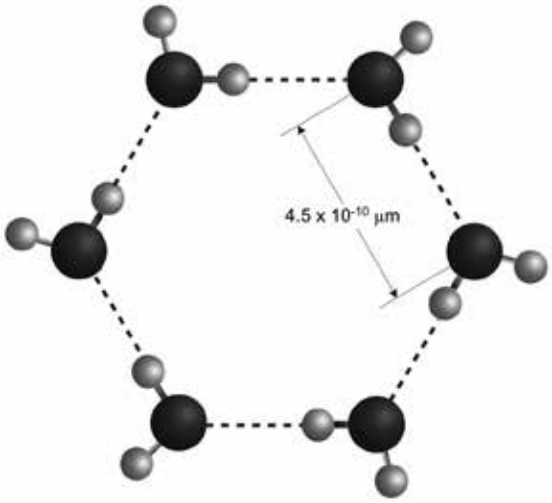

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2nd Law of Thermodynamics

Moisture Transport in Porous Media

Phase	Transport Process	Driving Potential
Vapor	Diffusion	Vapor Concentration
Adsorbate	Surface Diffusion	Concentration
Liquid	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration

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

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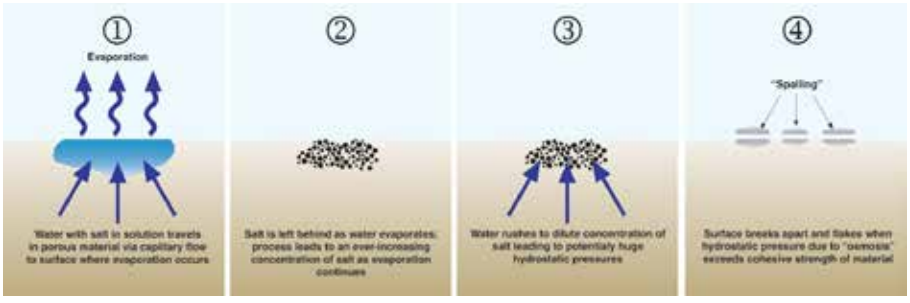

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Diffusion + Capillarity + Osmosis = Problem

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

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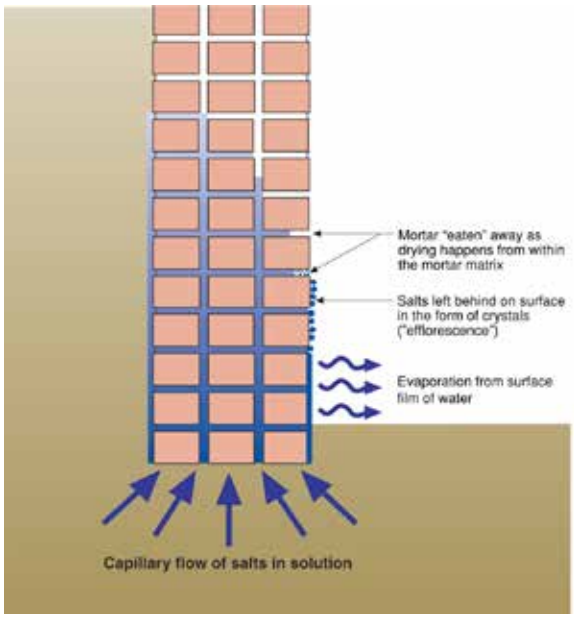

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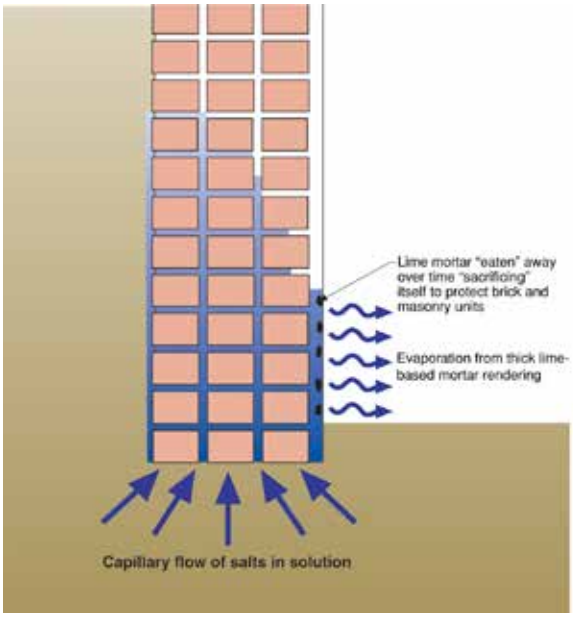

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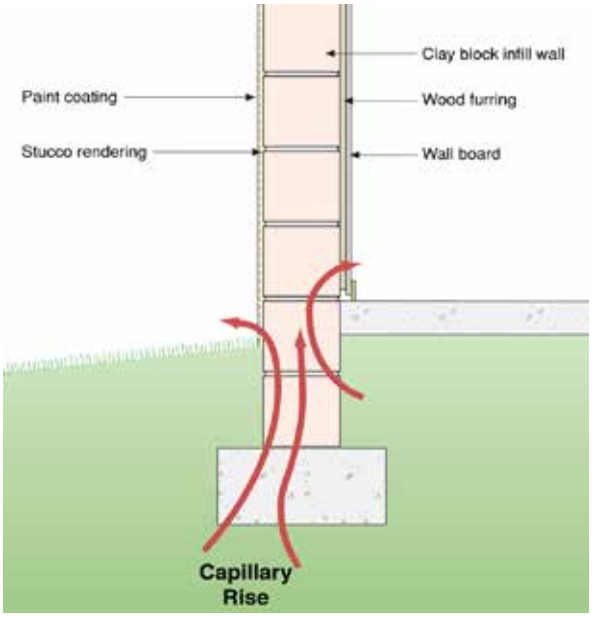

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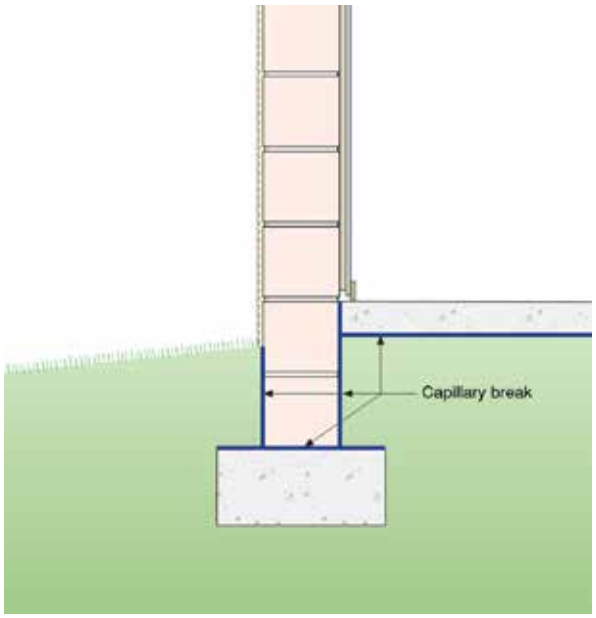

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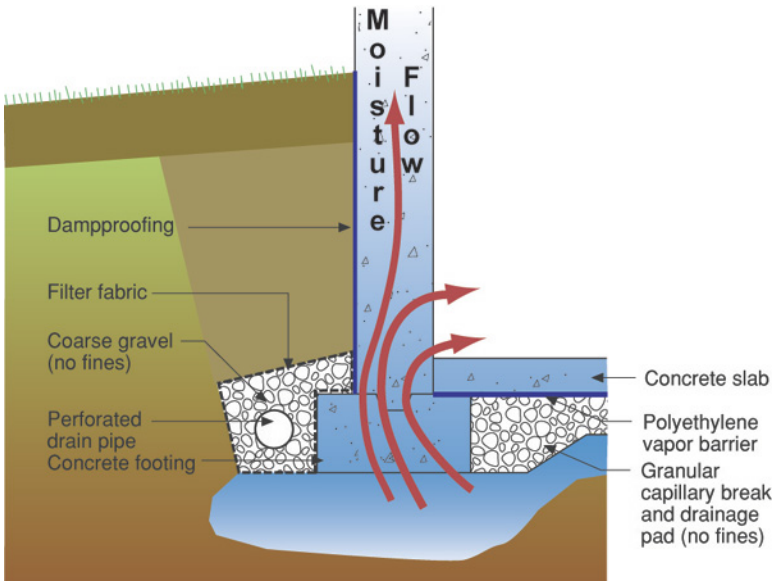

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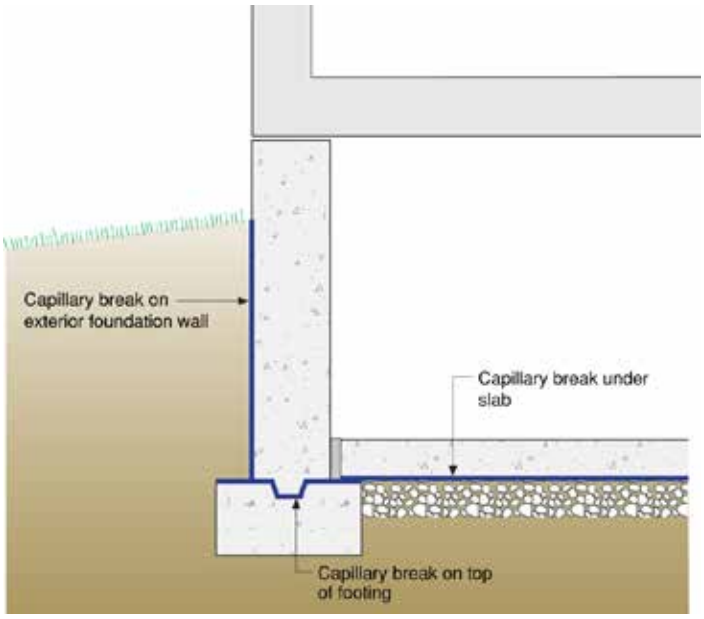

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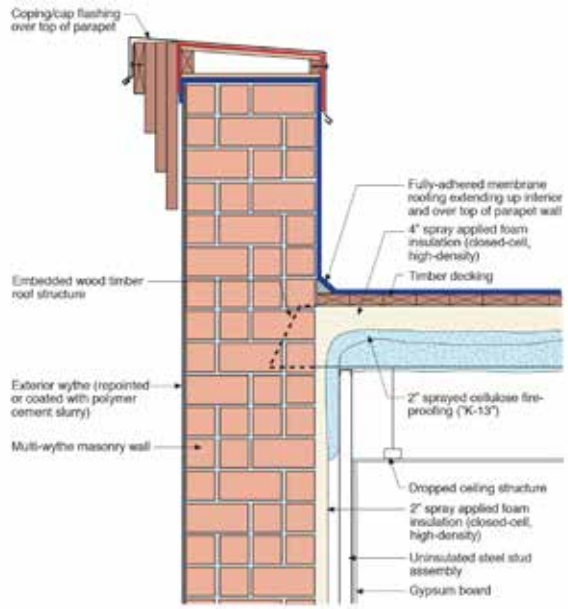

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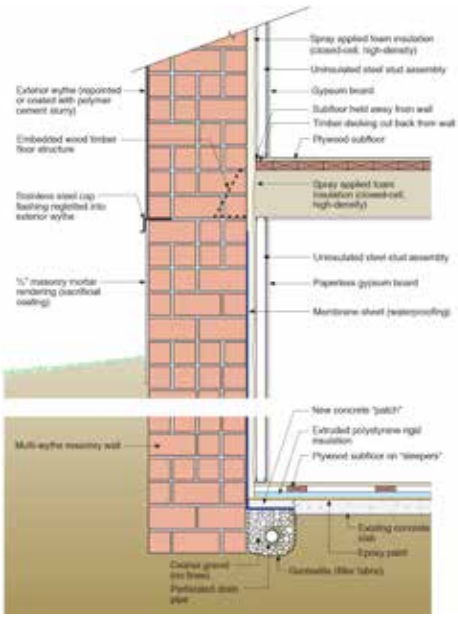

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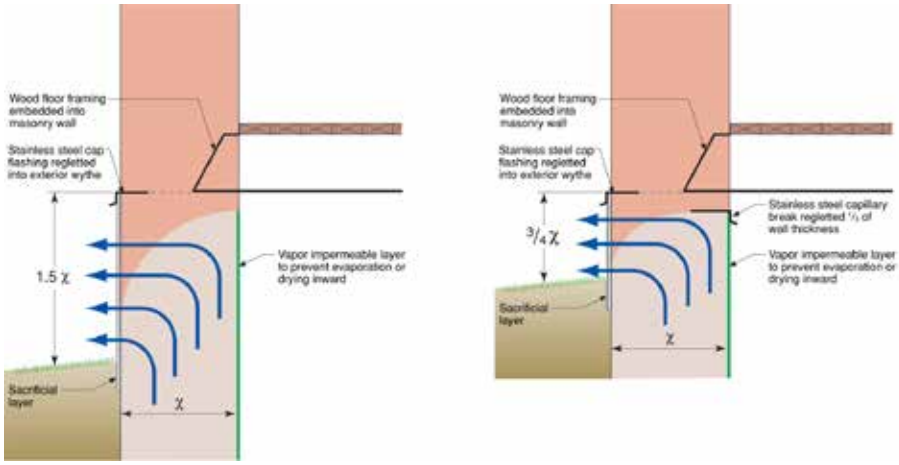

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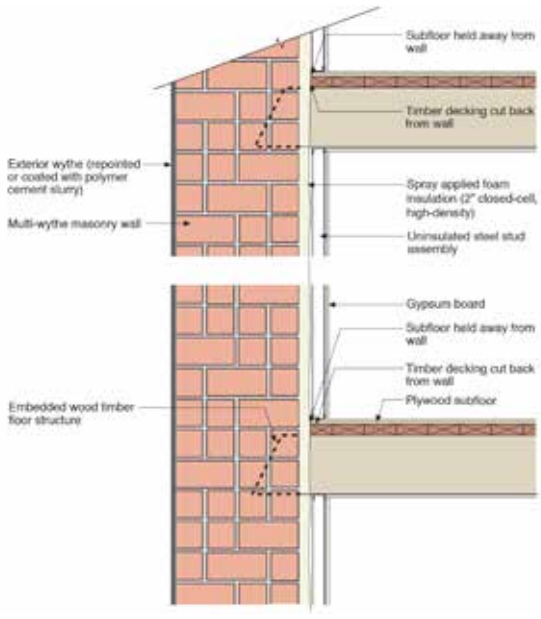

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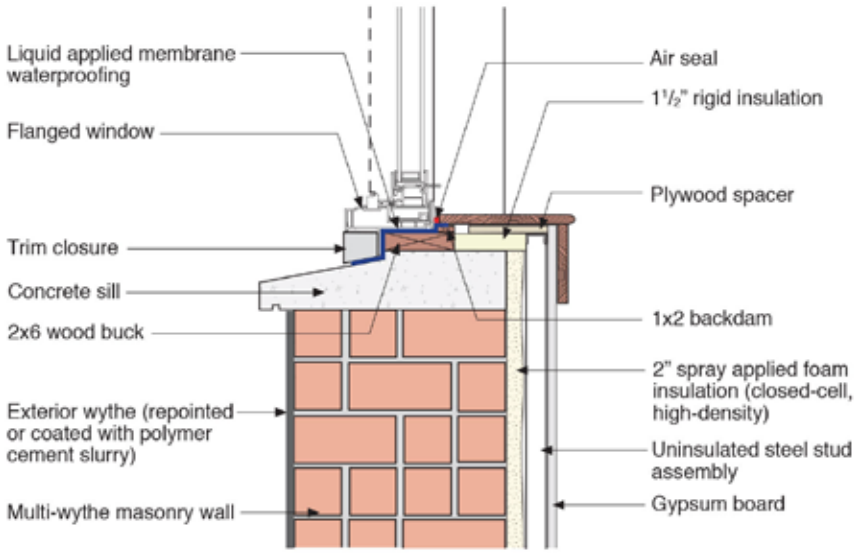

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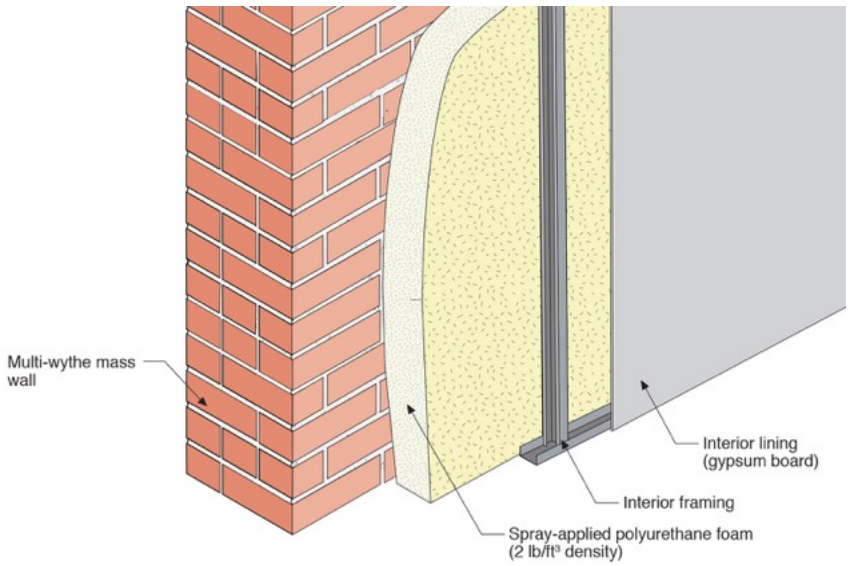

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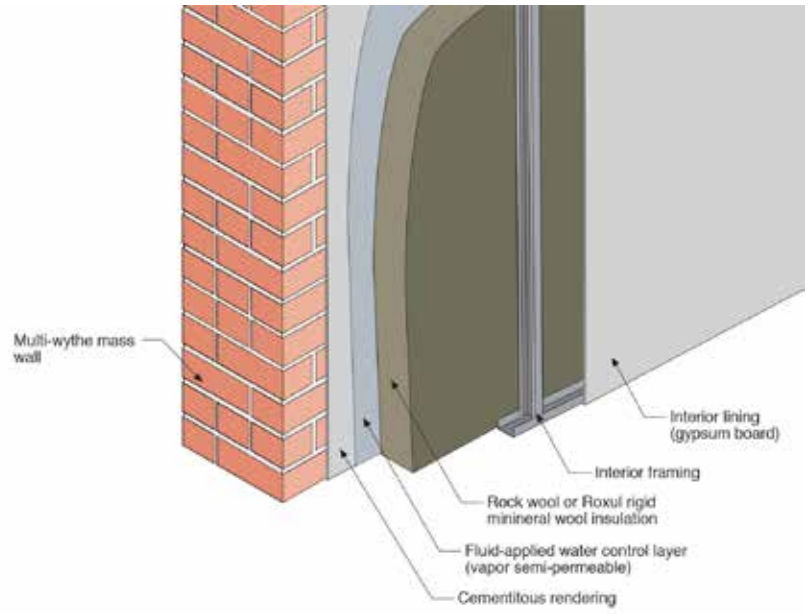

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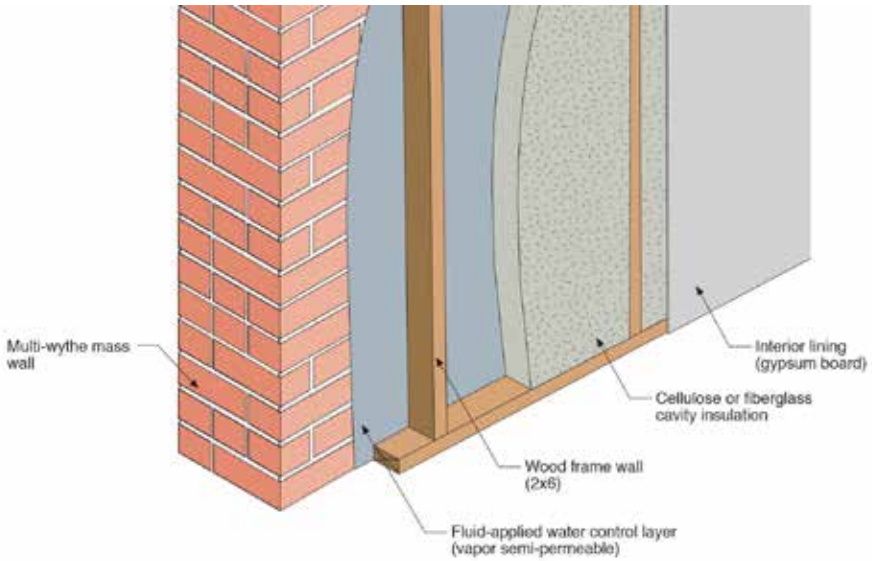

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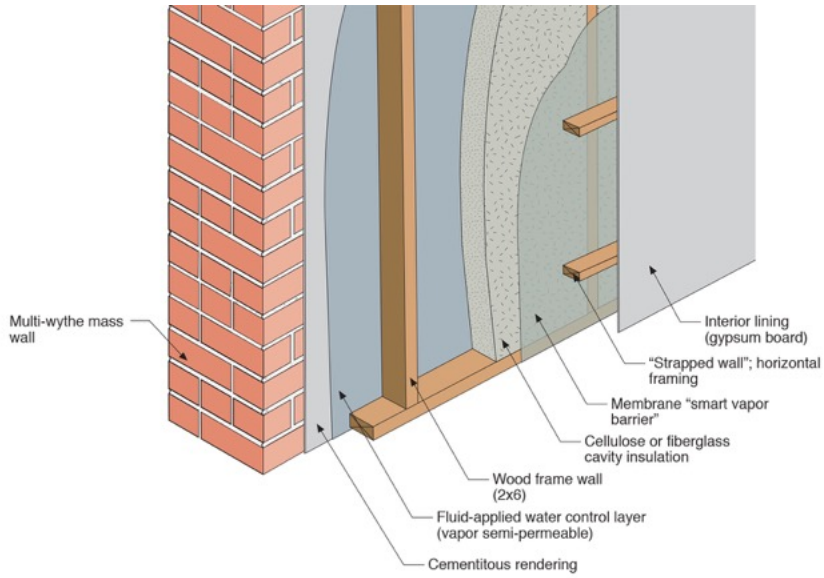

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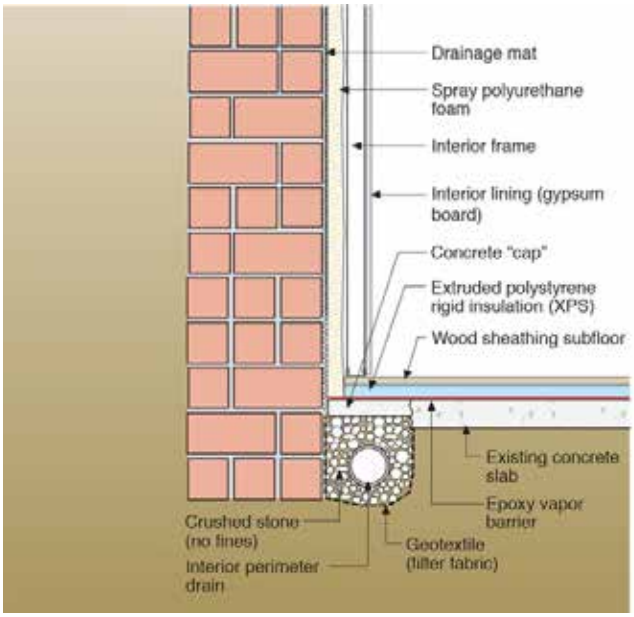

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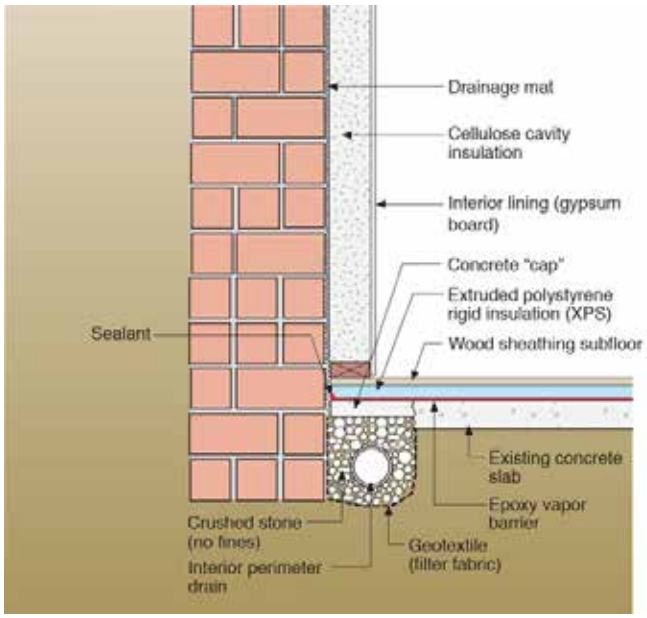

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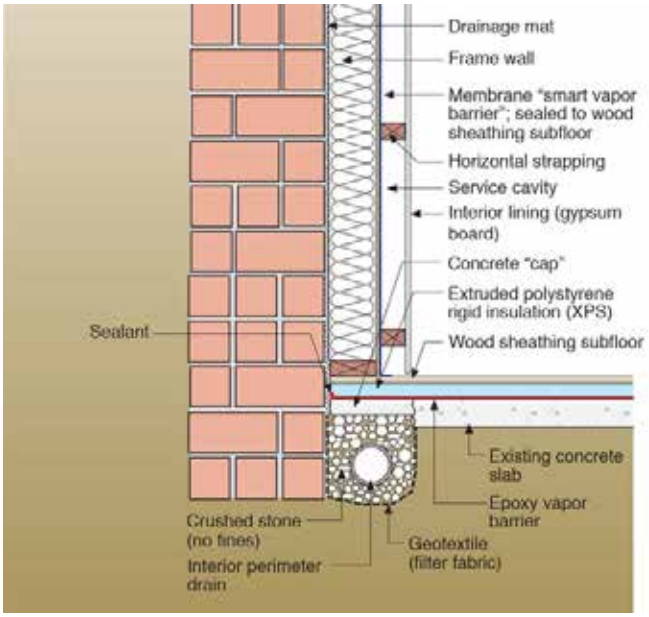

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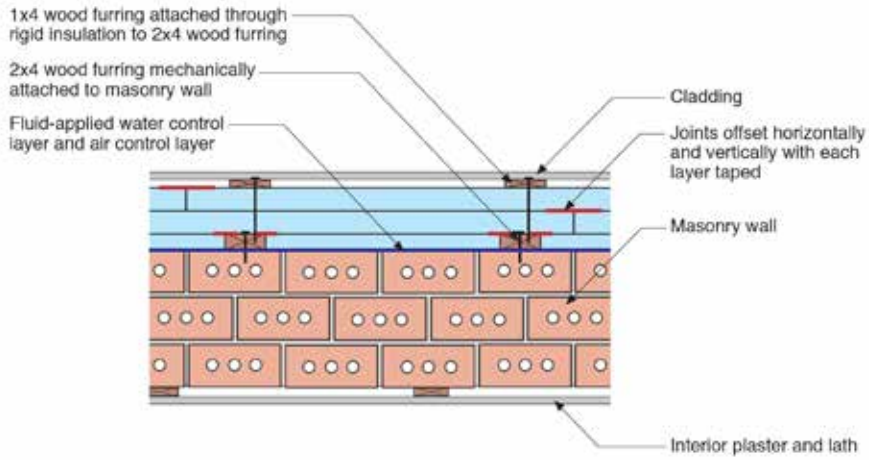

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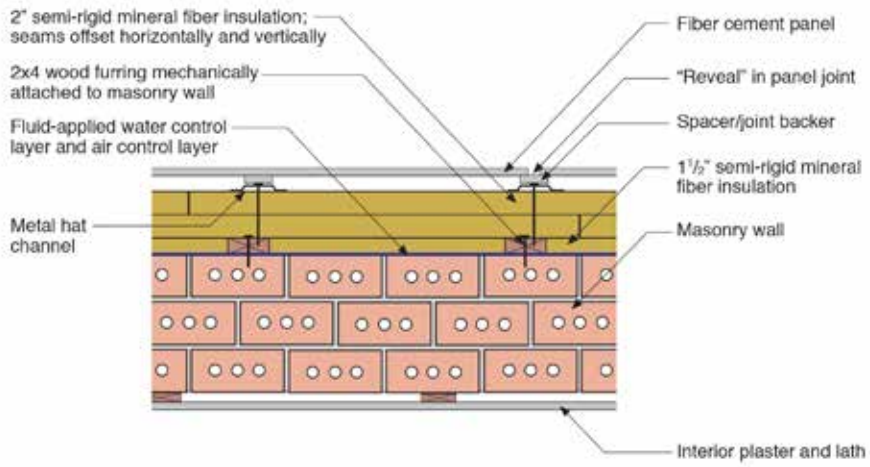

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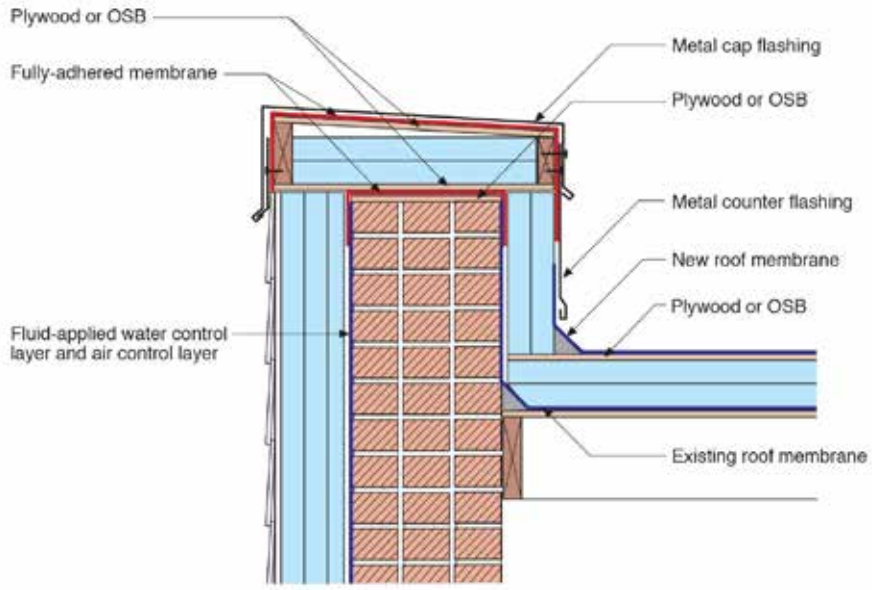

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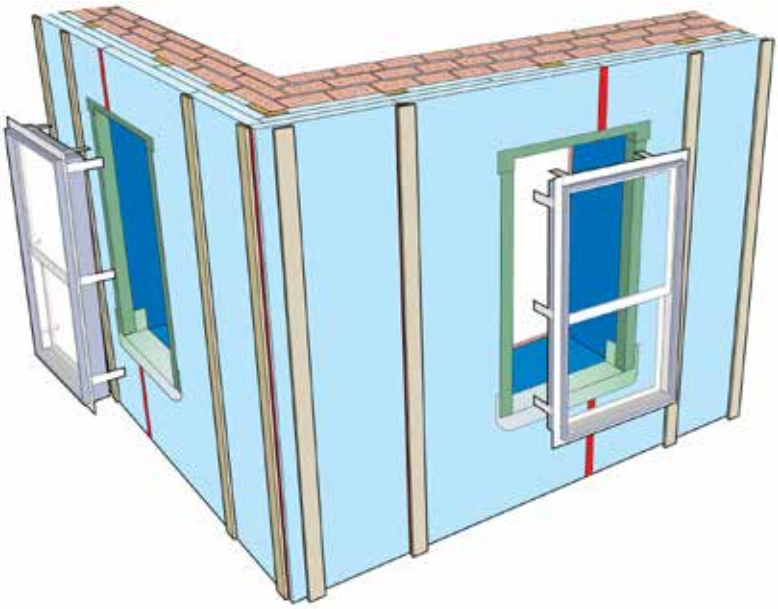
Joseph Lstiburek 131



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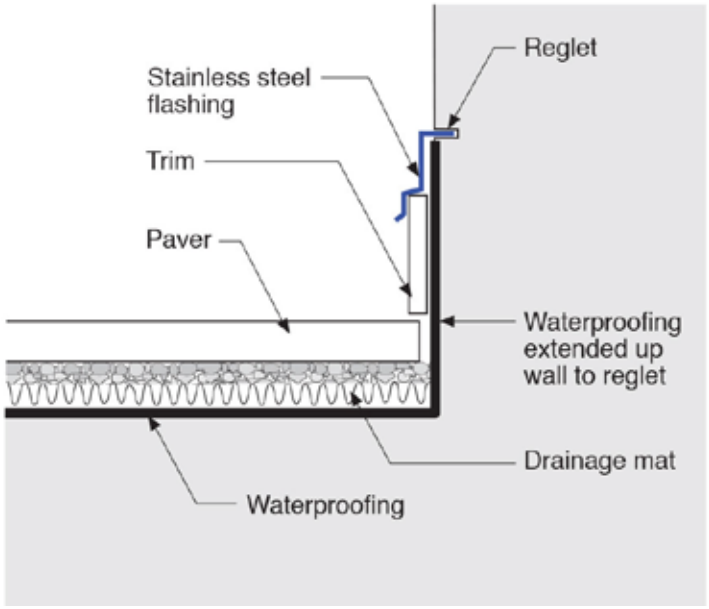

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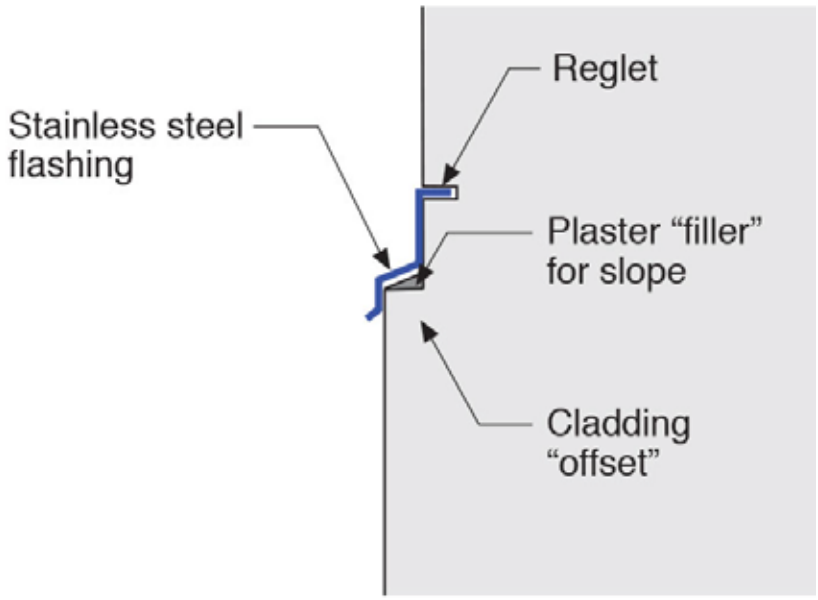
Joseph Lstiburek 140



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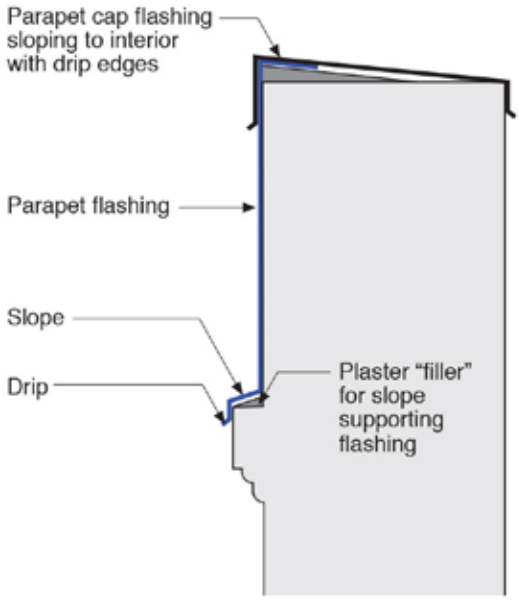

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Joseph Lstiburek 145

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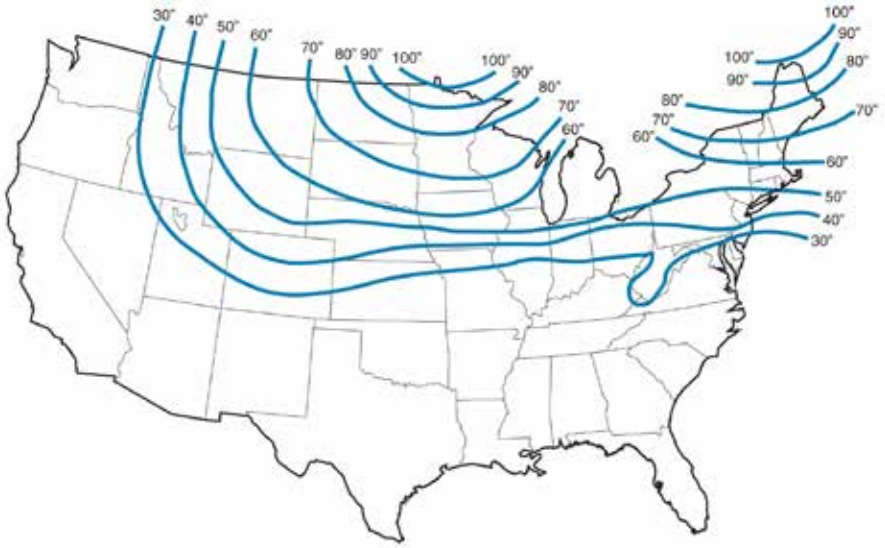
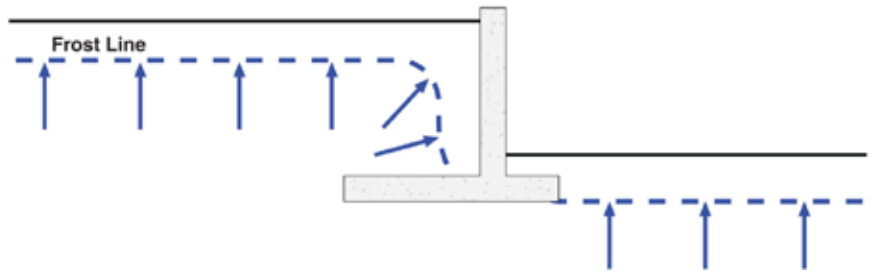
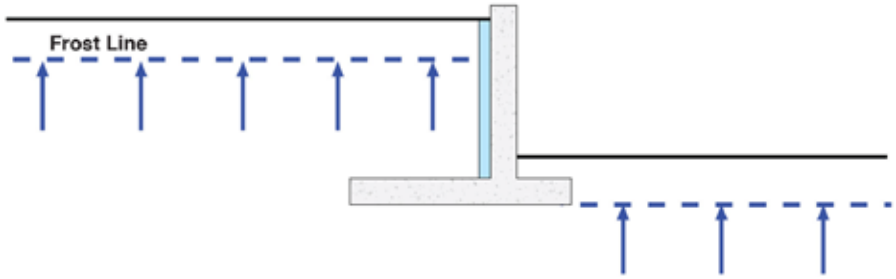
Joseph Lstiburek 146



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





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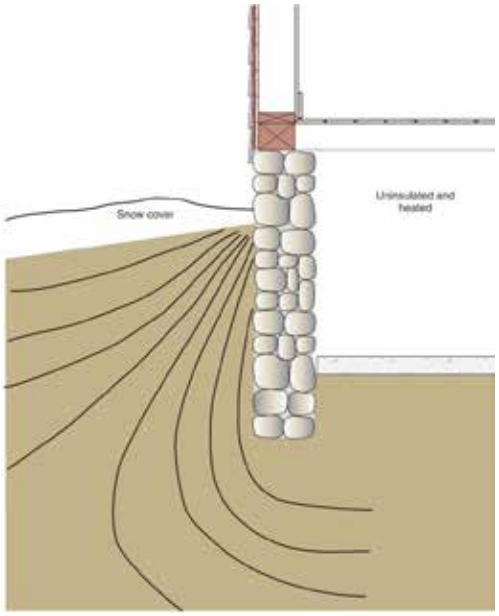

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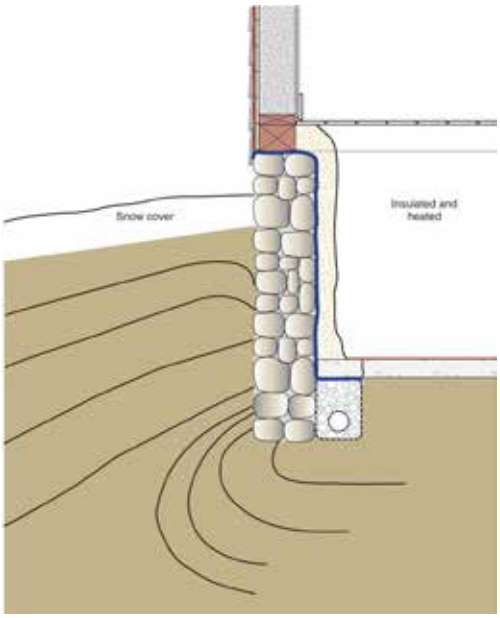

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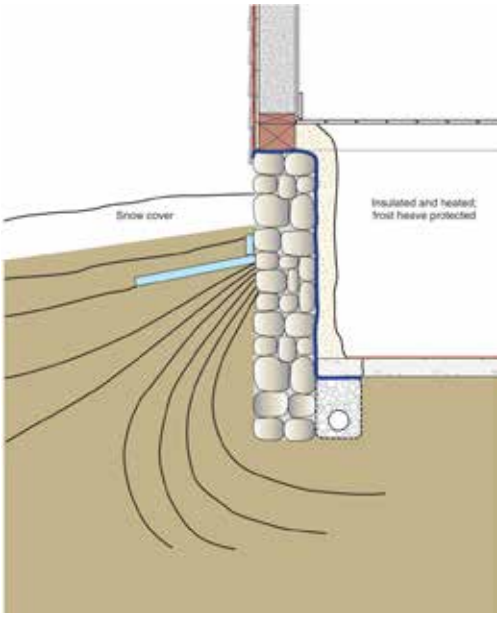

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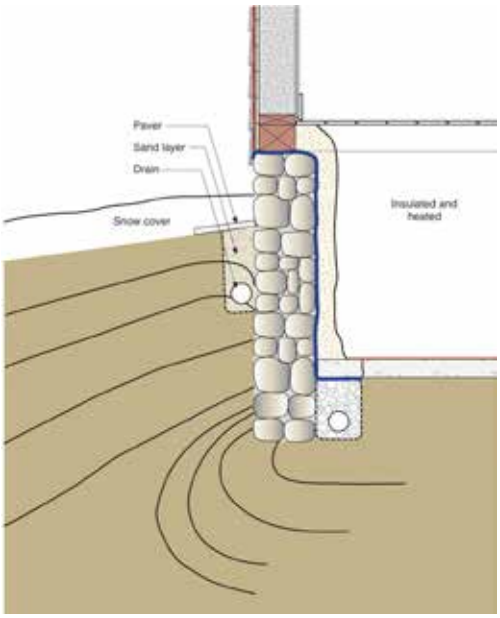

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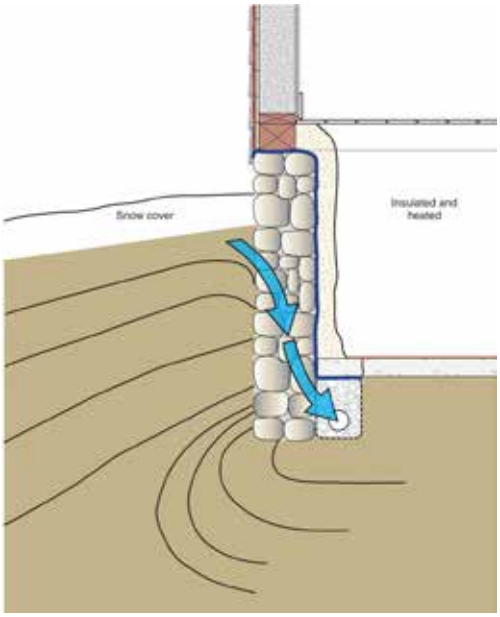

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