

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

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Adventures In Building Science

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Freeze-Thaw Damage

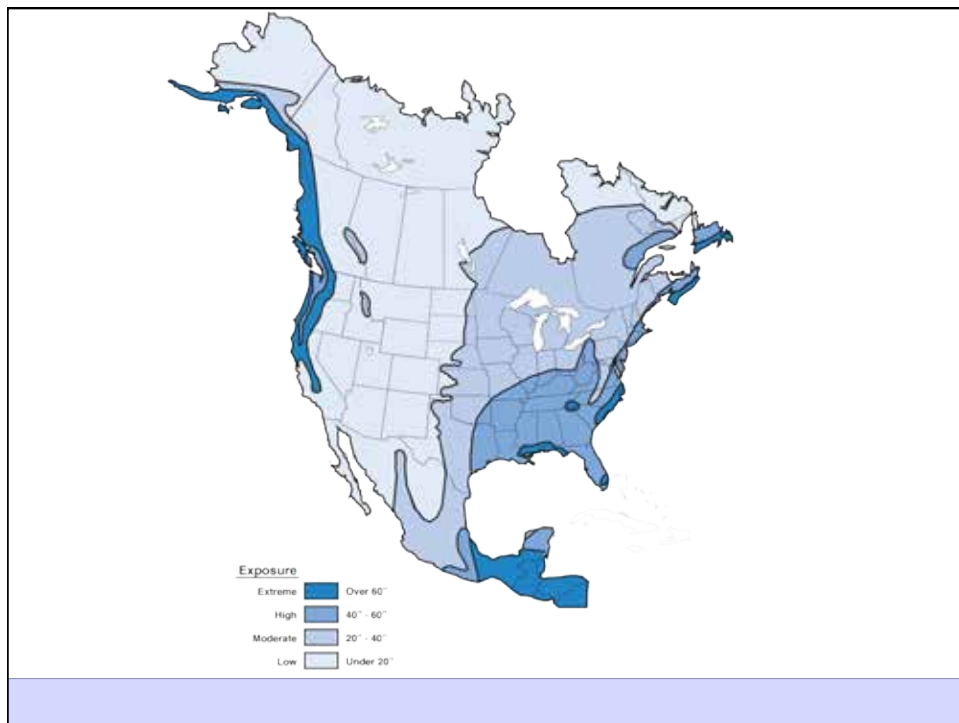
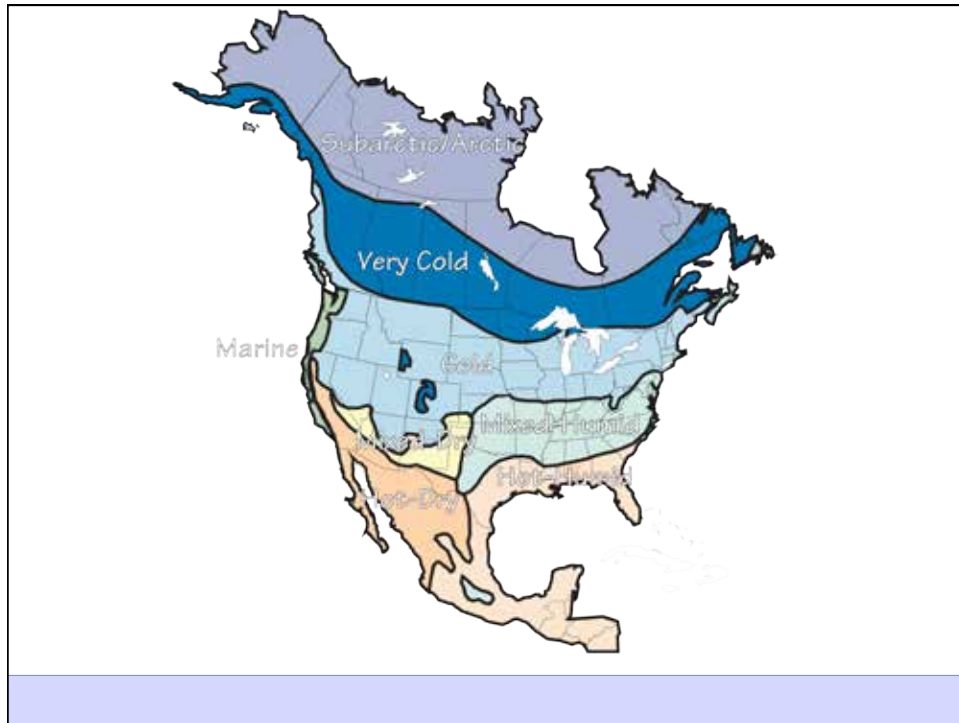
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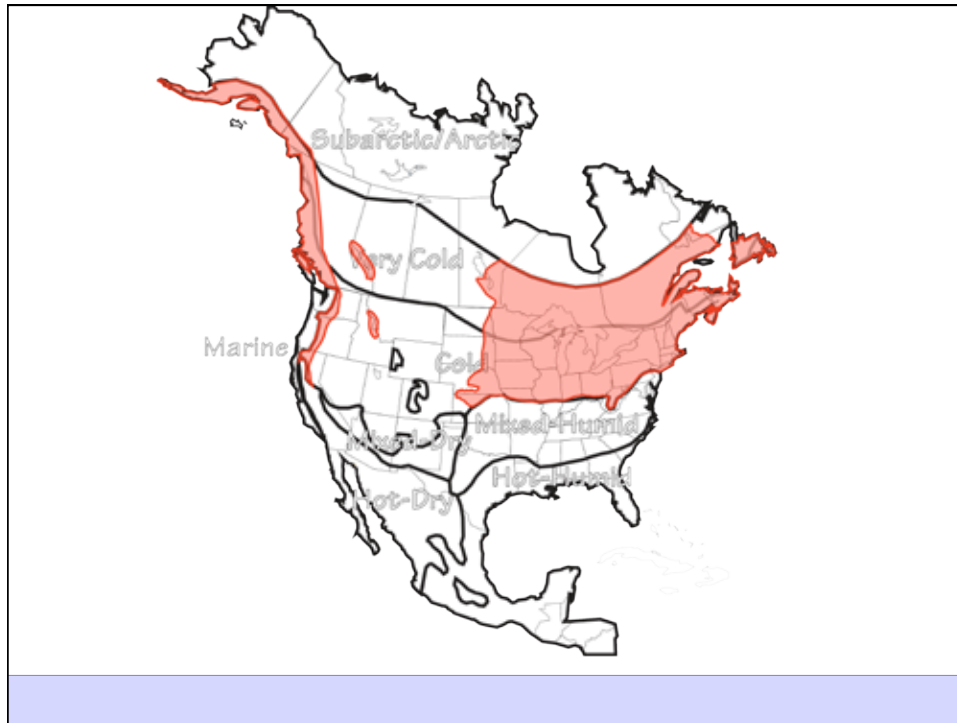
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Freeze-Thaw Damage
Freezing Temperatures
Water
Susceptible Brick

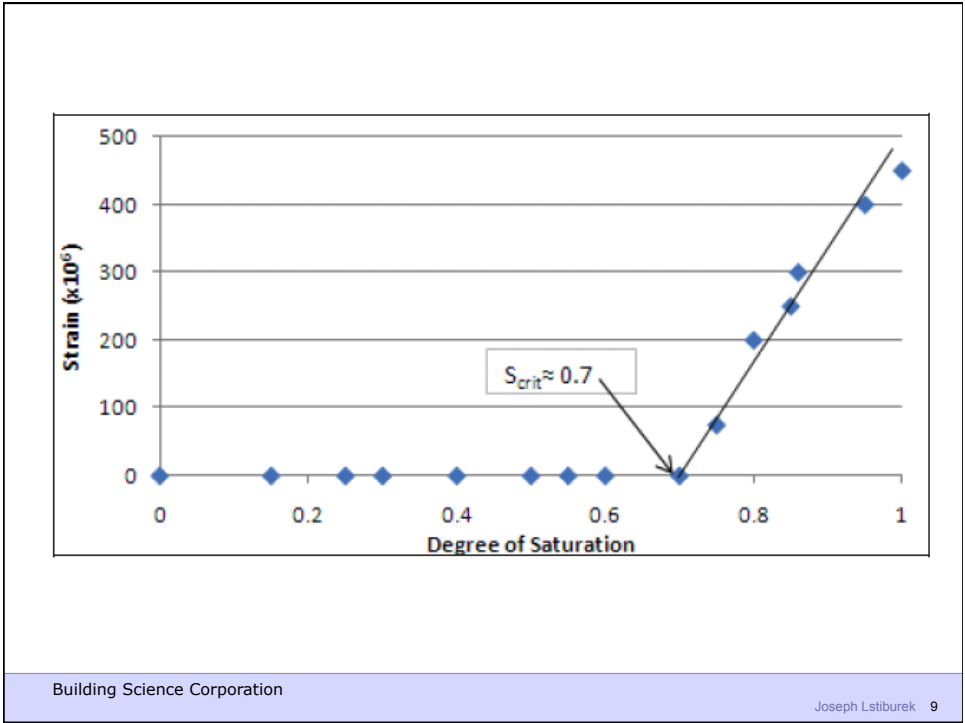
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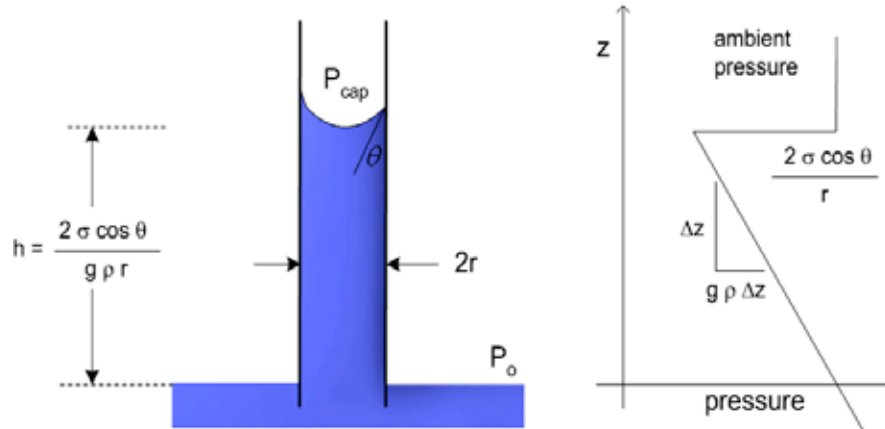




Susceptible Brick
Firing Temperature
Vitrification



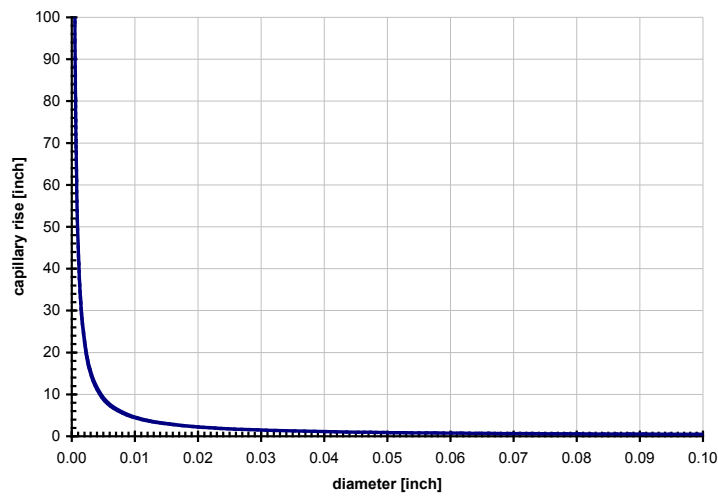
Calculating capillary rise



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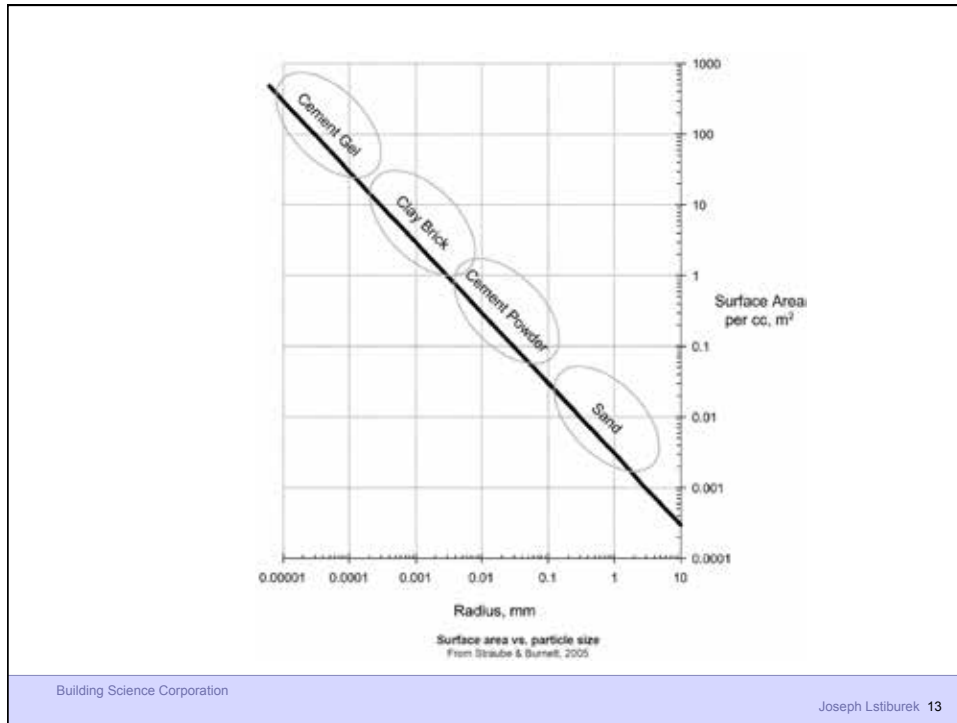
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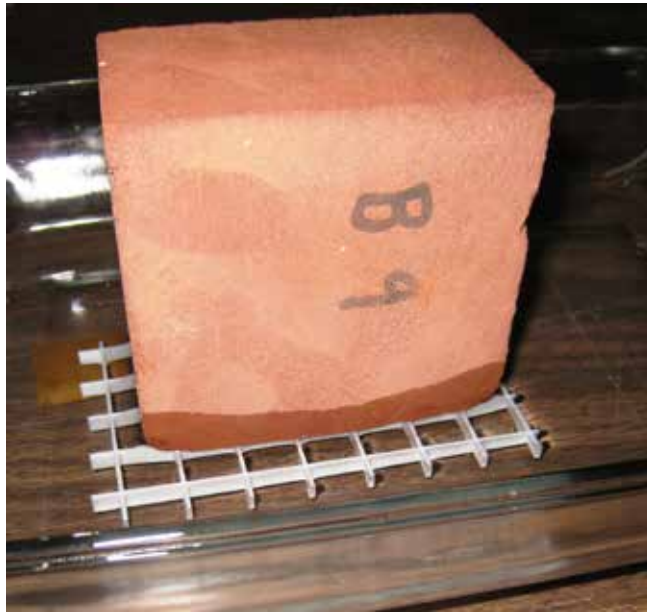
Capillary rise versus diameter



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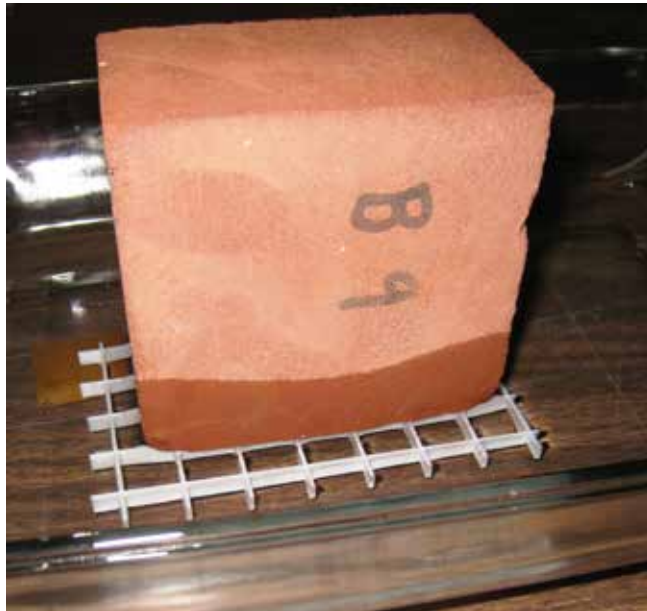
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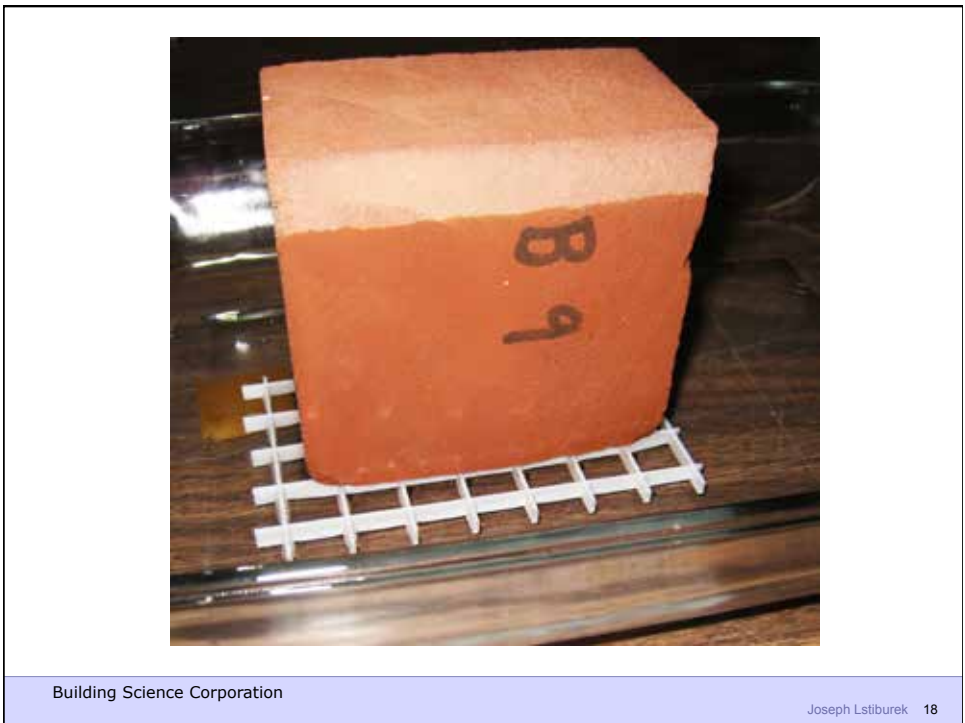
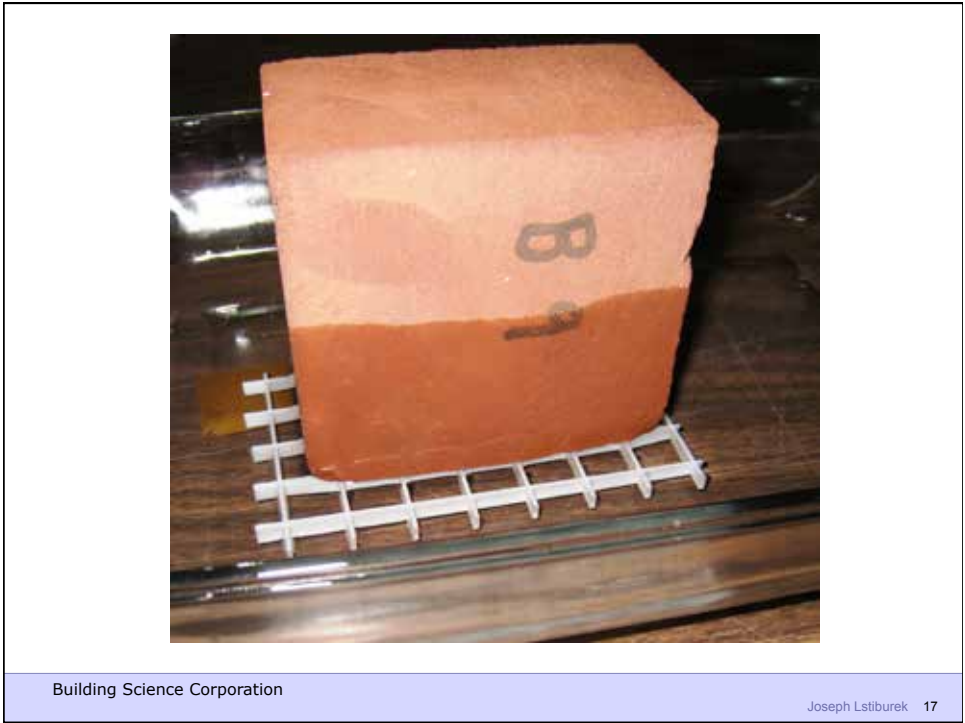
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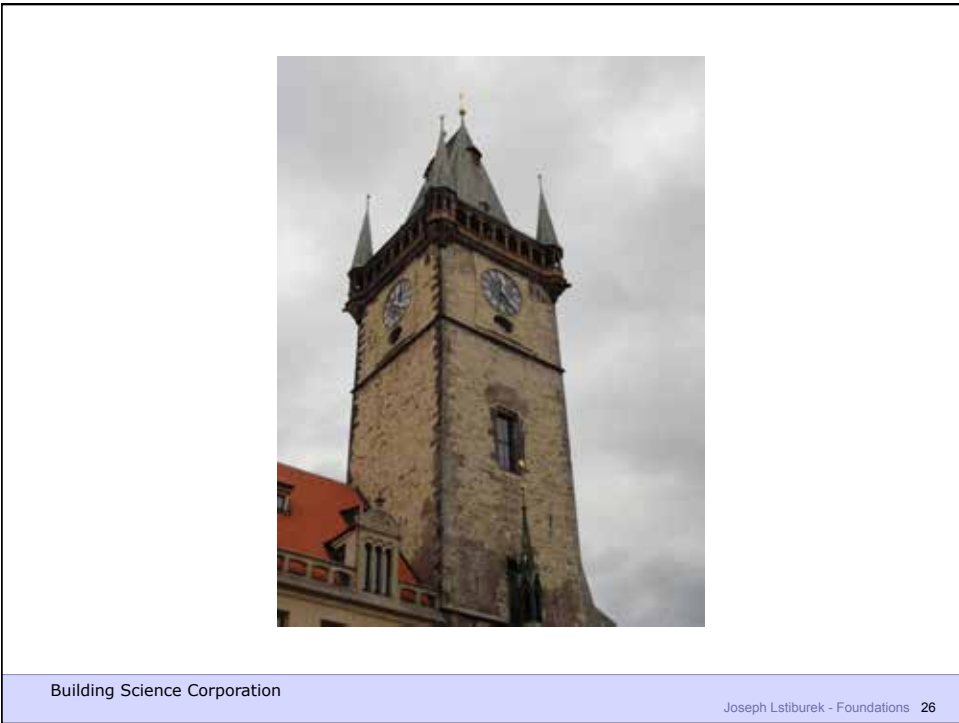
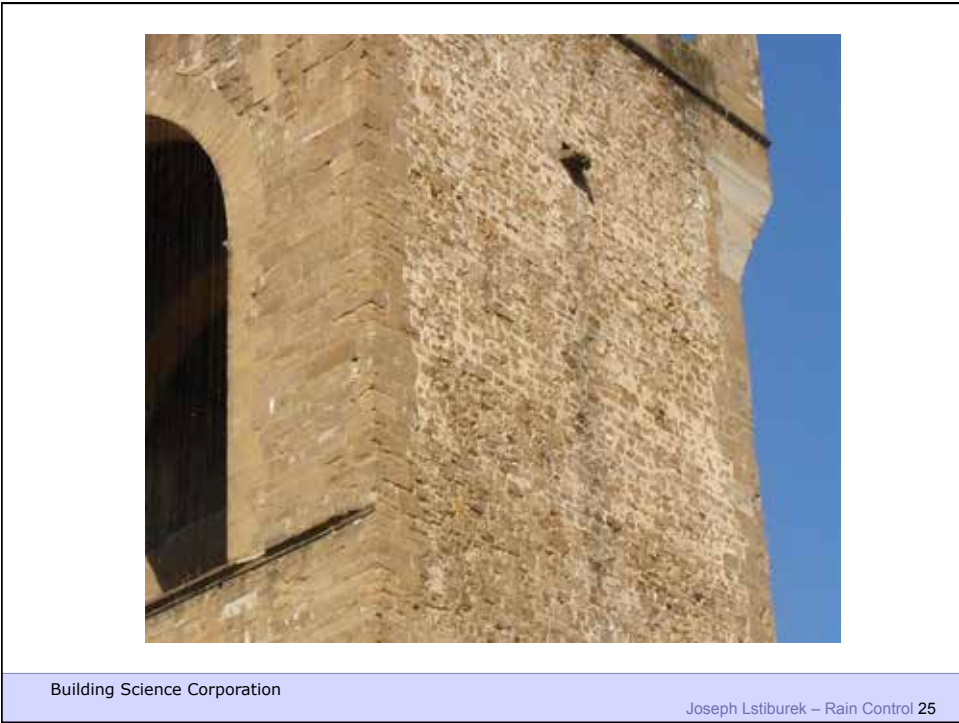
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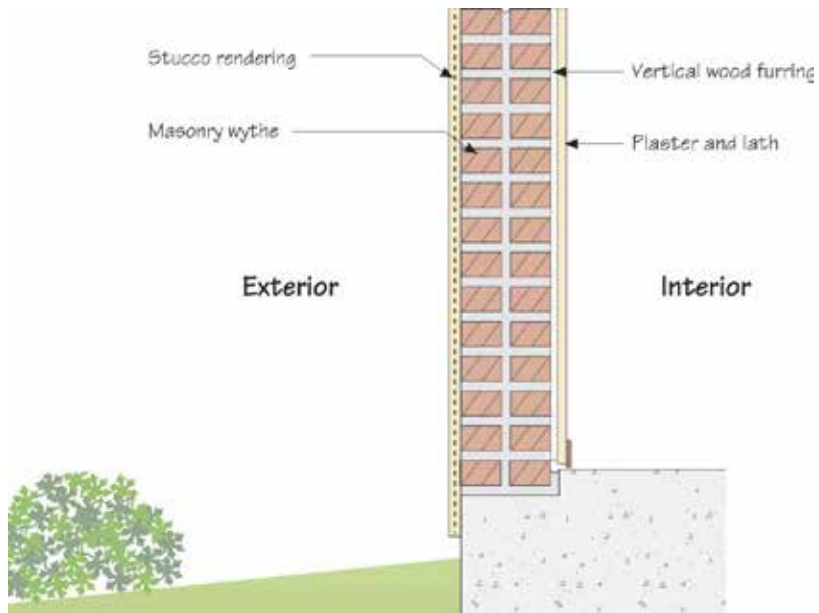
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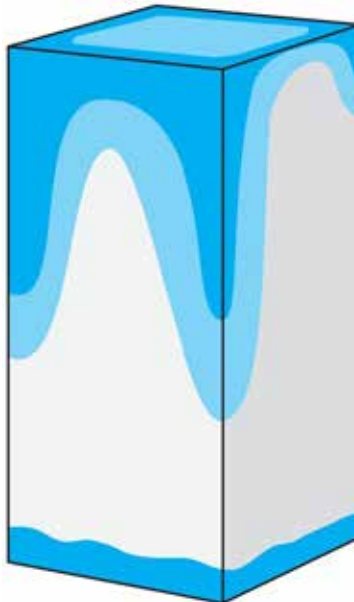


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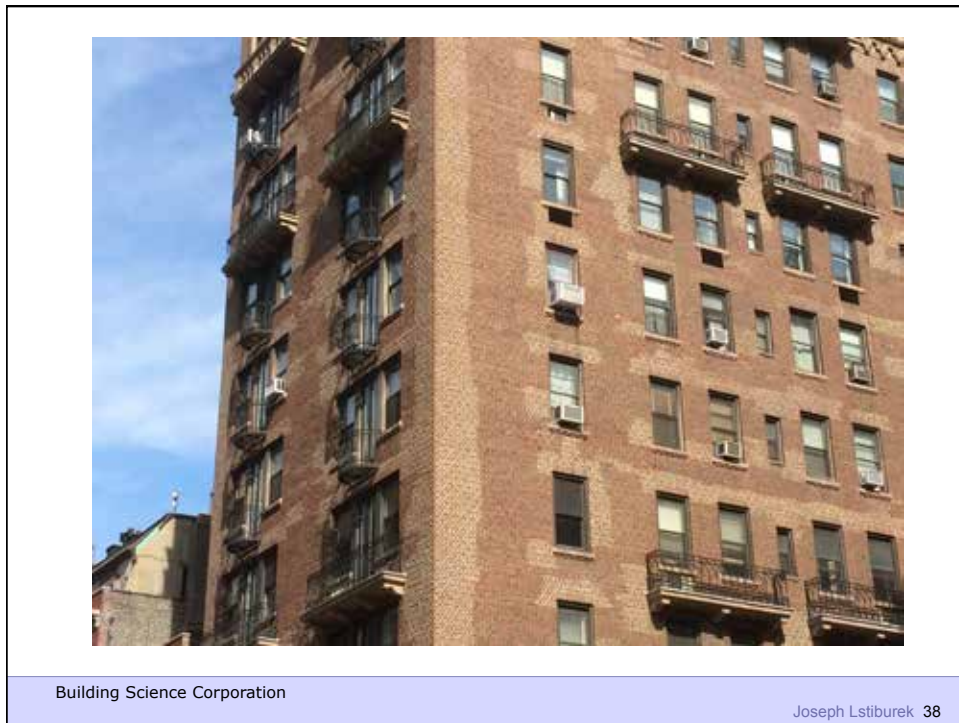
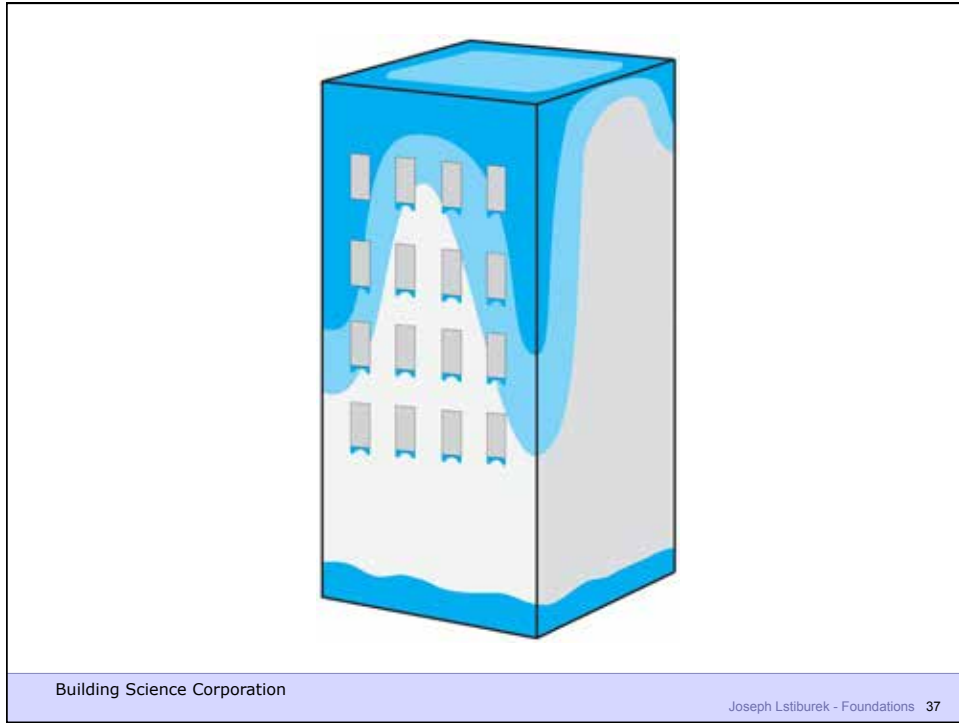
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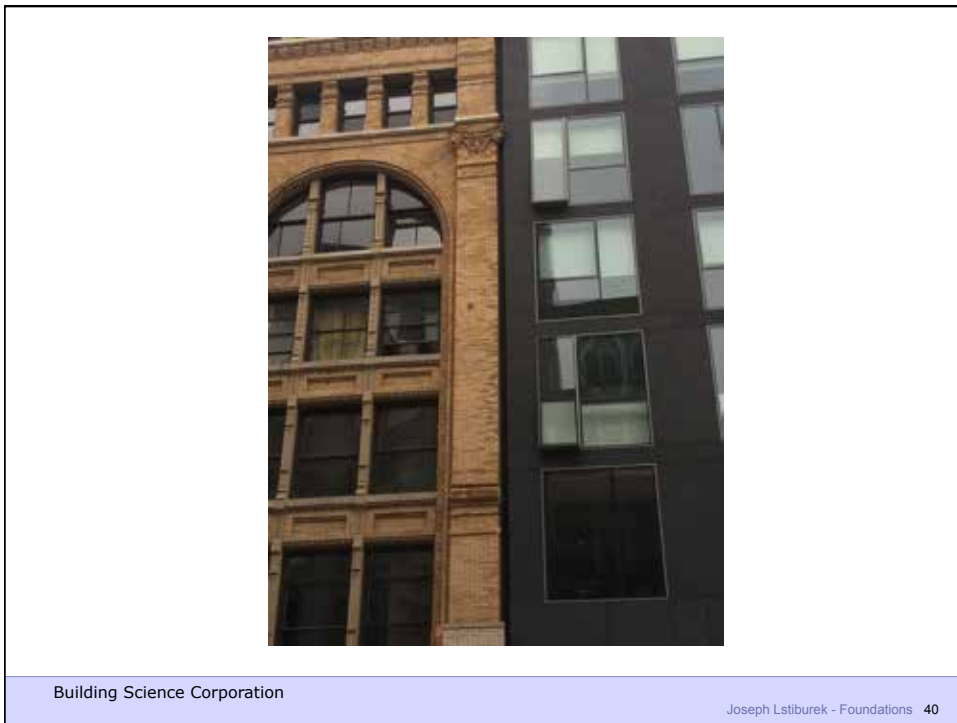


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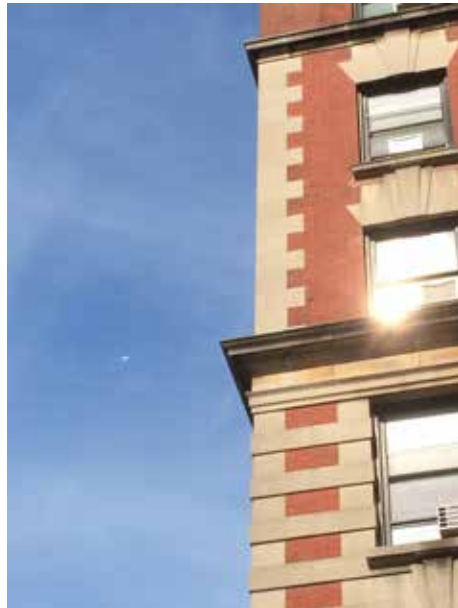






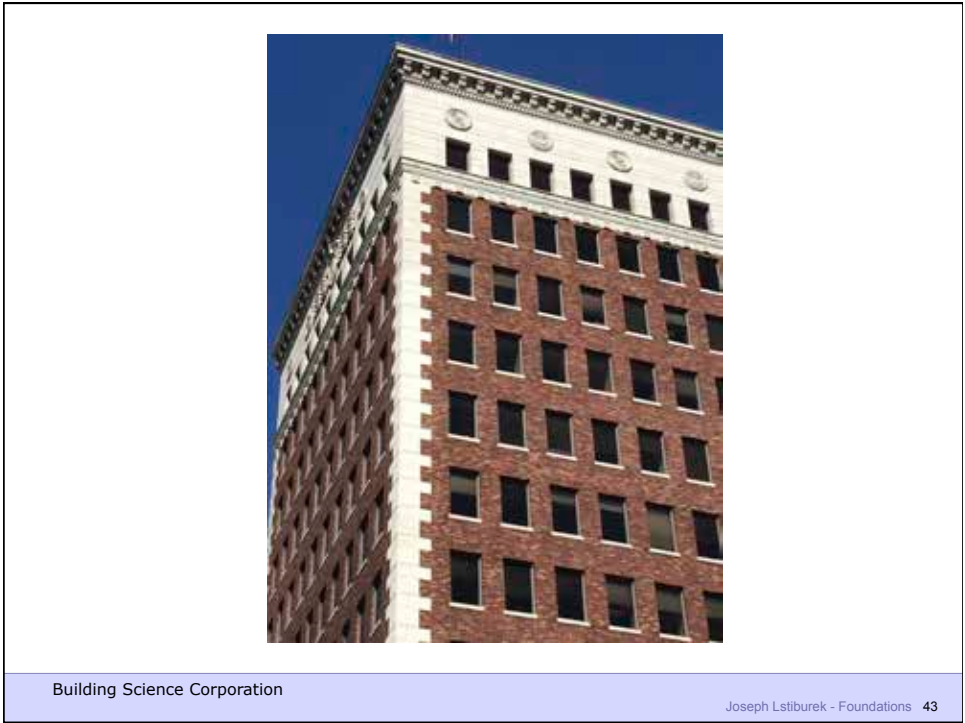
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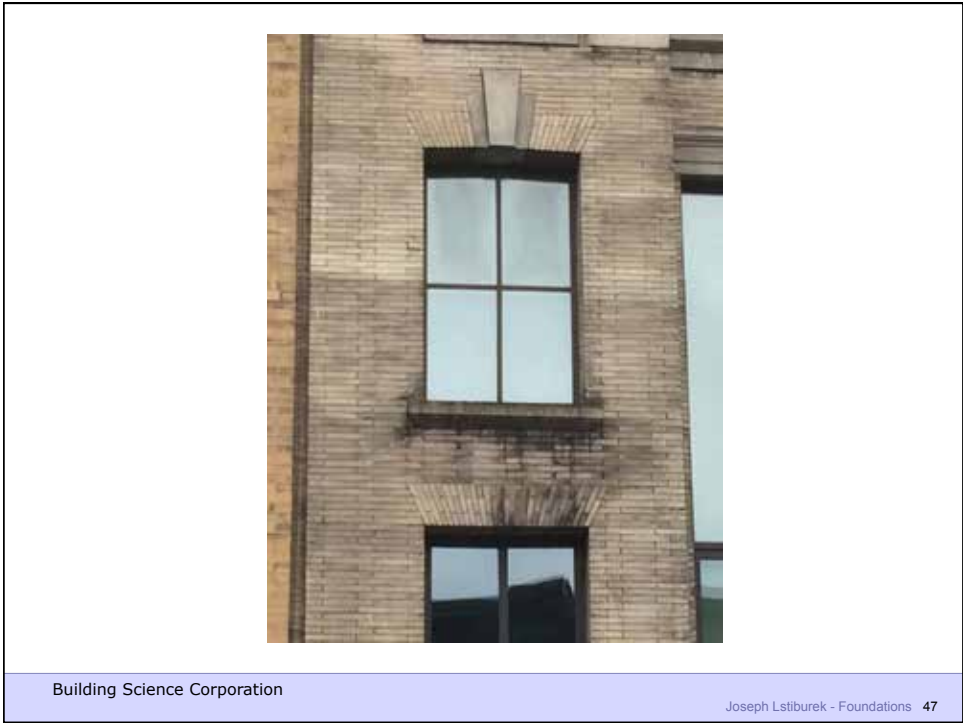
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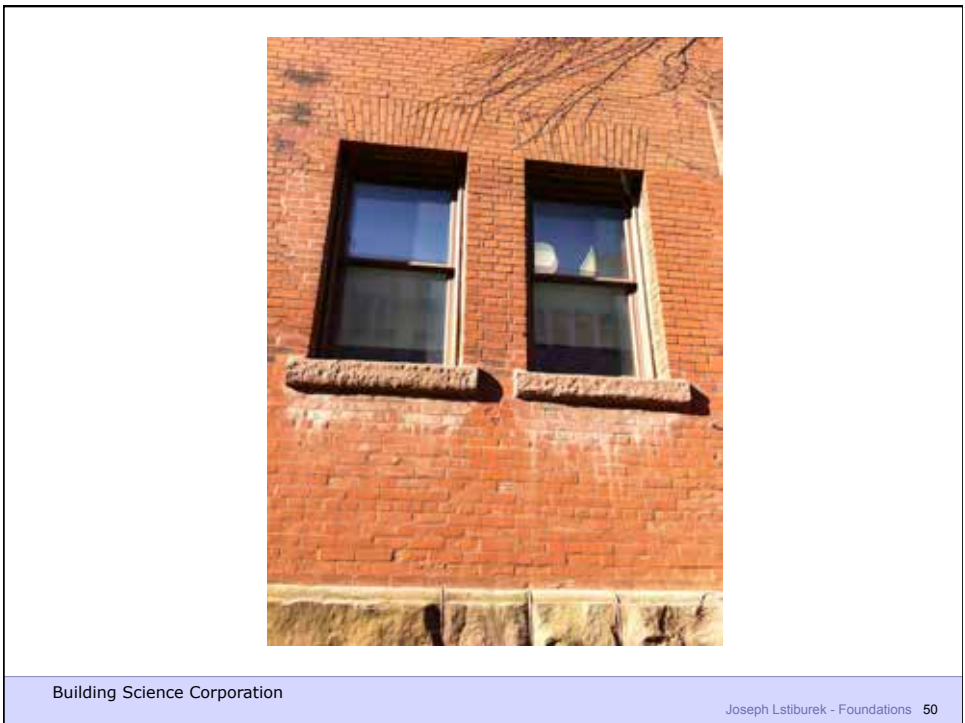
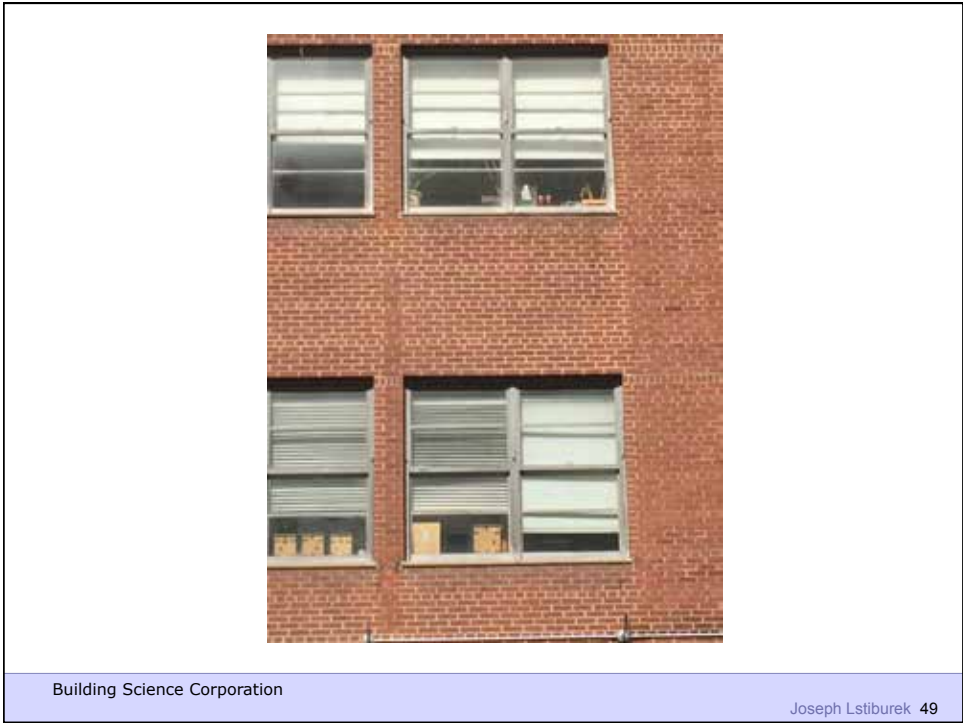
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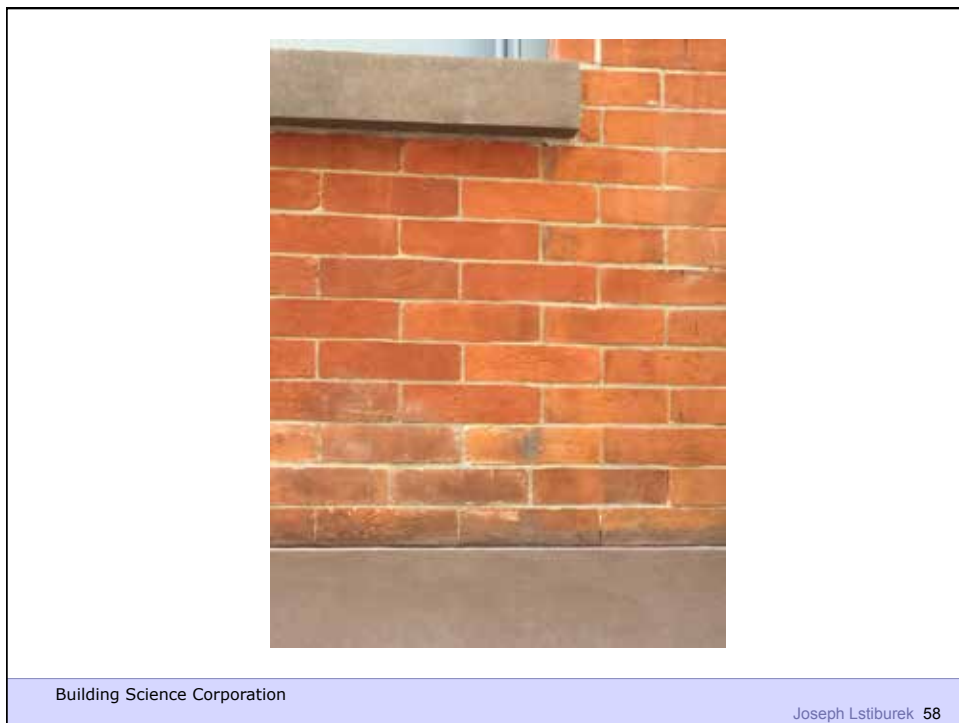
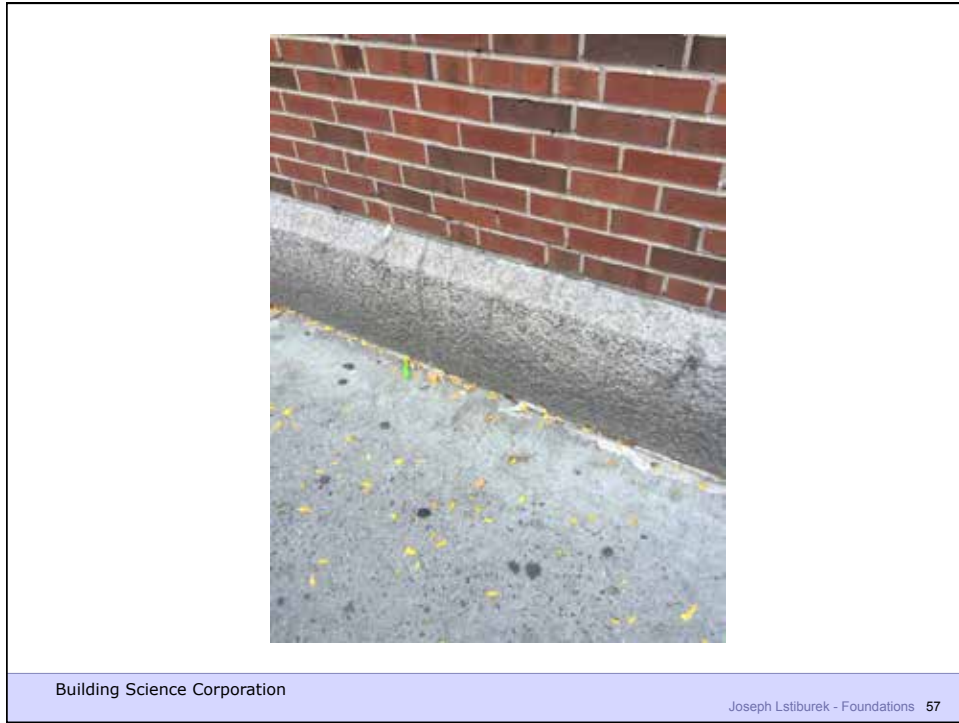


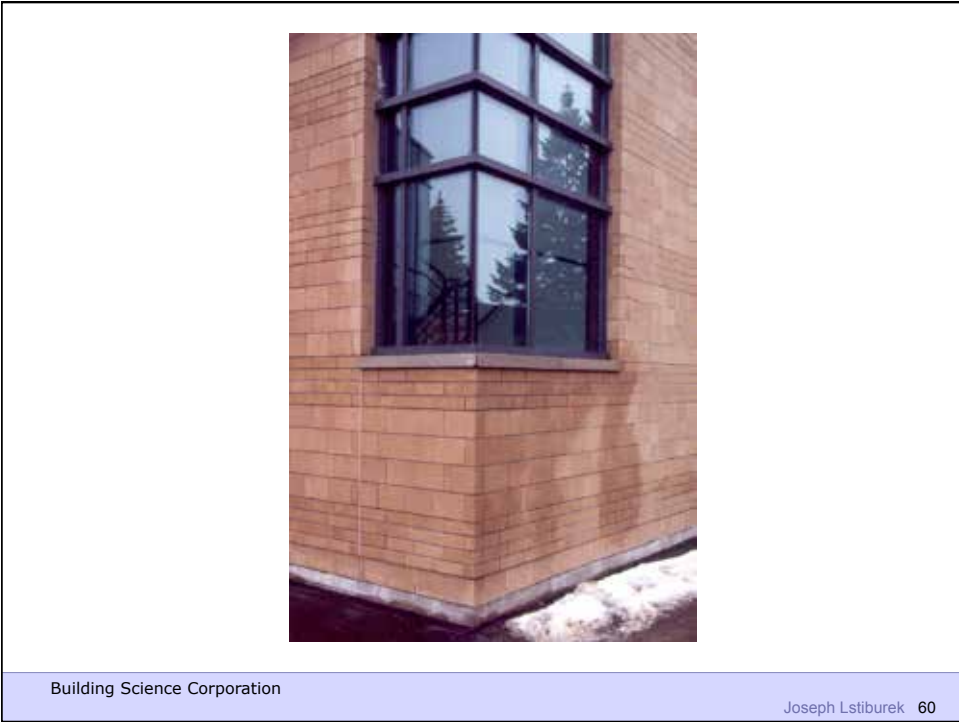
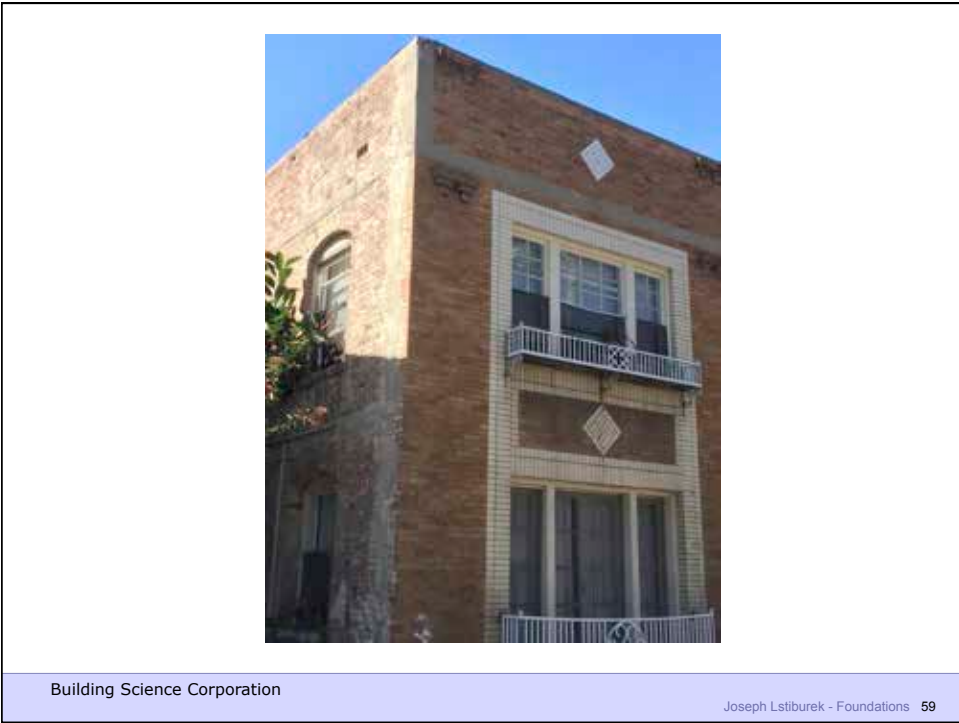
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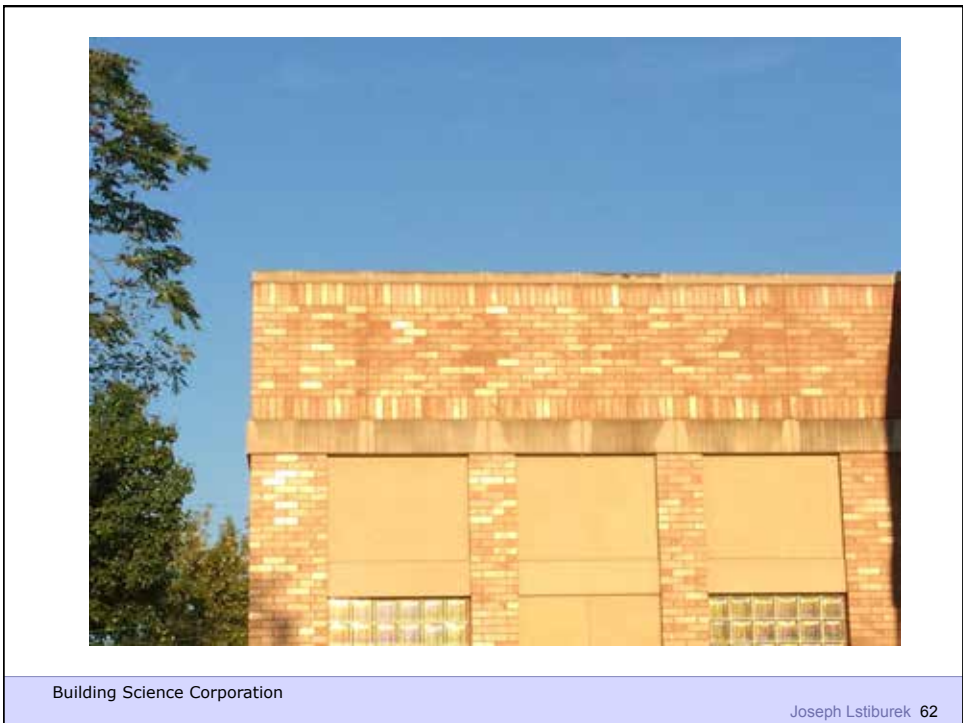


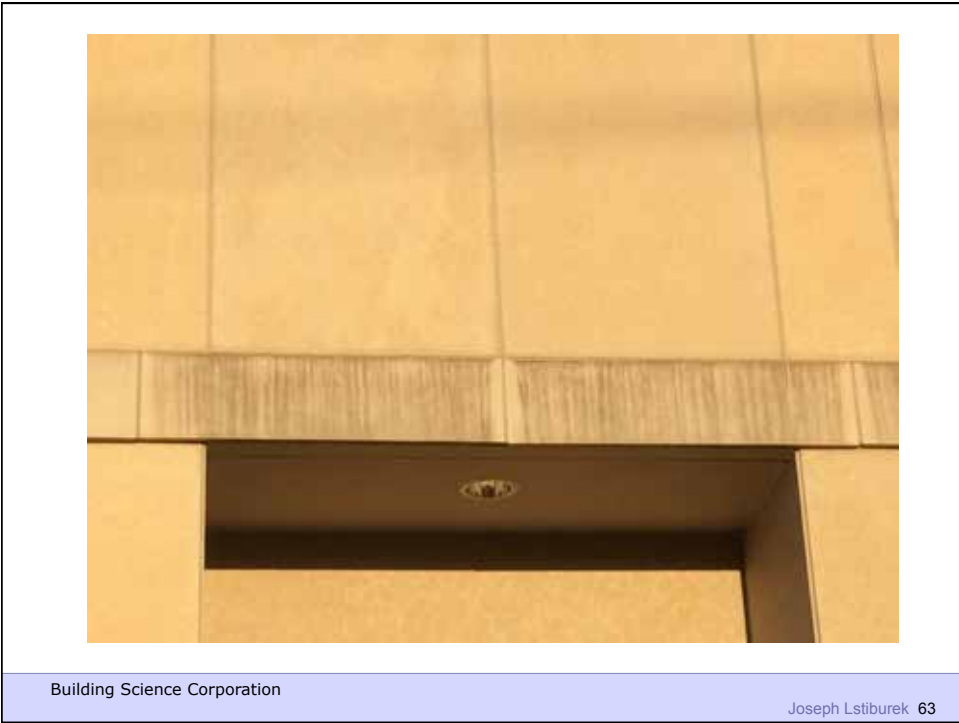
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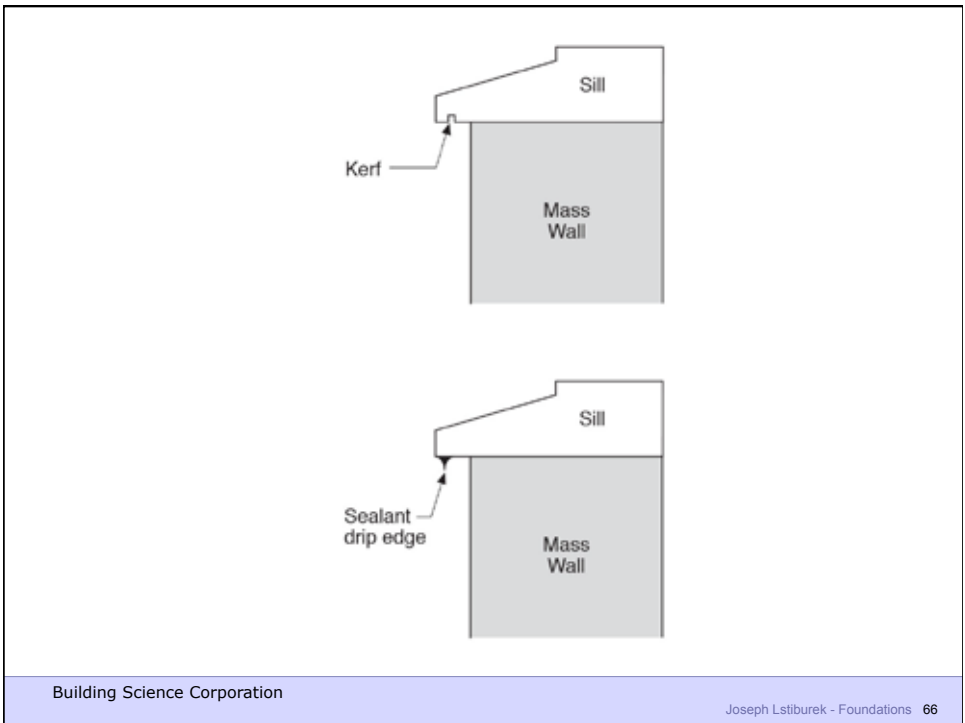


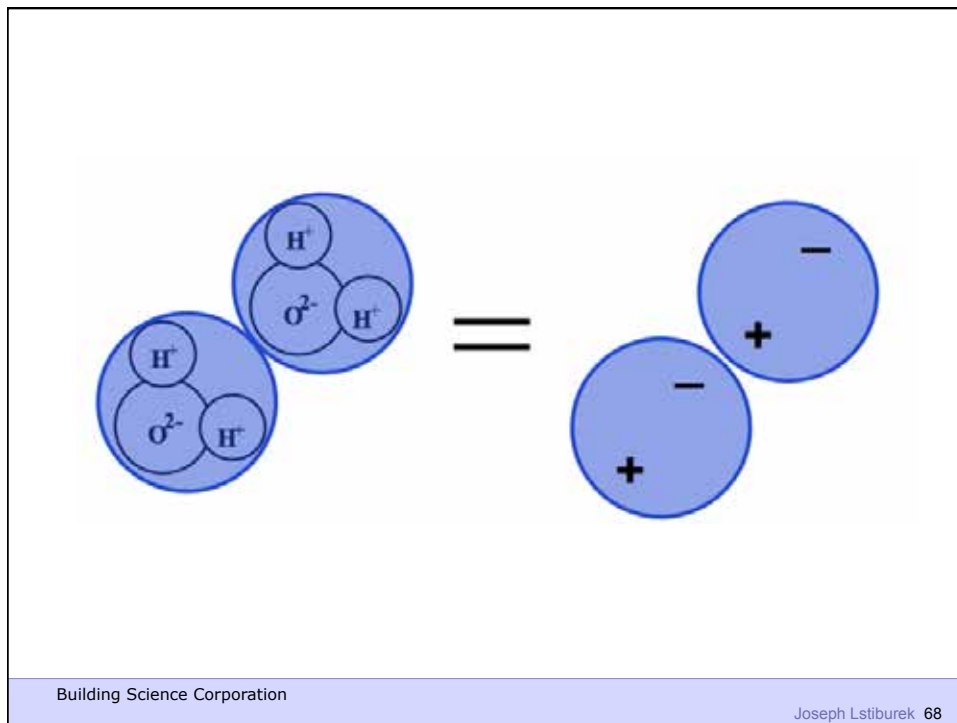
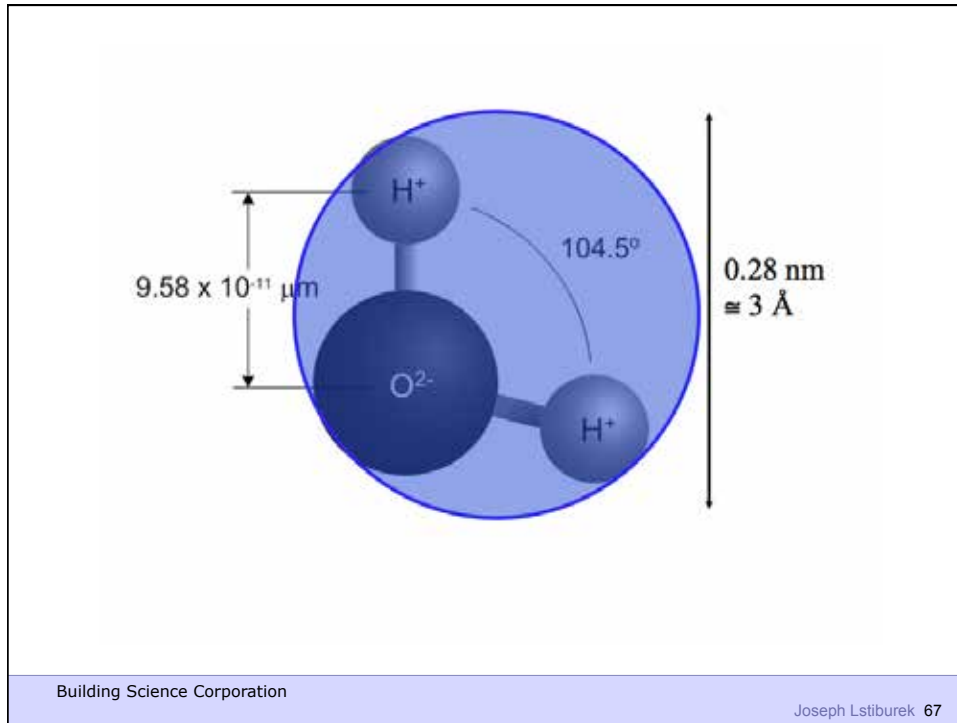


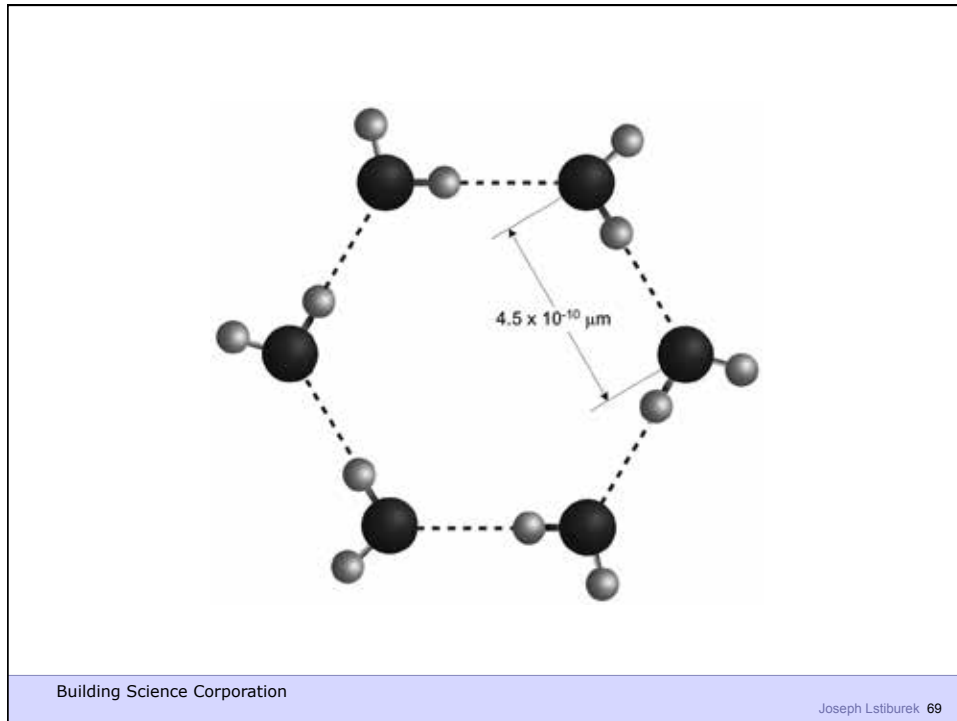












2nd Law of Thermodynamics

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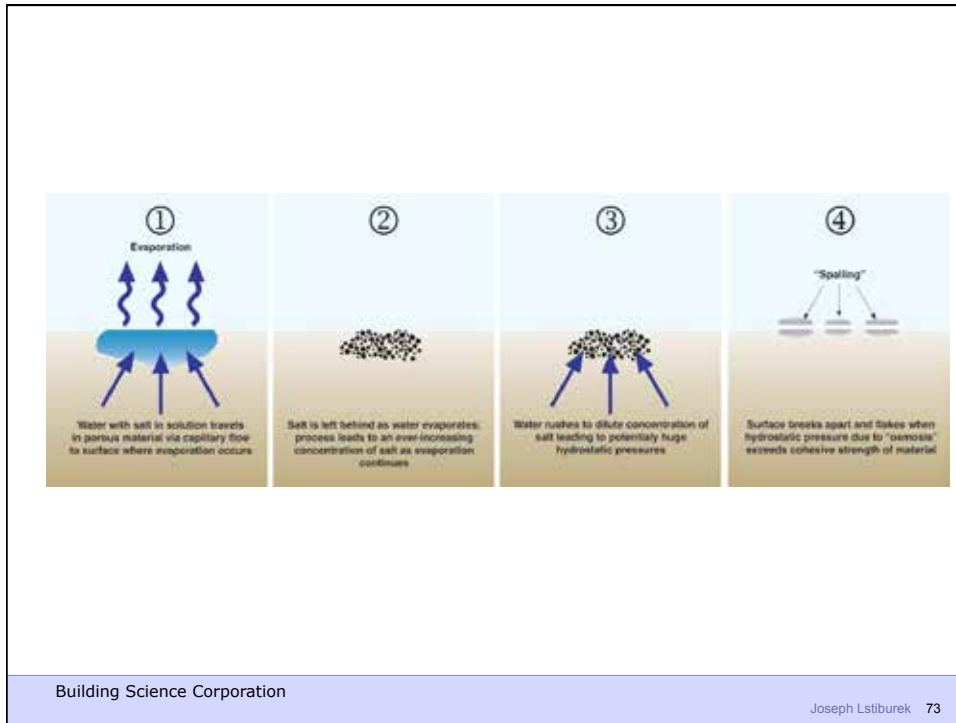
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Moisture Transport in Porous Media		
Phase	Transport Process	Driving Potential
Vapor	Diffusion	Vapor Concentration
Adsorbate	Surface Diffusion	Concentration
Liquid	Capillary Flow Osmosis	Suction Pressure Solute Concentration

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Capillarity + Salt = Osmosis		
<ul style="list-style-type: none"> • 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 		

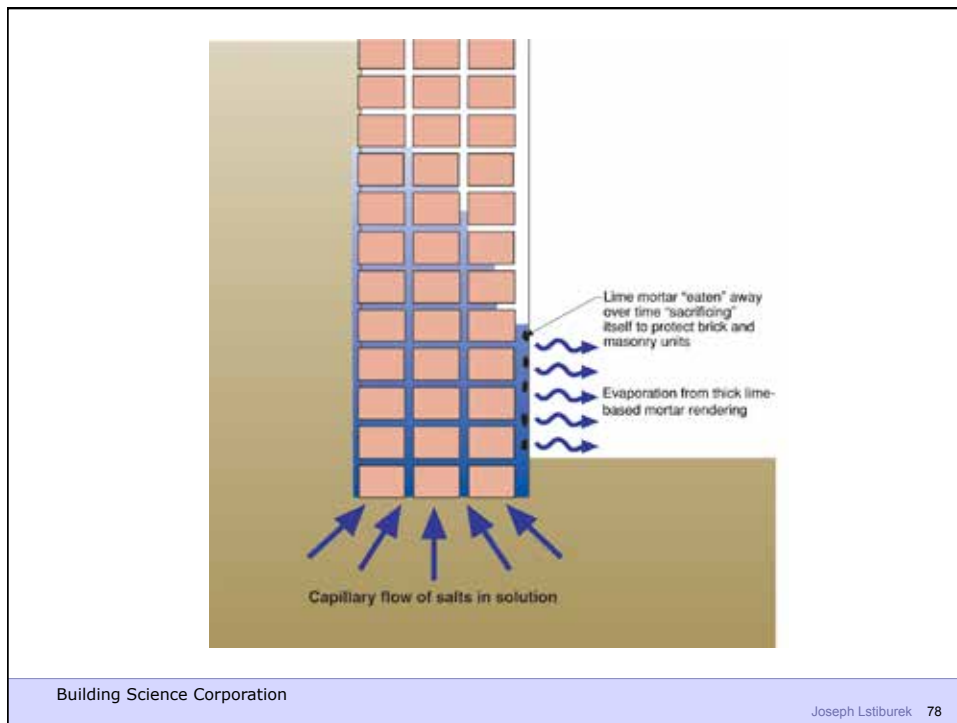
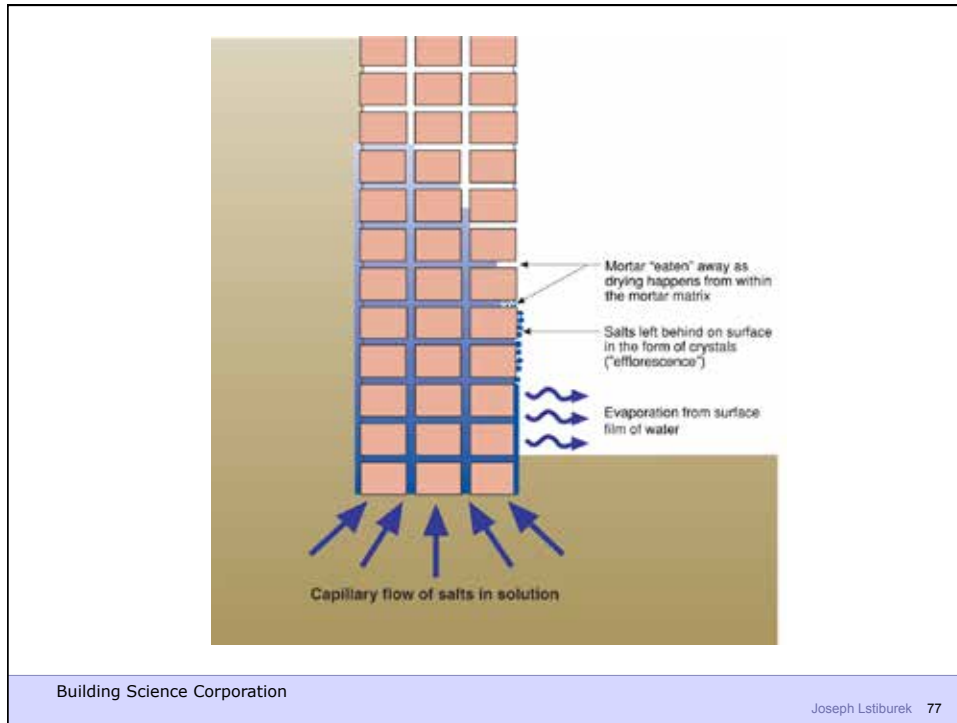
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Diffusion + Capillarity + Osmosis = Problem

- 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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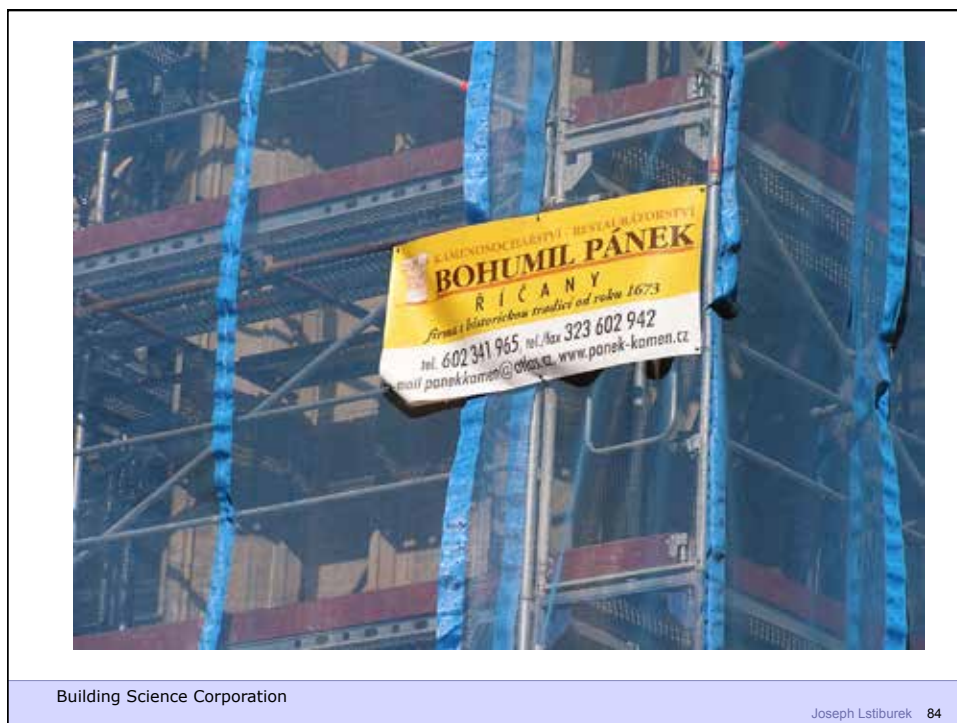
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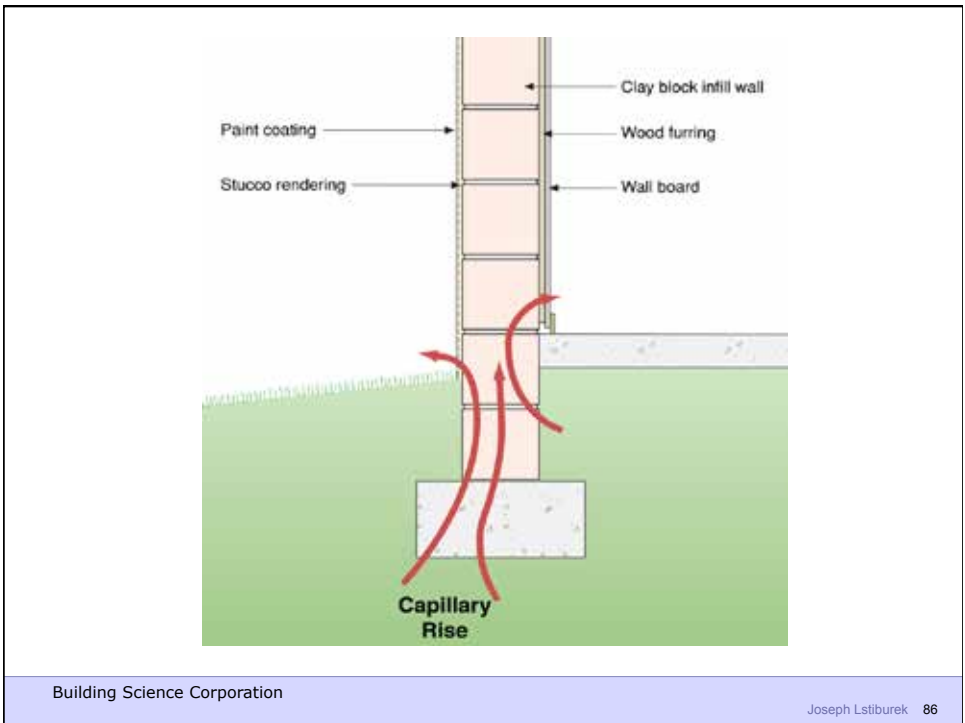


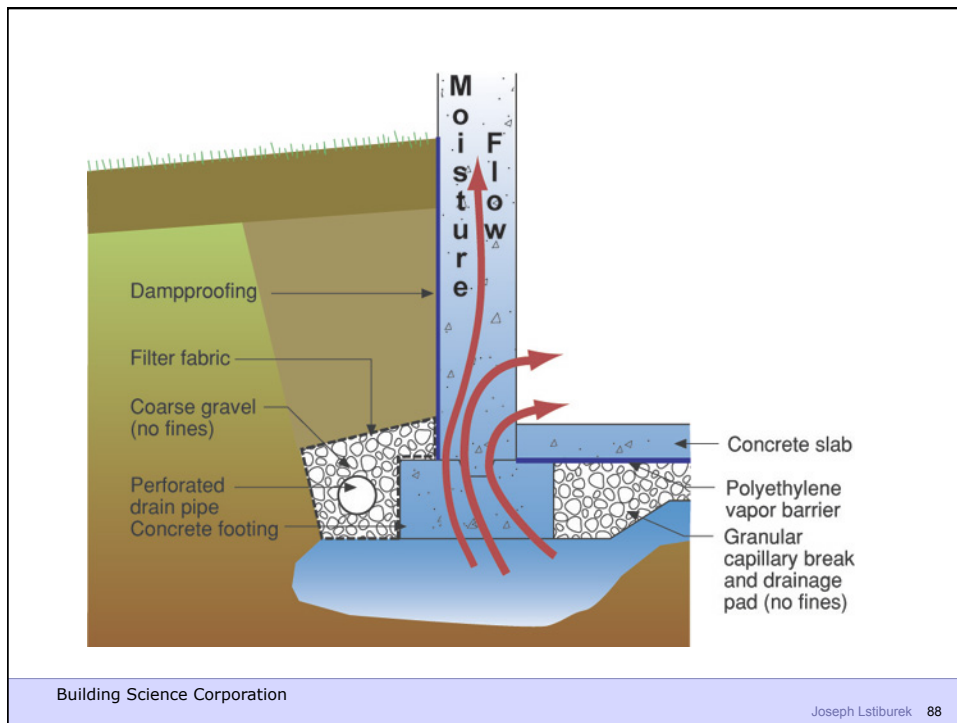
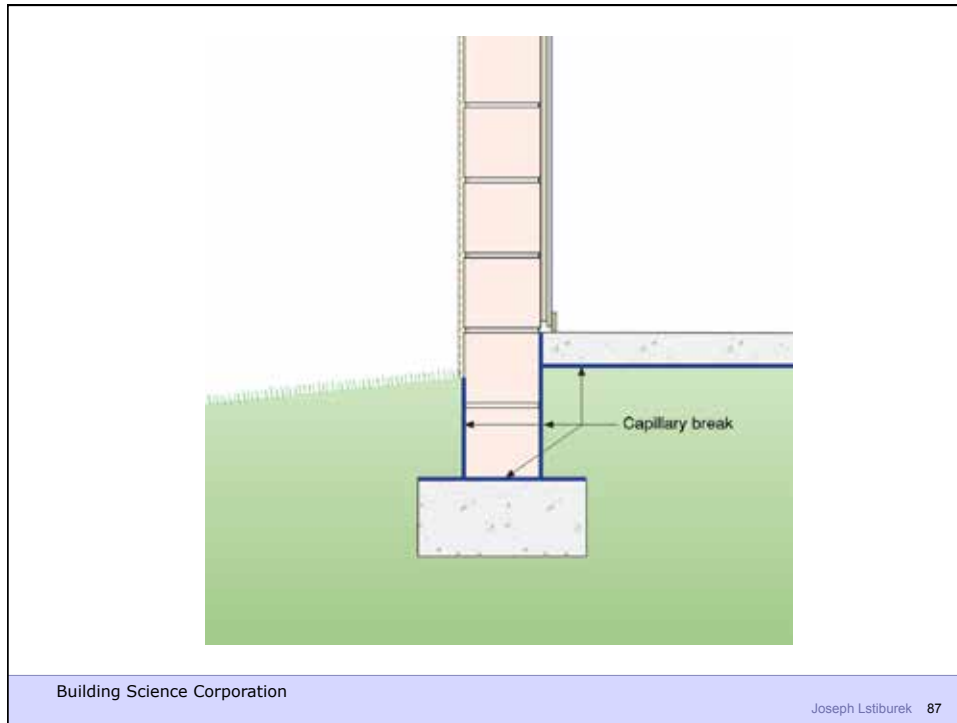
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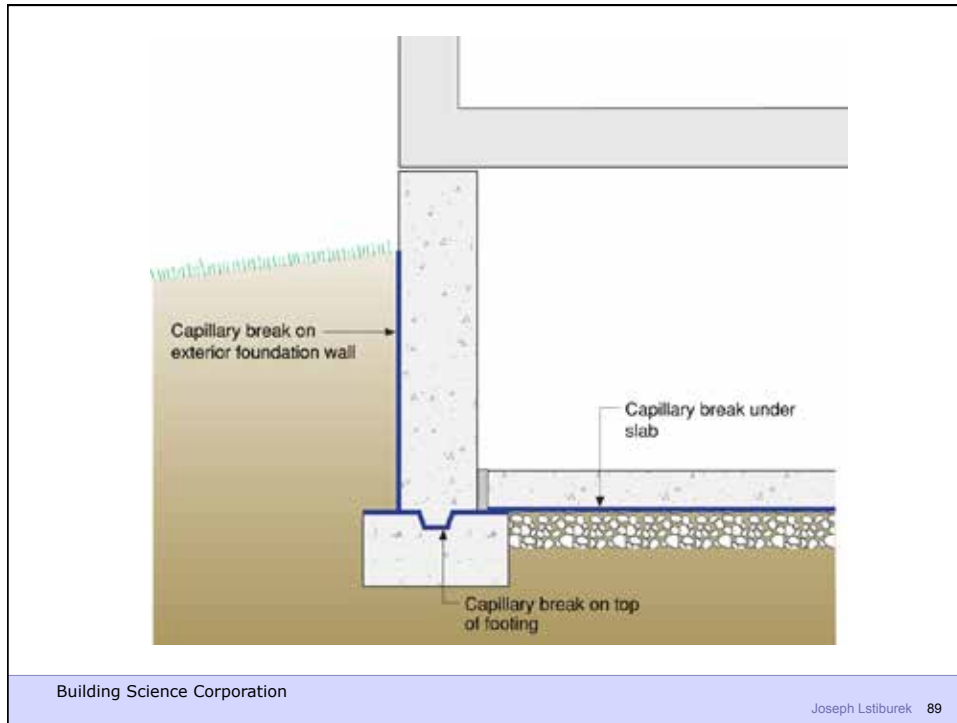
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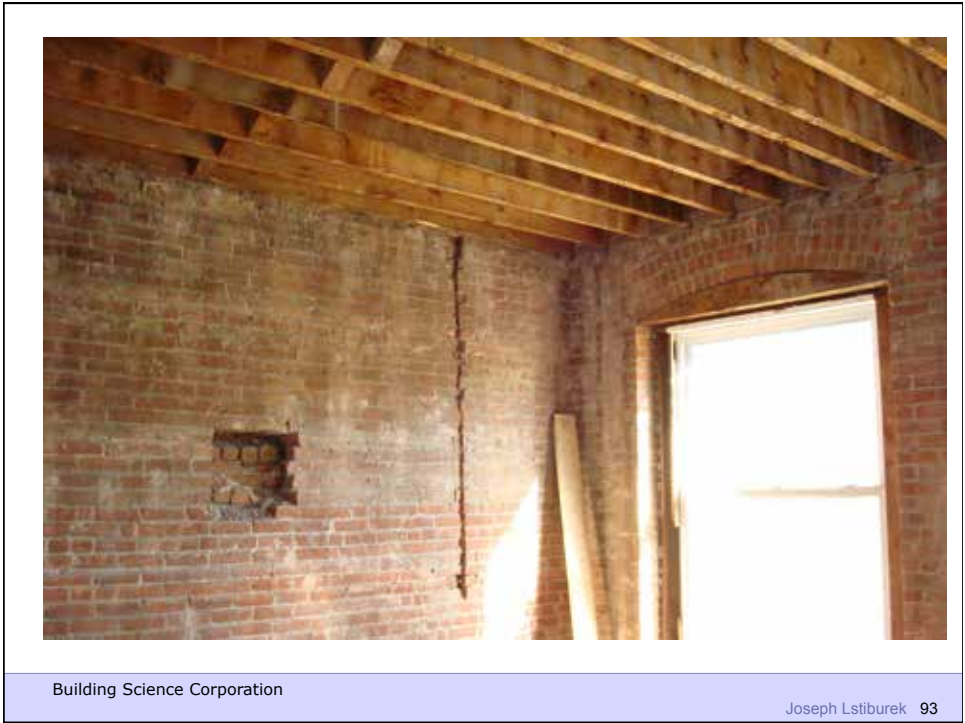














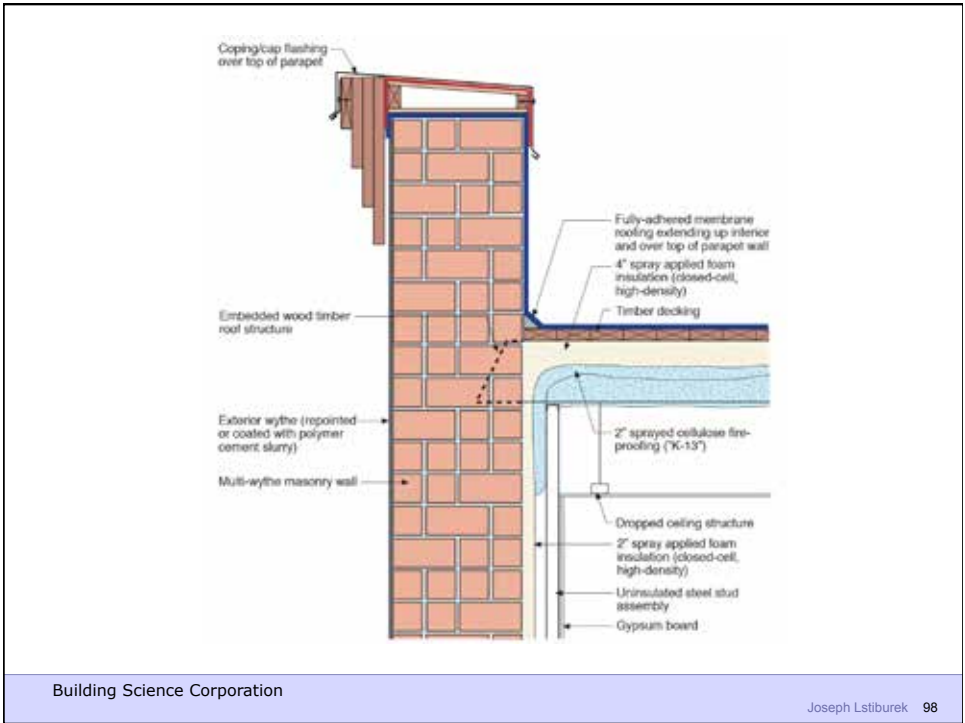
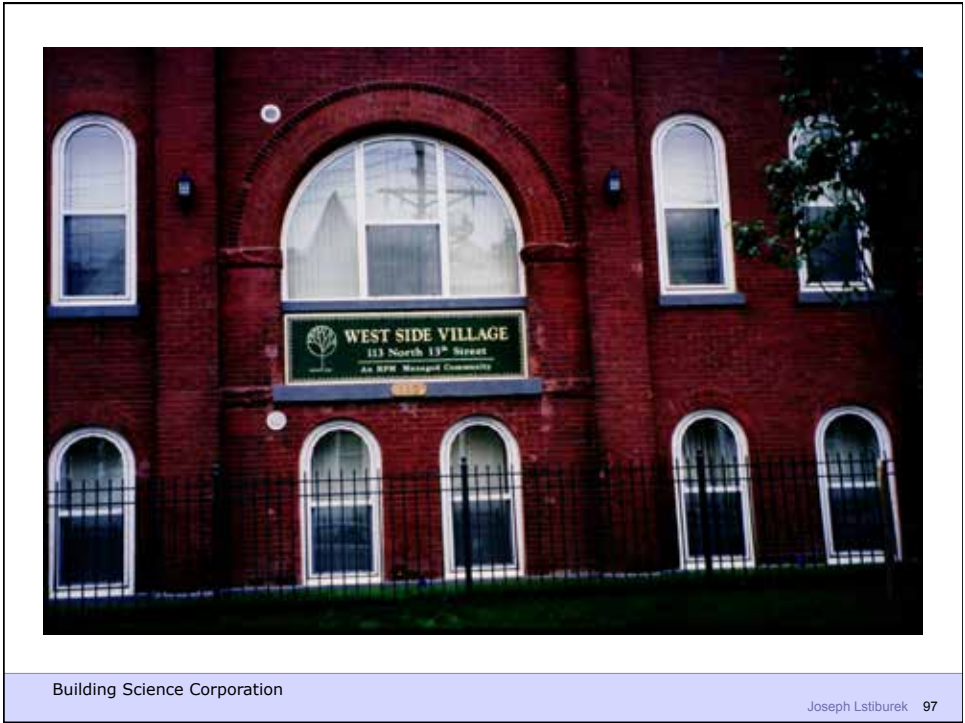
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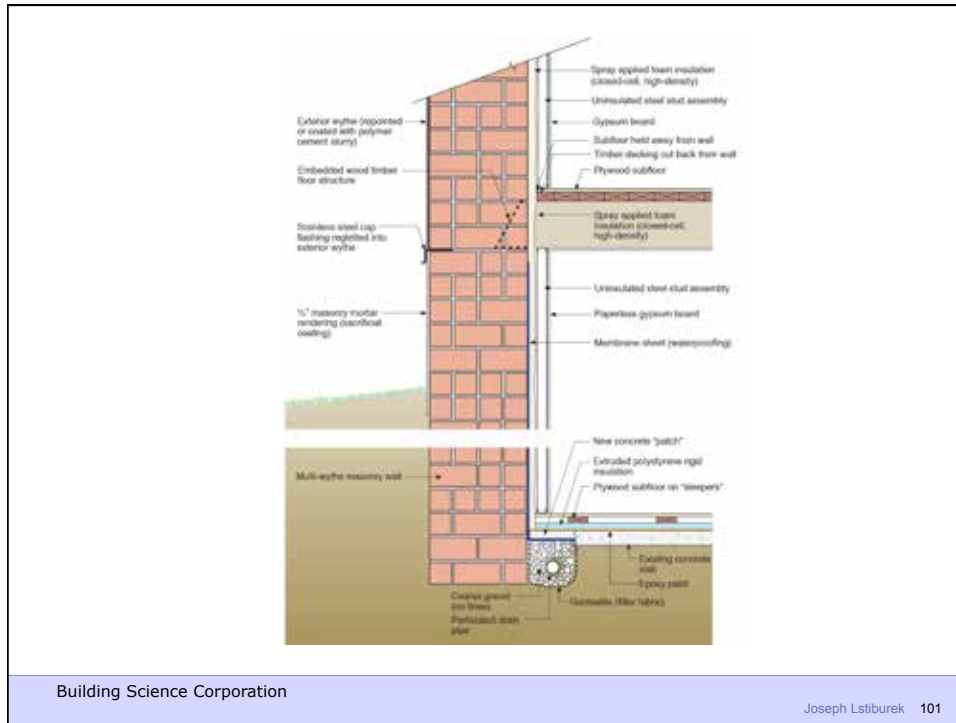
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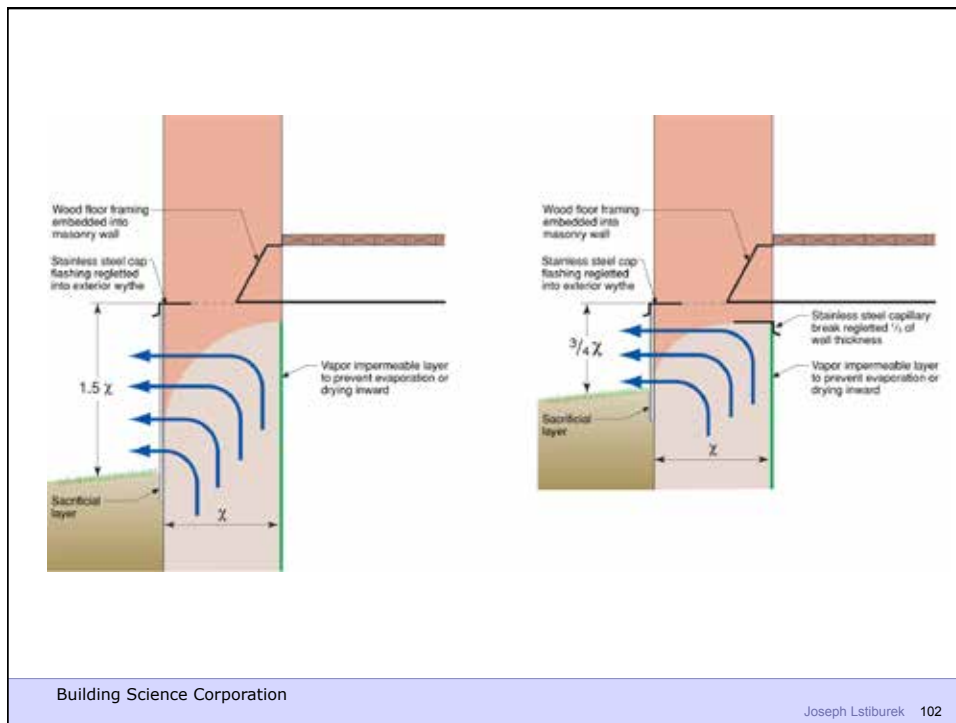
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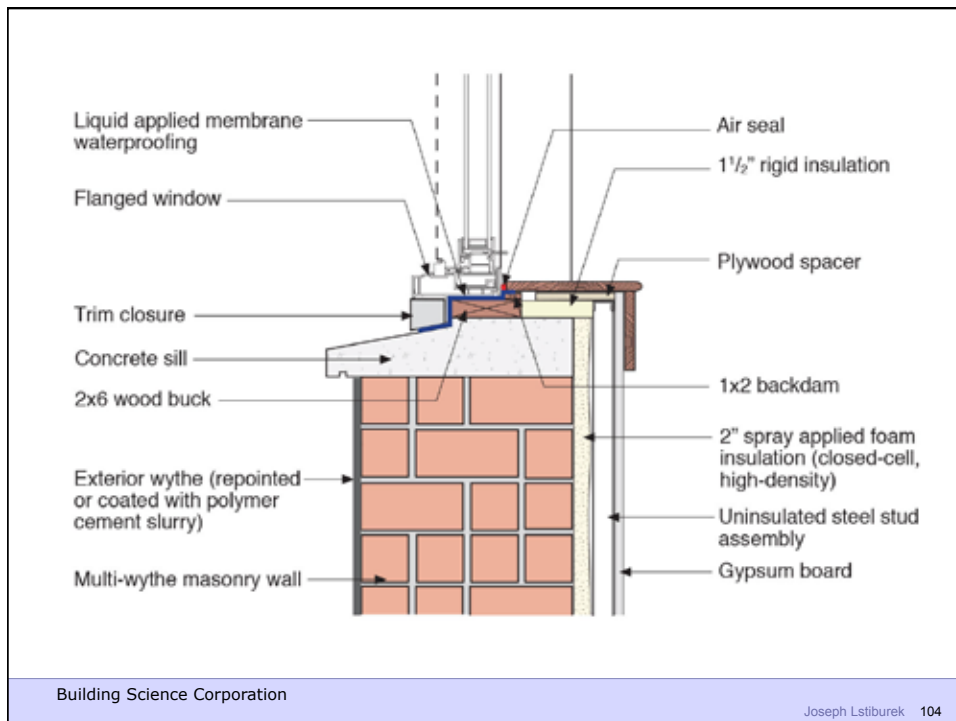
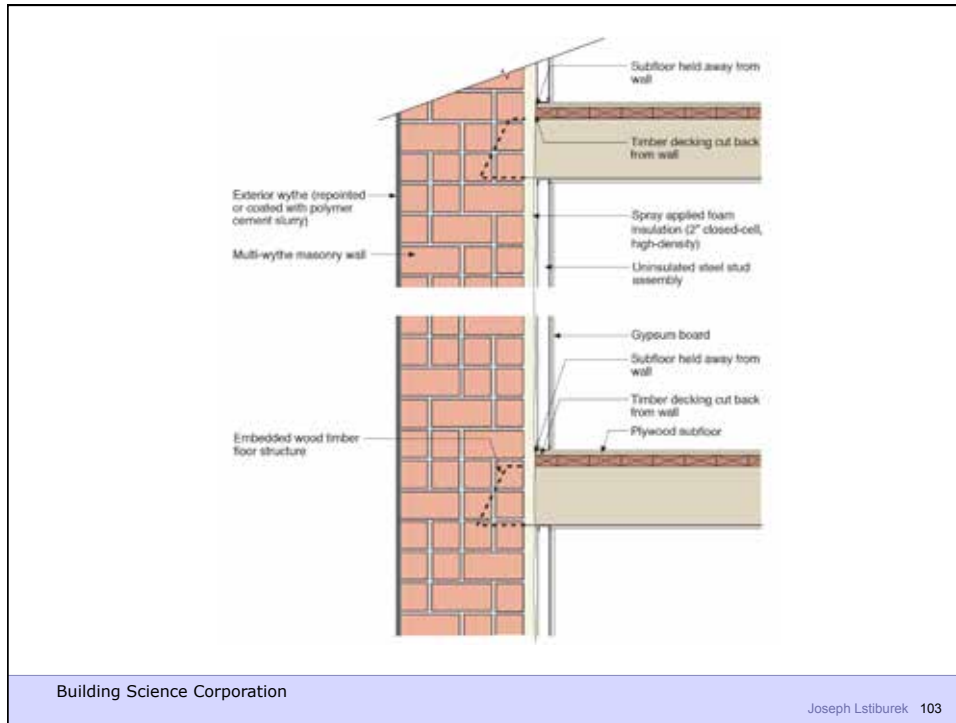
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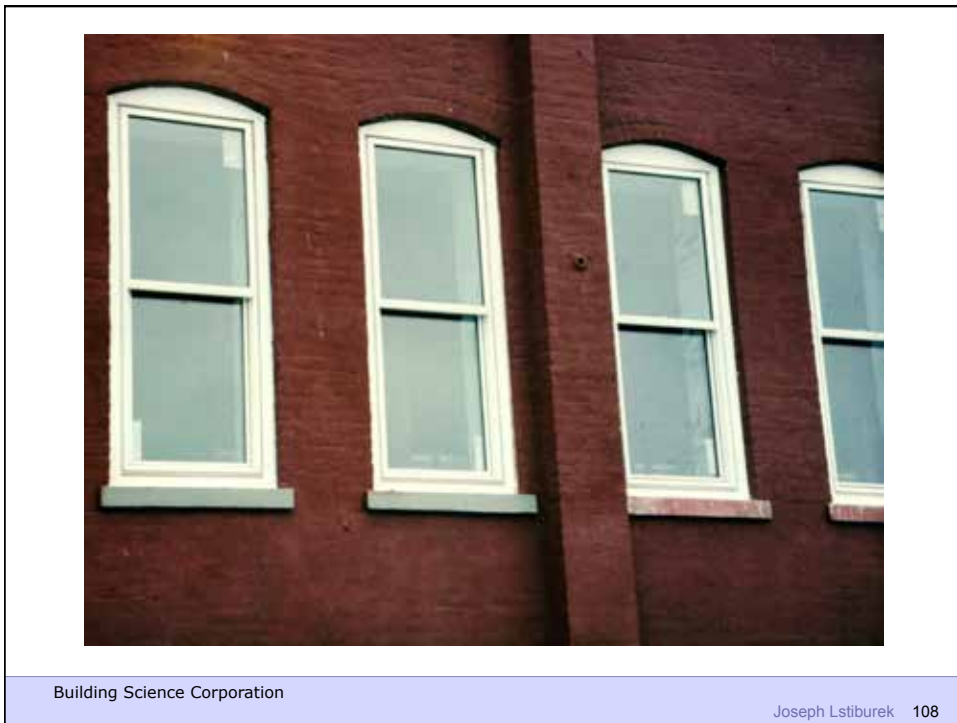


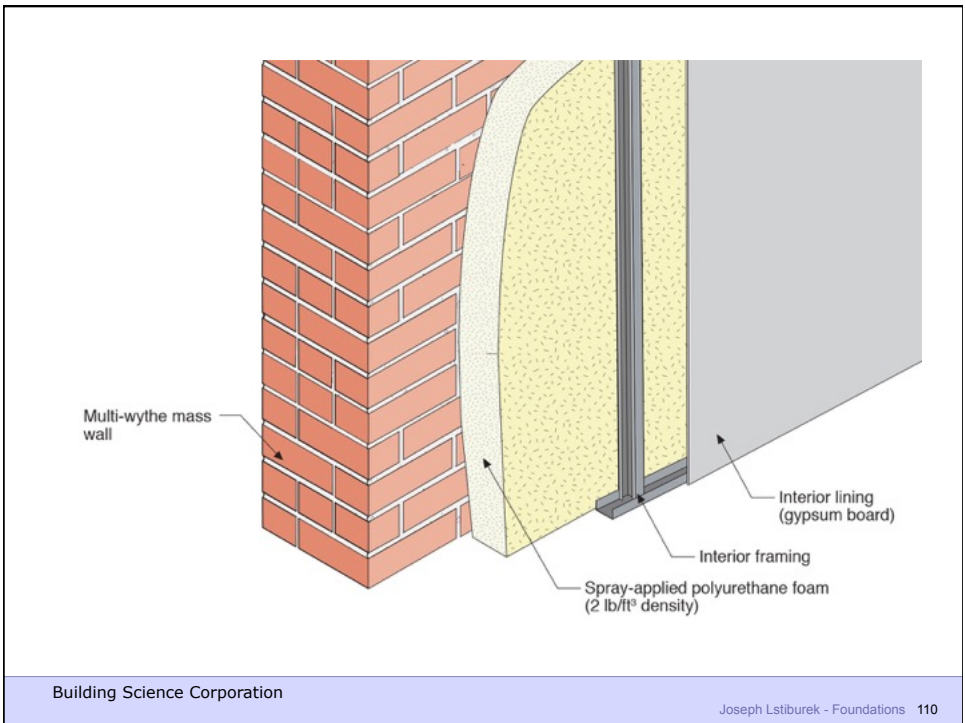
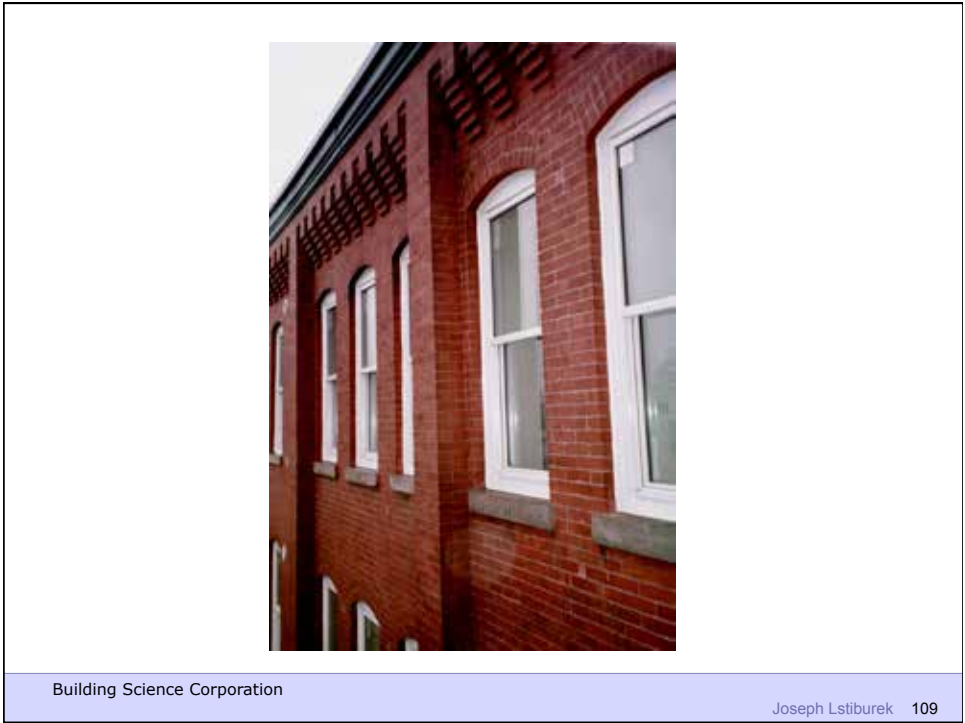
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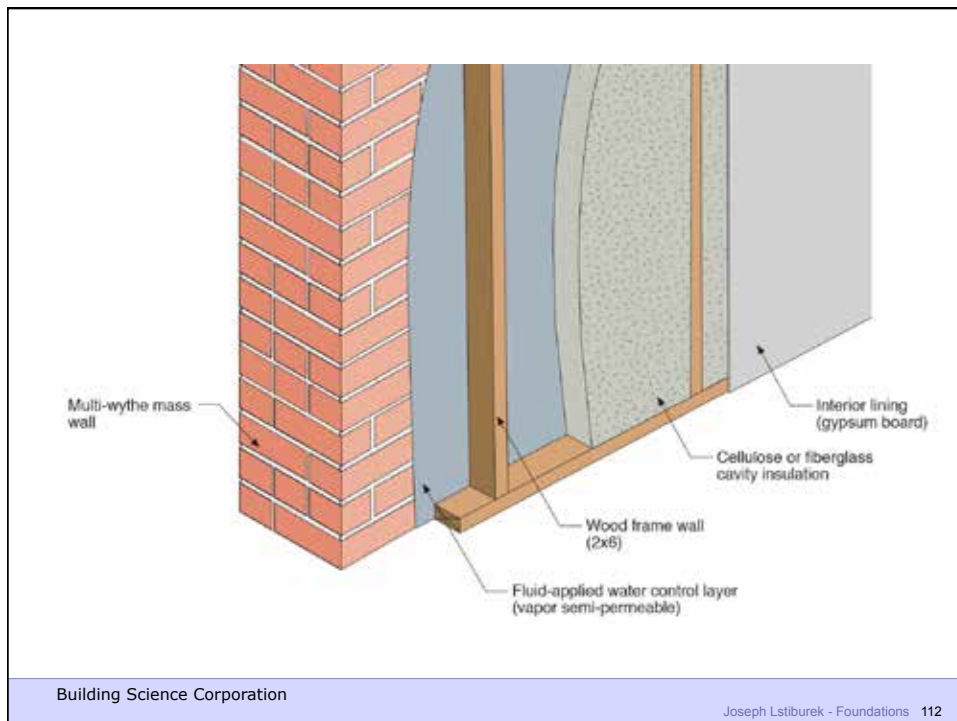
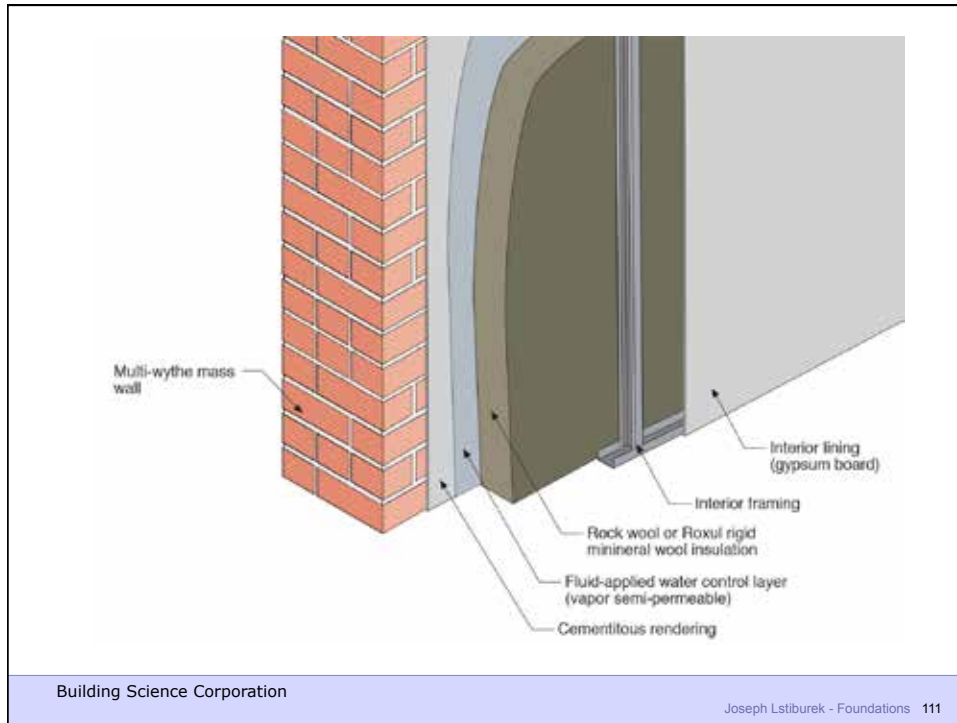
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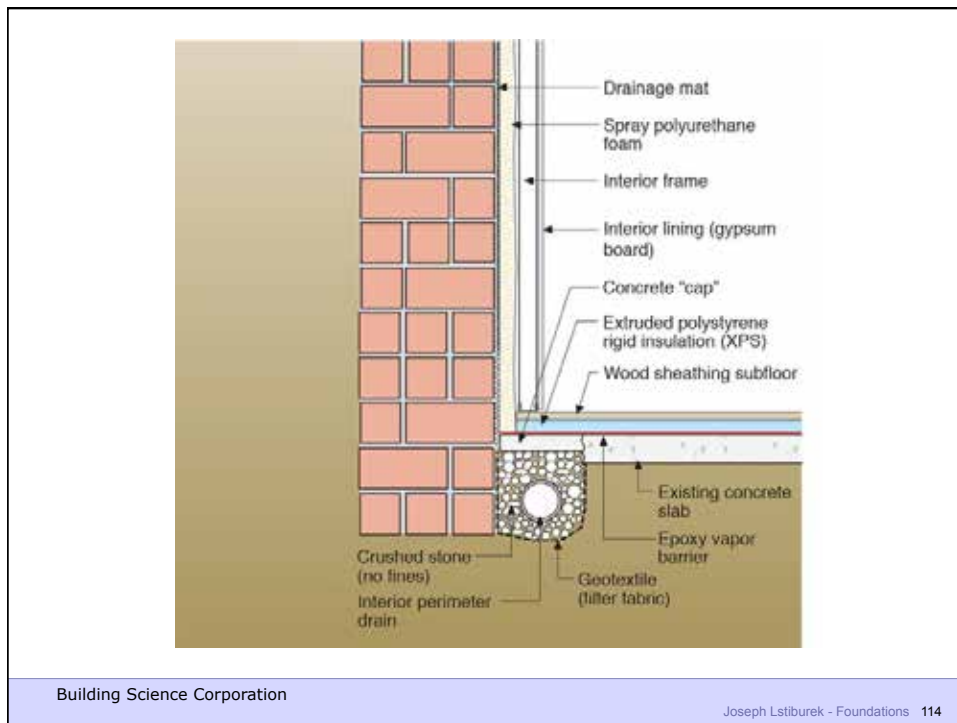
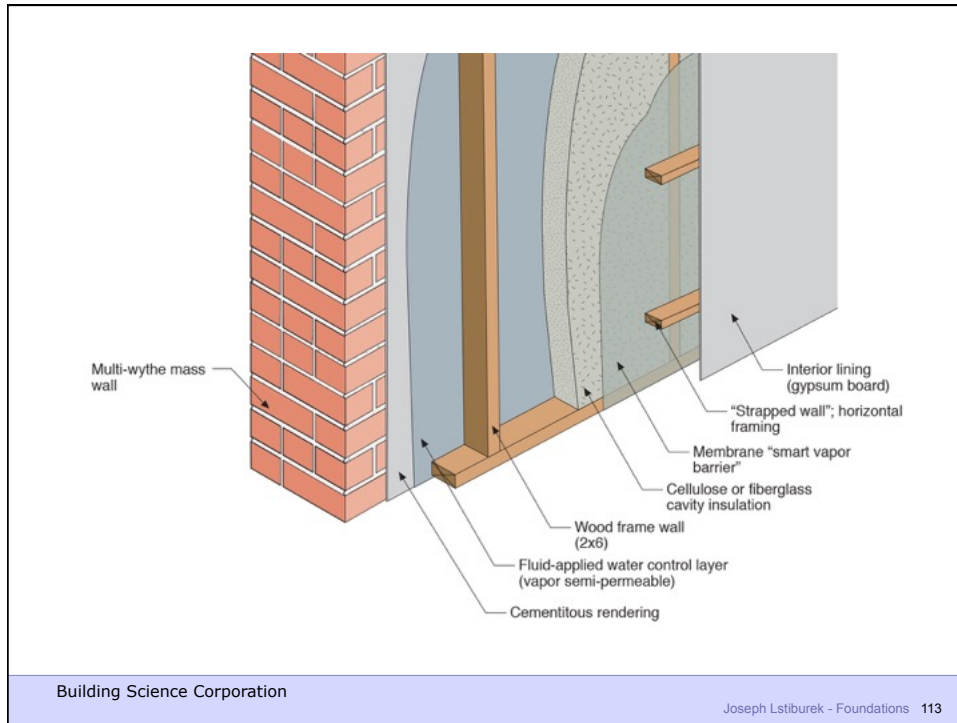


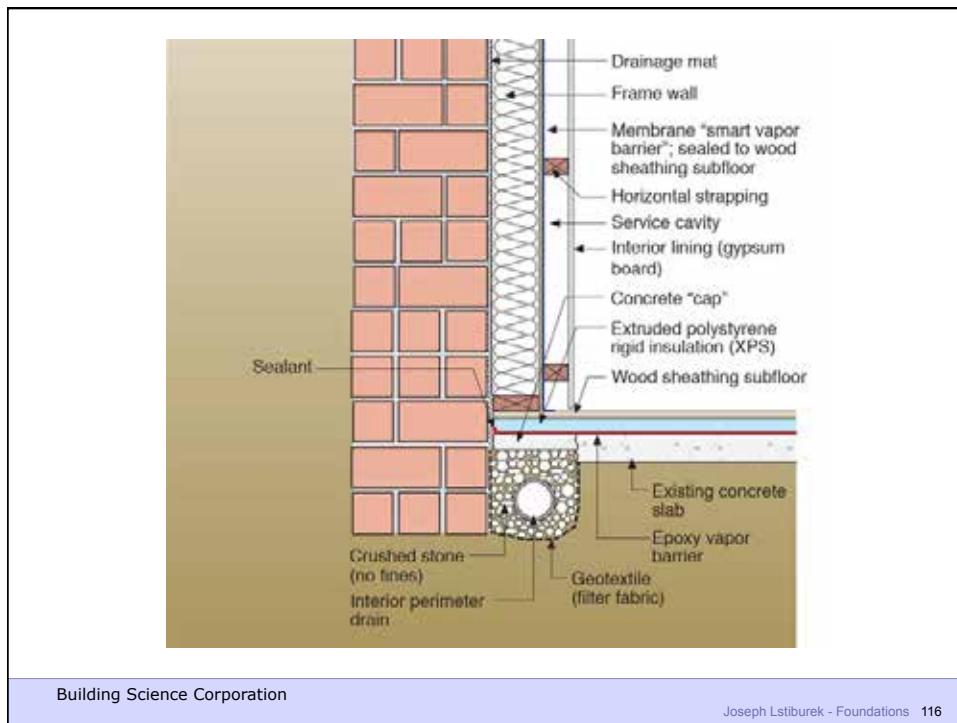
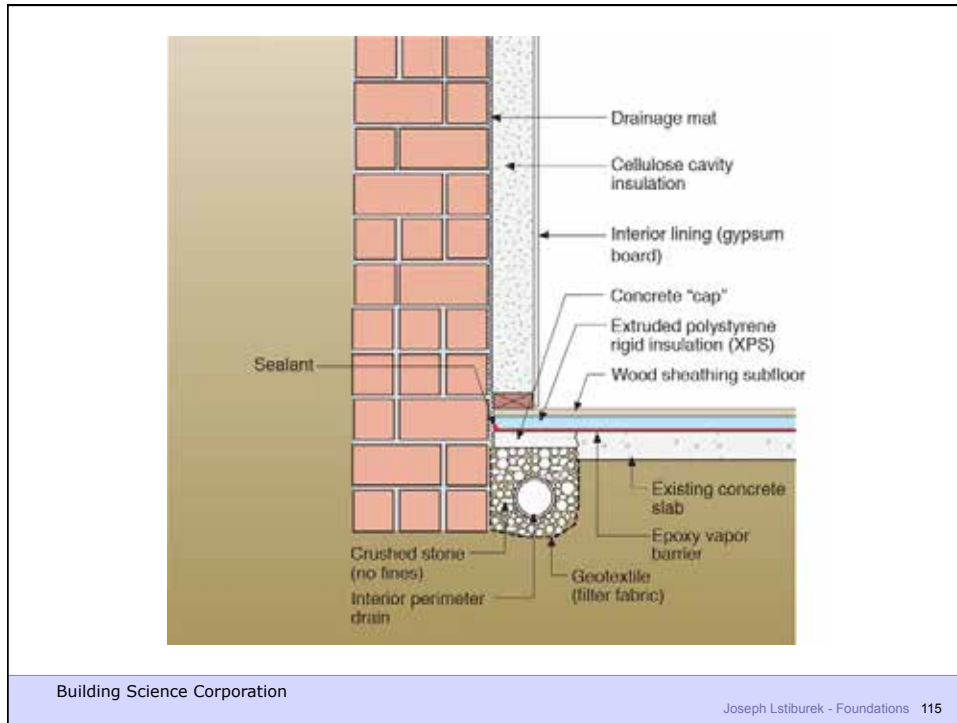














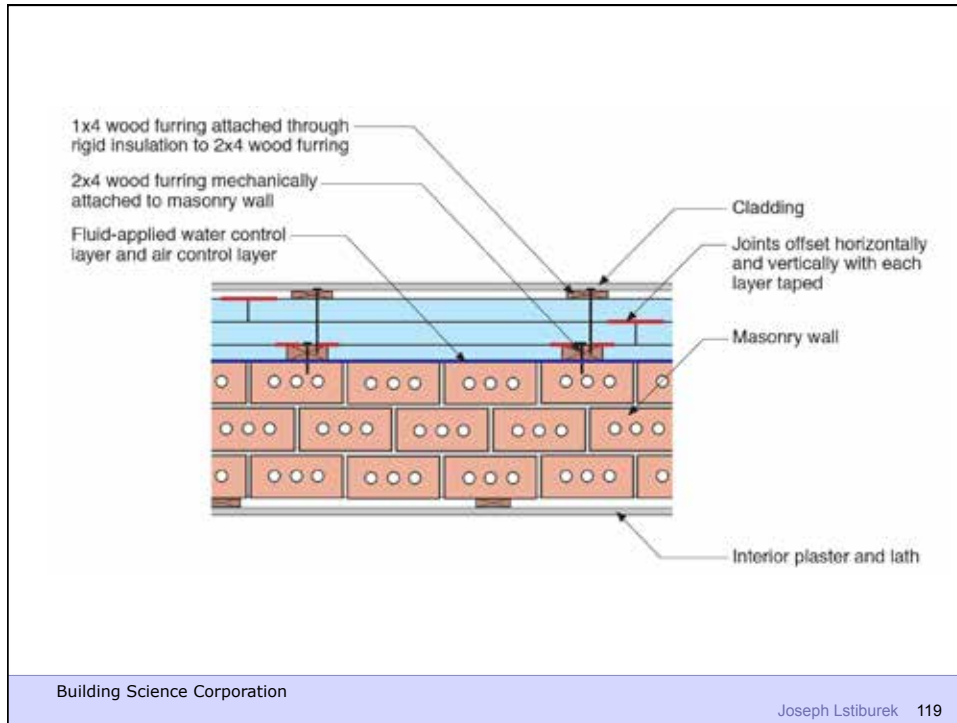
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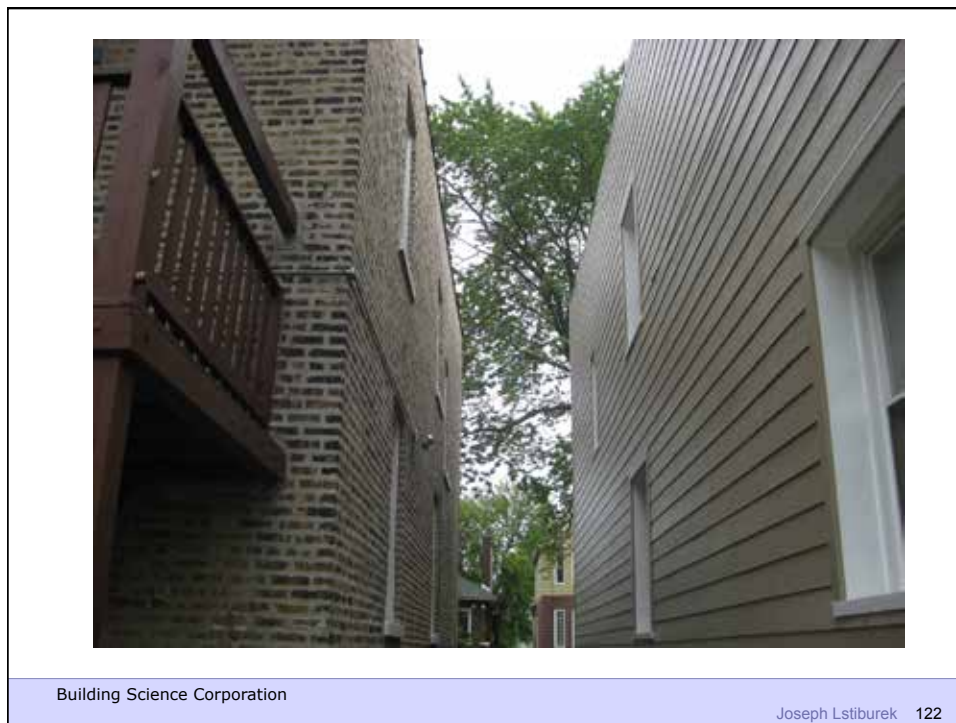
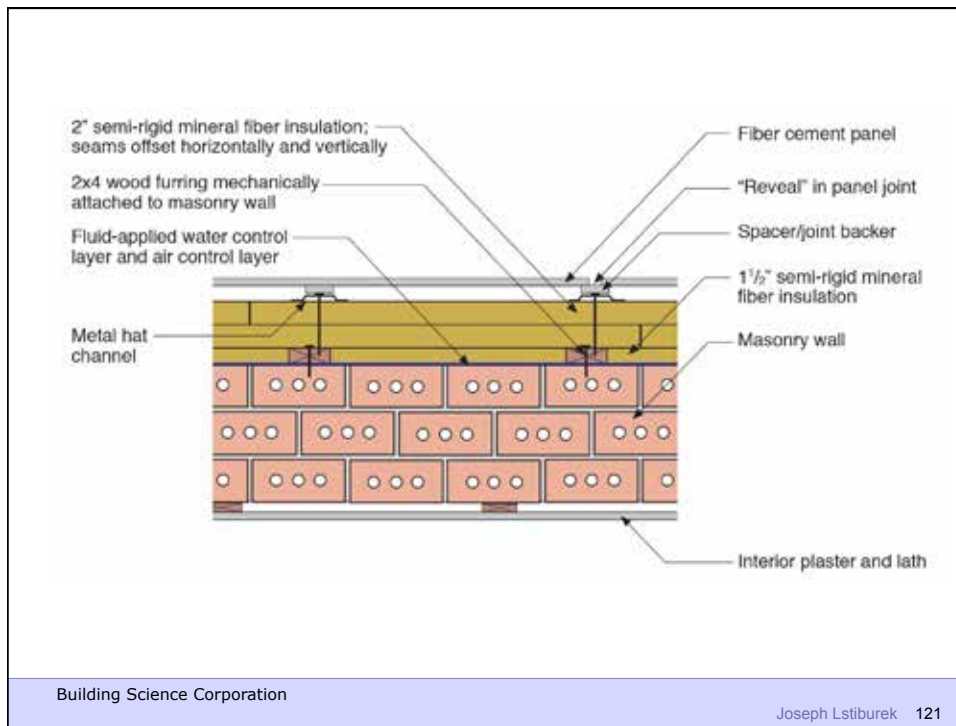
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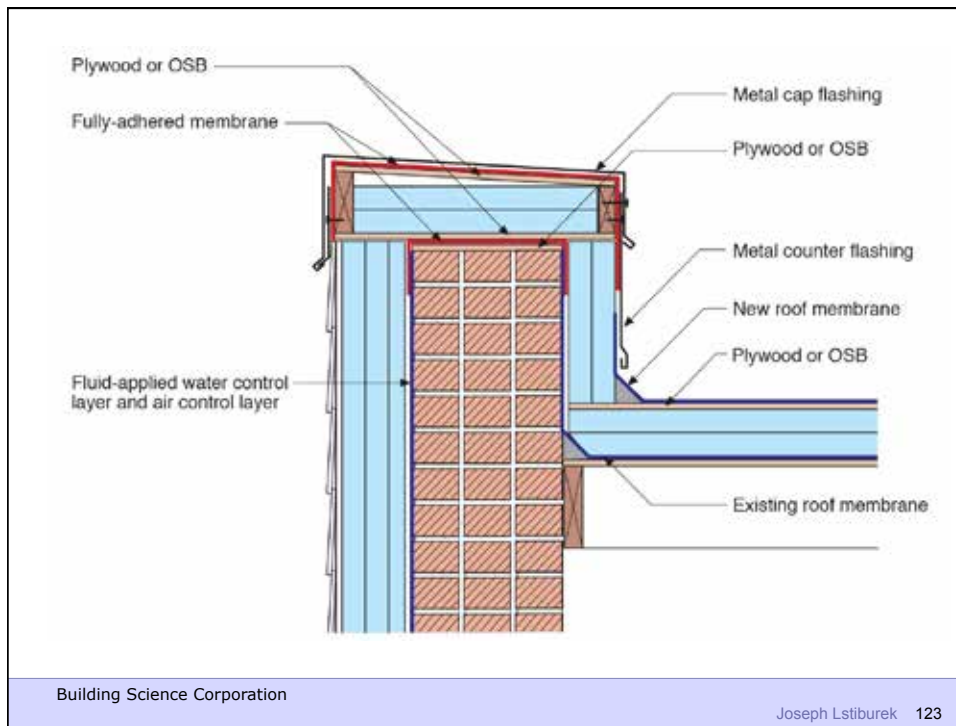


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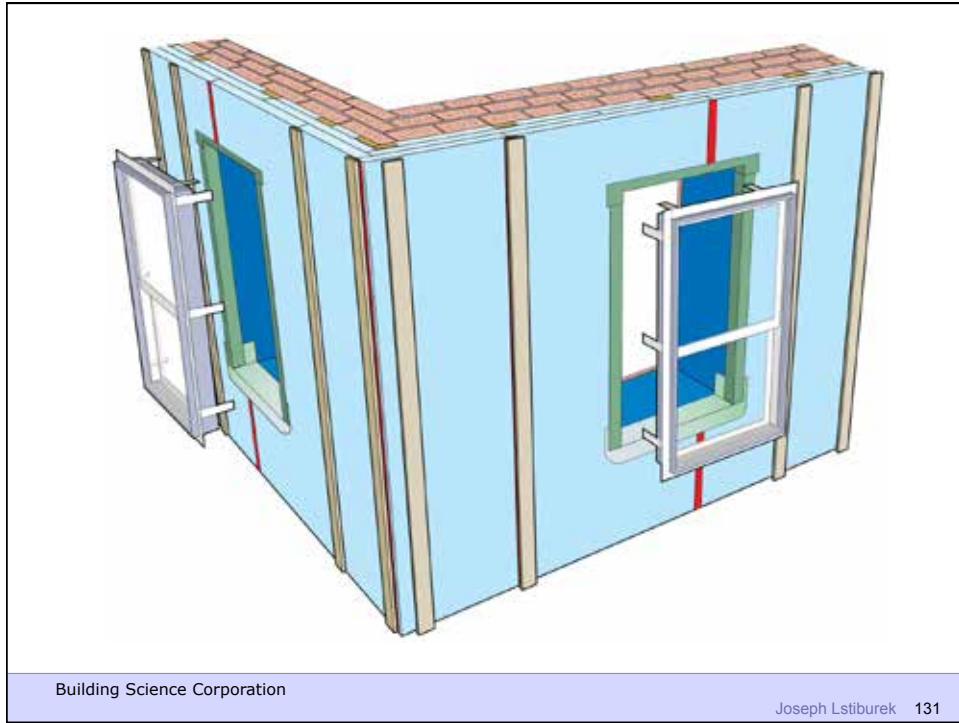
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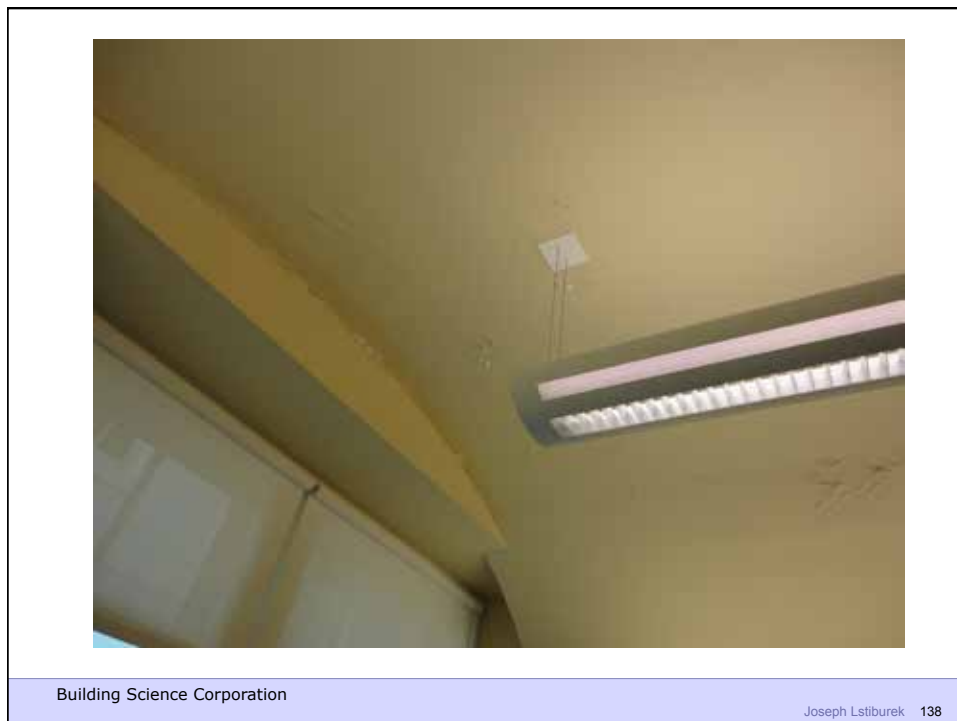
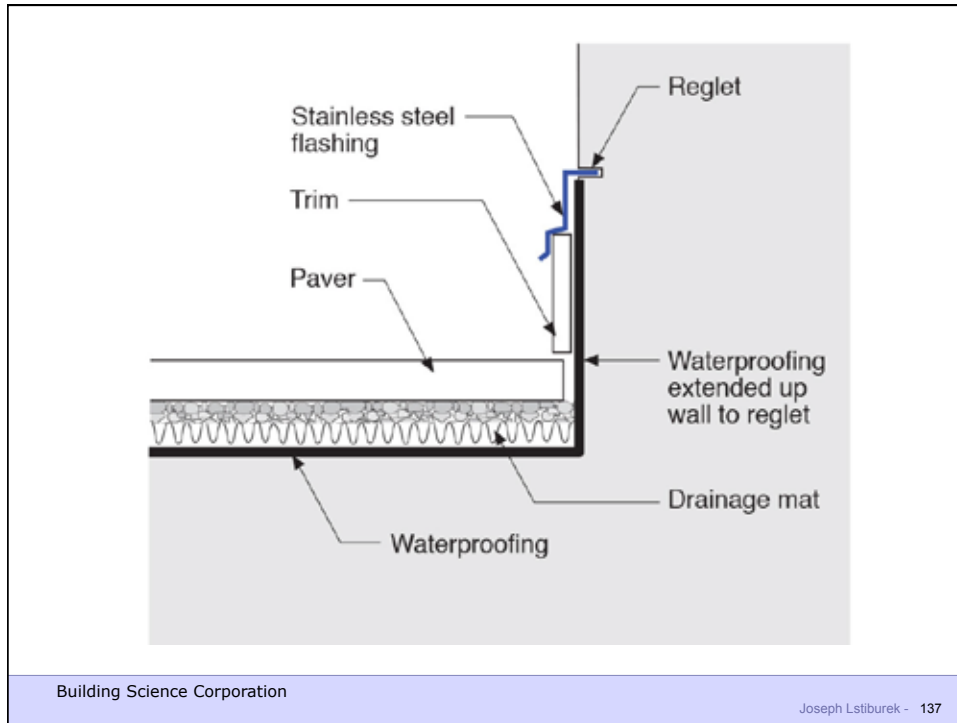
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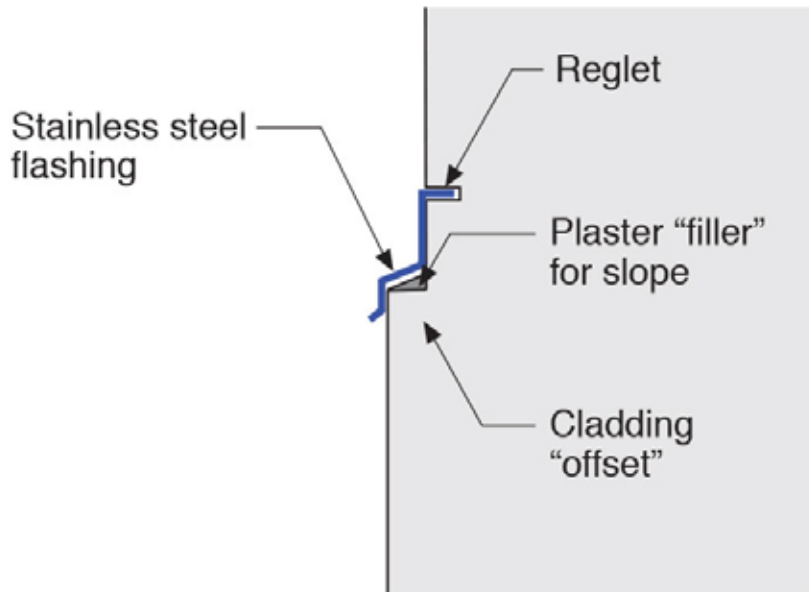
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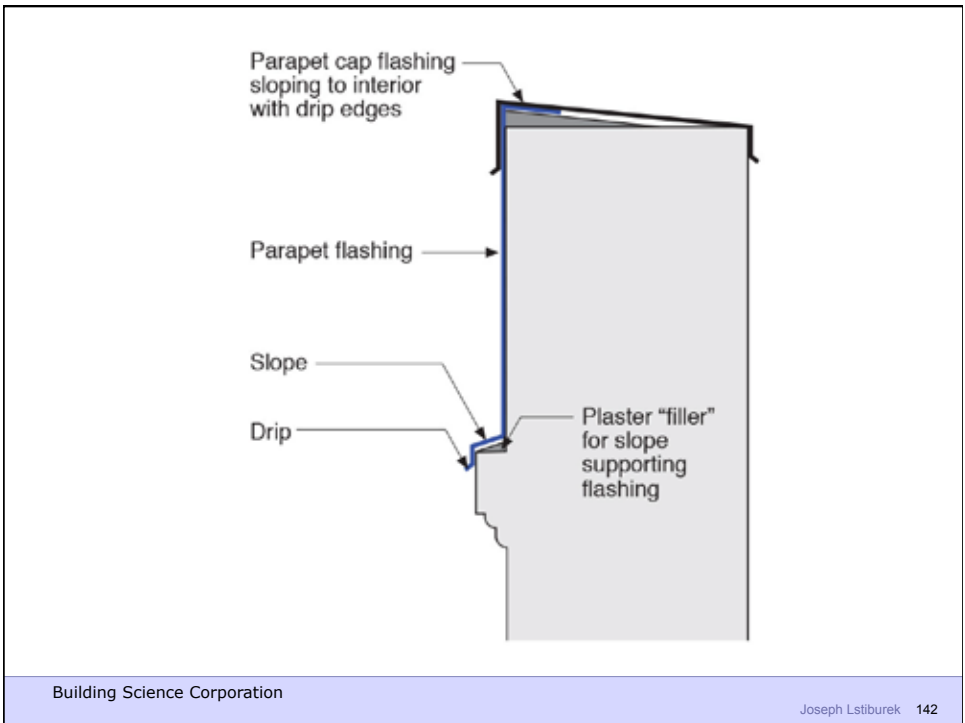
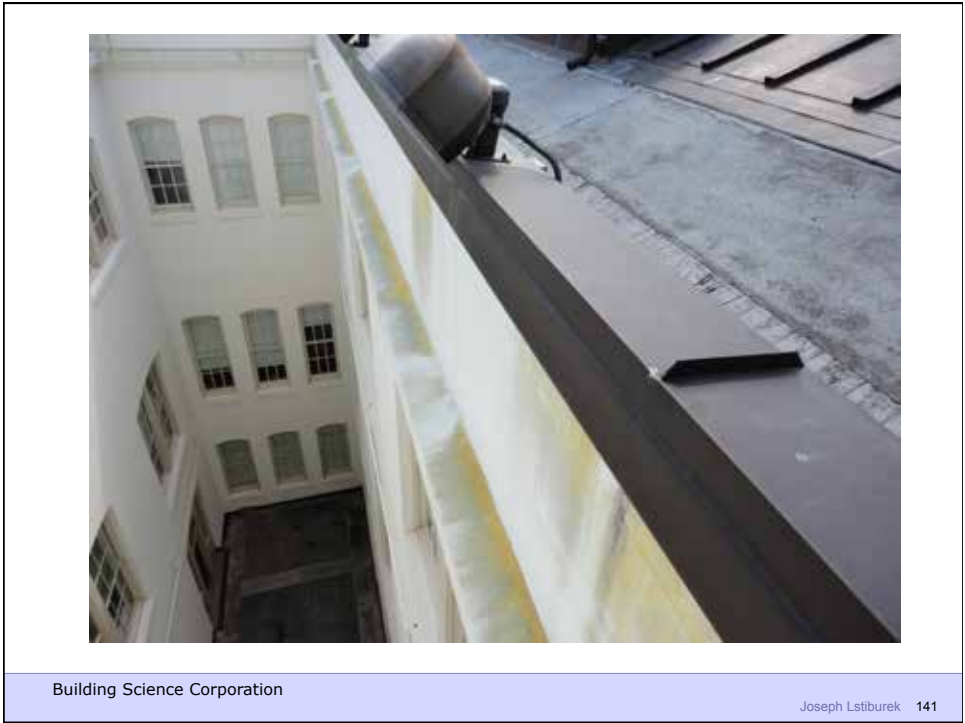
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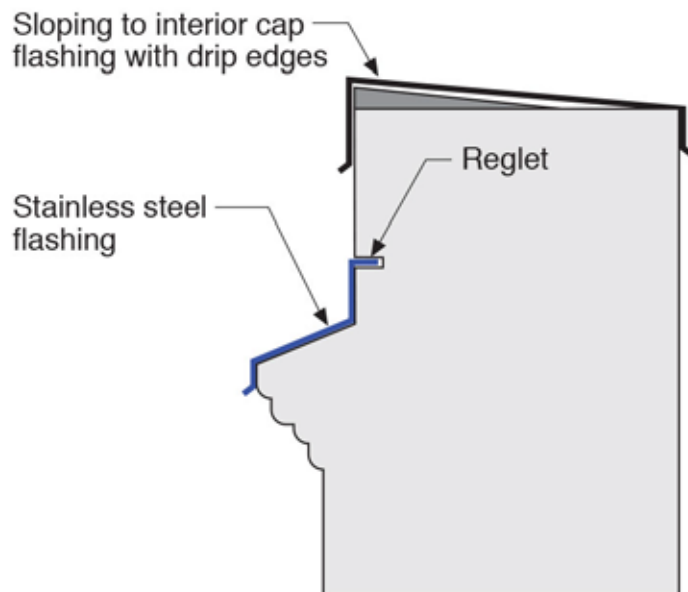
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