

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

# Building Science

## Adventures In Building Science

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## Freeze-Thaw Damage

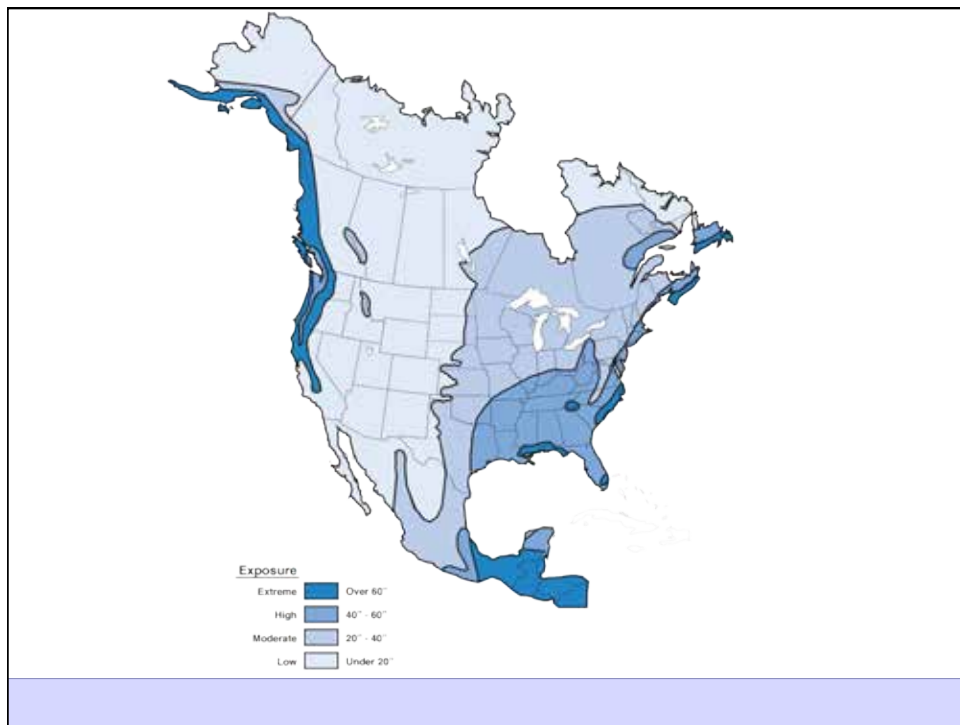
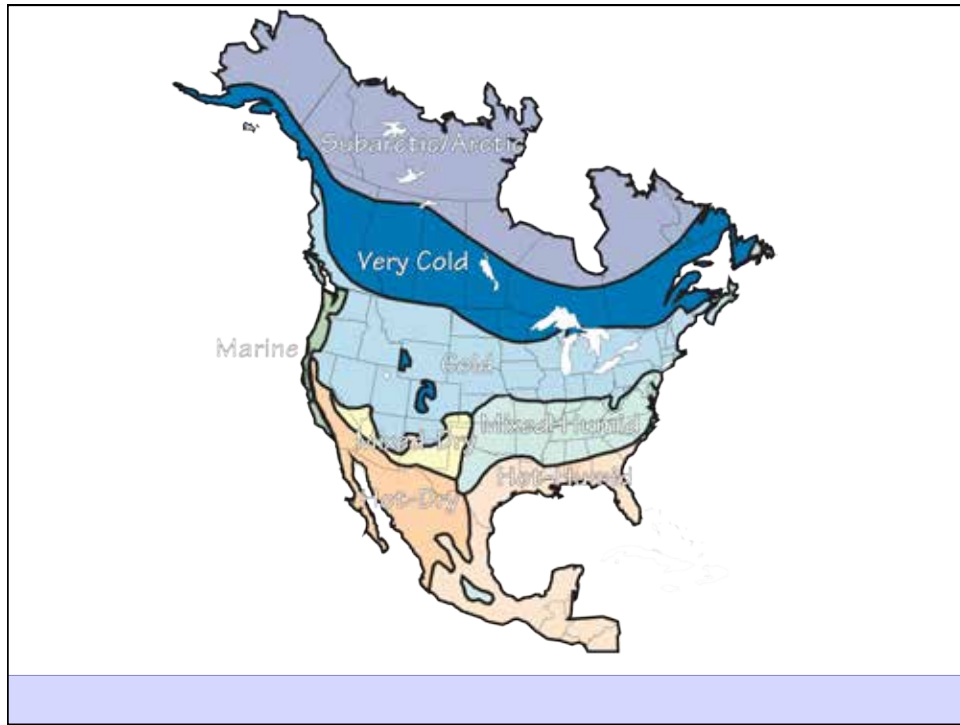
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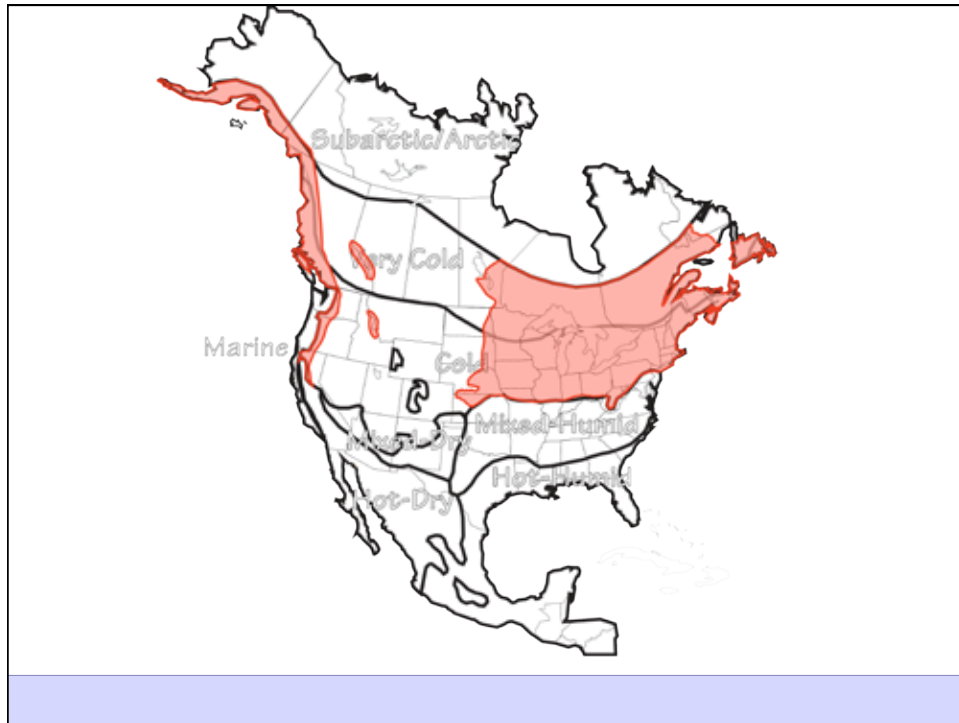
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Freeze-Thaw Damage  
Freezing Temperatures  
Water  
Susceptible Brick

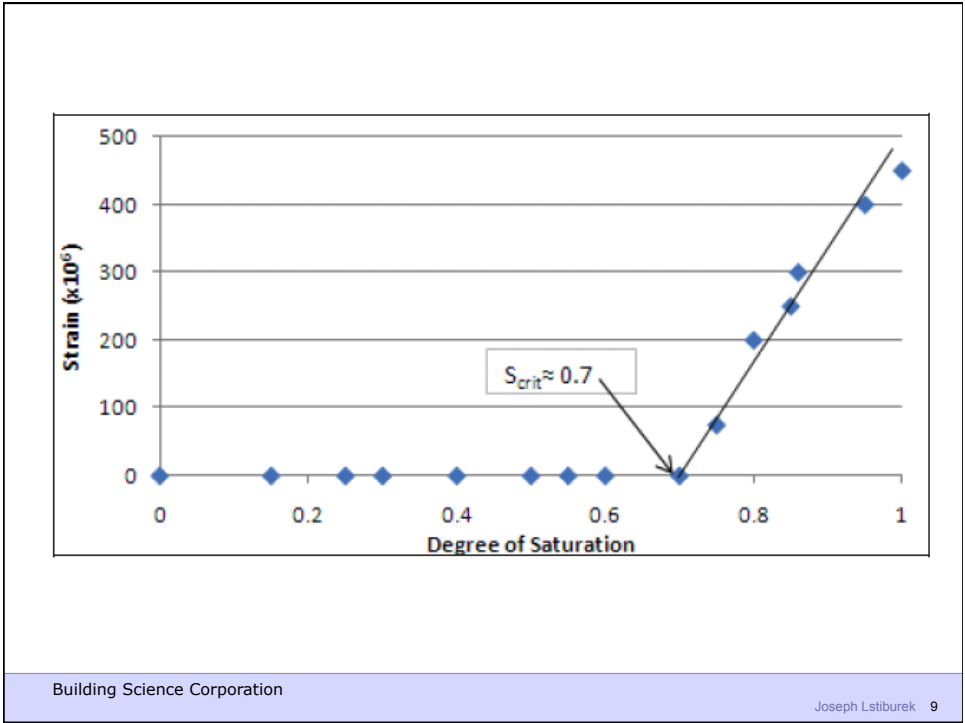
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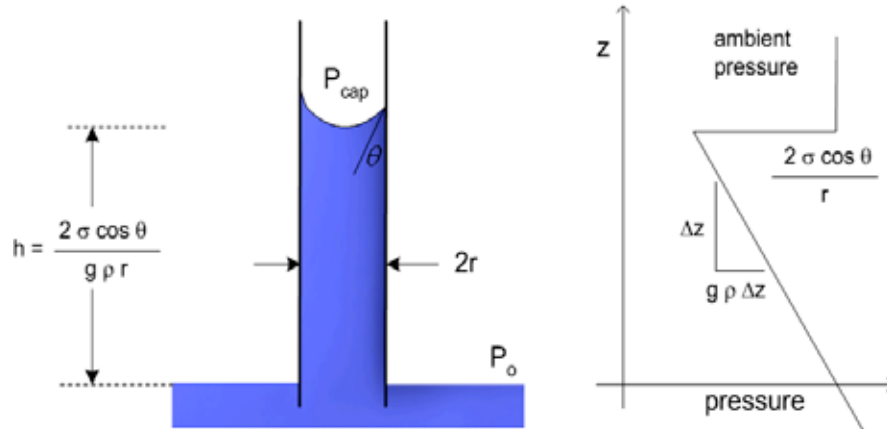




Susceptible Brick  
Firing Temperature  
Vitrification



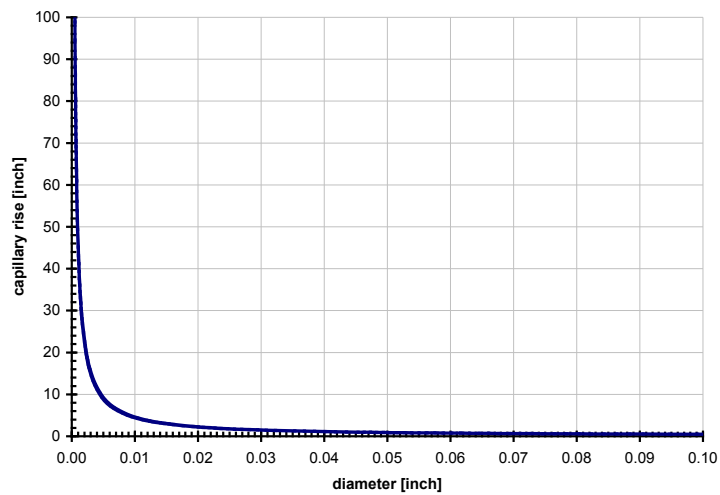
## Calculating capillary rise



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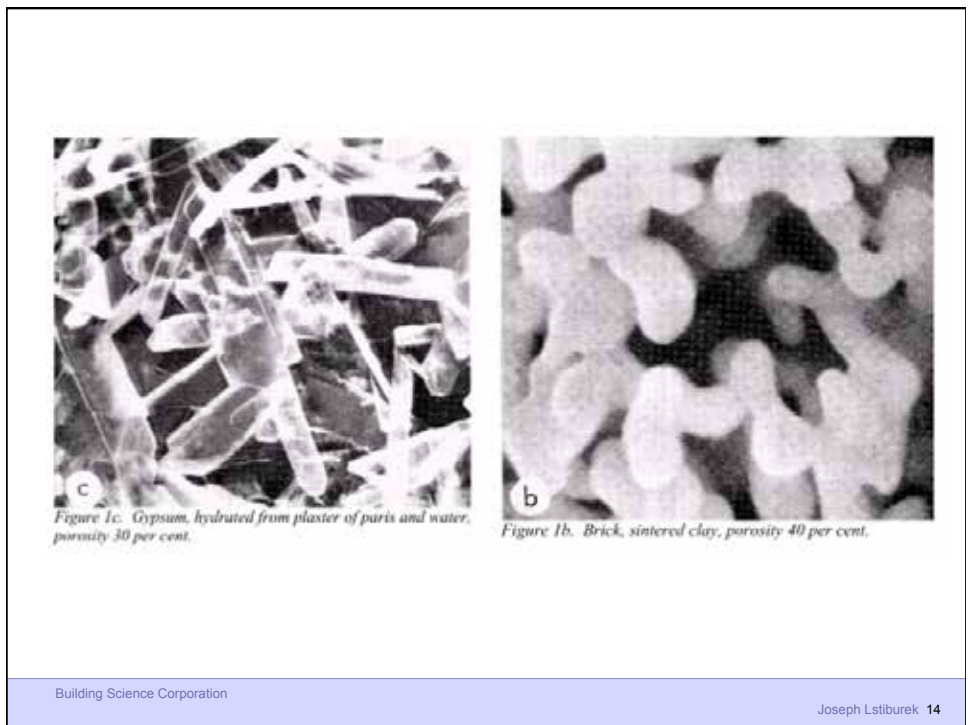
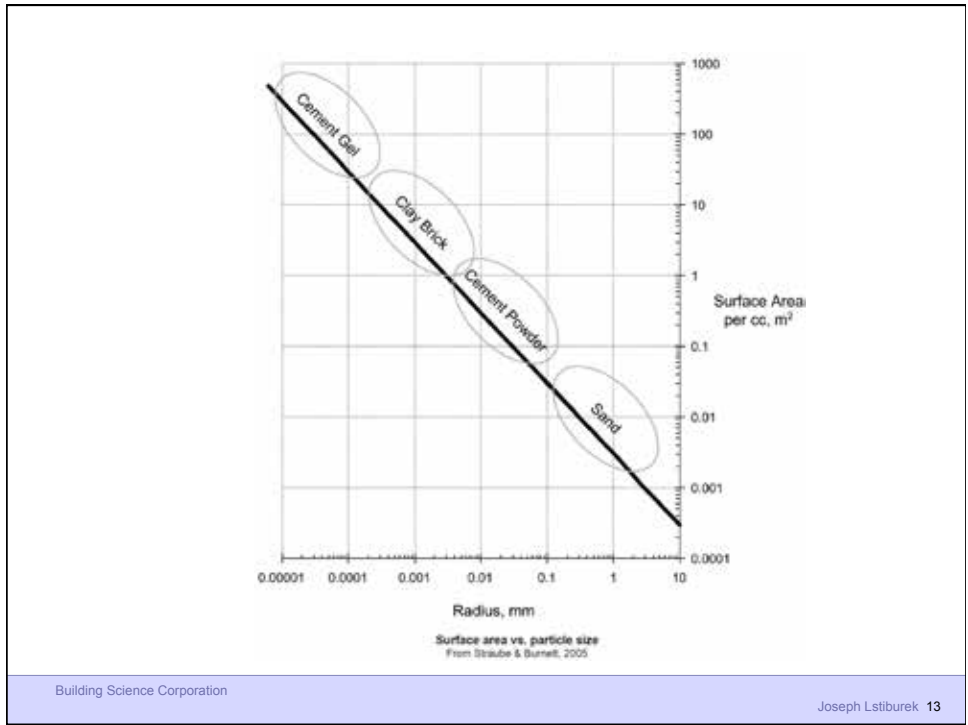
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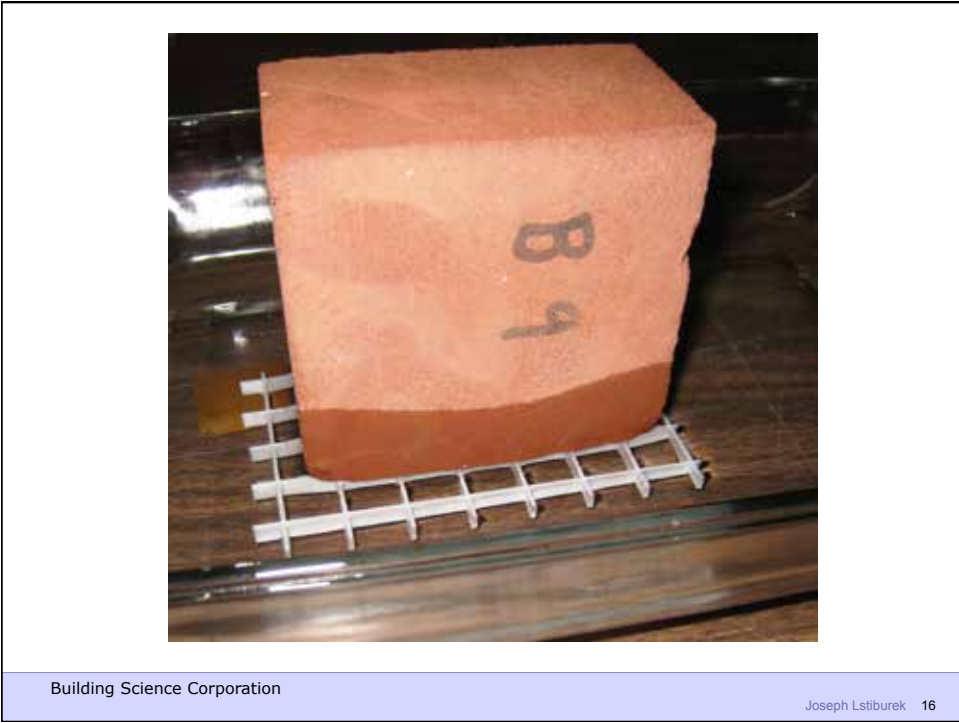
## Capillary rise versus diameter



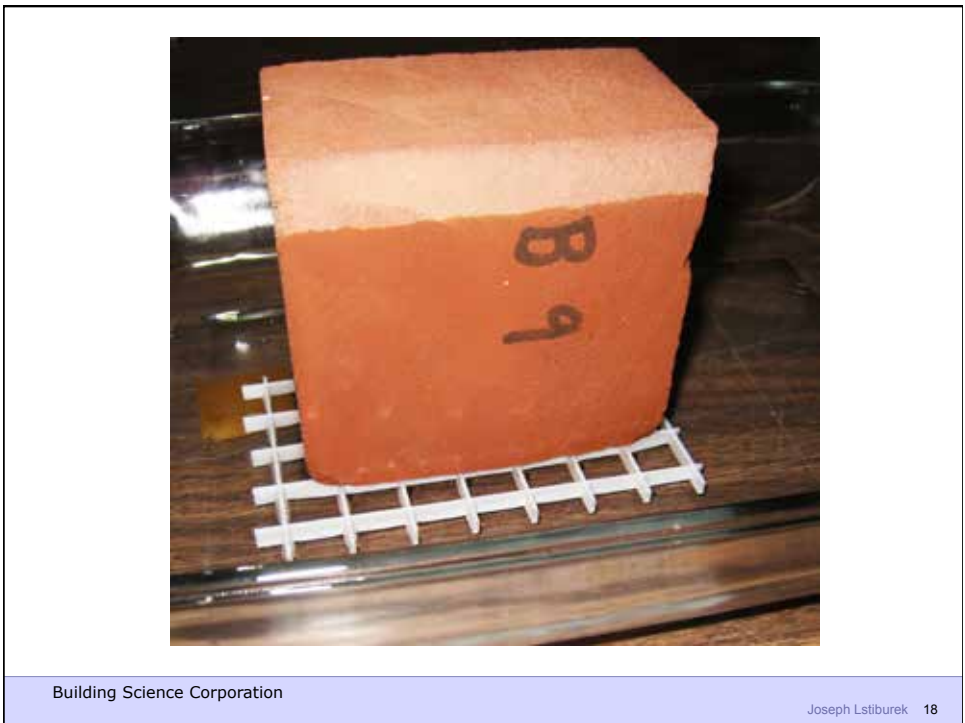
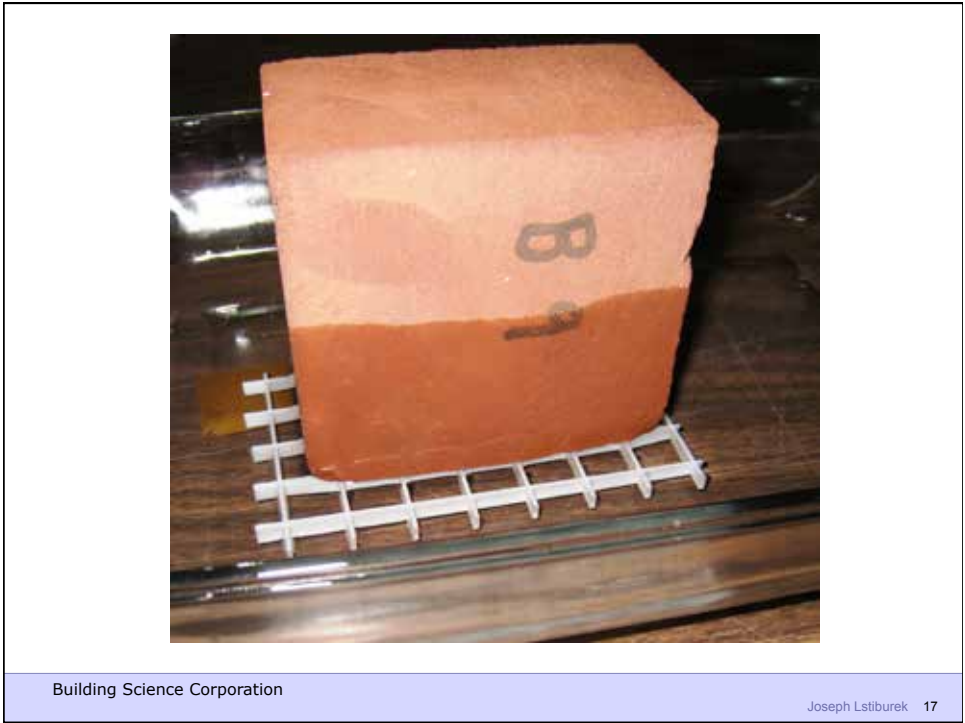
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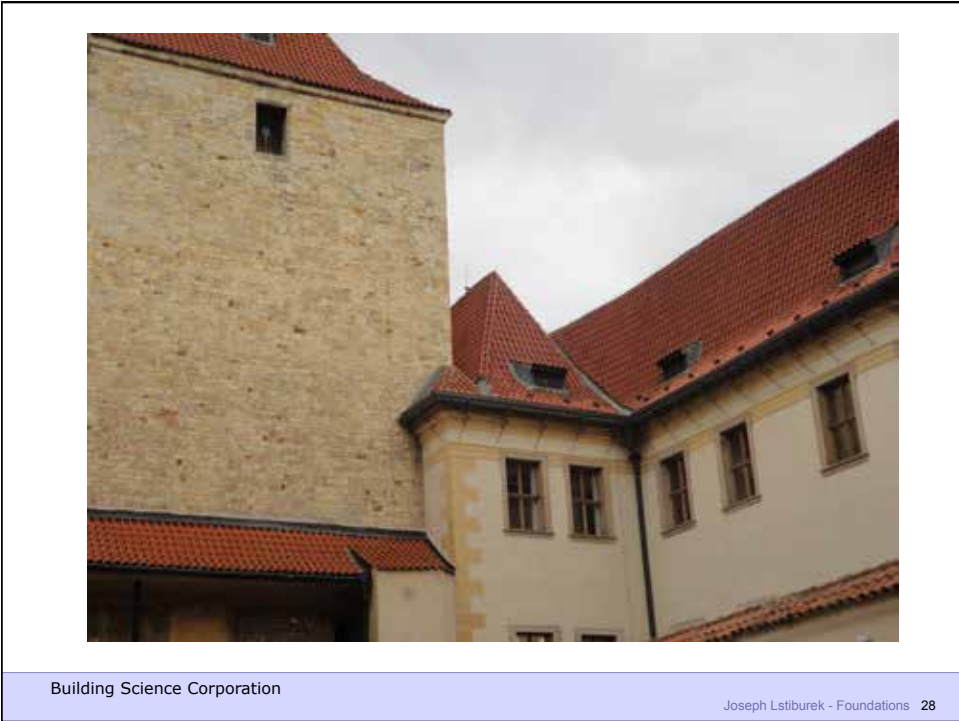
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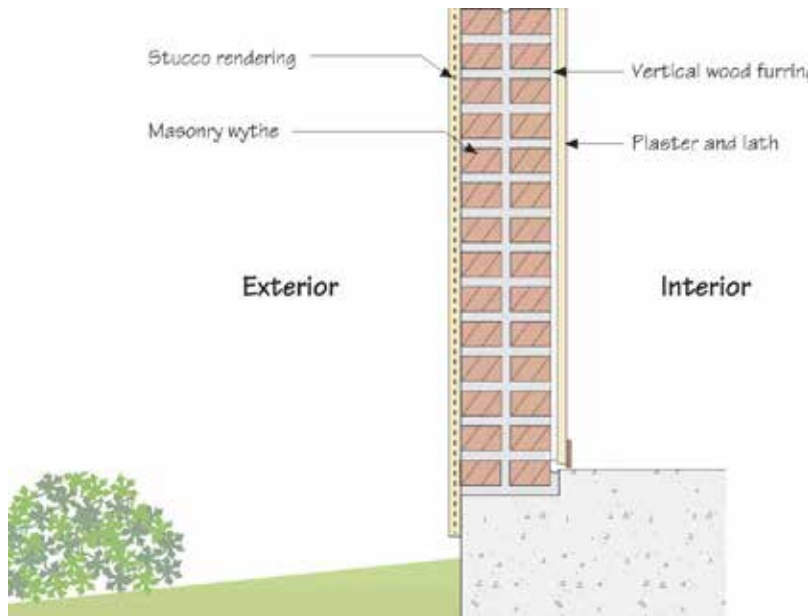
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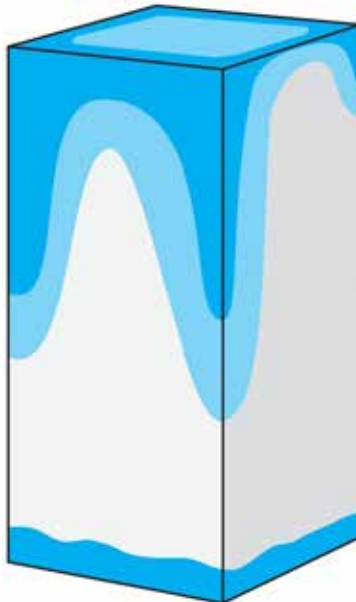
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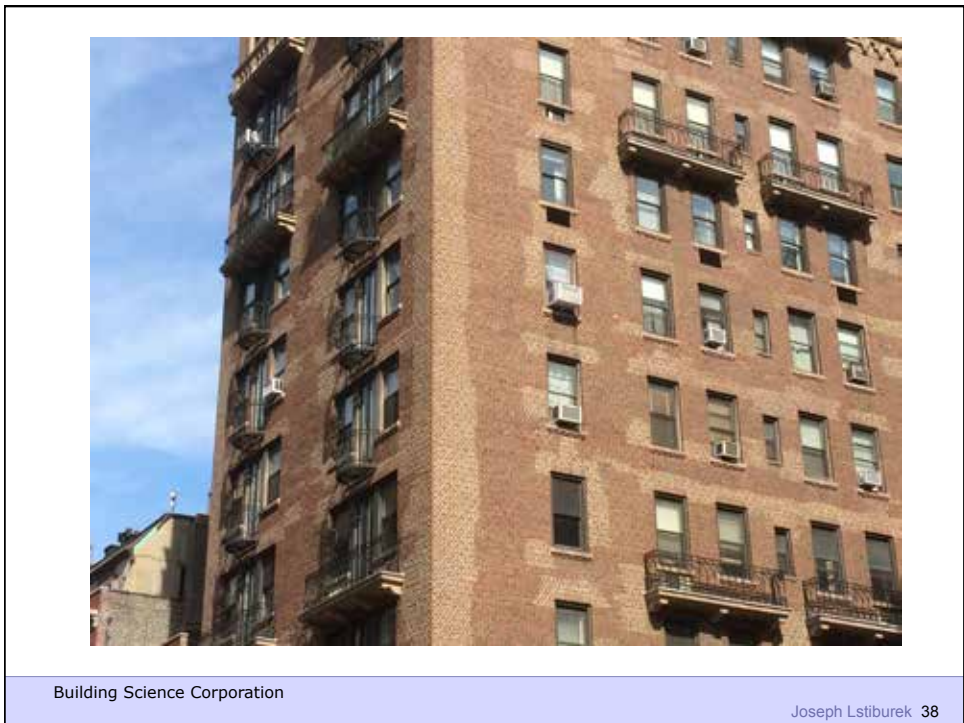
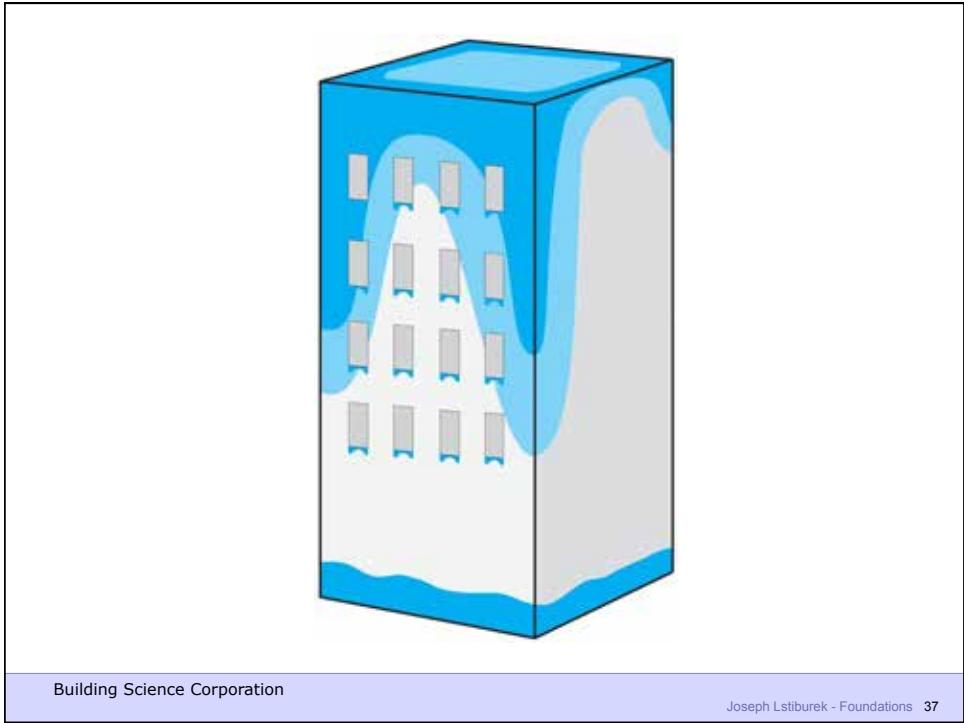
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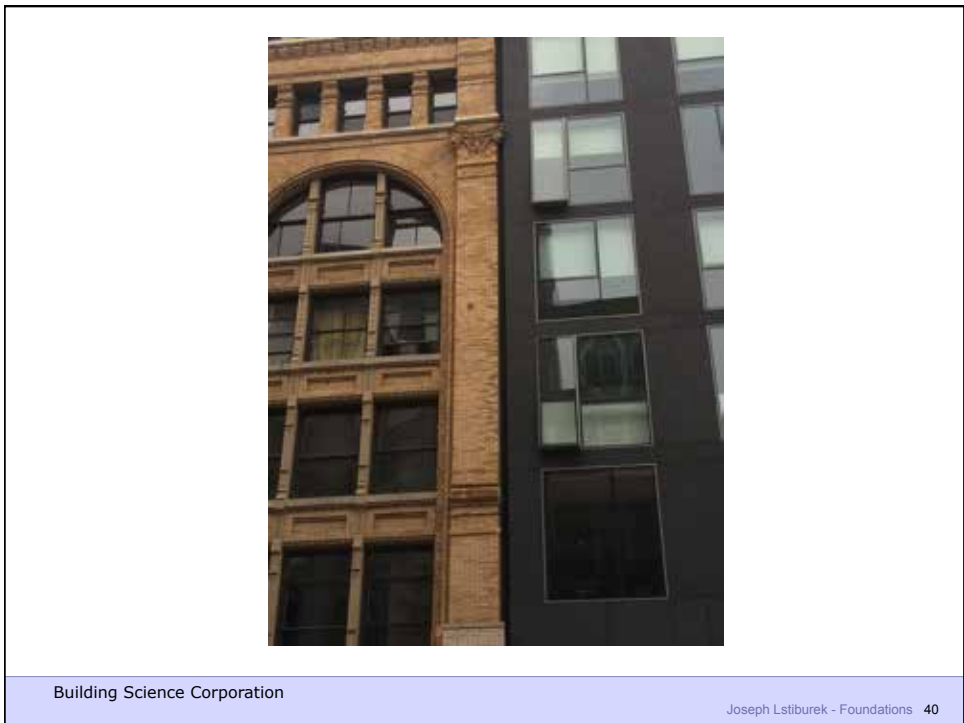


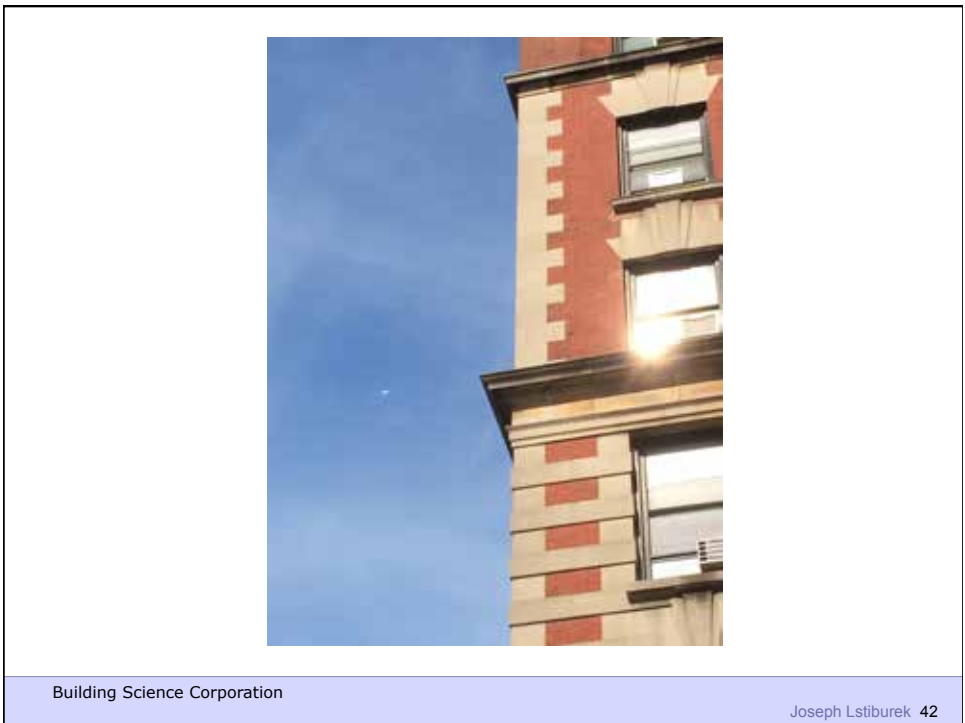
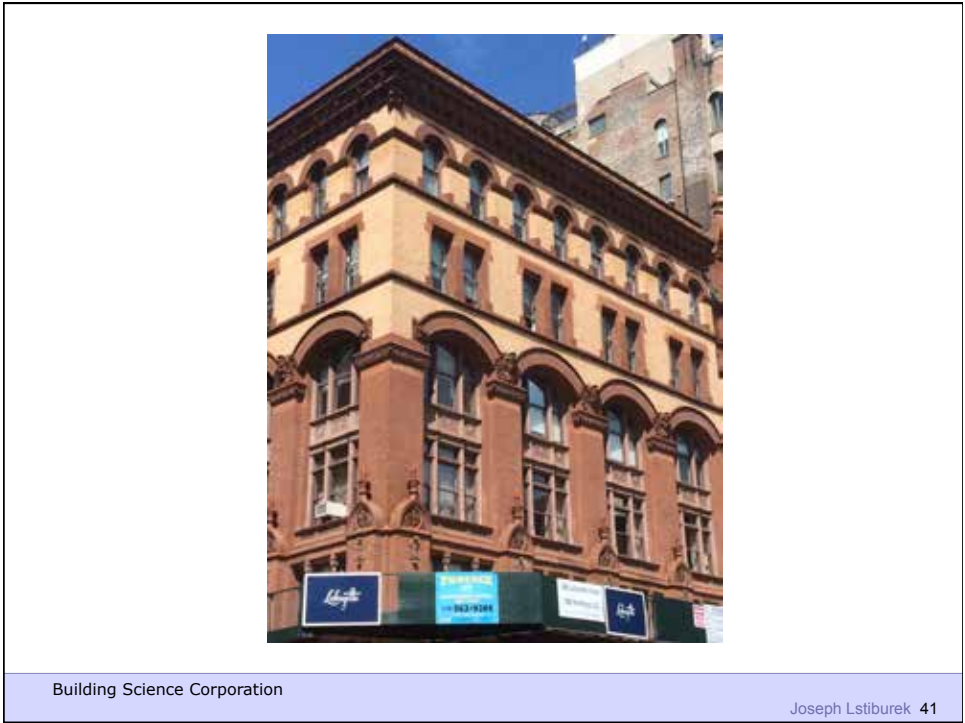
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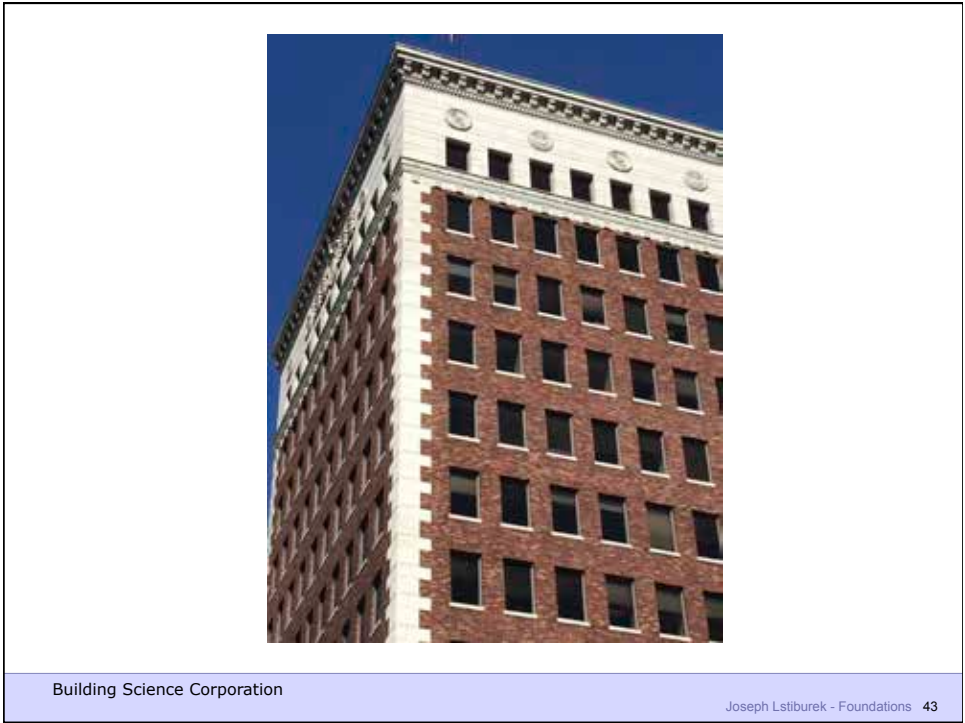


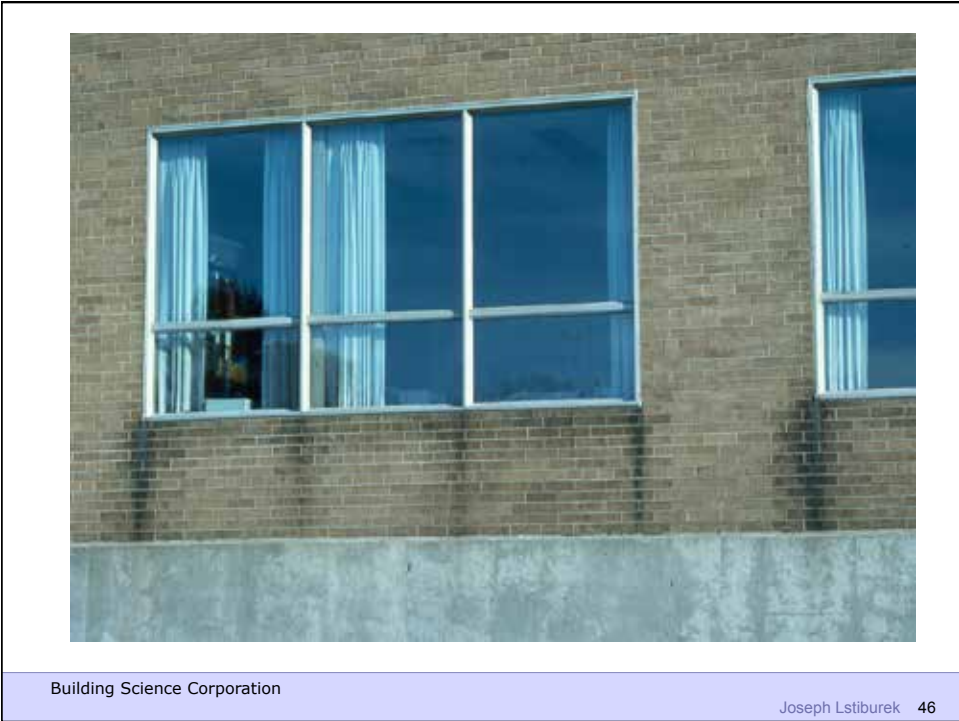
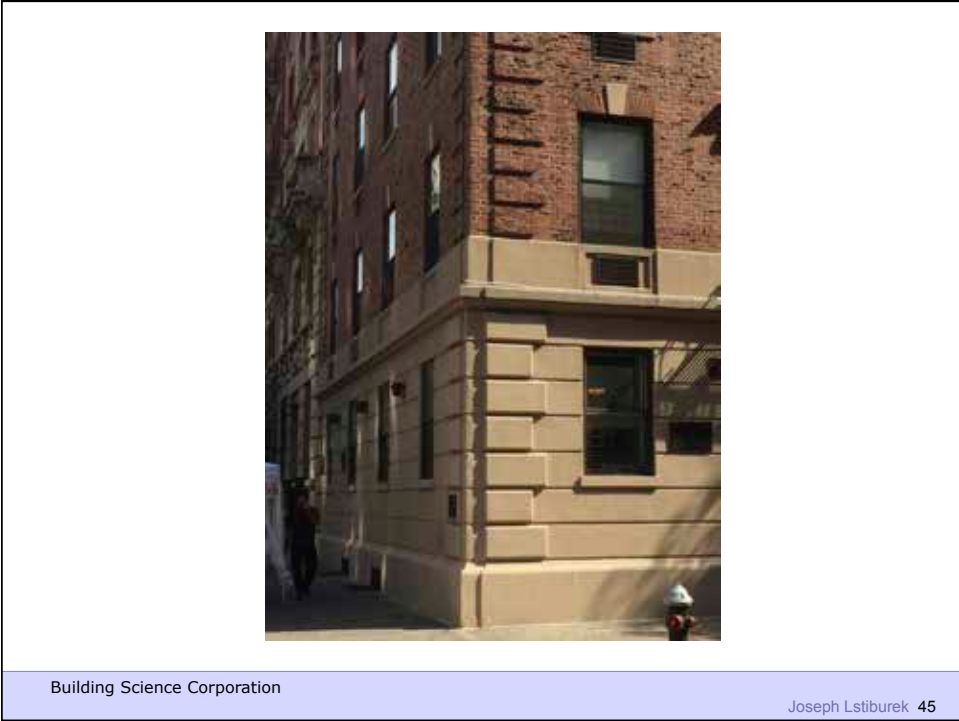
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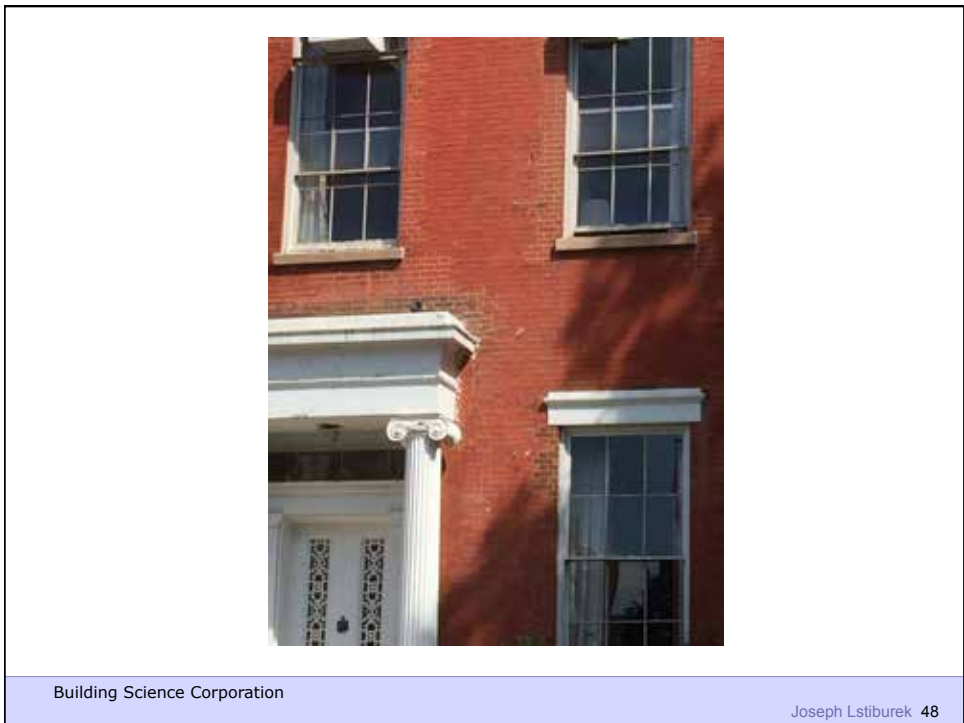
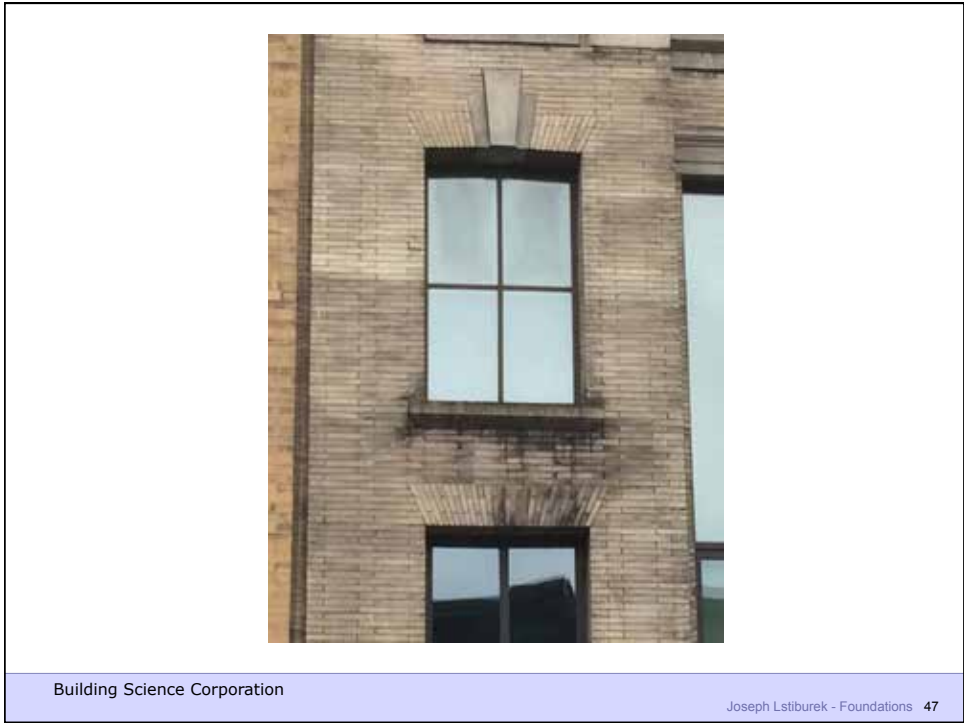




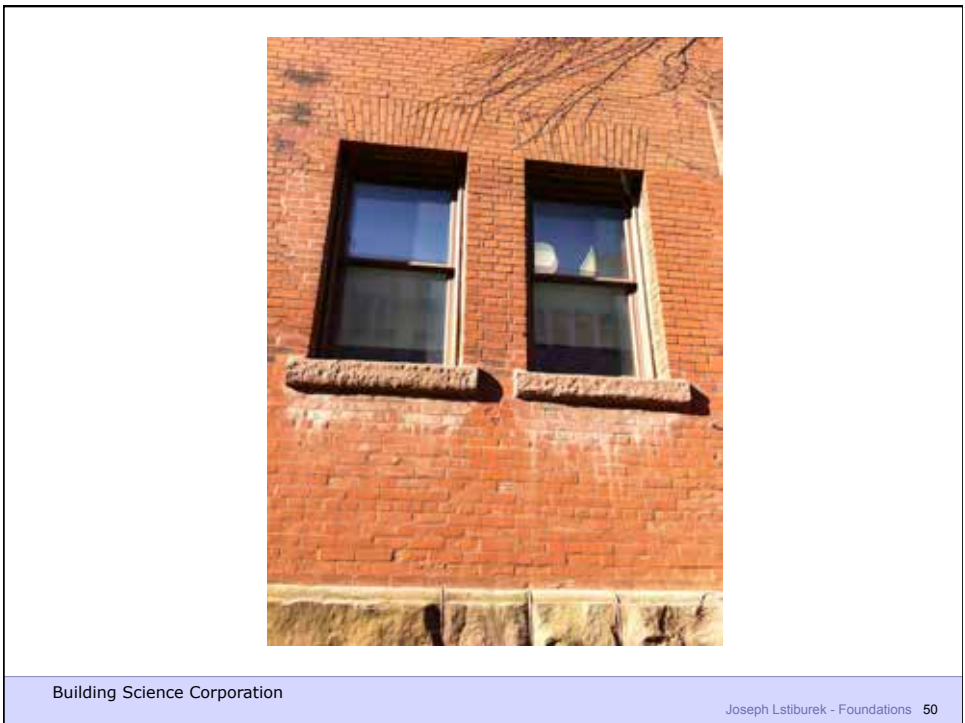
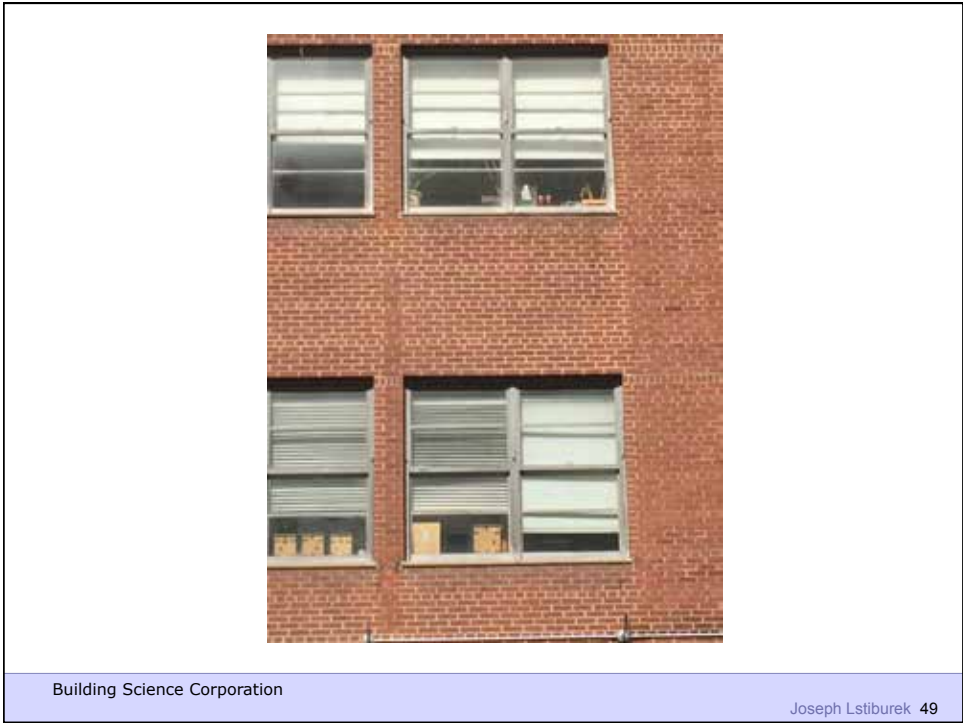


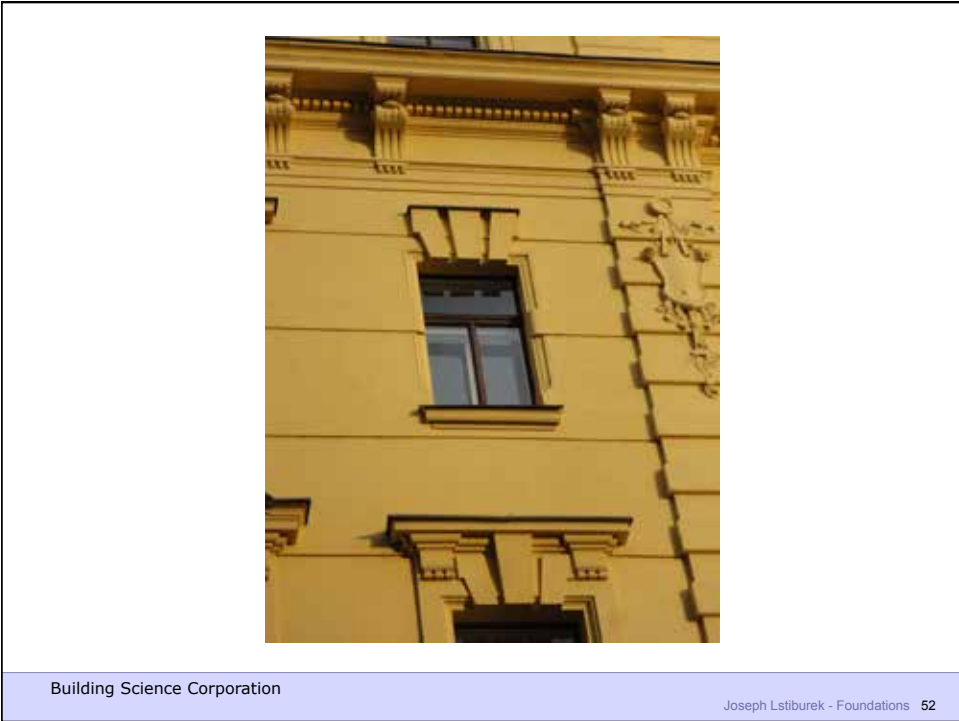












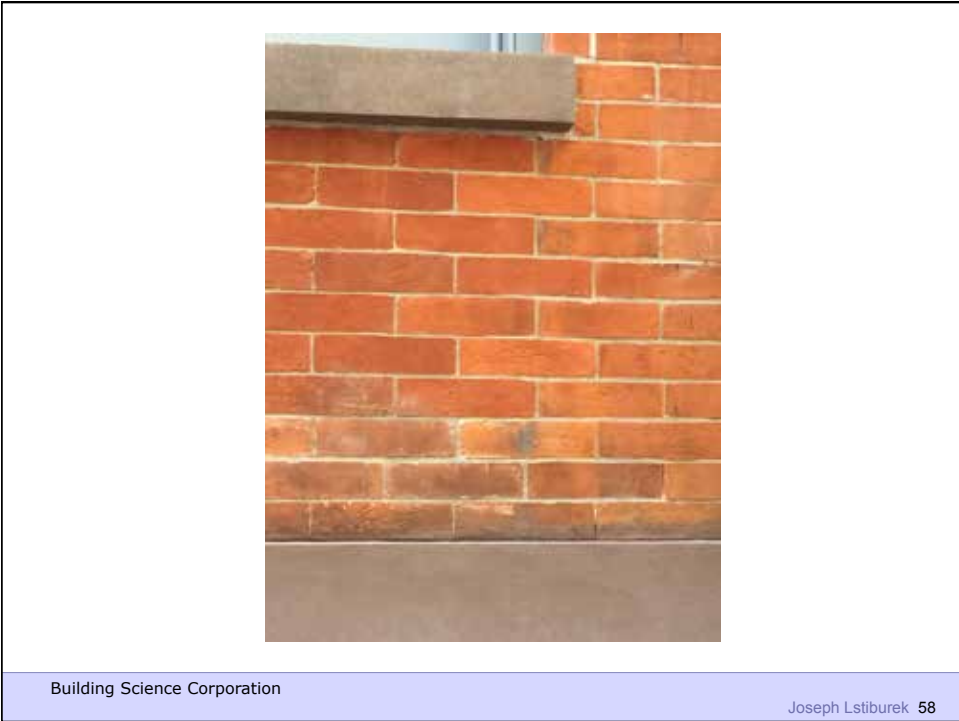
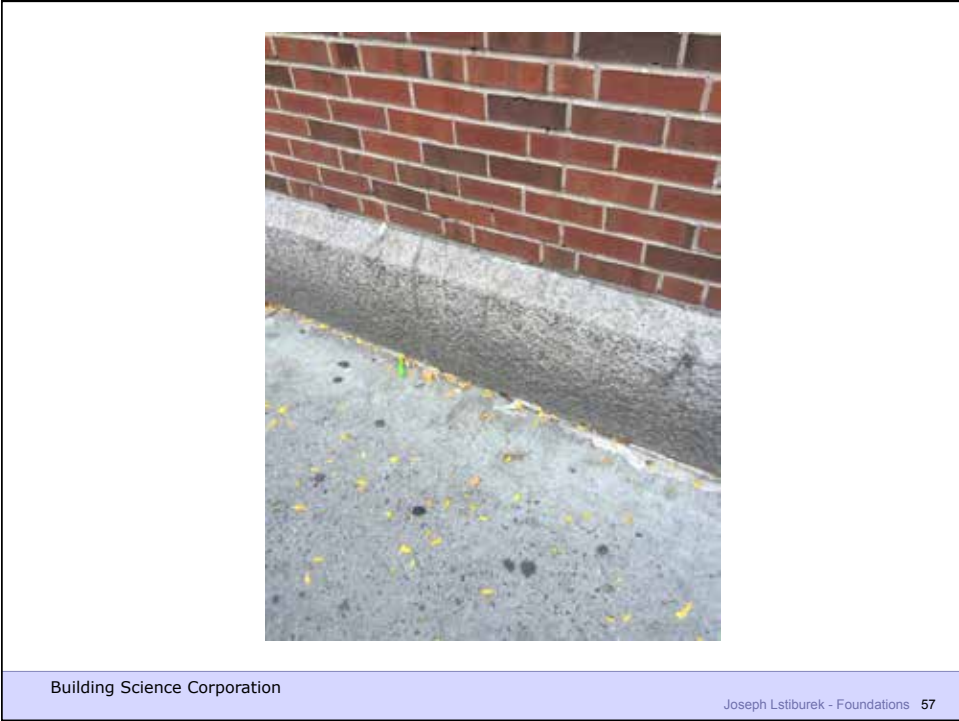


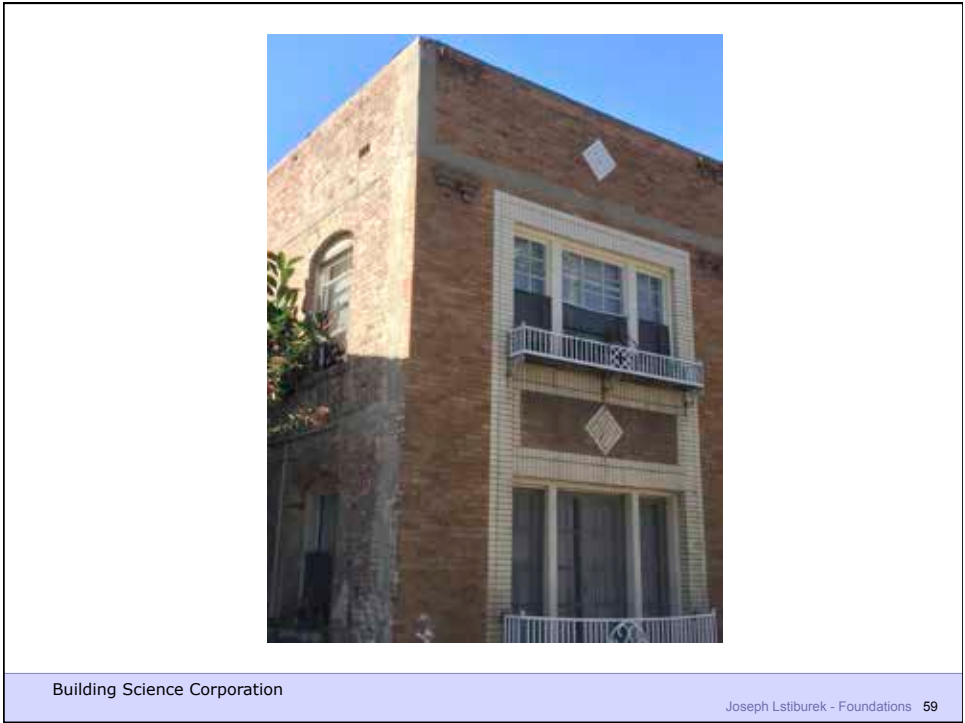
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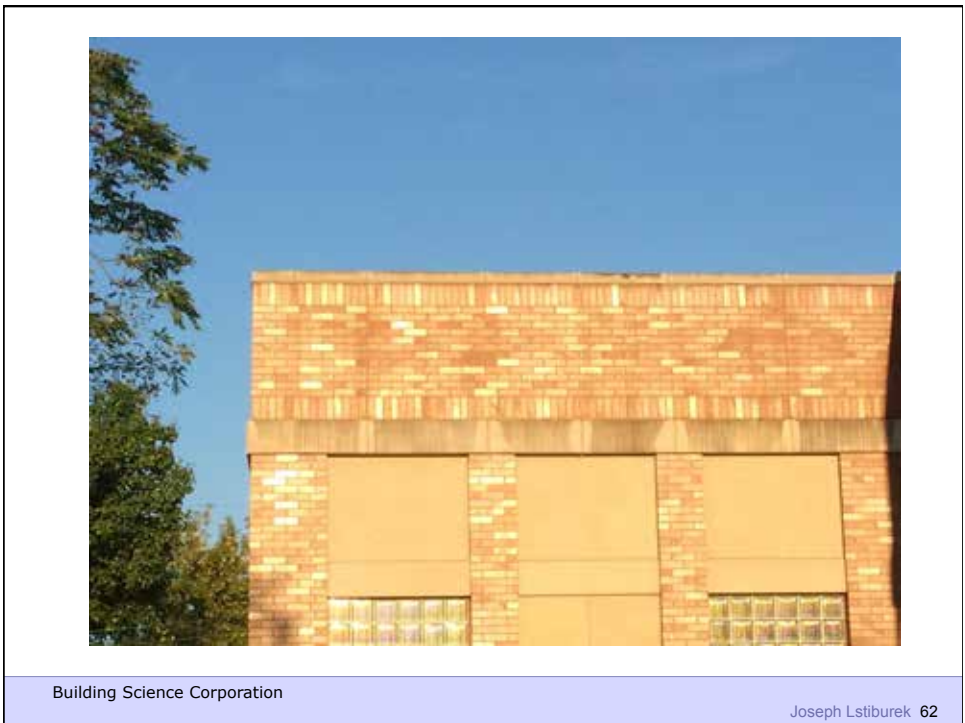


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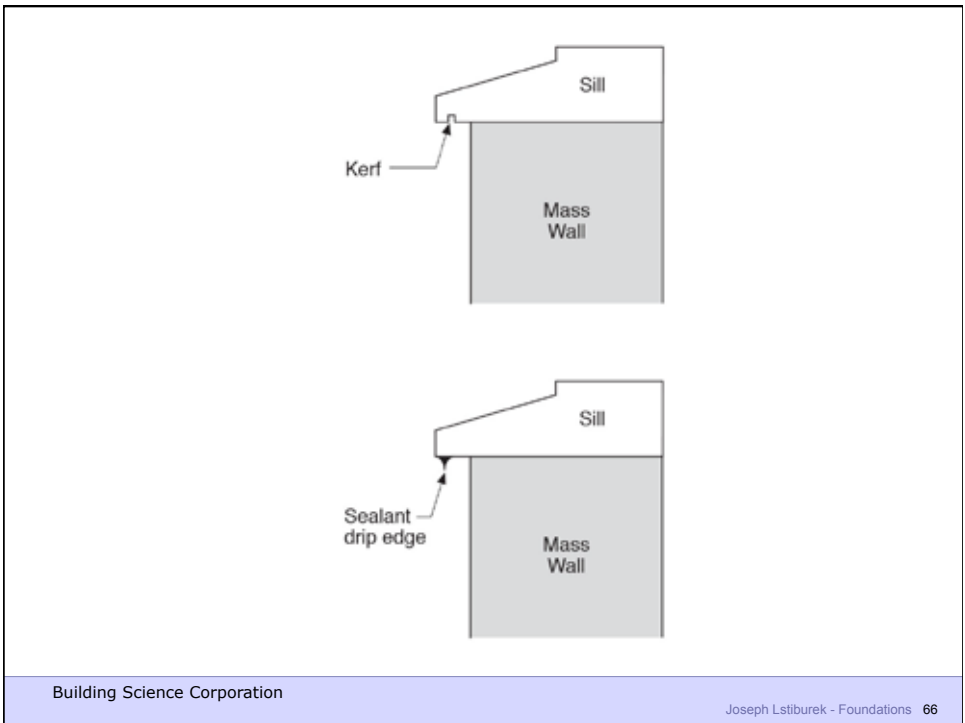
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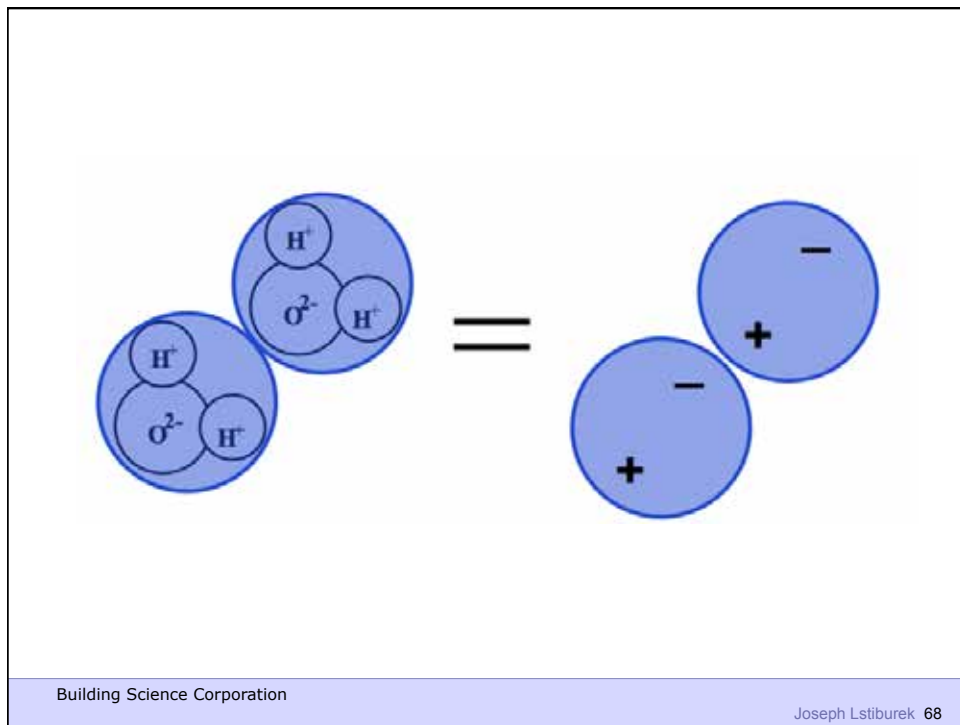
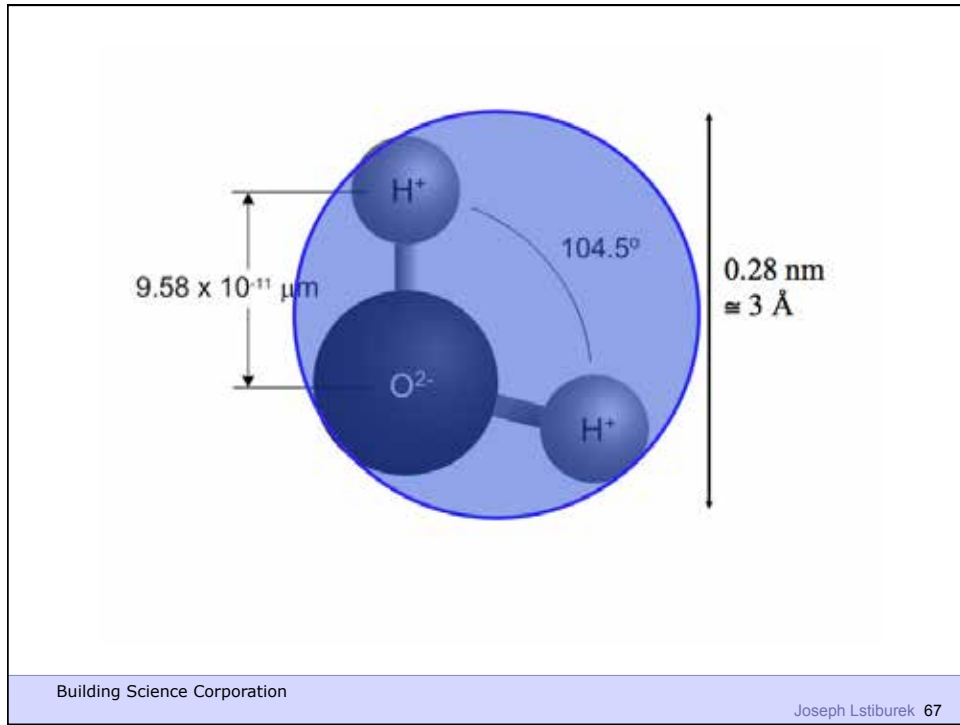


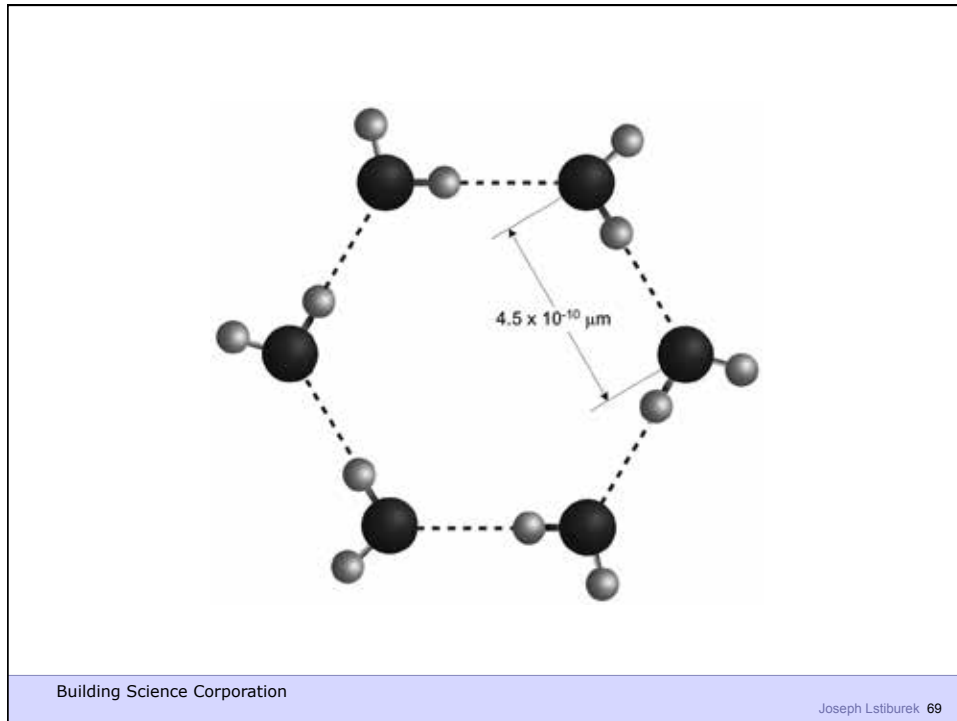
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2<sup>nd</sup> Law of Thermodynamics

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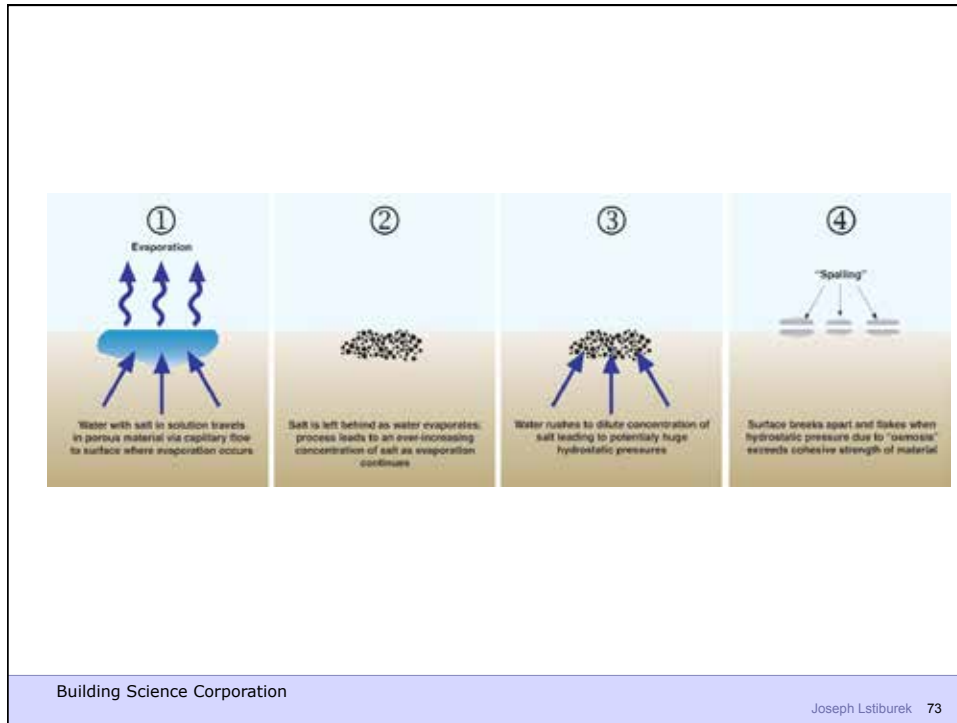
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<b>Moisture Transport in Porous Media</b>		
<b>Phase</b>	<b>Transport Process</b>	<b>Driving Potential</b>
<b>Vapor</b>	Diffusion	Vapor Concentration
<b>Adsorbate</b>	Surface Diffusion	Concentration
<b>Liquid</b>	Capillary Flow Osmosis	Suction Pressure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

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<b>Capillarity + Salt = Osmosis</b>		
<ul style="list-style-type: none"> <li>• Mineral salts carried in solution by capillary water</li> <li>• When water evaporates from a surface the salts left behind form crystals in process called efflorescence</li> <li>• When water evaporated beneath a surface the salts crystallize within the pore structure of the material in called sub-efflorescence</li> <li>• The salt crystallization causes expansive forces that can exceed the cohesive strength of the material leading to spalling</li> </ul>		

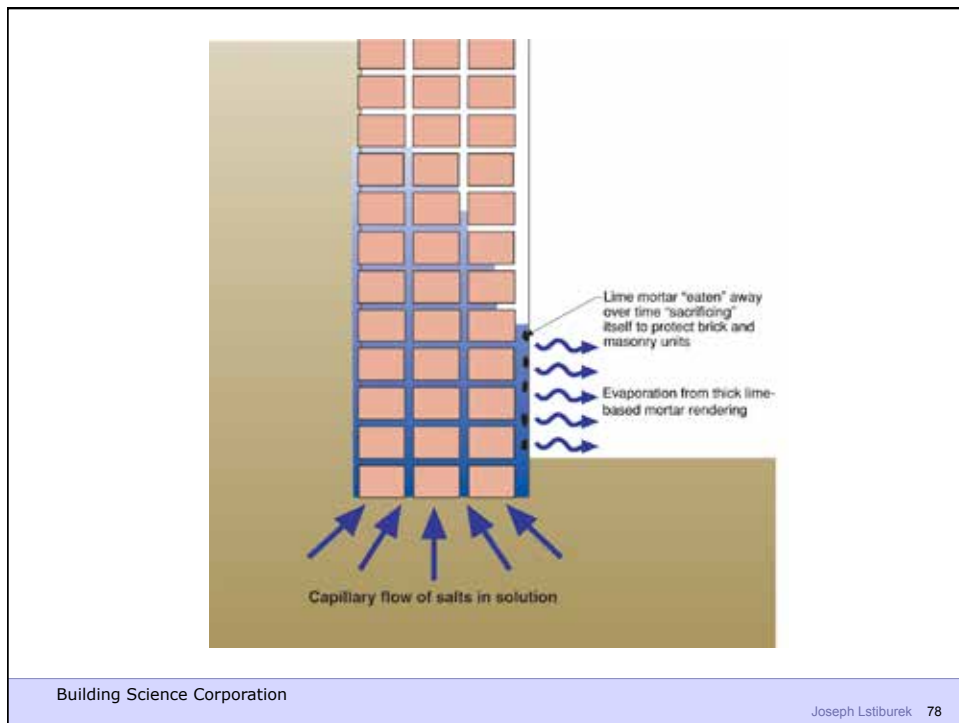
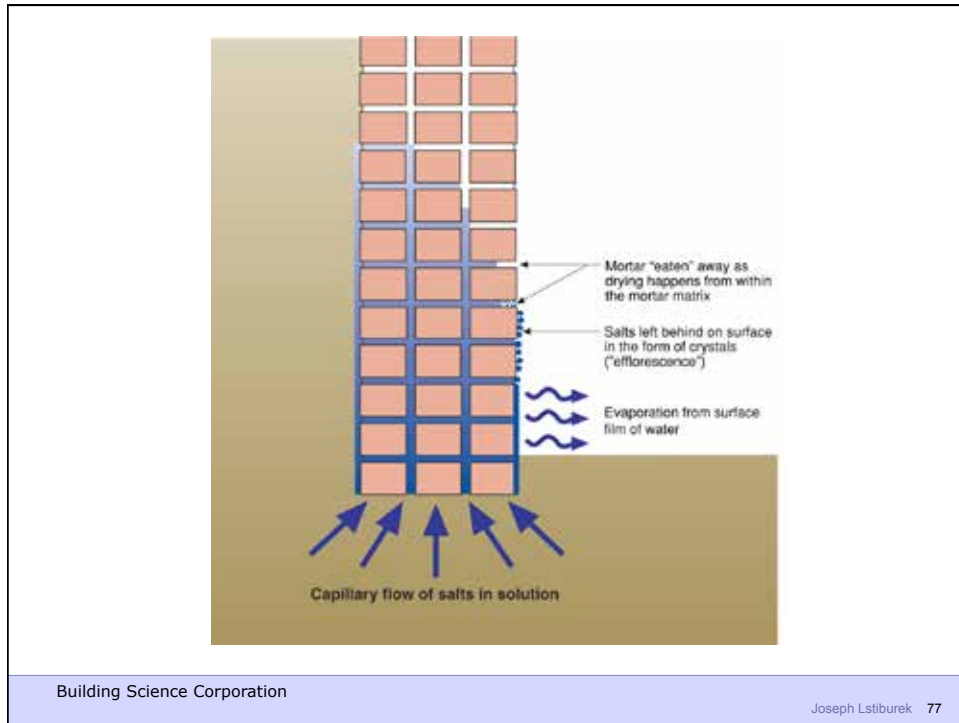
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## Diffusion + Capillarity + Osmosis = Problem

- 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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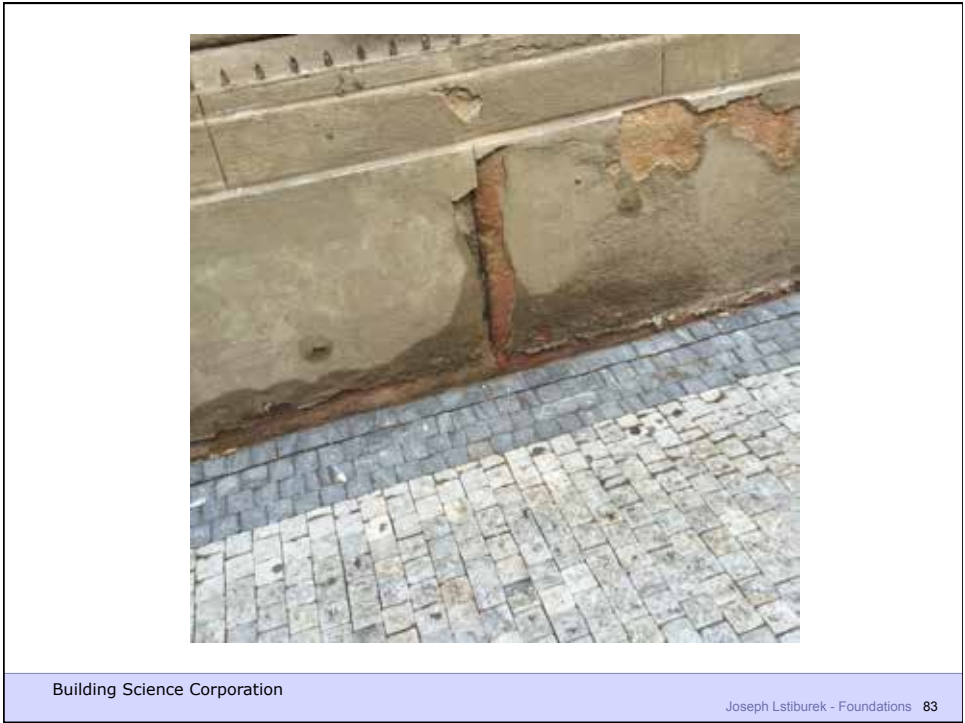
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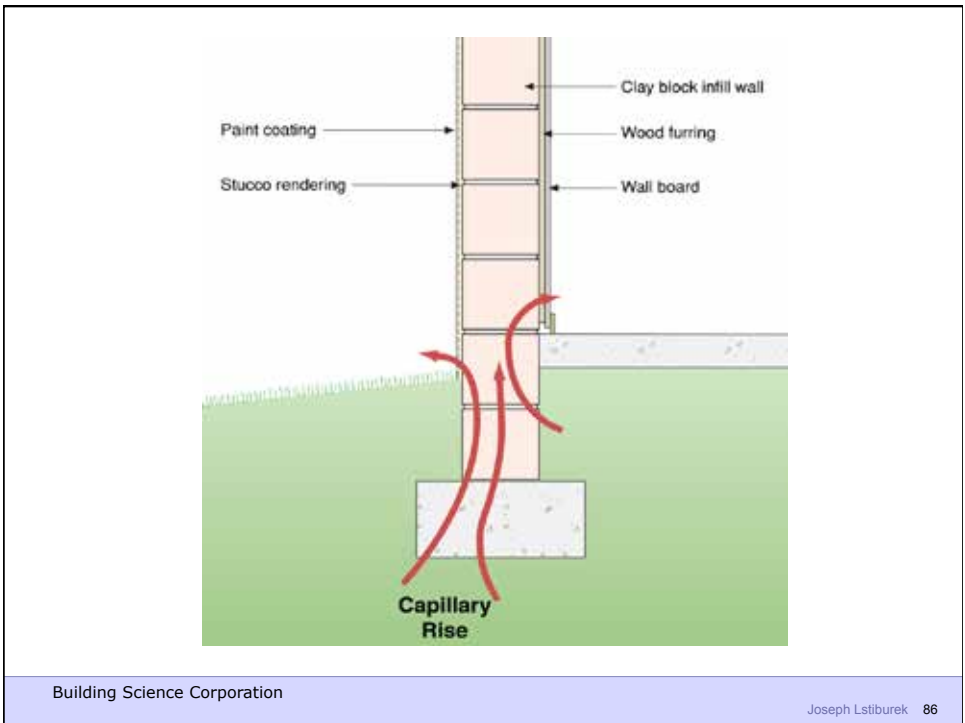
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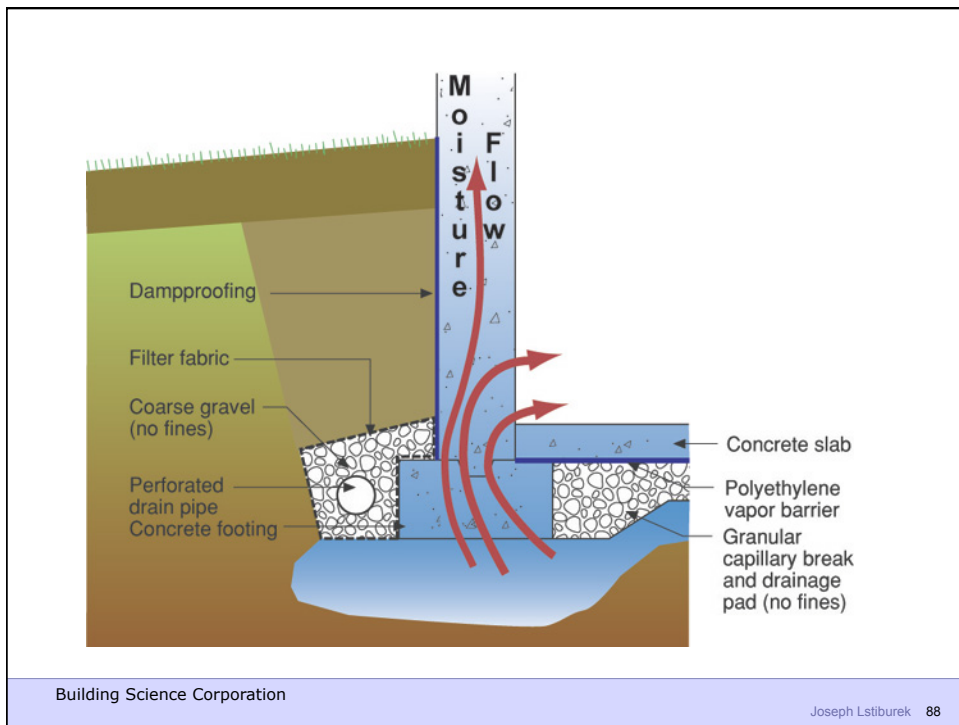
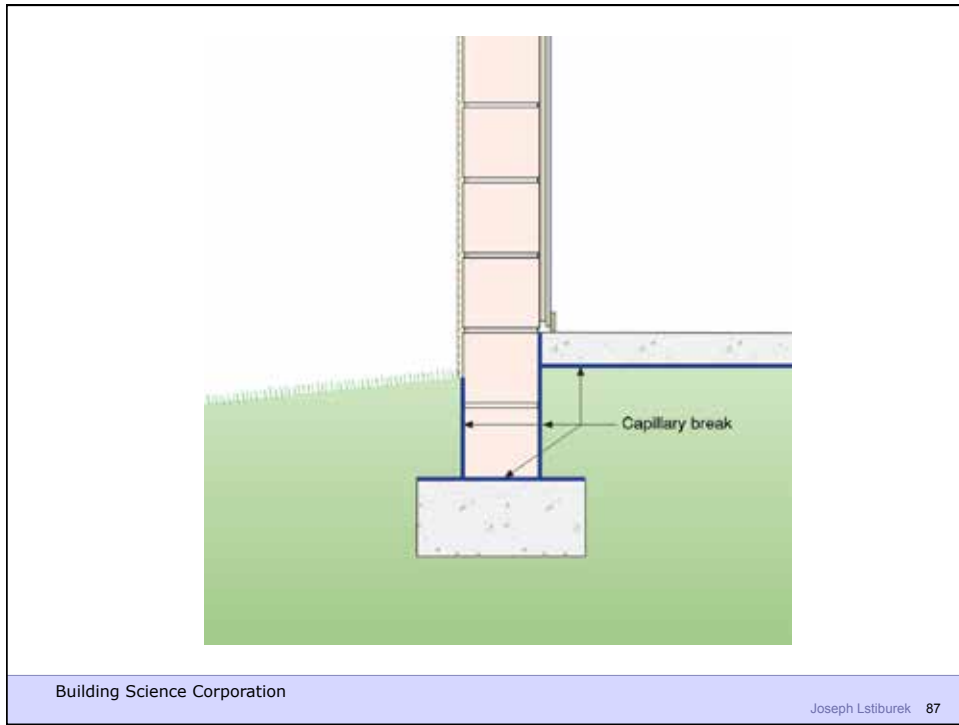


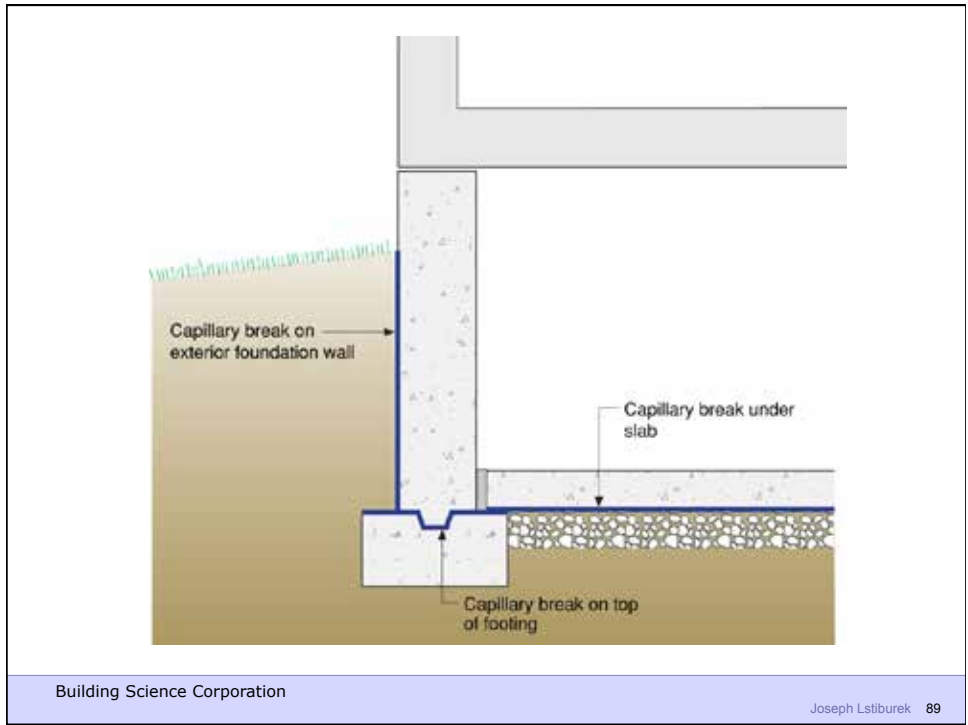
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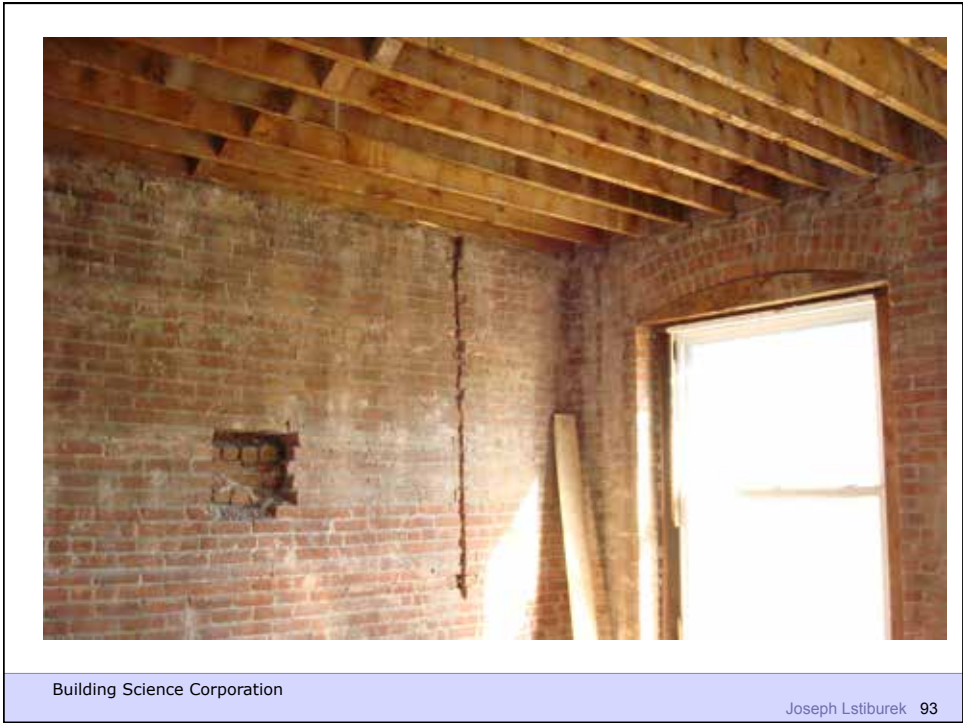






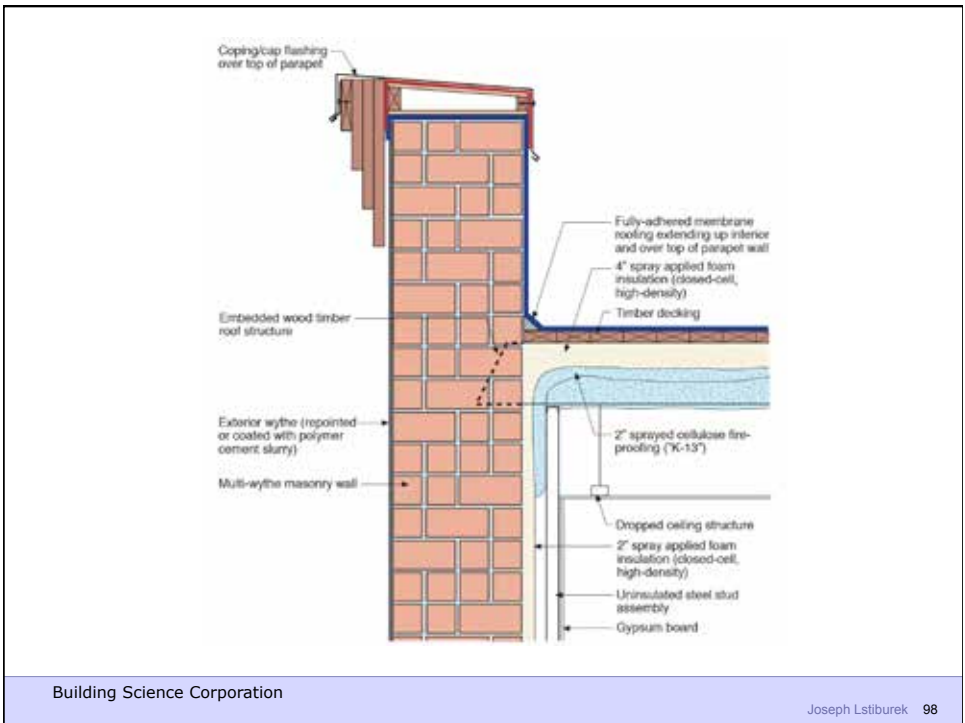
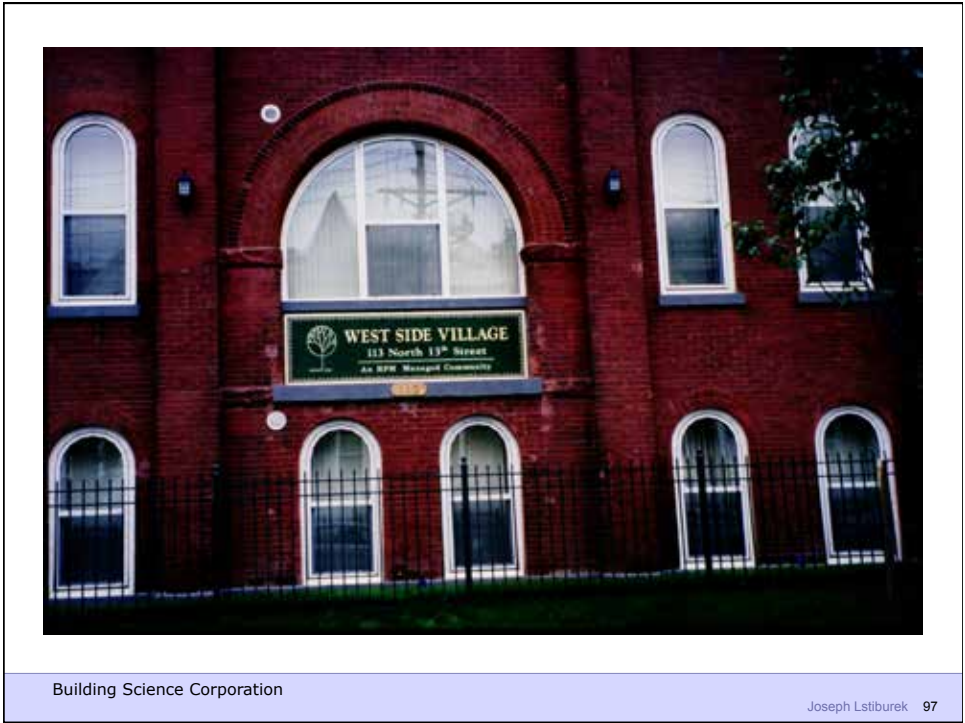


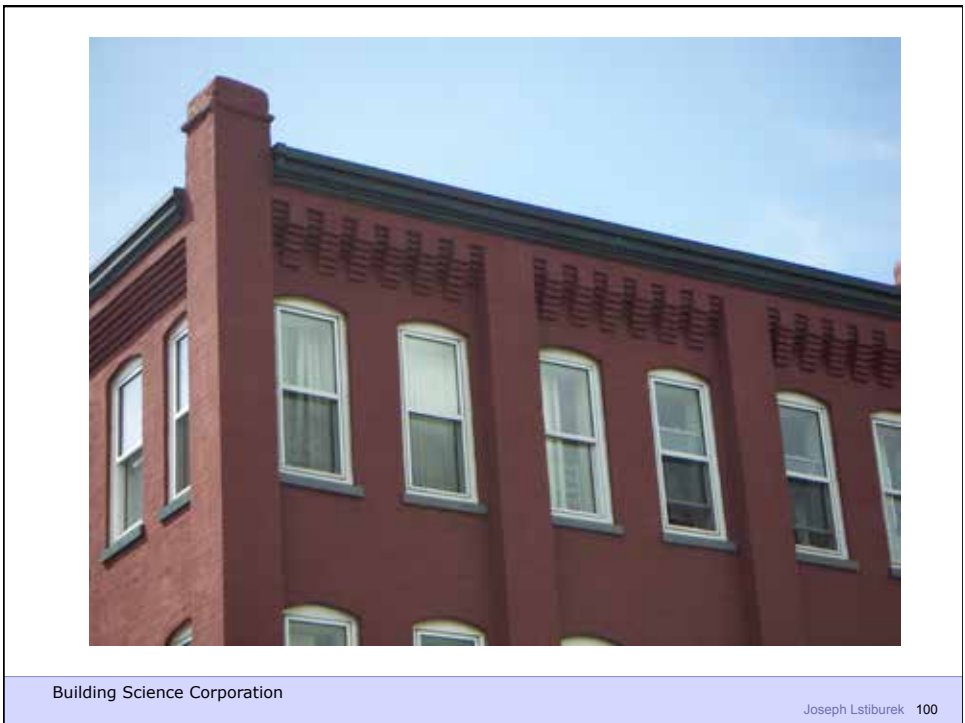


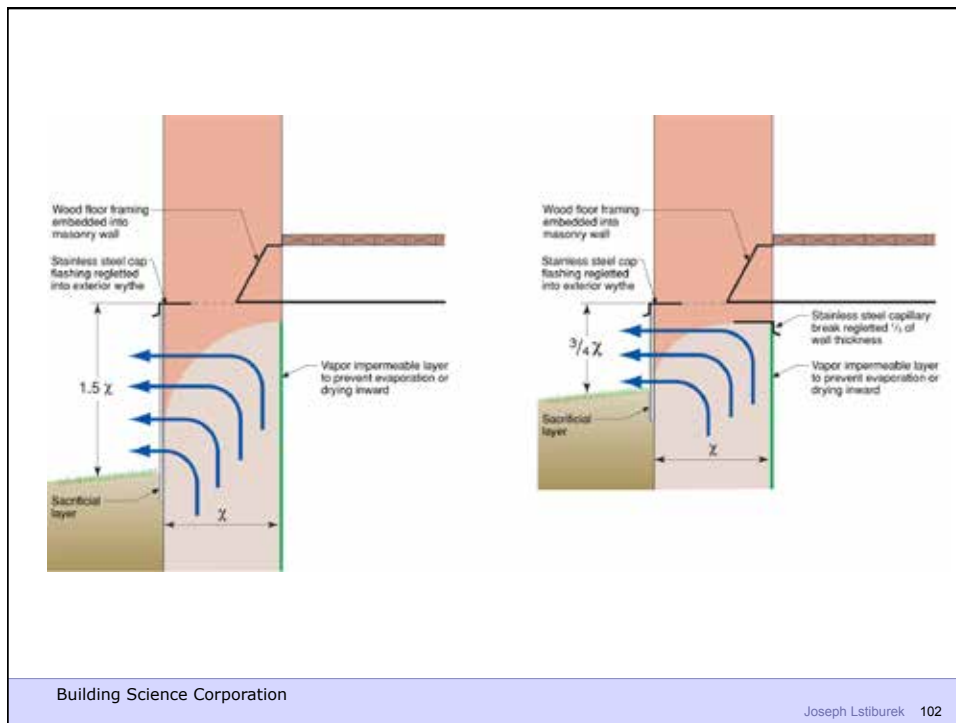
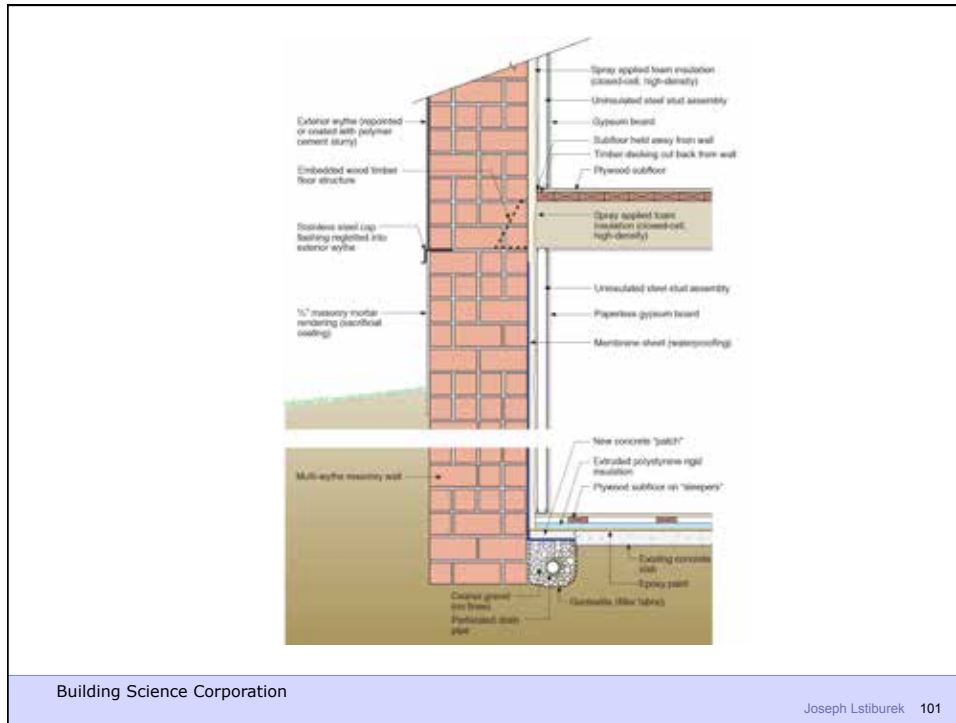


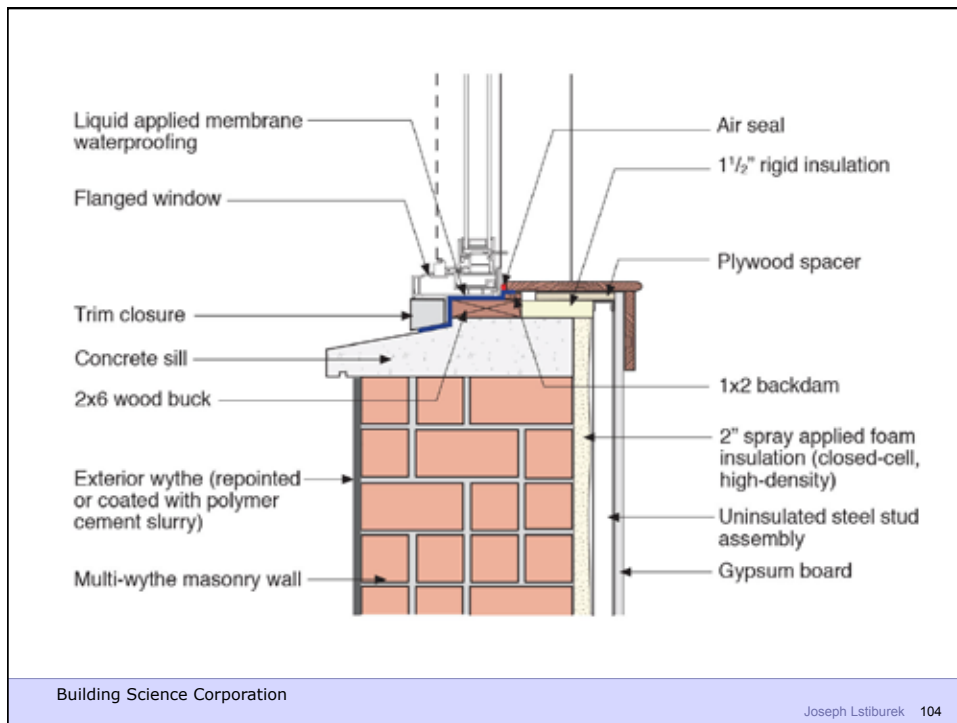
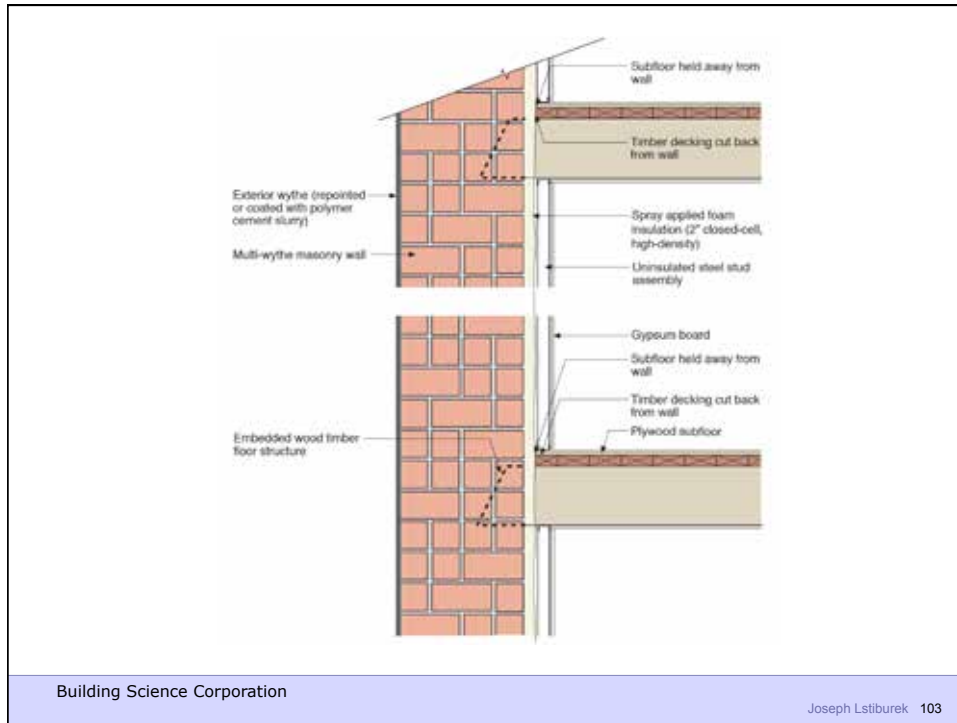




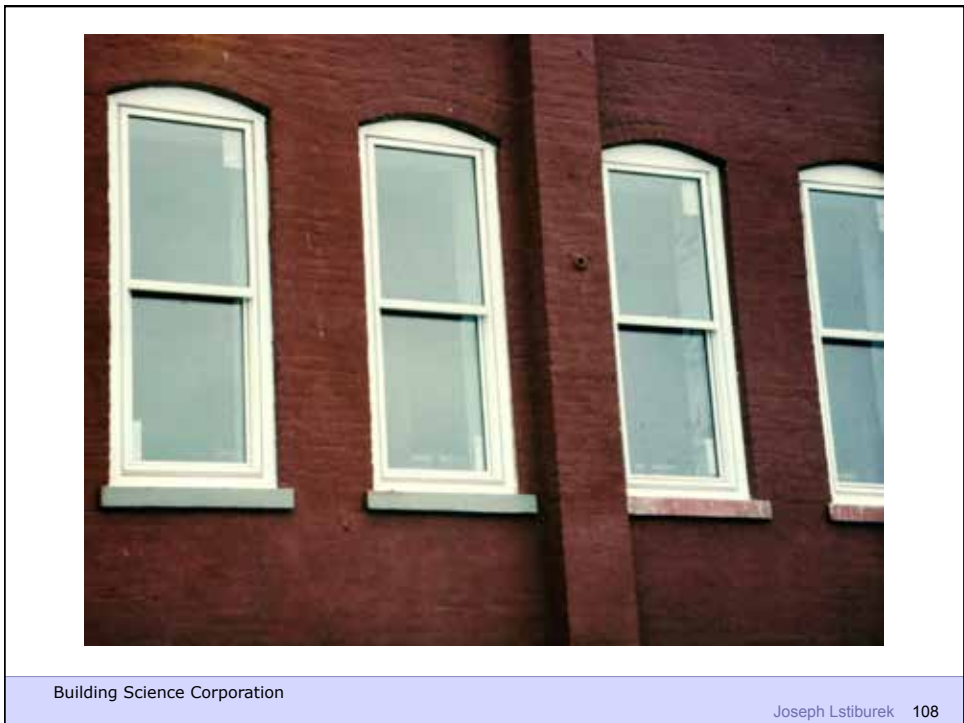


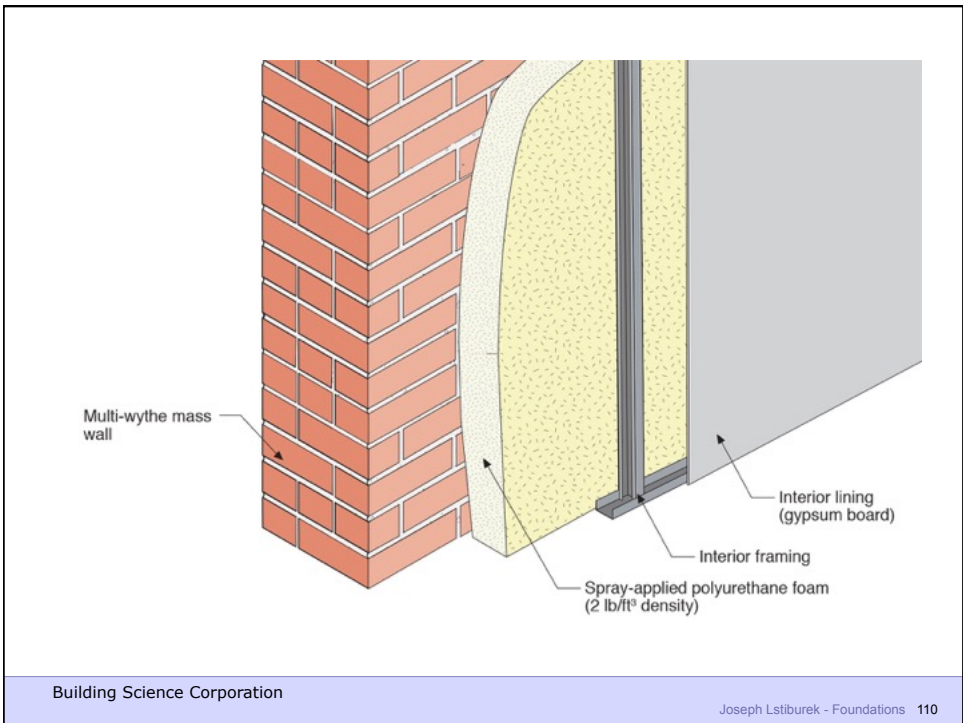
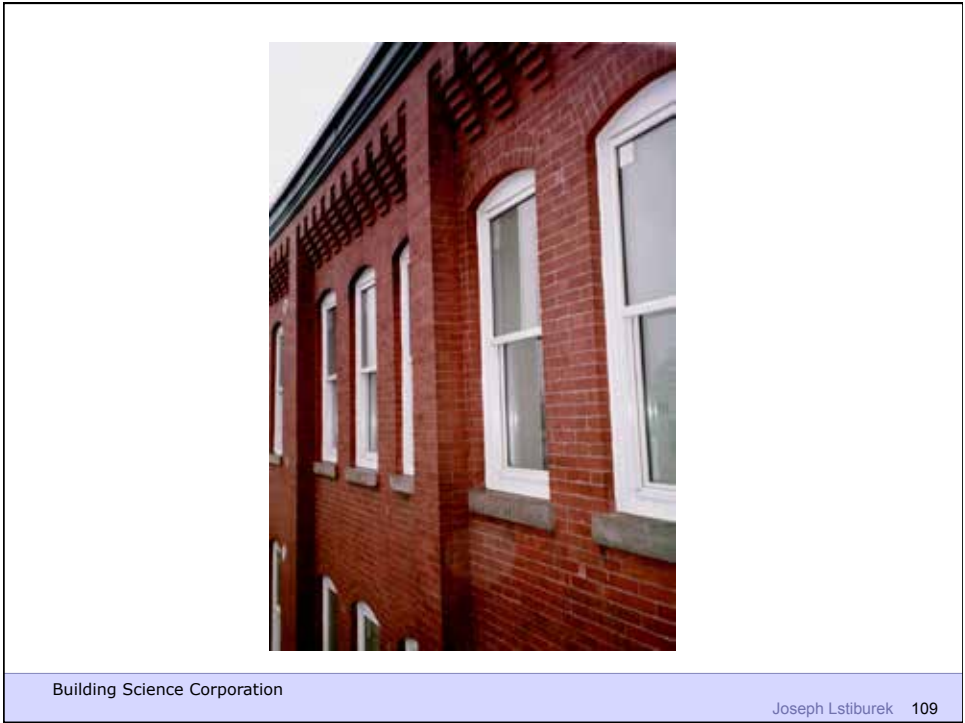


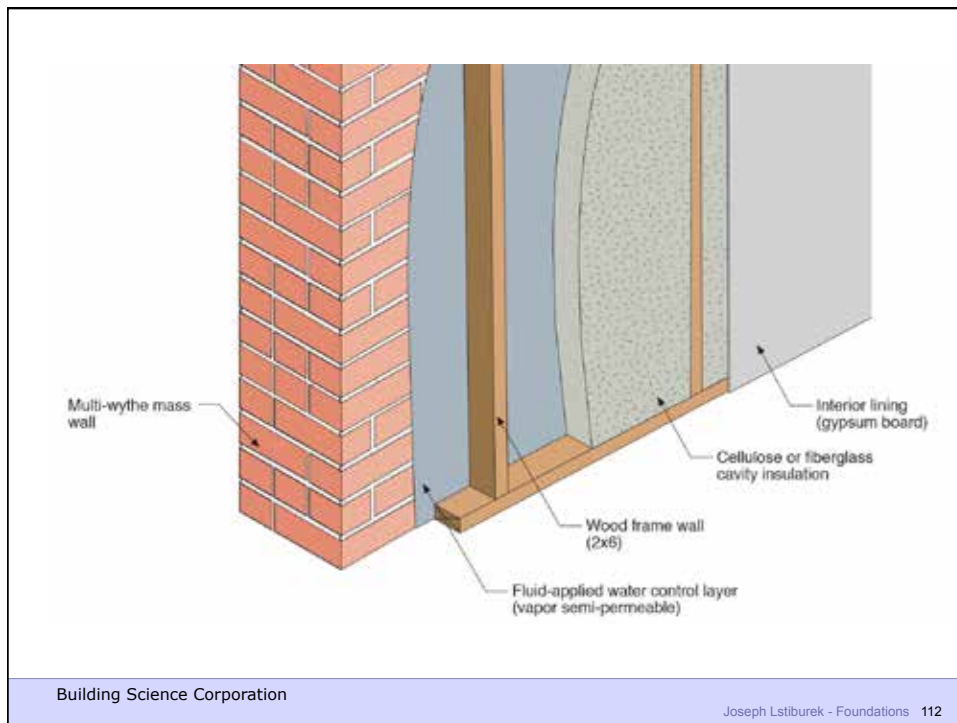
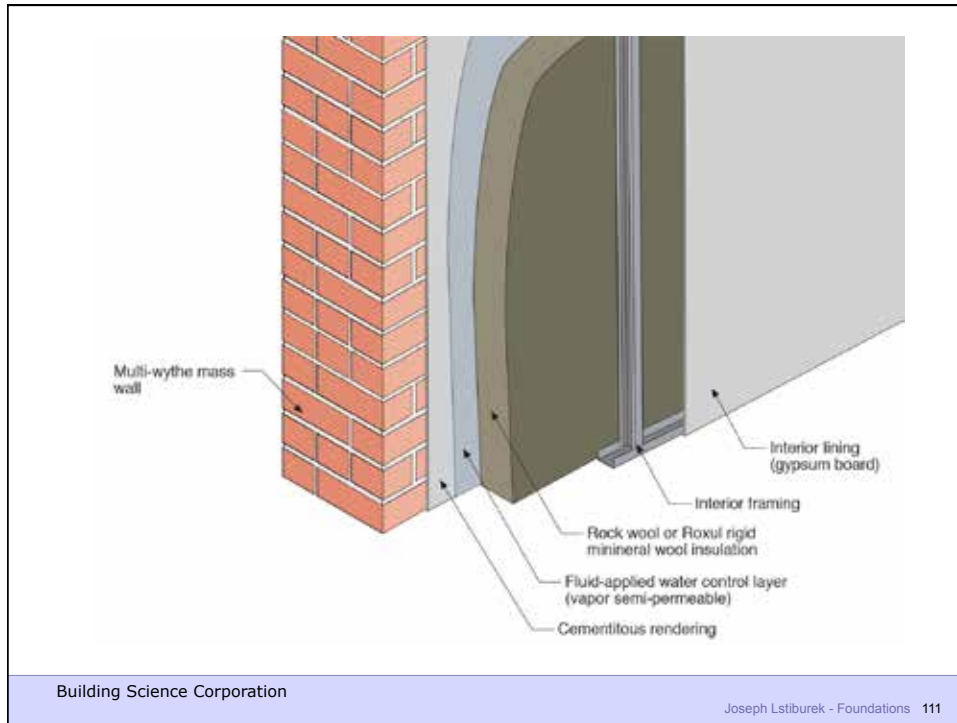




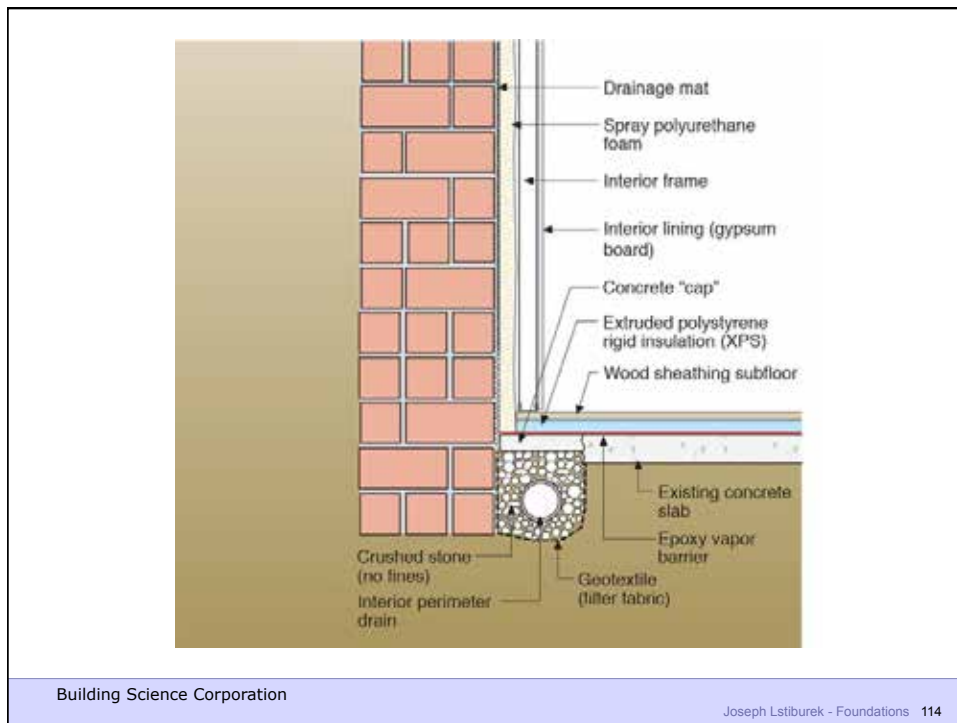
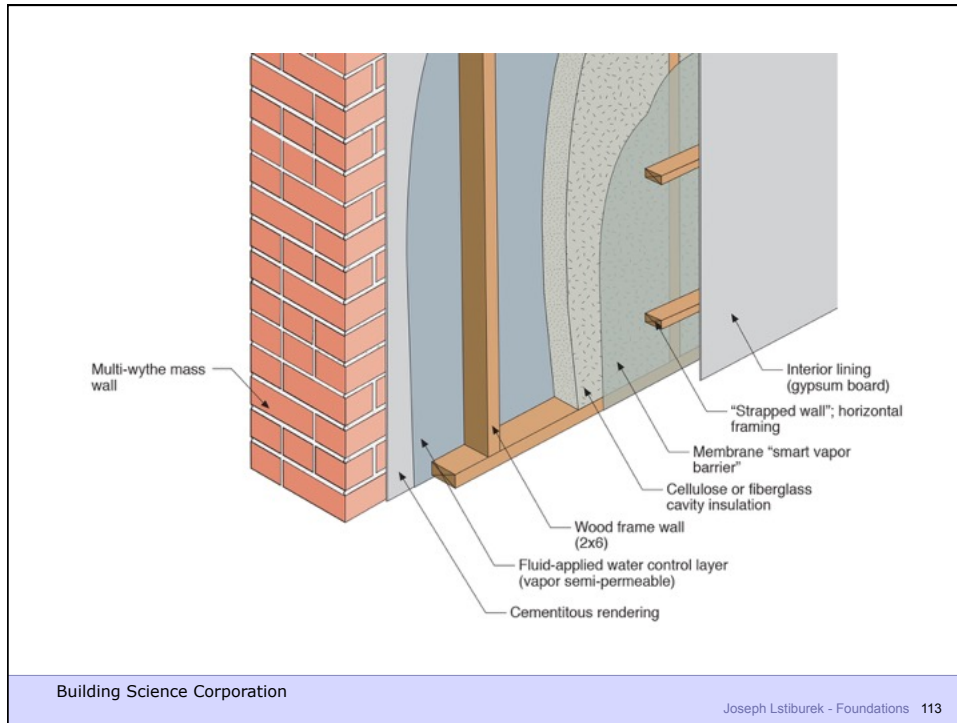


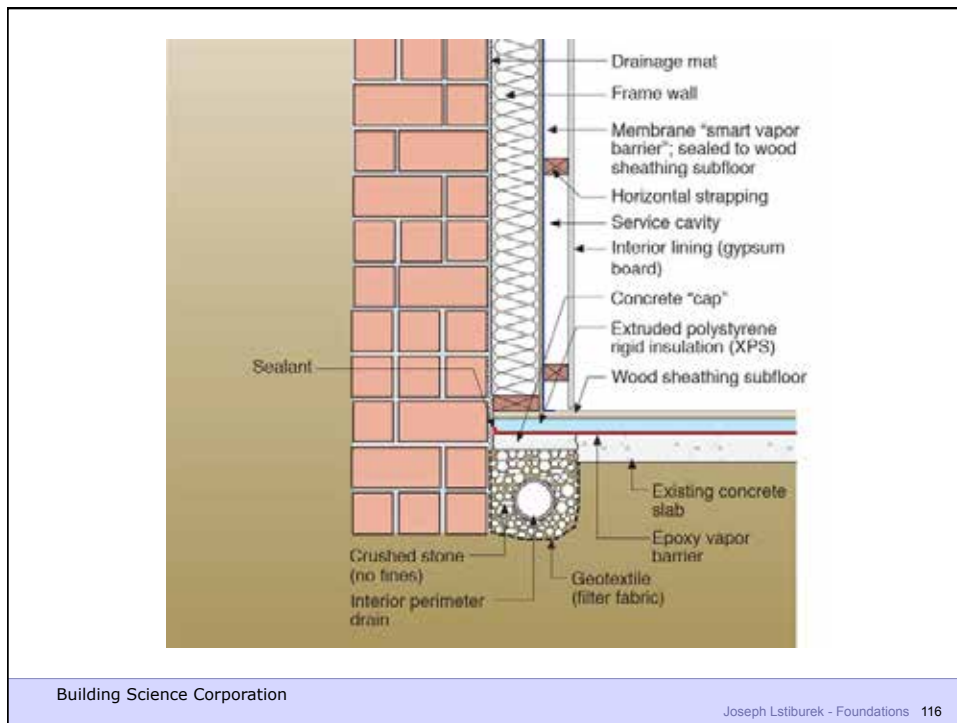
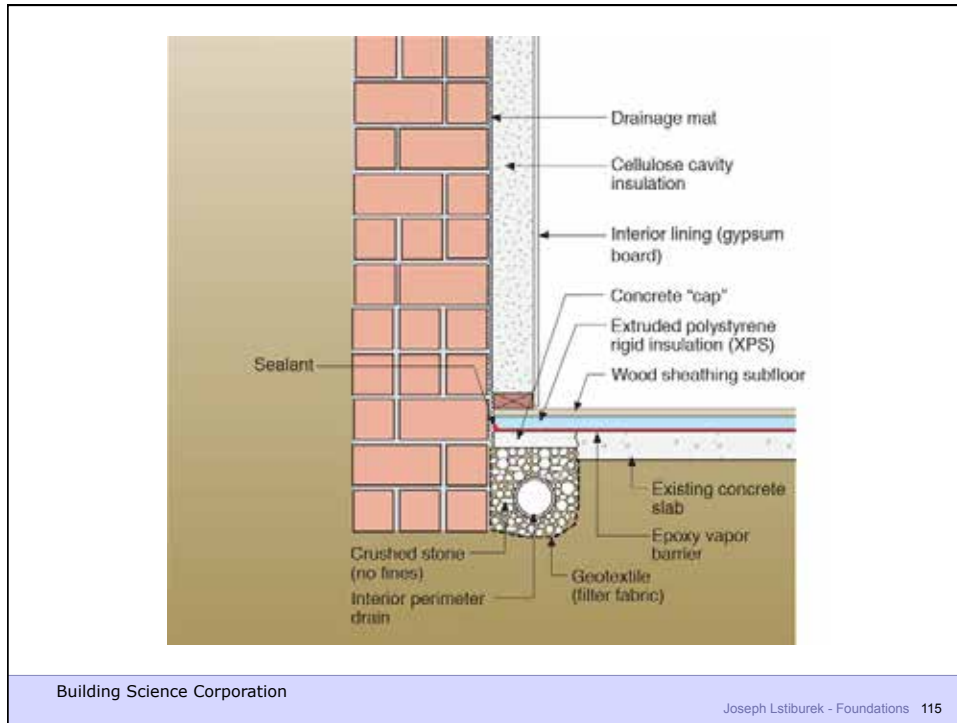














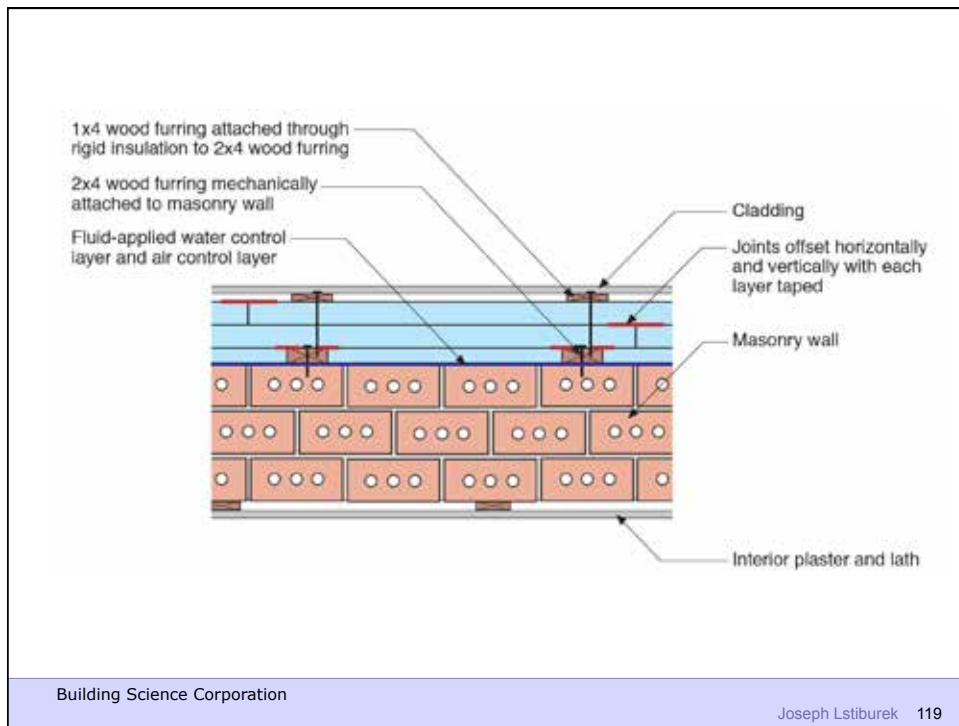
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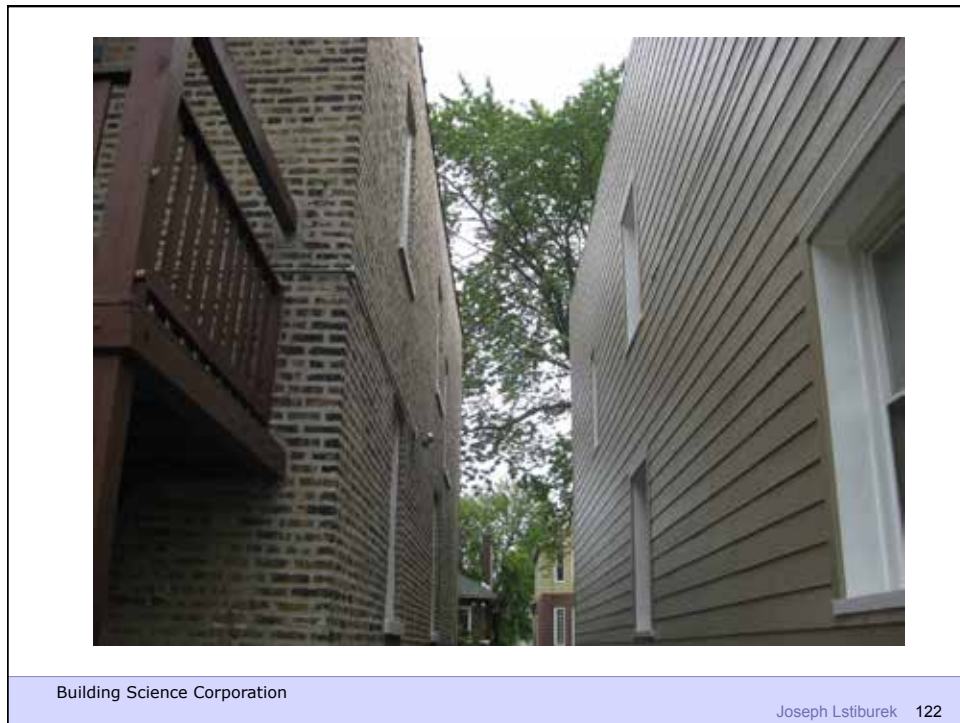
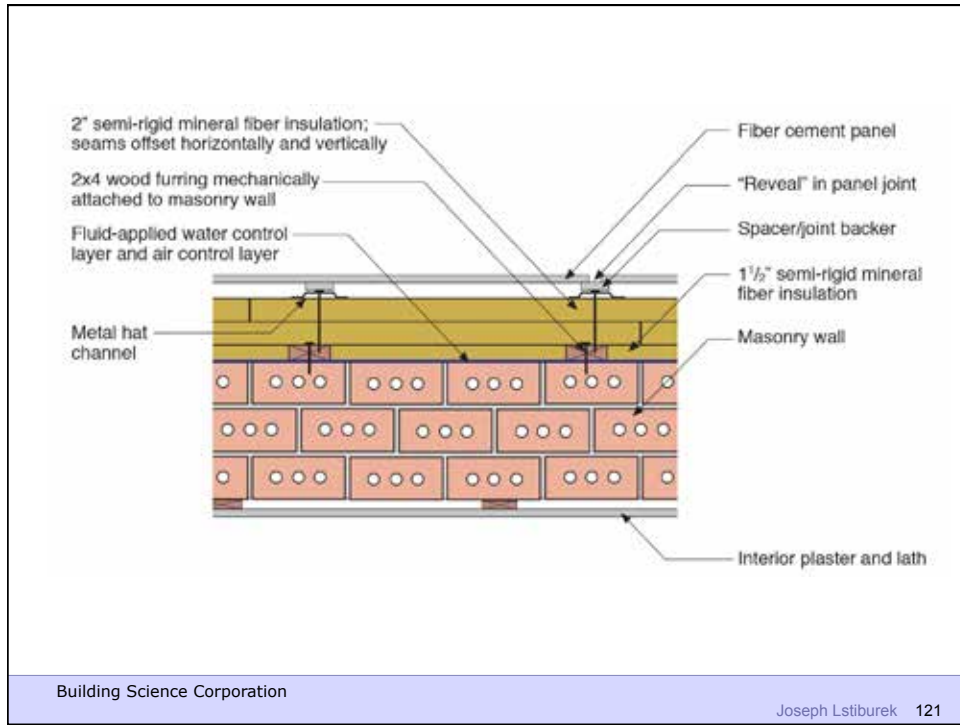
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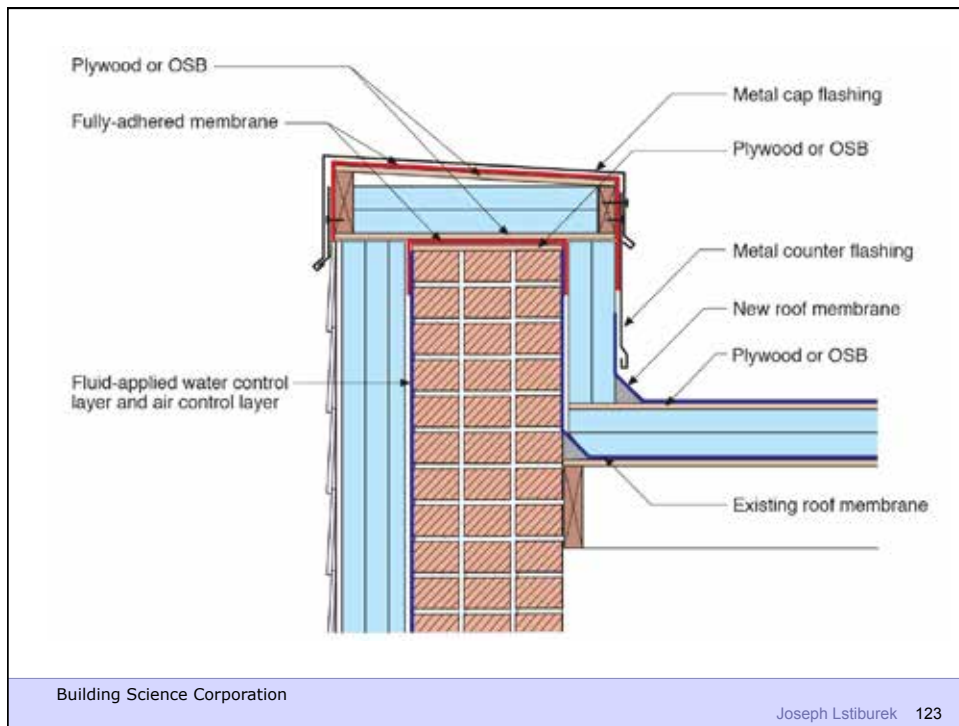


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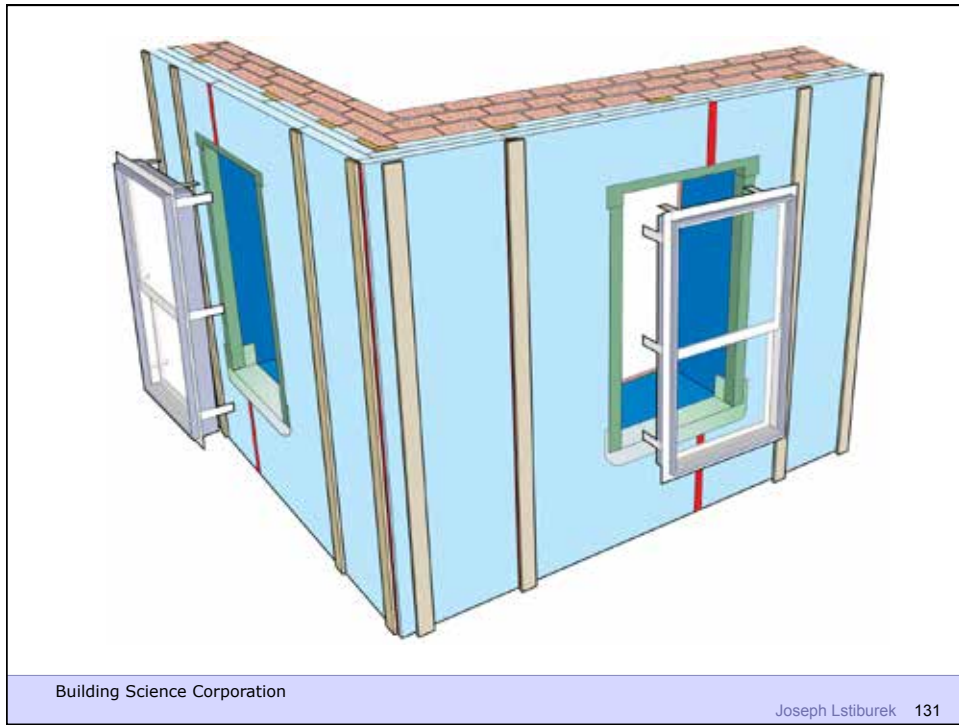
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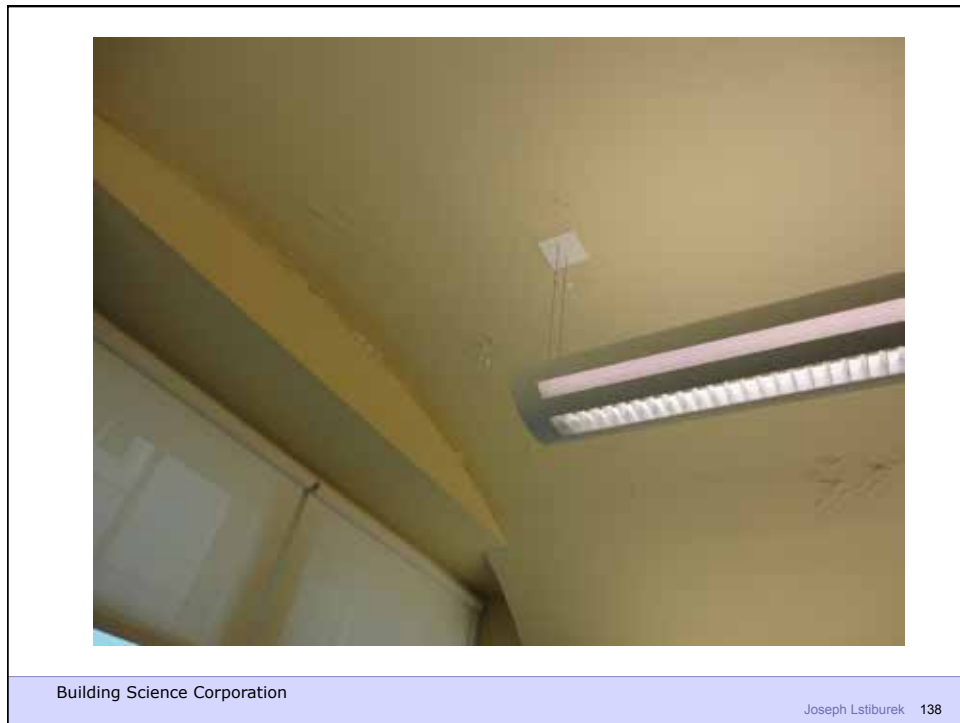
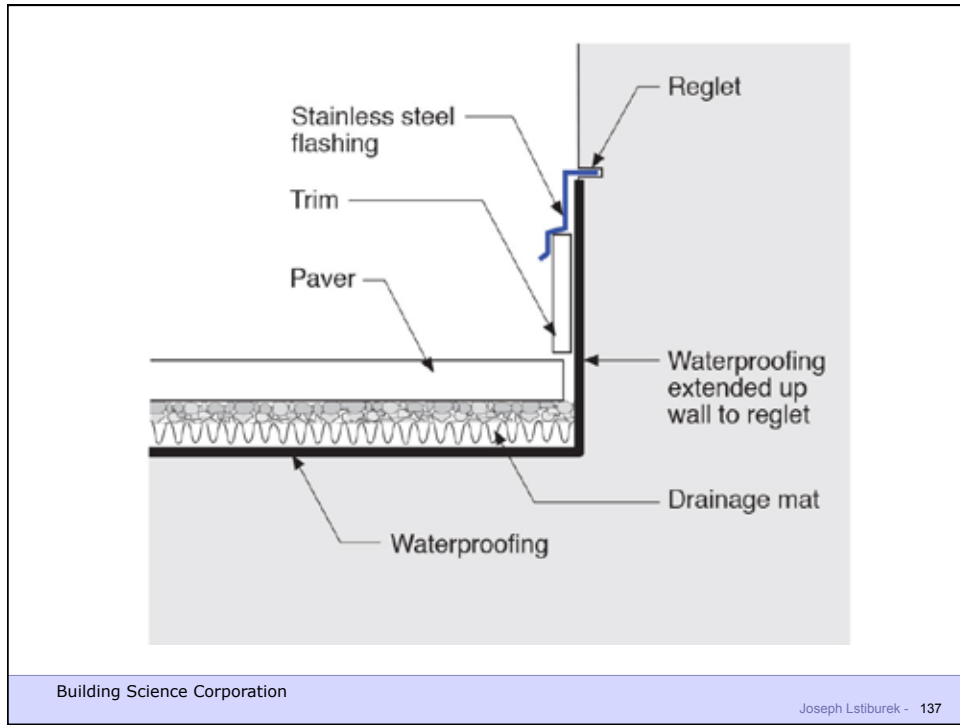
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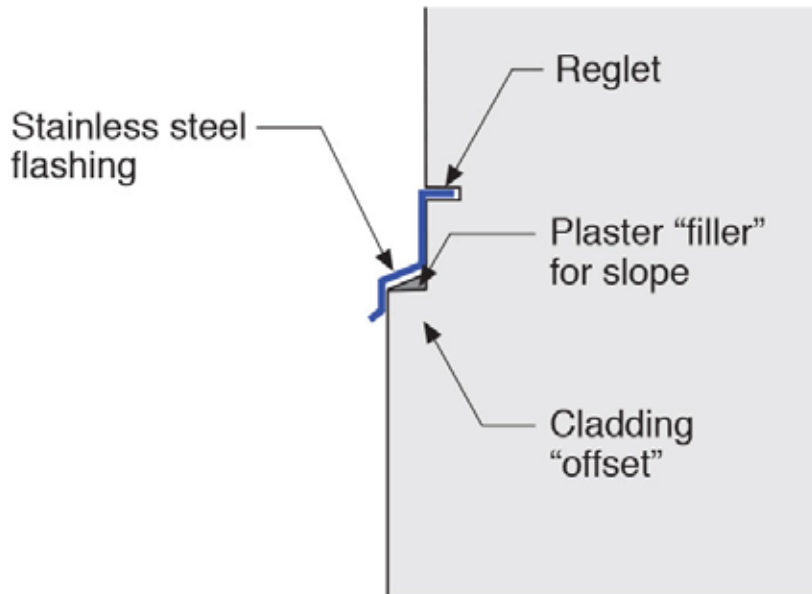






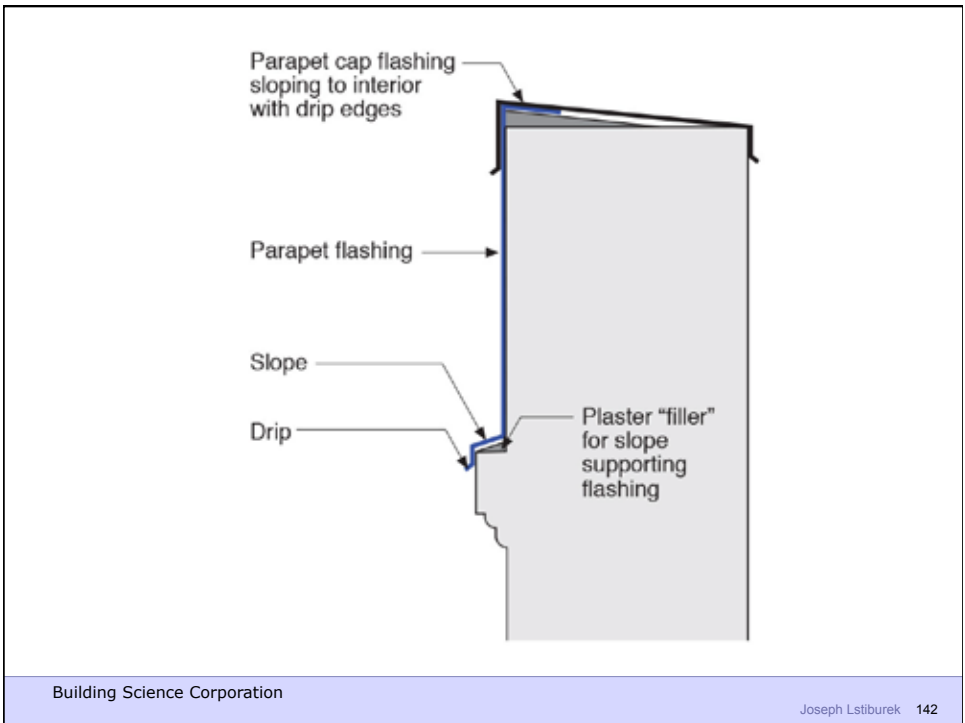
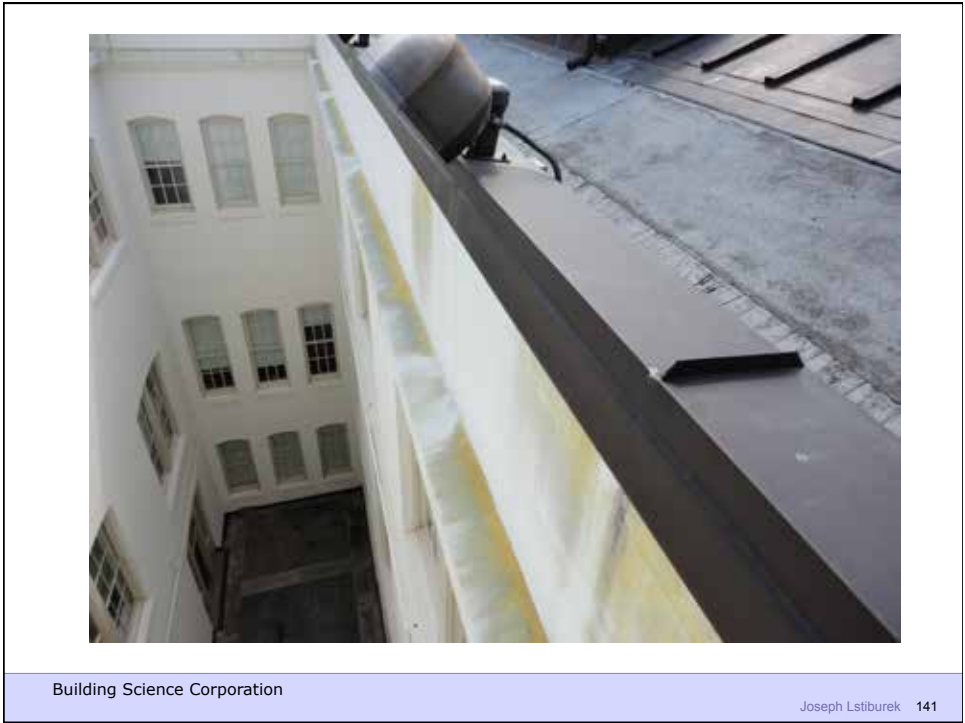
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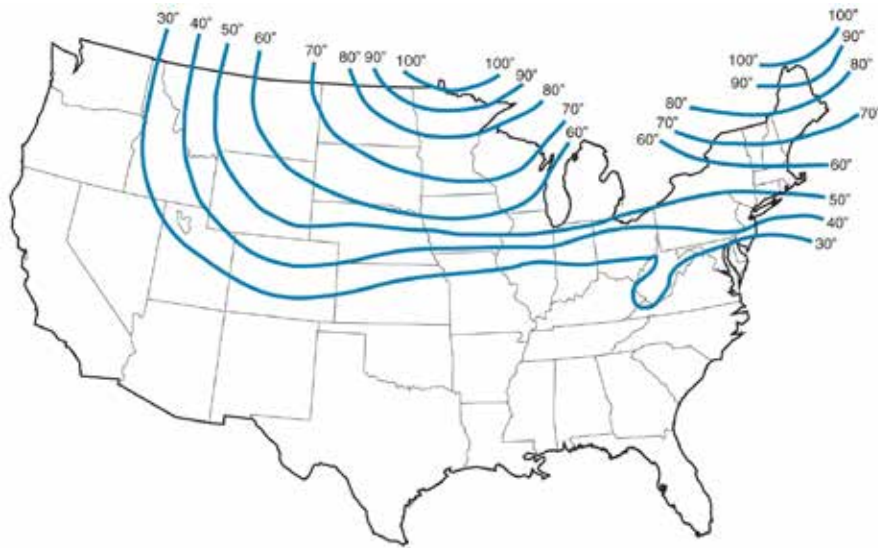
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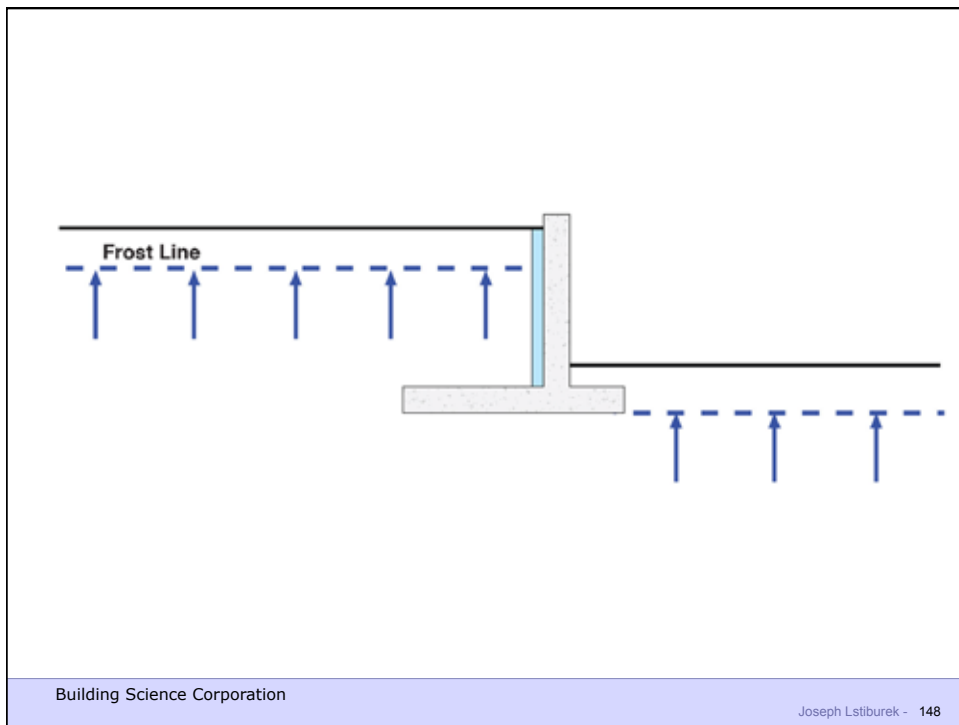
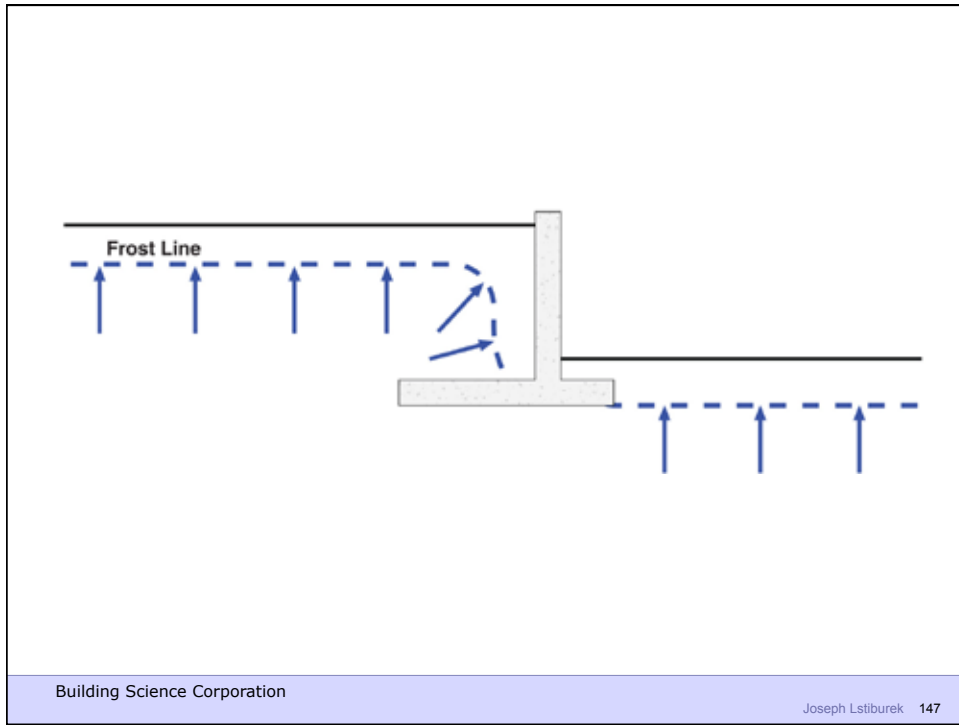
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From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.

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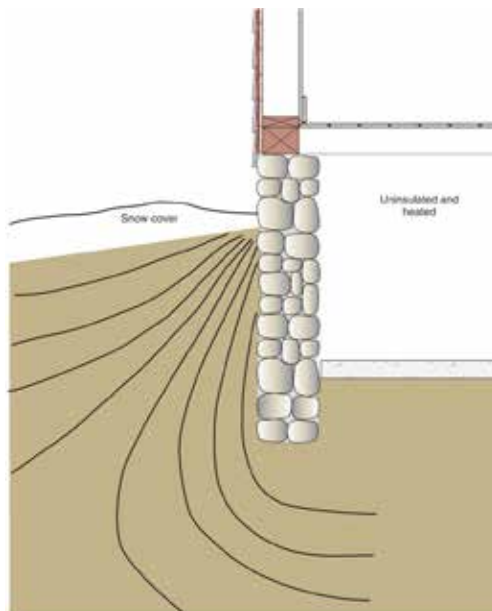
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