

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

# Building Science

## More Case Studies

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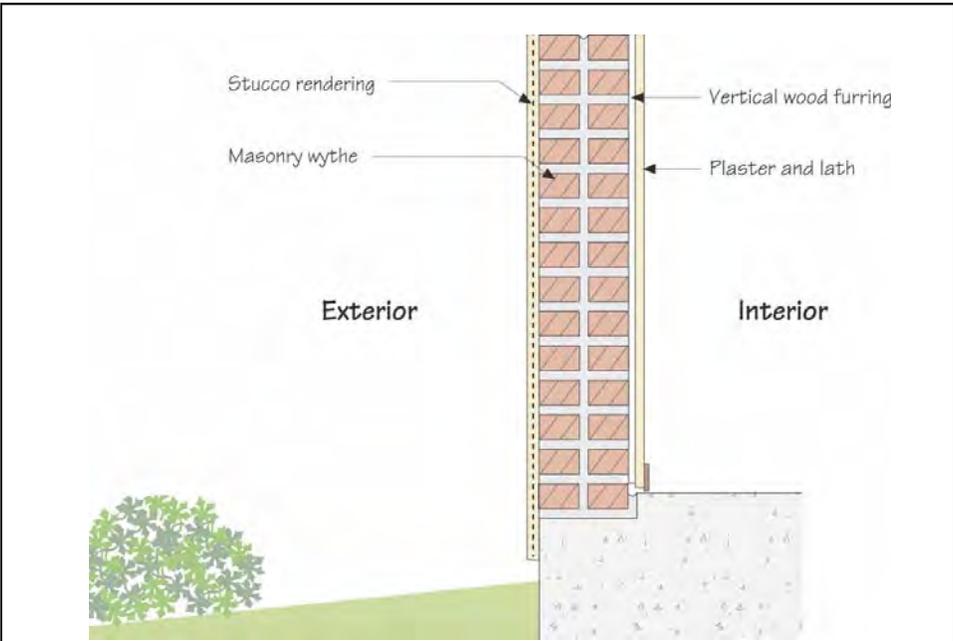


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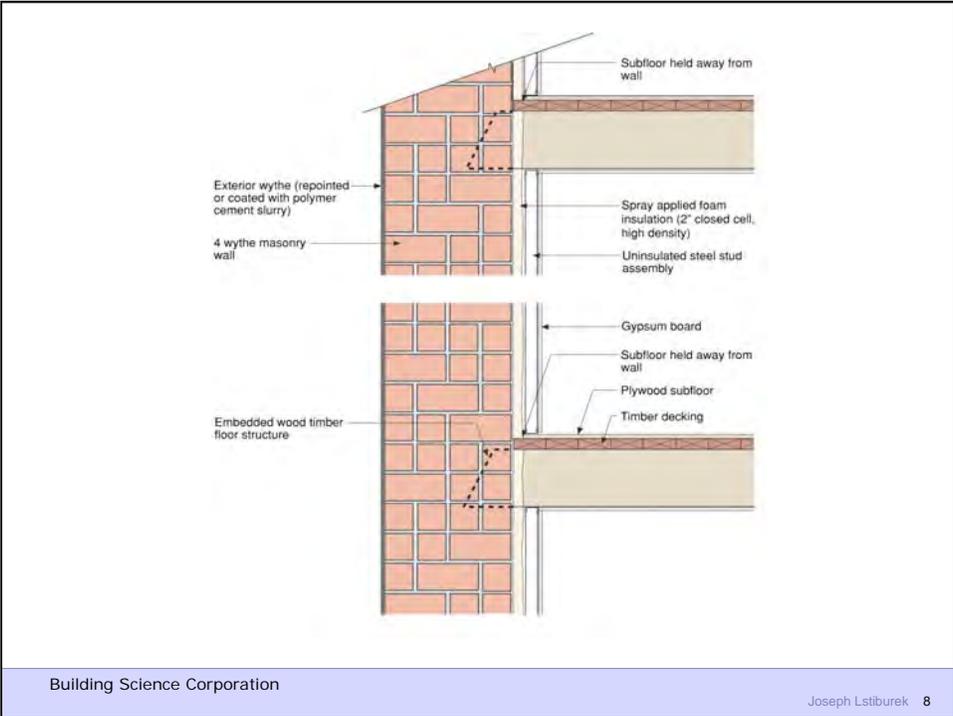
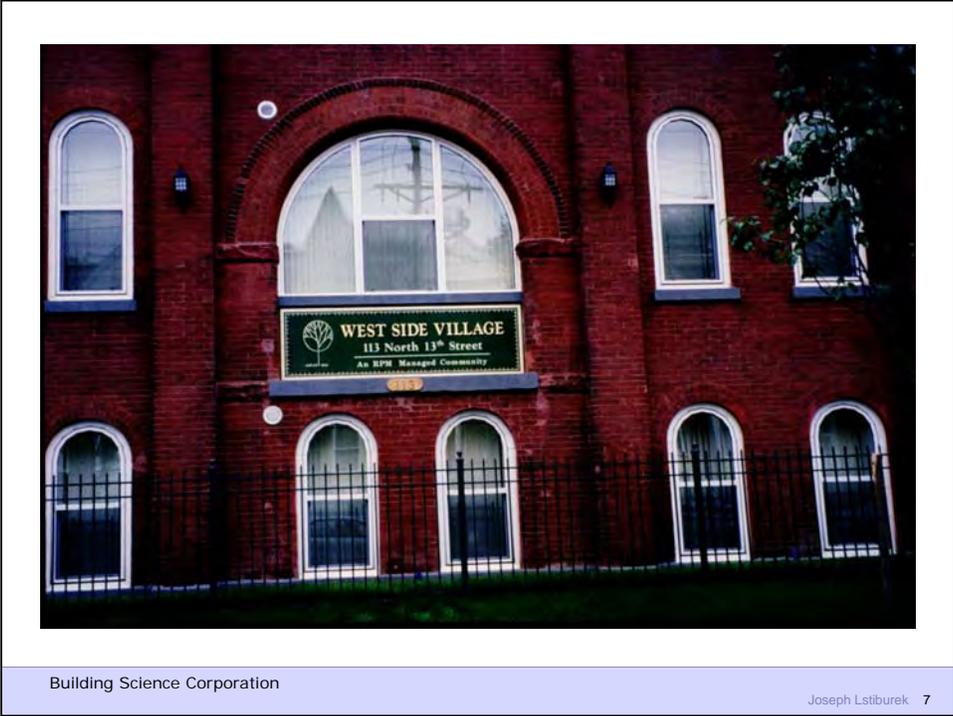


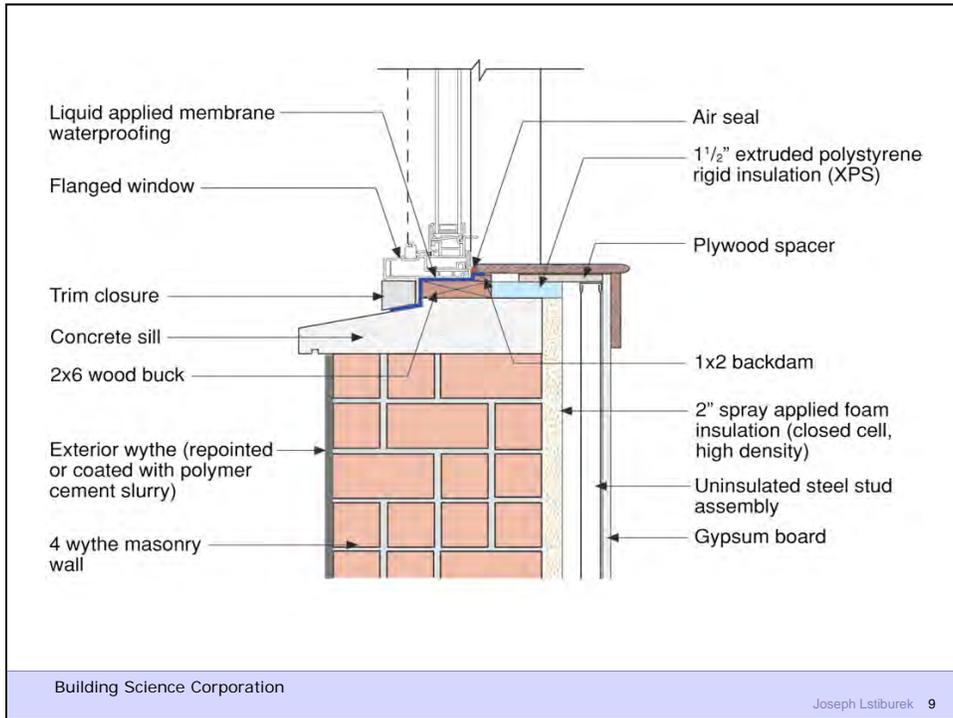
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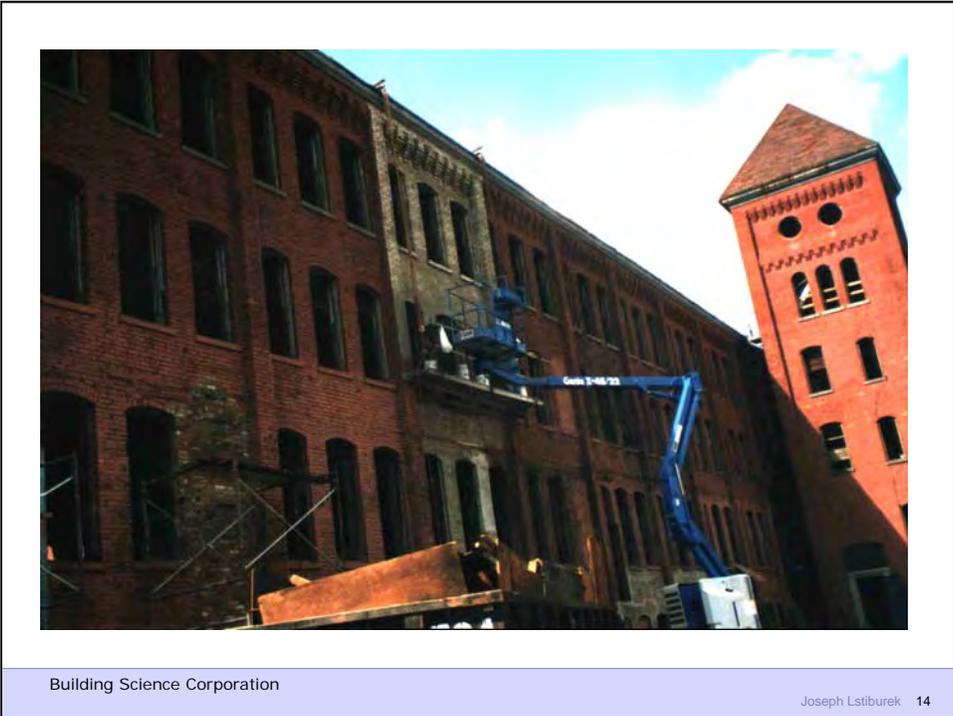
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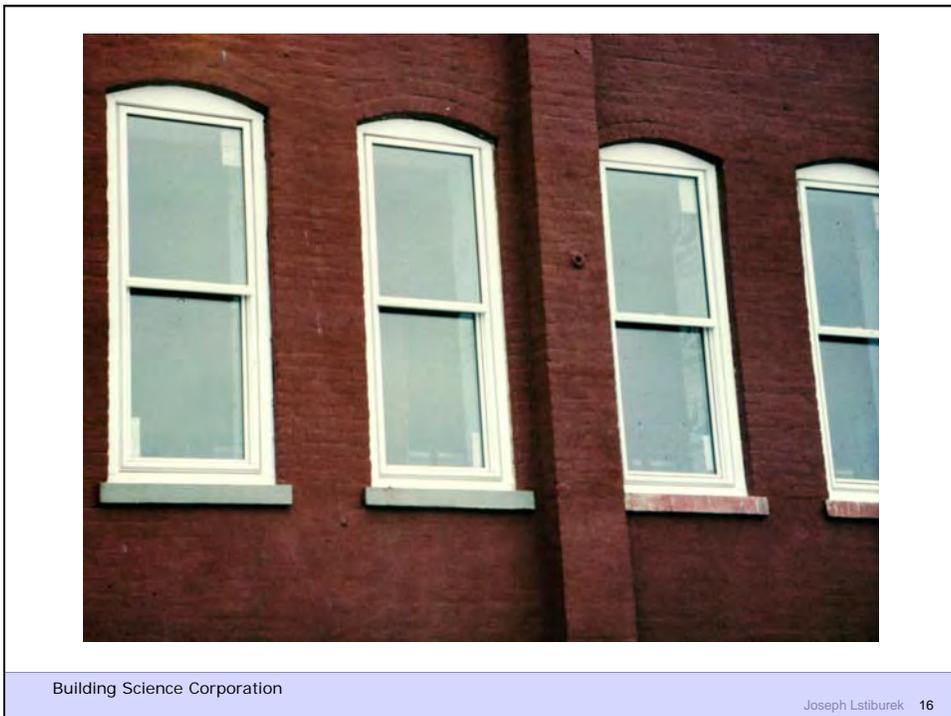
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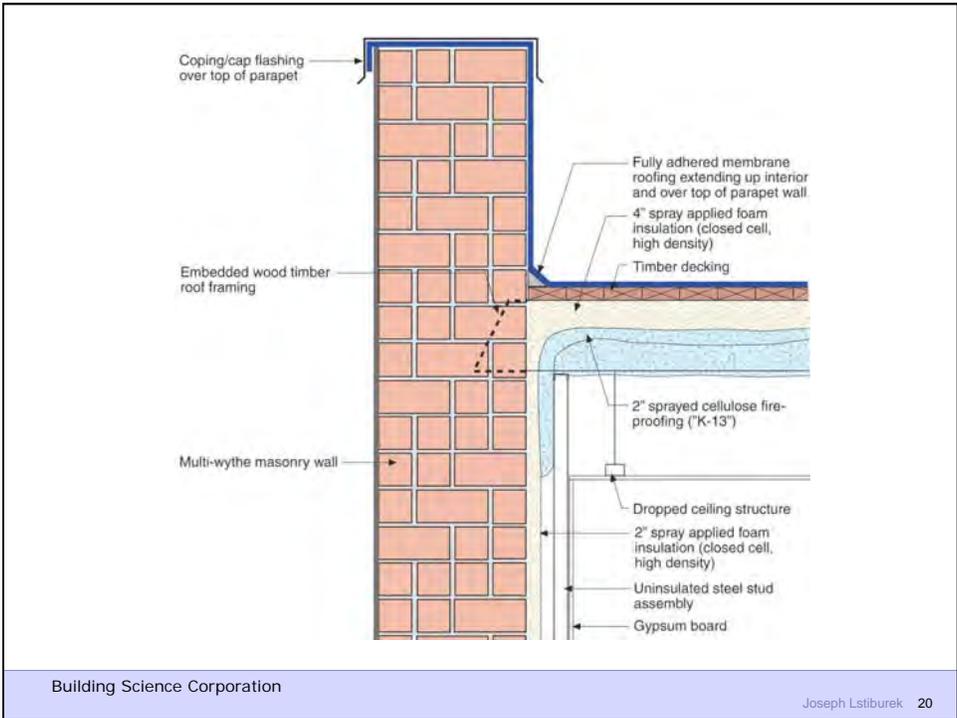
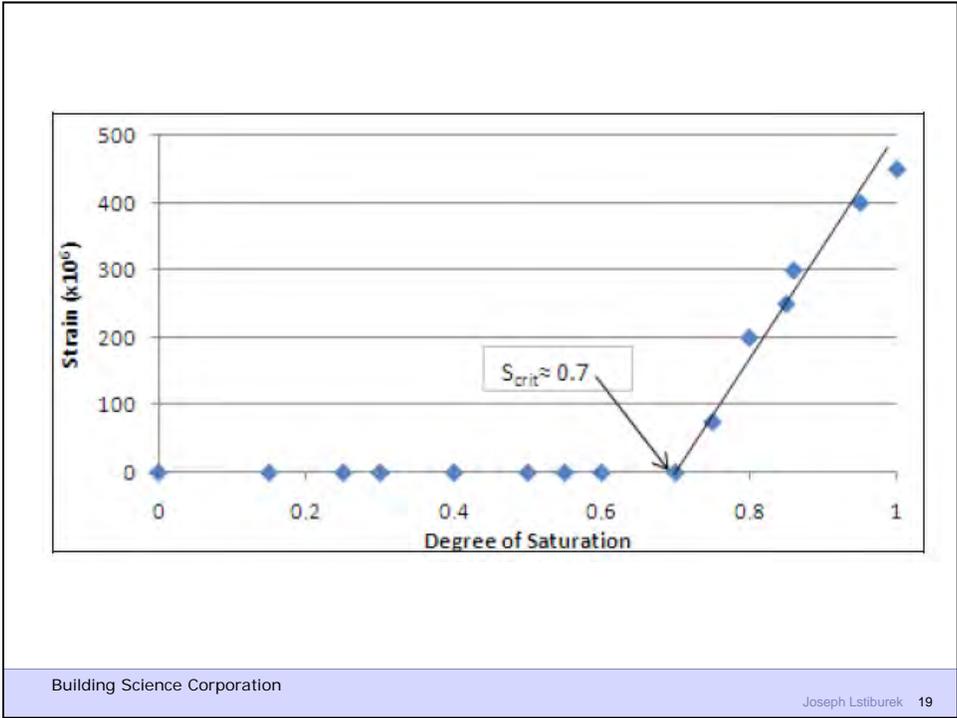
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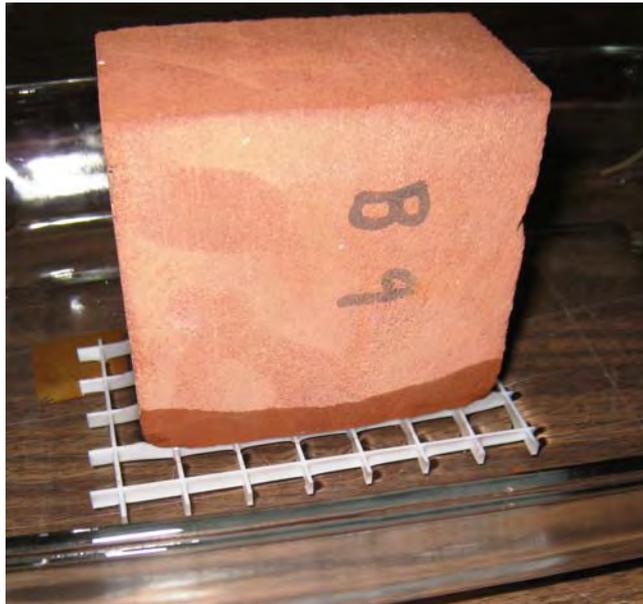


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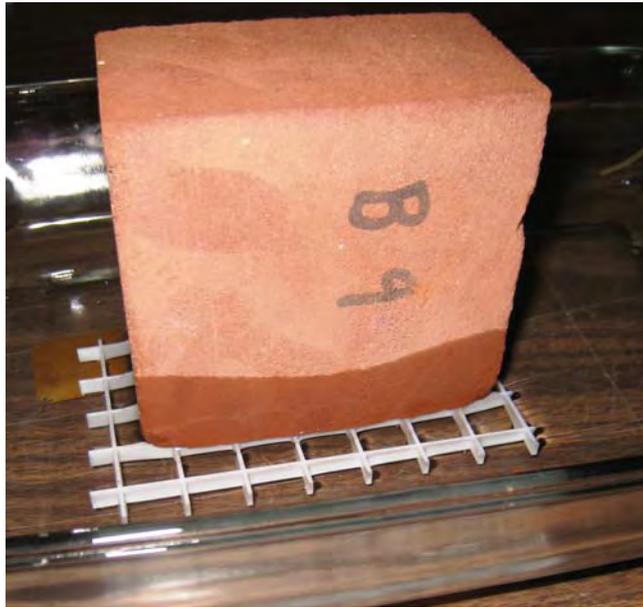
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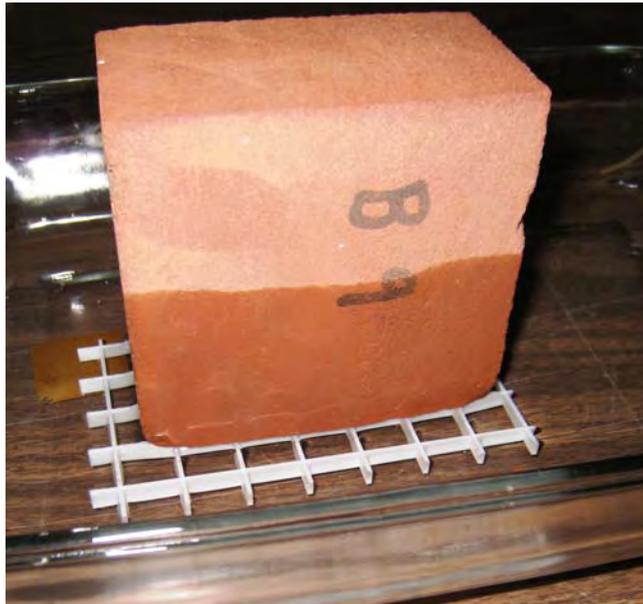
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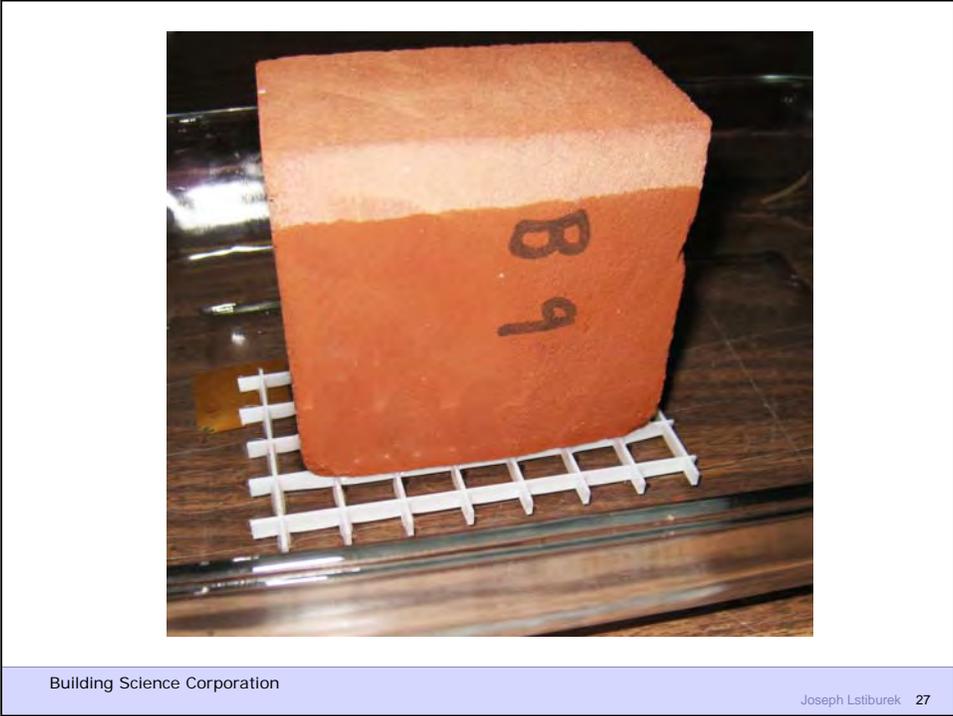
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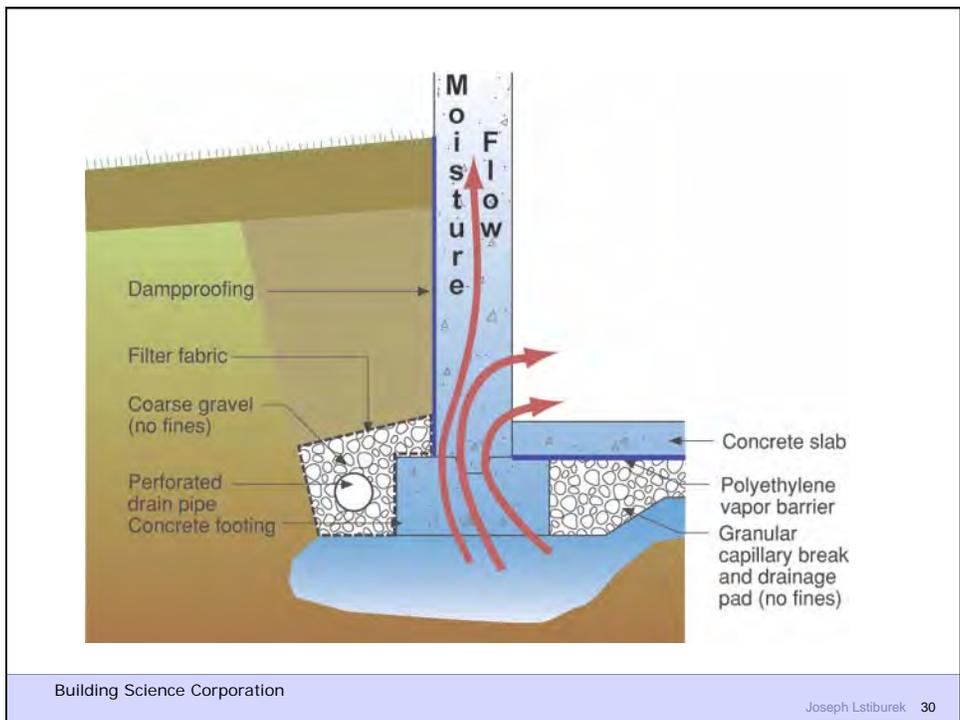
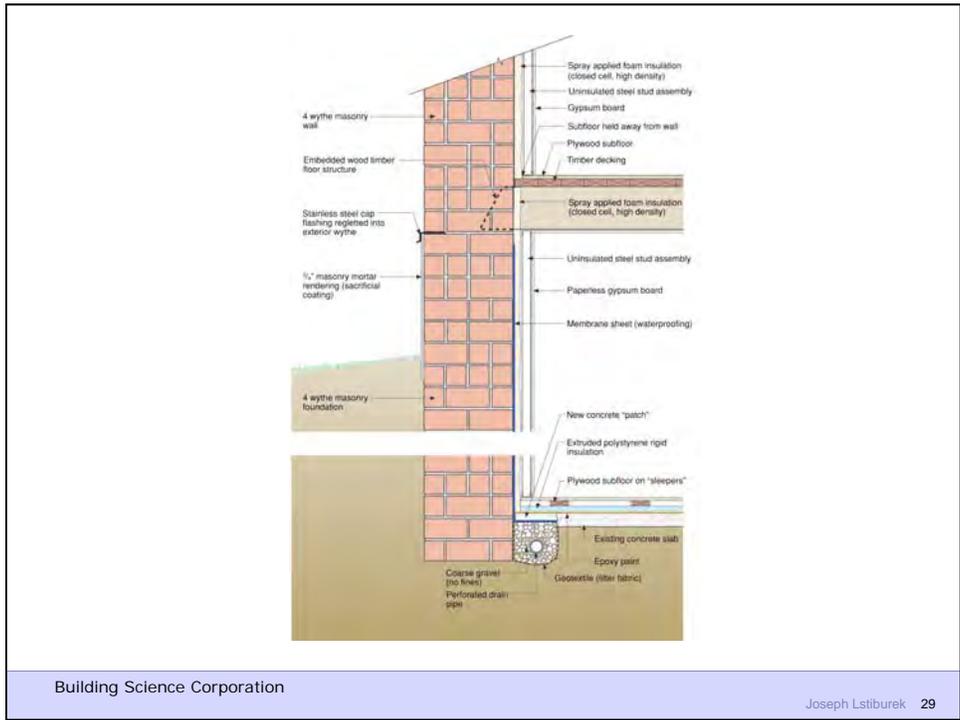
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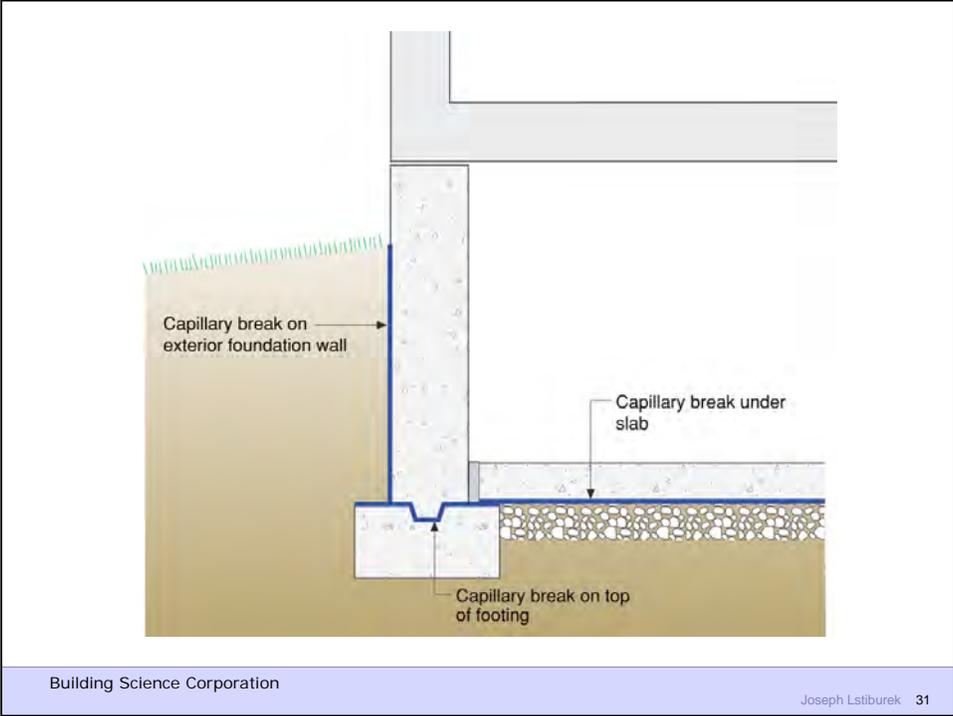


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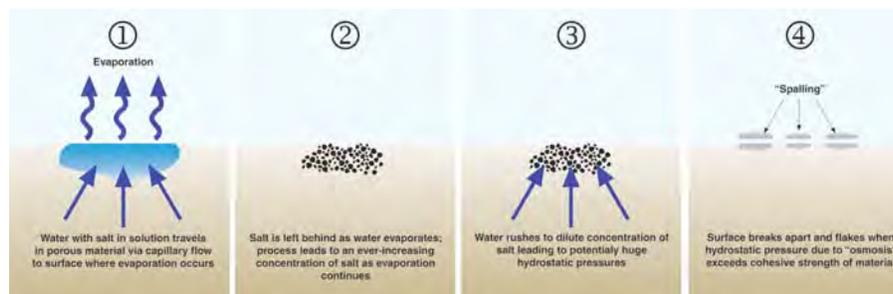






## Capillarity + Salt = Osmosis

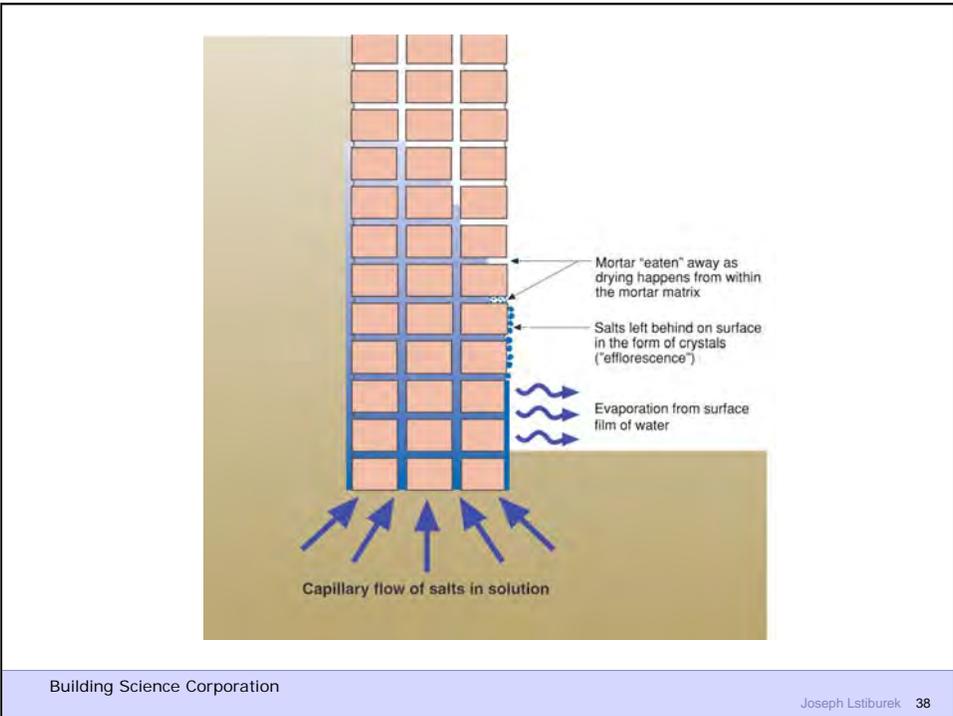
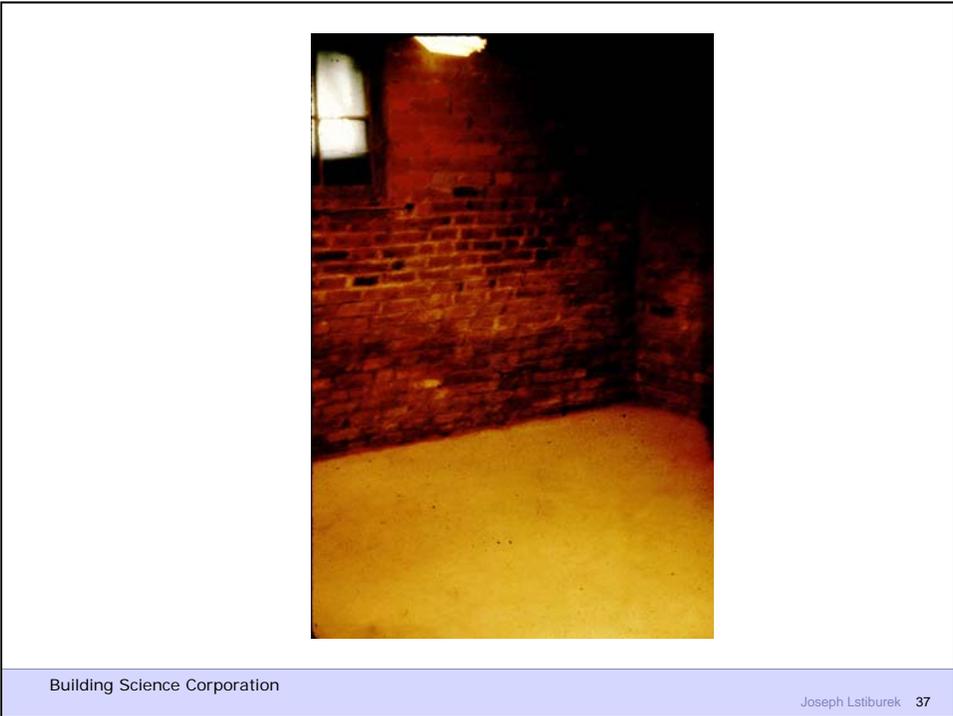
- Mineral salts carried in solution by capillary water
- When water evaporates from a surface the salts left behind form crystals in process called efflorescence
- When water evaporated beneath a surface the salts crystallize within the pore structure of the material in called sub-efflorescence
- The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

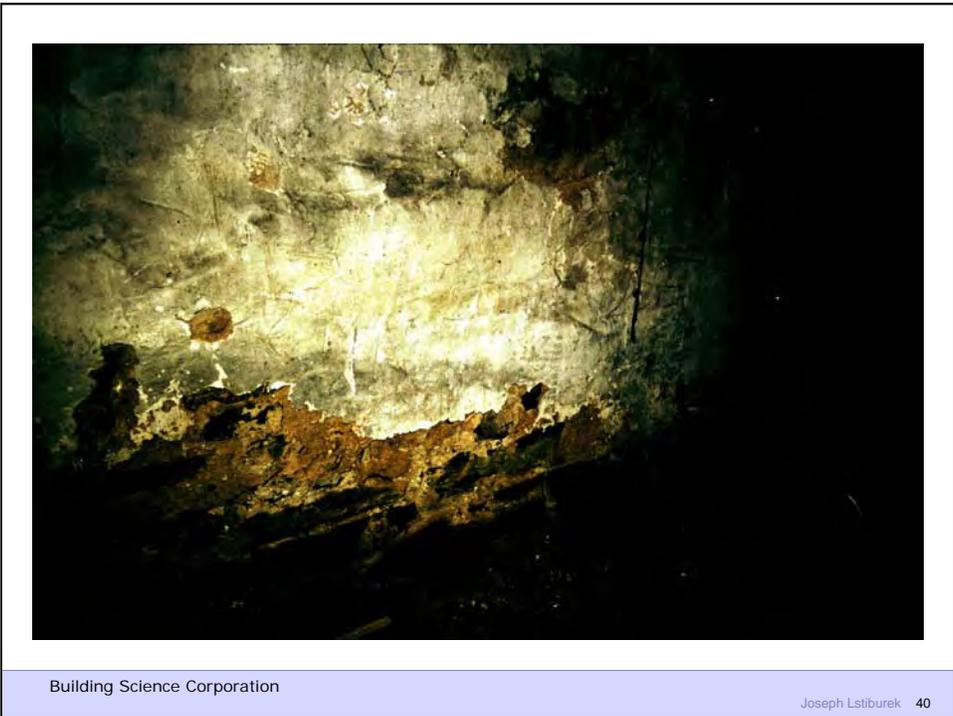
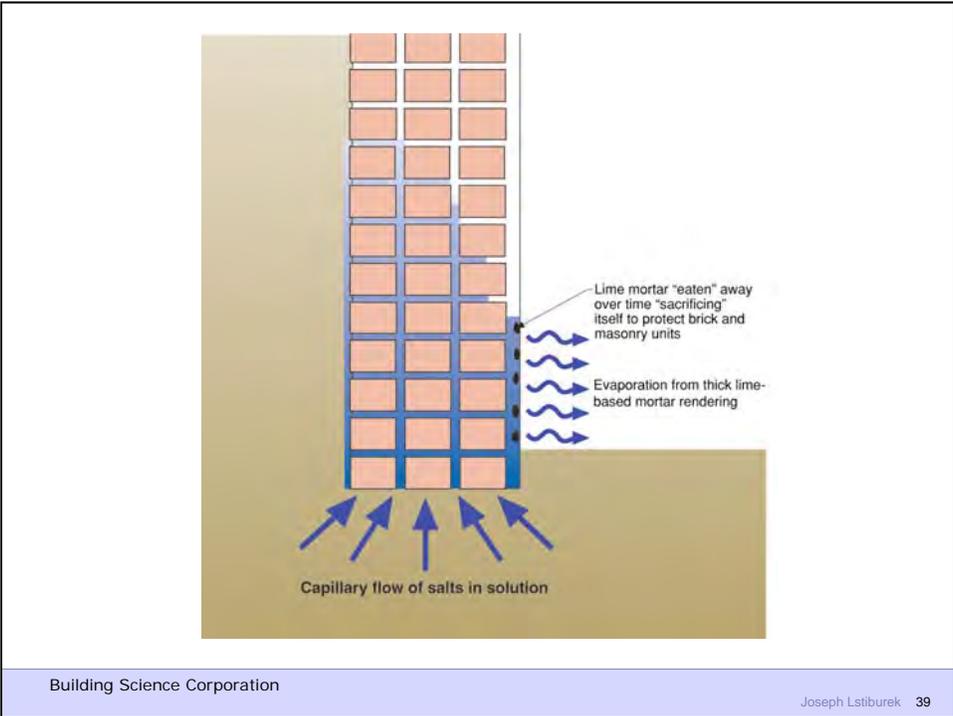


## Diffusion + Capillarity + Osmosis = Problem

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









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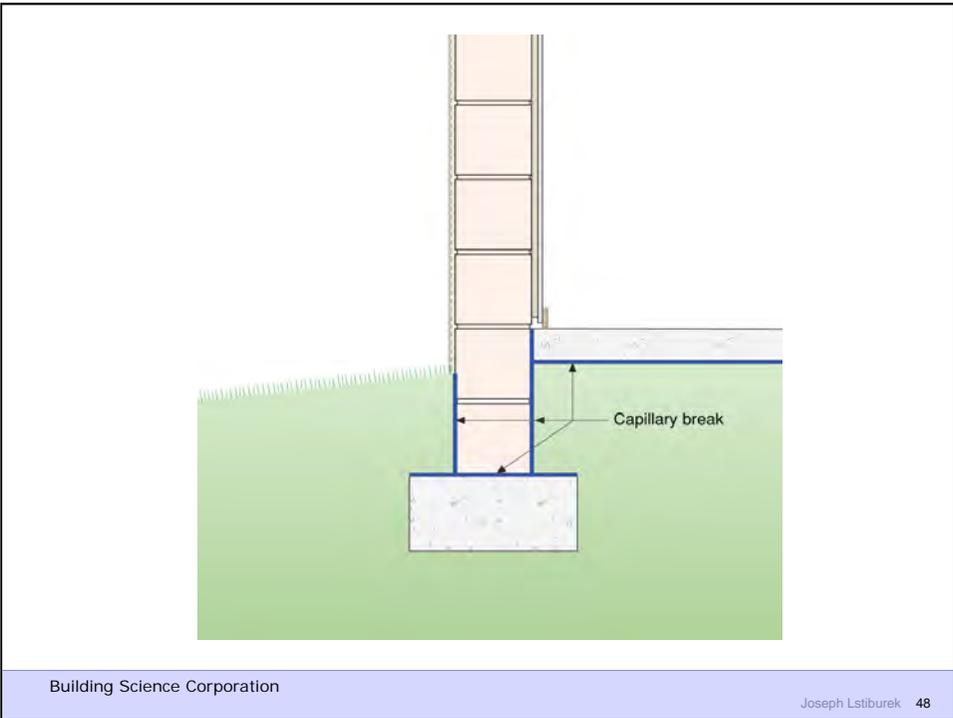
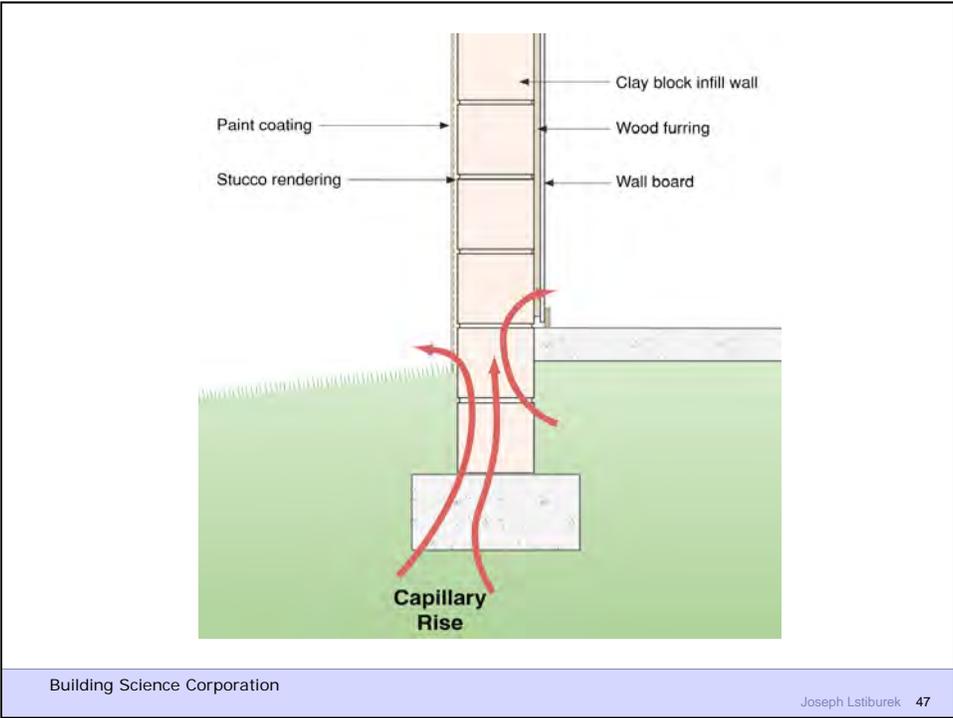
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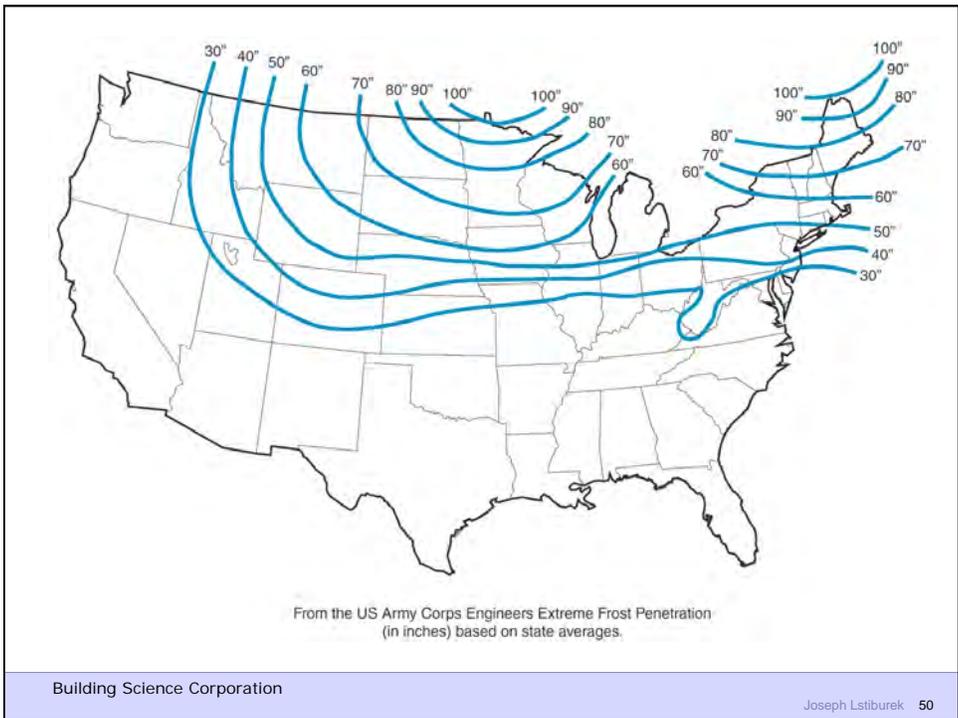
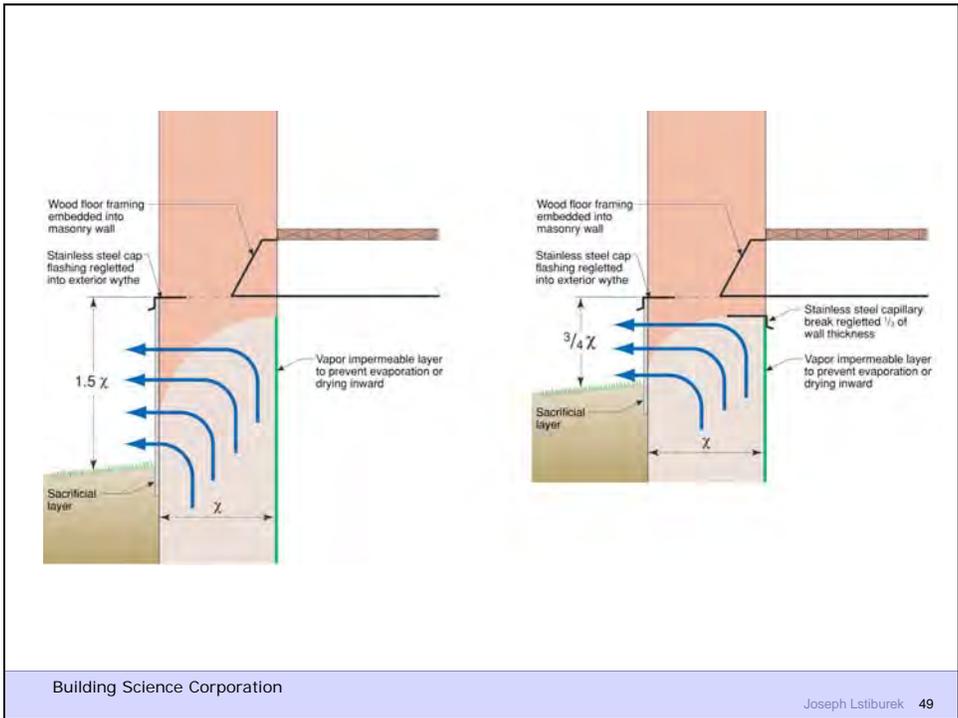


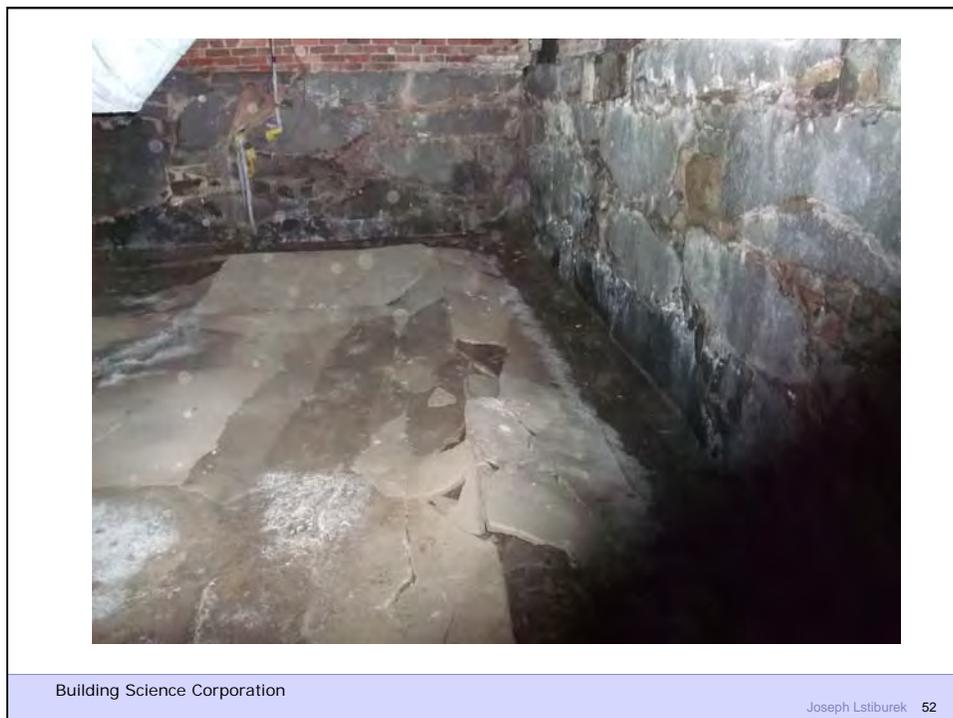
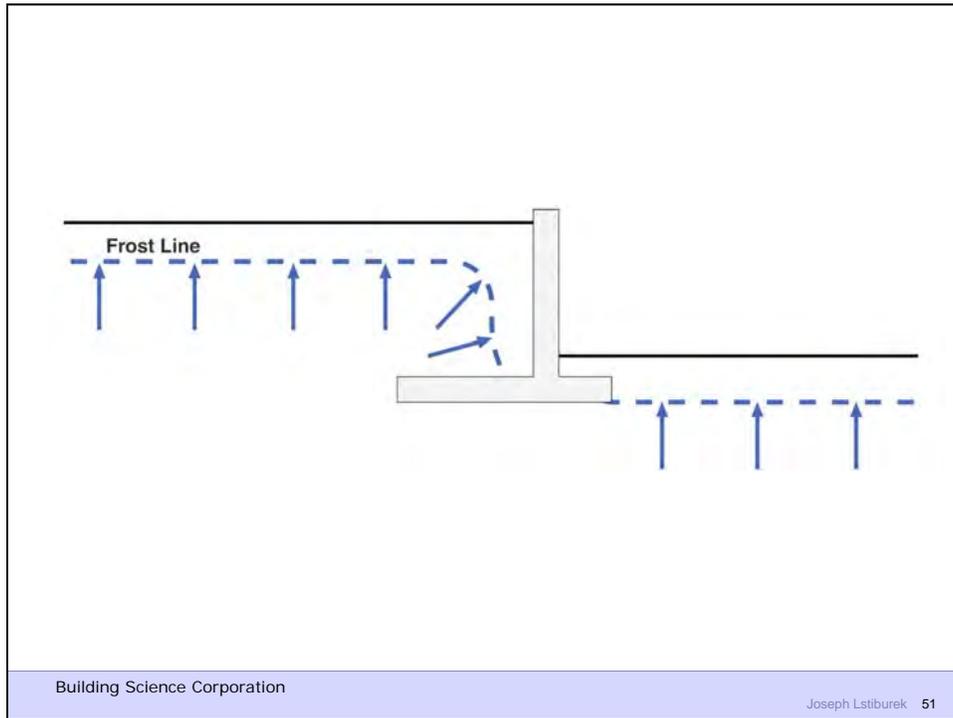
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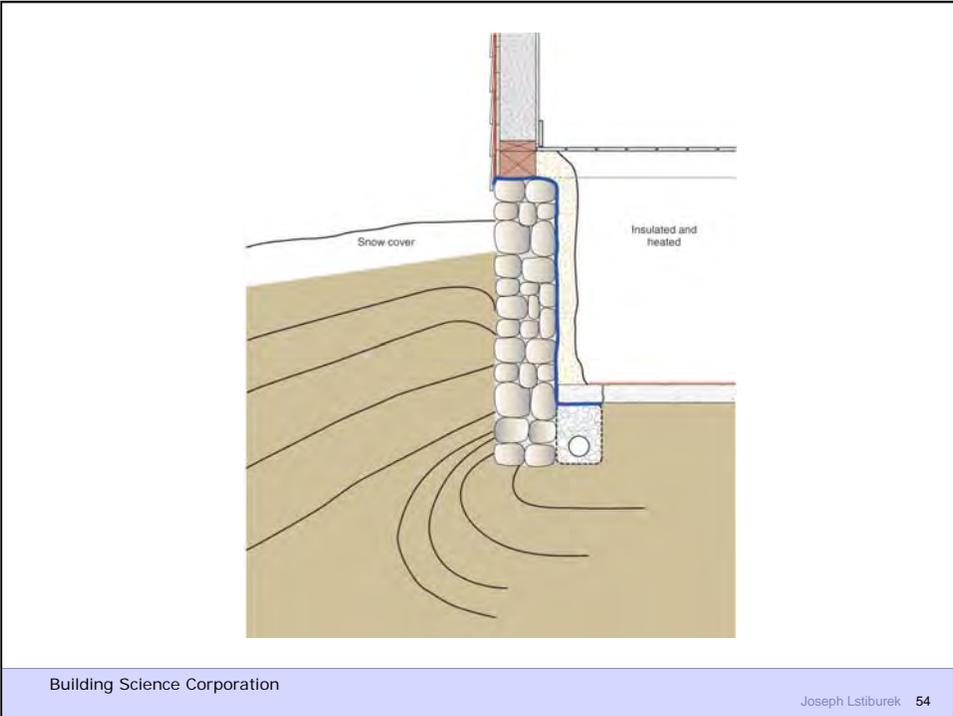
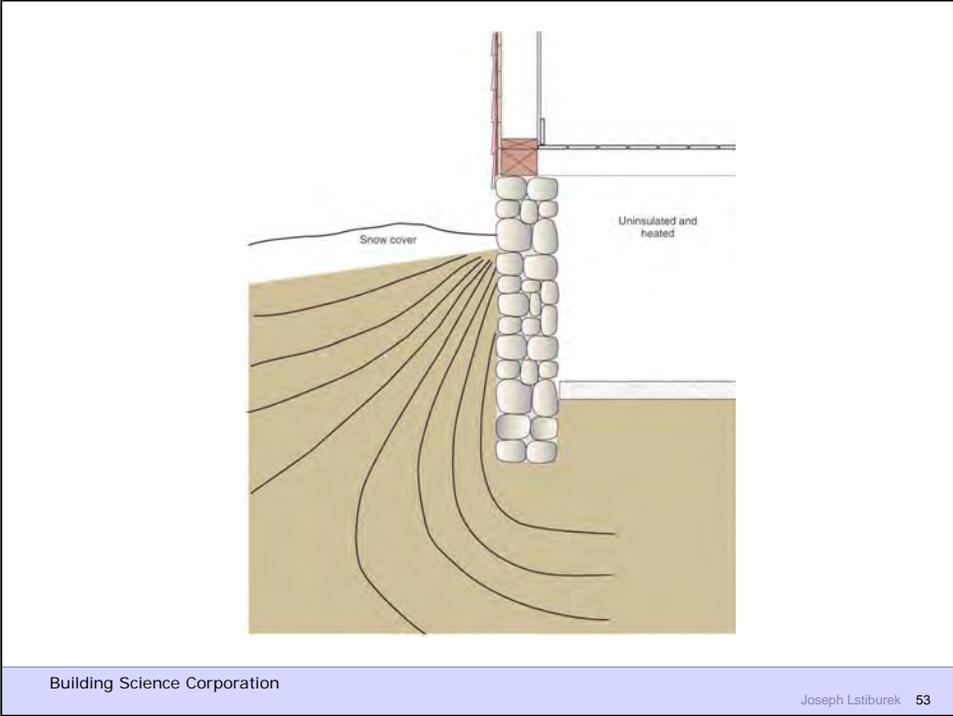


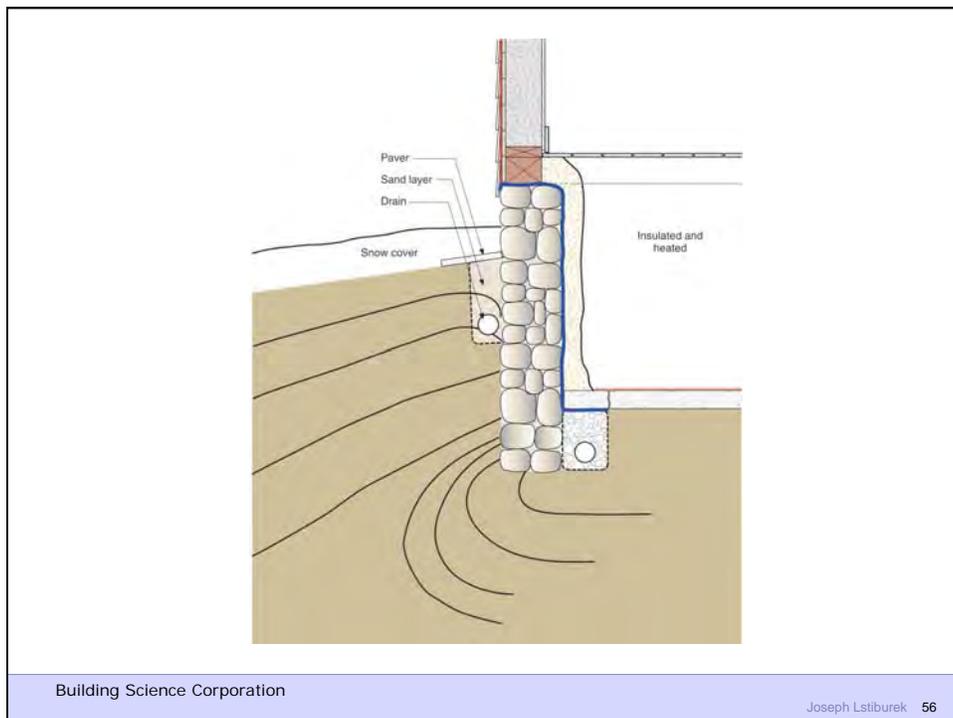
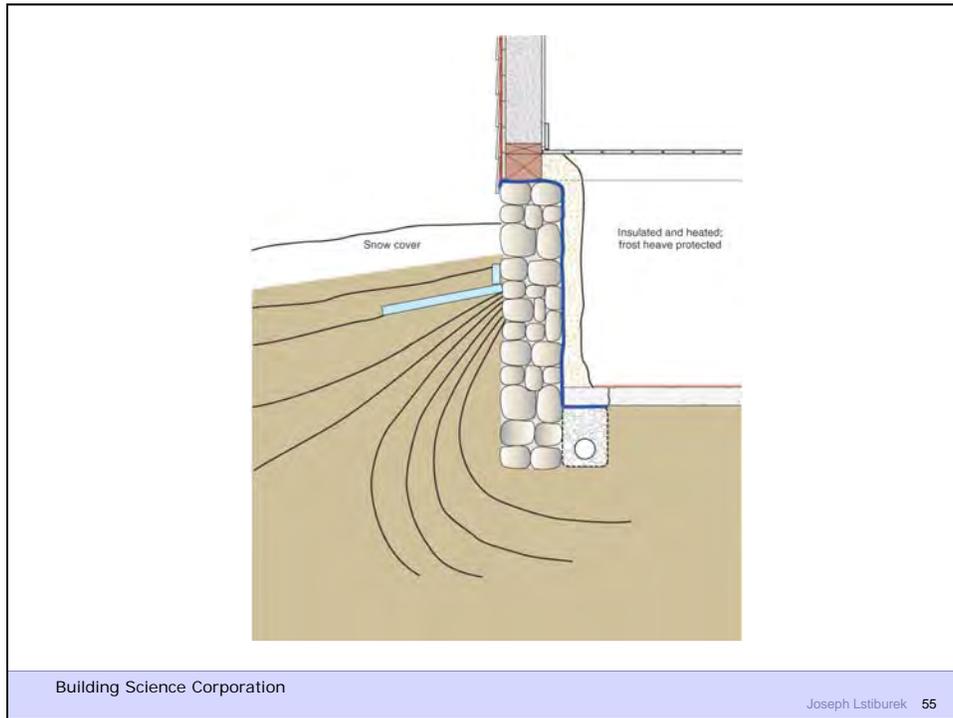
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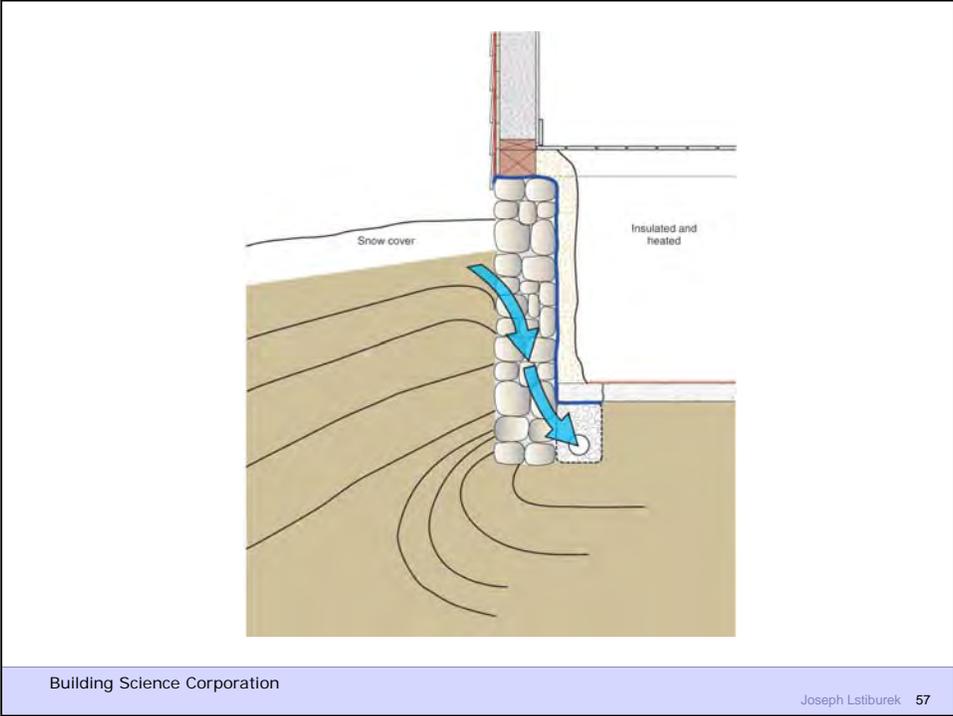


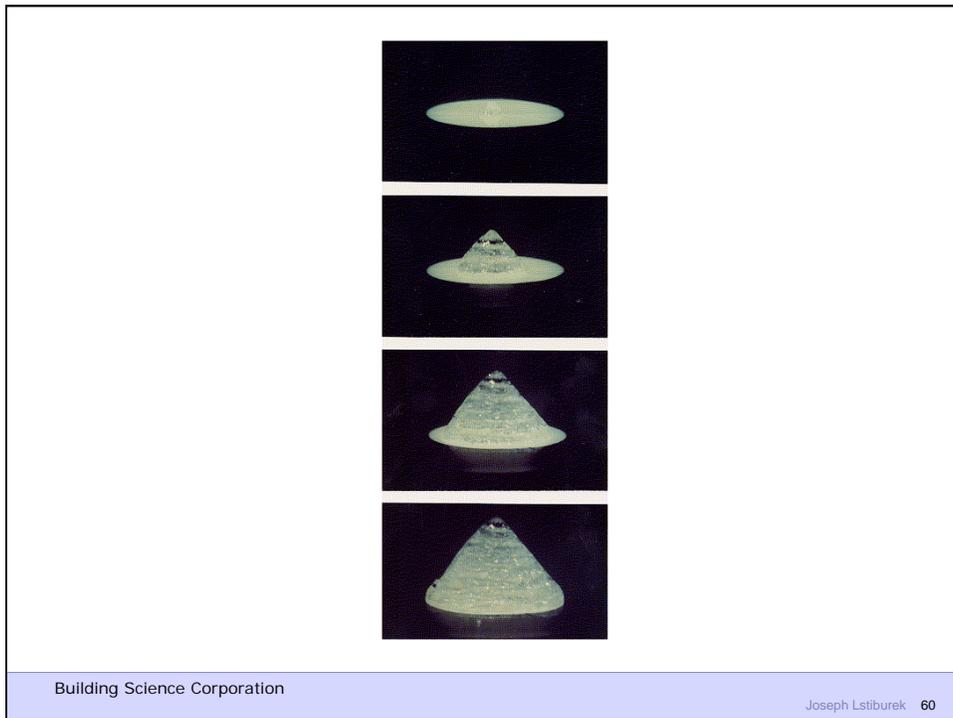
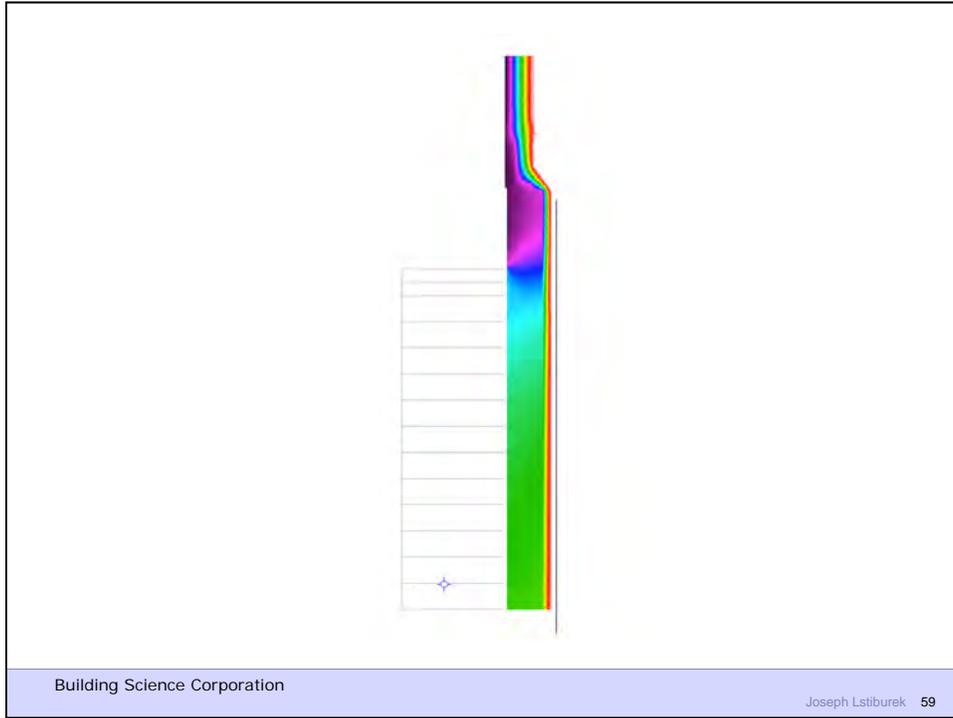














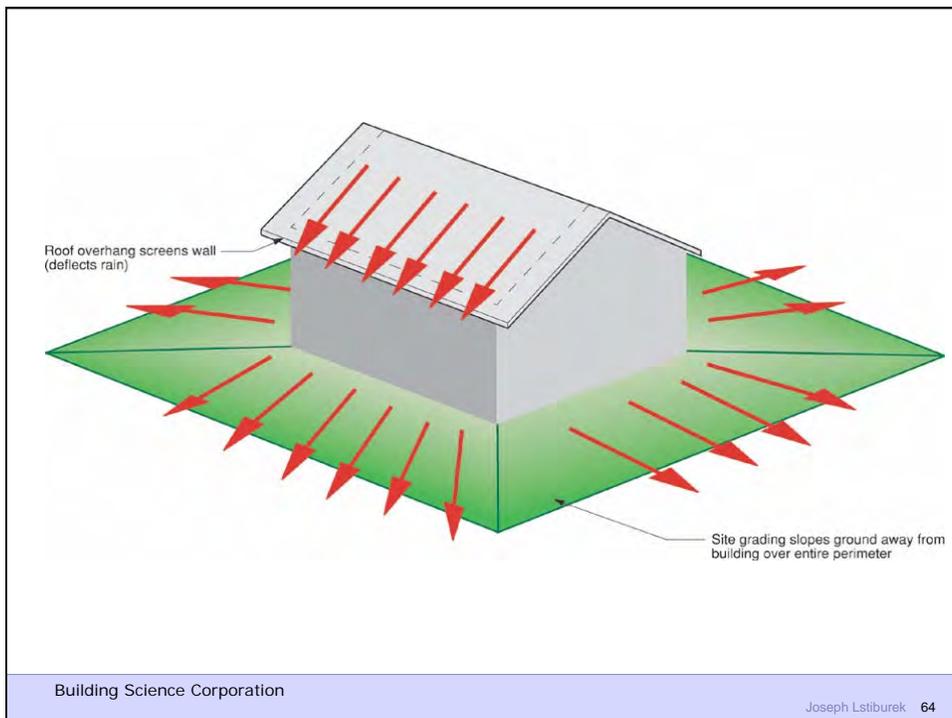
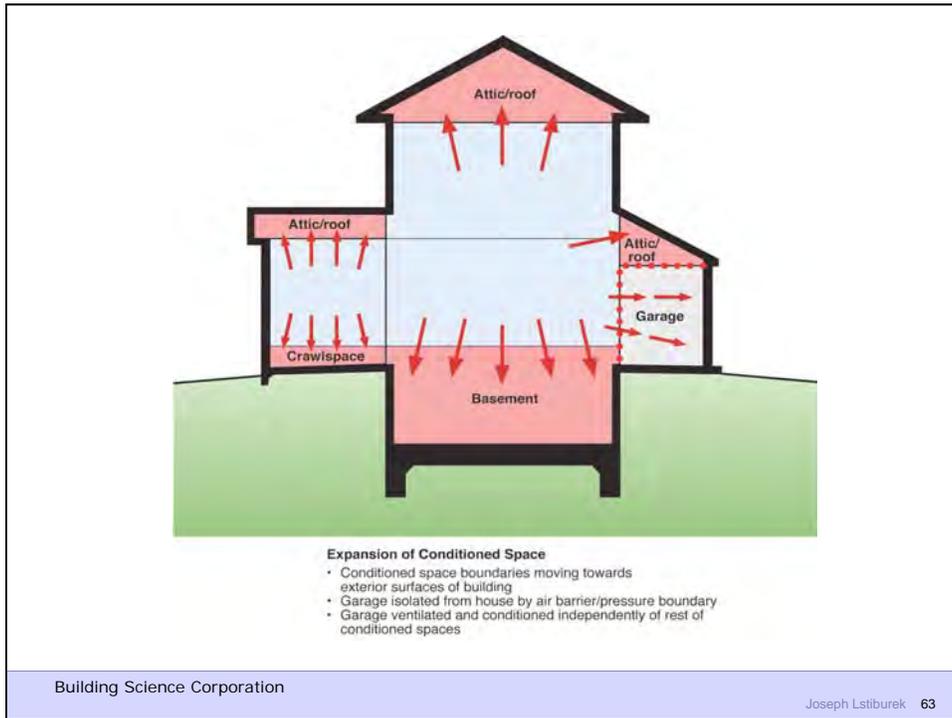
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The diagram illustrates a cross-section of a house with various exterior features. Red arrows indicate the direction of water runoff. Key features include:
 

- Roof:** Arrows pointing down from the roofline.
- Walkway slopes:** Arrows pointing away from the main building.
- Patio slopes:** Arrows pointing away from the building.
- Grade slopes:** Arrows pointing away from the main floor level.
- Garage floor slopes:** Arrows pointing away from the main building.
- Driveway slopes:** Arrows pointing away from the building.
- Seal:** Located at the garage floor junction.
- "Kick out" flashing:** A detail showing water being directed away from the wall at a roof/wall intersection.

- Patios and decks lower than floors and slope away from building
- Garage floor lower than main floor and slope away from building
- Driveway lower than garage floor and slope away from building
- Grade lower than main floor and slope away from building
- Stoops and walkways lower than main floor and slope away from building
- Kick out flashings or diverters direct water away from walls at roof/wall intersections

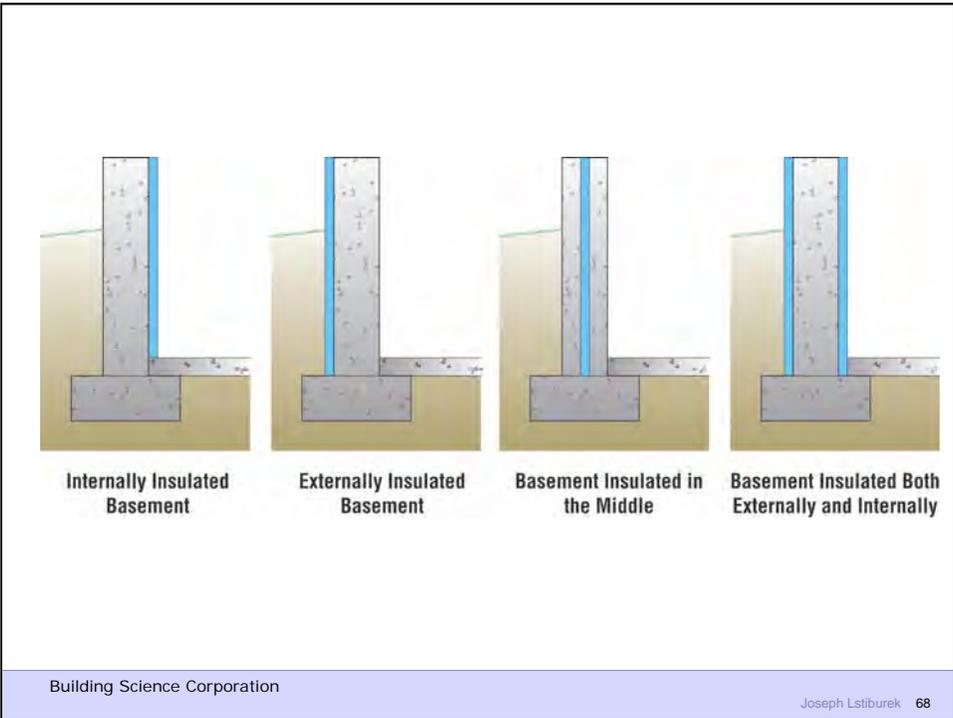
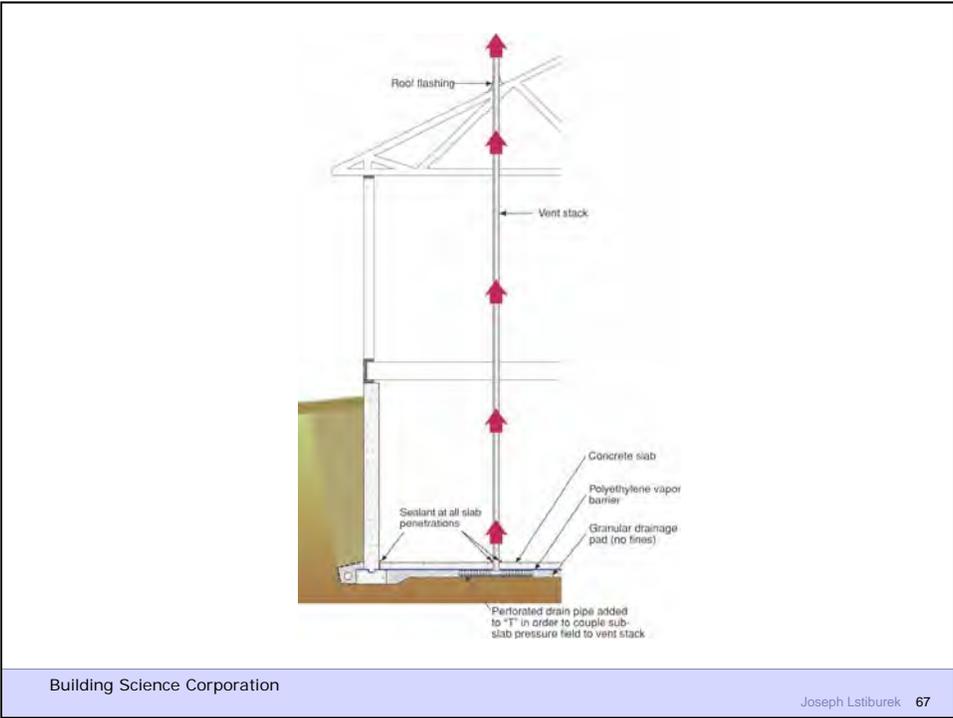
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This detailed diagram shows the foundation wall and its connection to the ground. Key components and their functions are labeled:
 

- Rain water falling on roof is collected in gutters.**
- Overhang protects the ground around the foundation from getting saturated.**
- Flash roof into gutter.**
- Down spouts carry rainwater from the roof away from the foundation.**
- Ground slopes away from the foundation.**
- Concrete foundation wall.**
- Impermeable top layer of backfill (clay caps) prevents ground adjacent to foundation from getting saturated.**
- Free-draining backfill (or drainage board).**
- Filter fabric (stone) and below drain pipe.**
- Coarse gravel (no fines).**
- Perforated drain pipe located below final walk level (piped to sump or daylight).**
- Pipe connection through footing connects exterior perimeter drain to granular drainage pad under basement slab.**
- Capillary break over footing.**
- Slab isolation joint.**
- Polyethylene vapor diffusion retarder.**
- Granular drainage pad (coarse gravel, no fines).**
- Groundwater flow is downward (not horizontal) under the influence of gravity to the perimeter drainage system.**

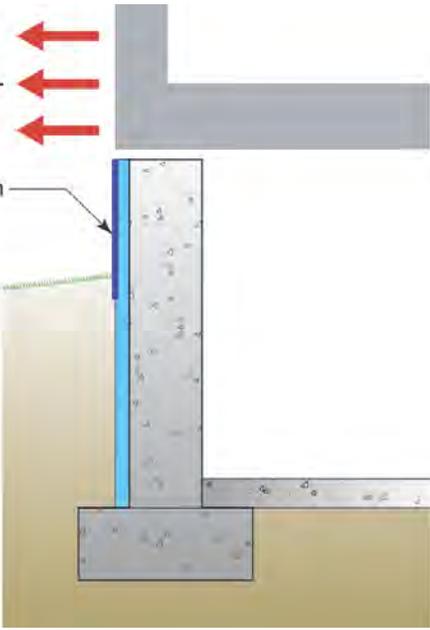
- Keep rain water away from the foundation basement.
- Drain groundwater away in rain-garde basement footing drains, sump or sump or the foundation wall.

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

Protection layer/system



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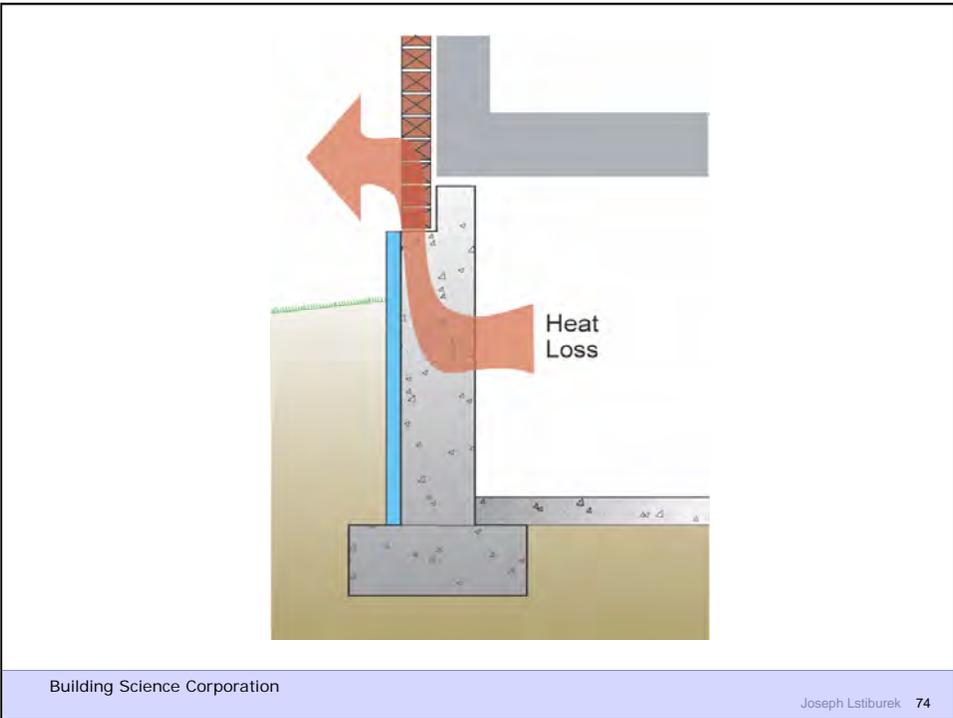
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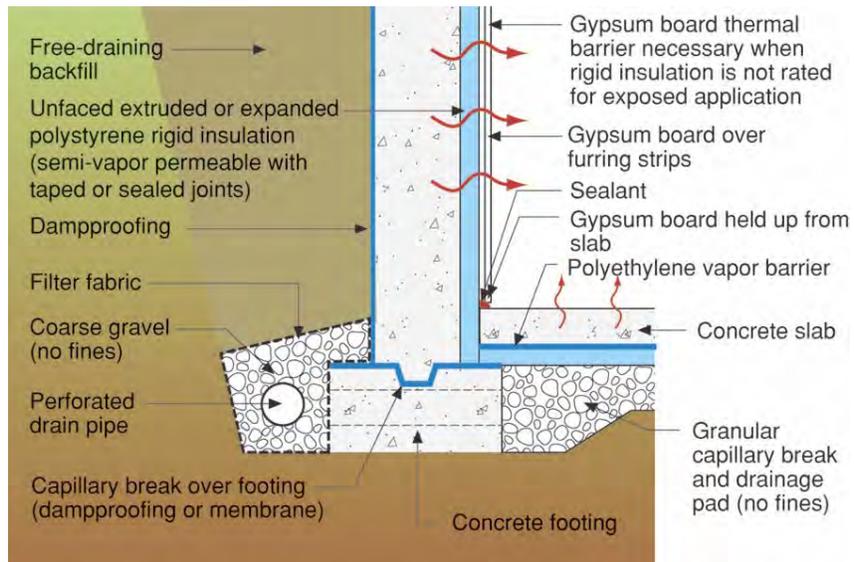
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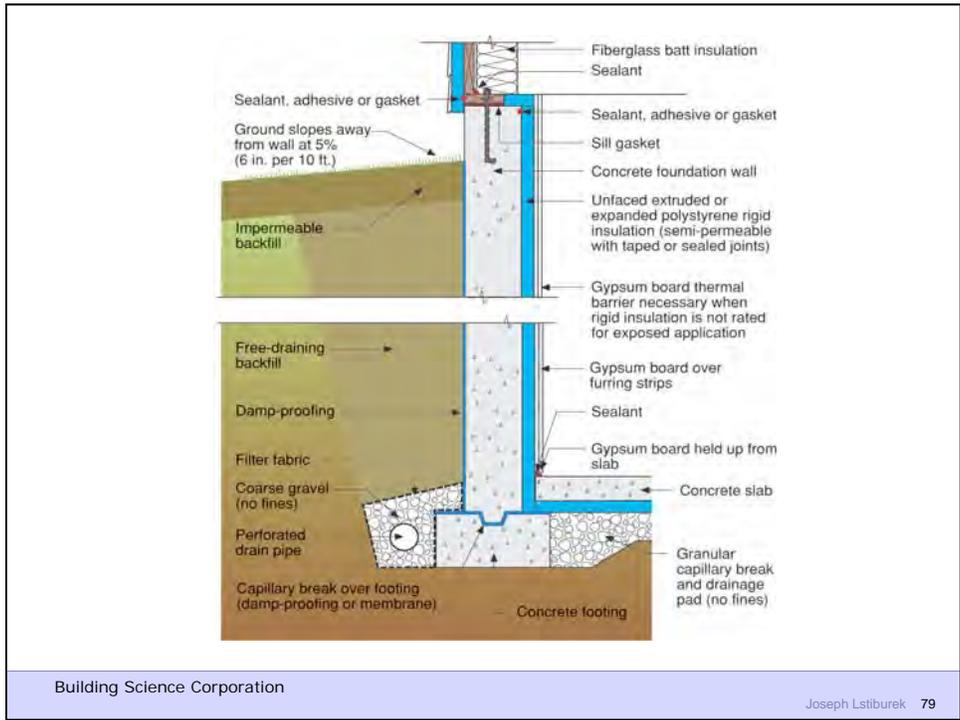
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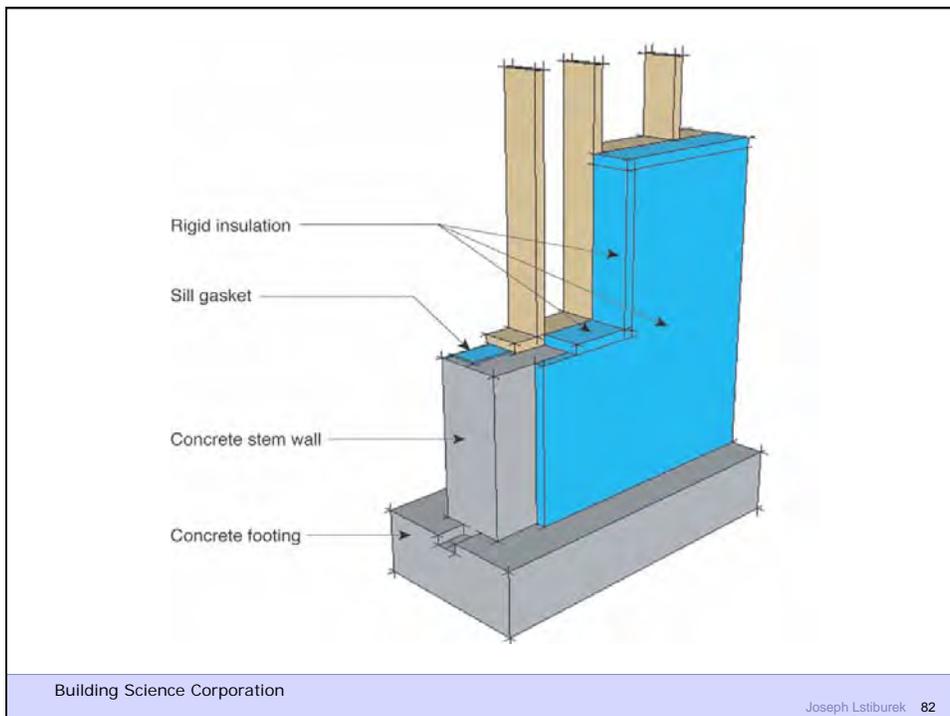
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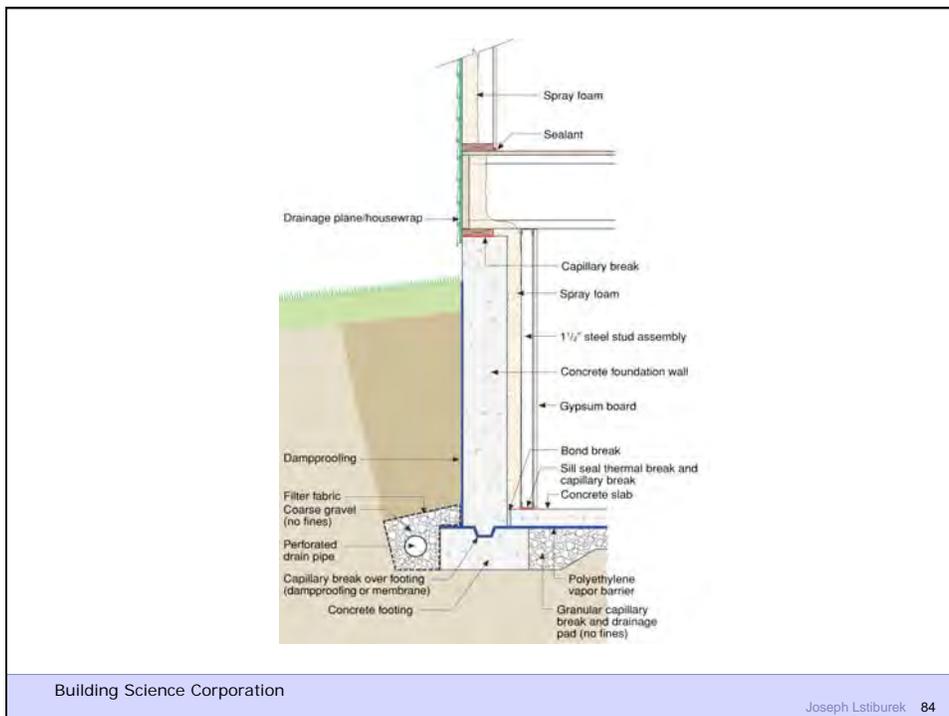
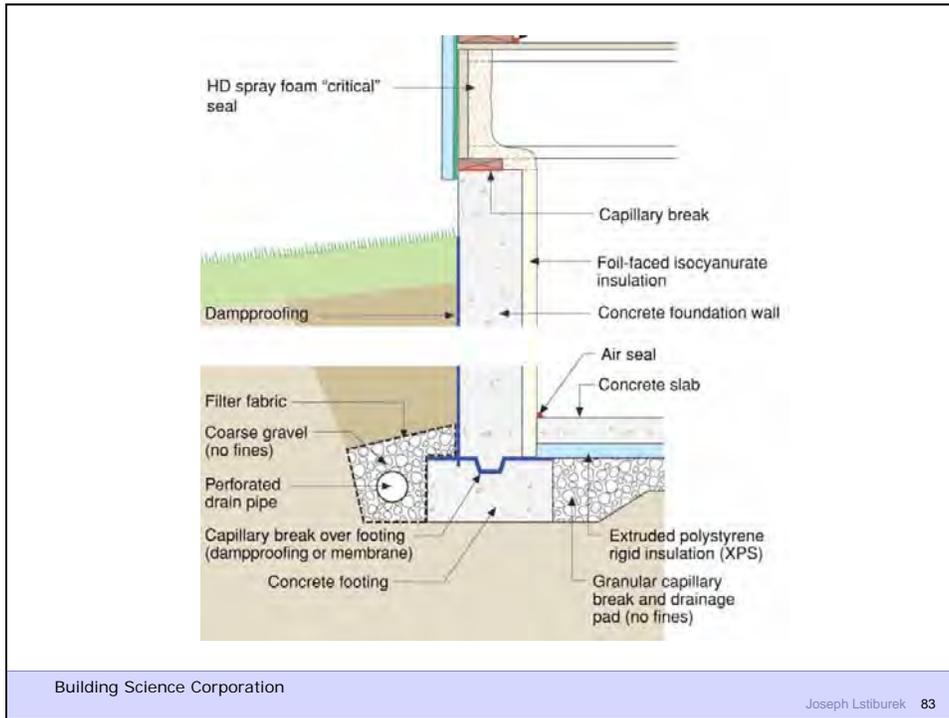




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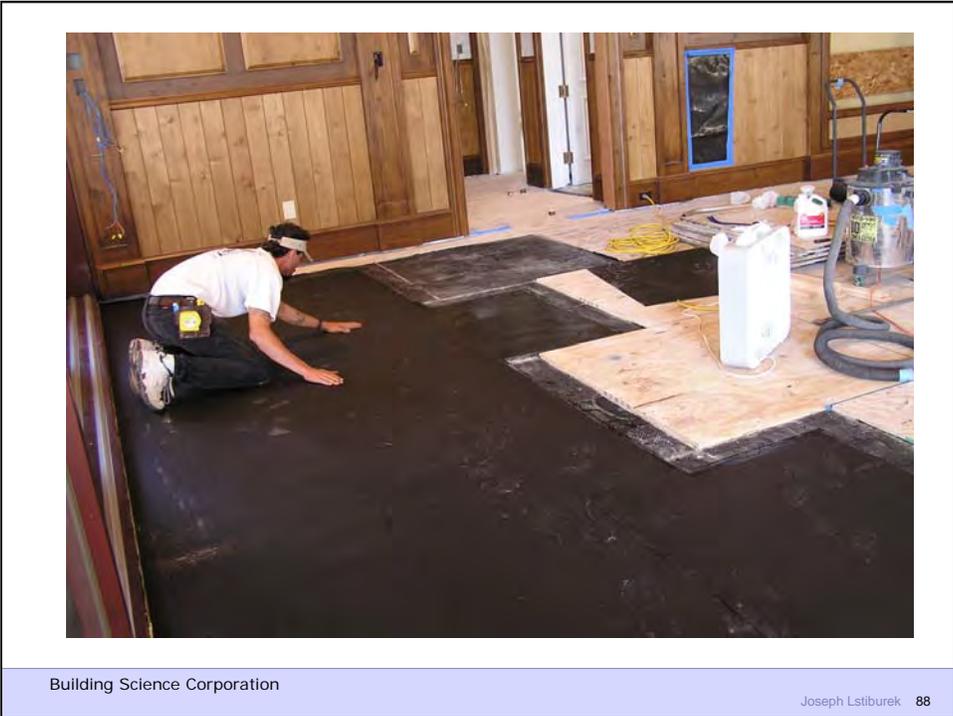
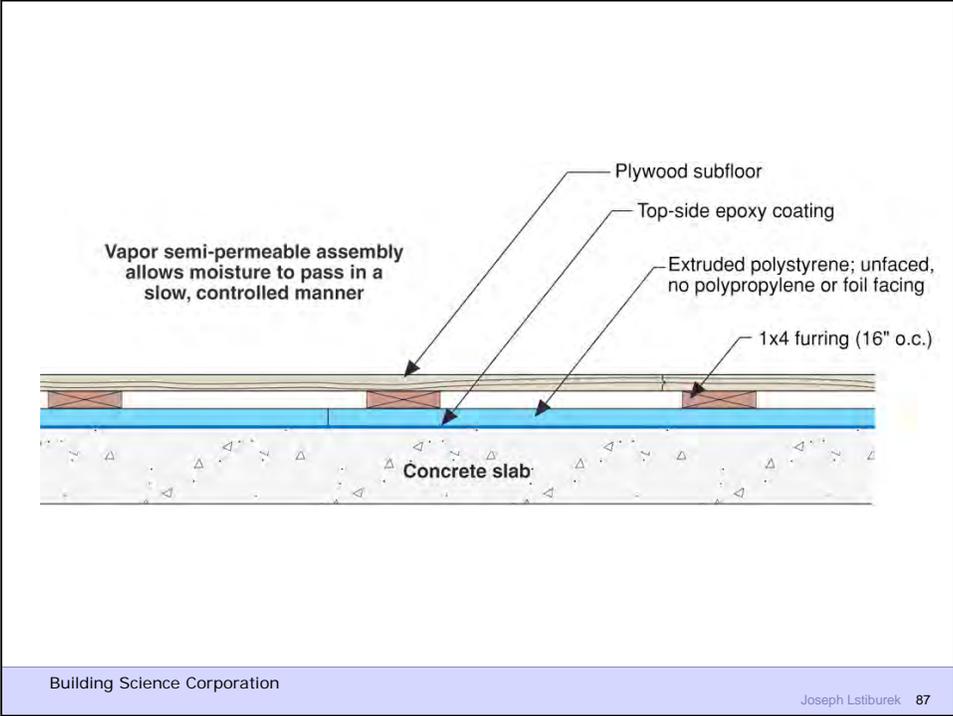




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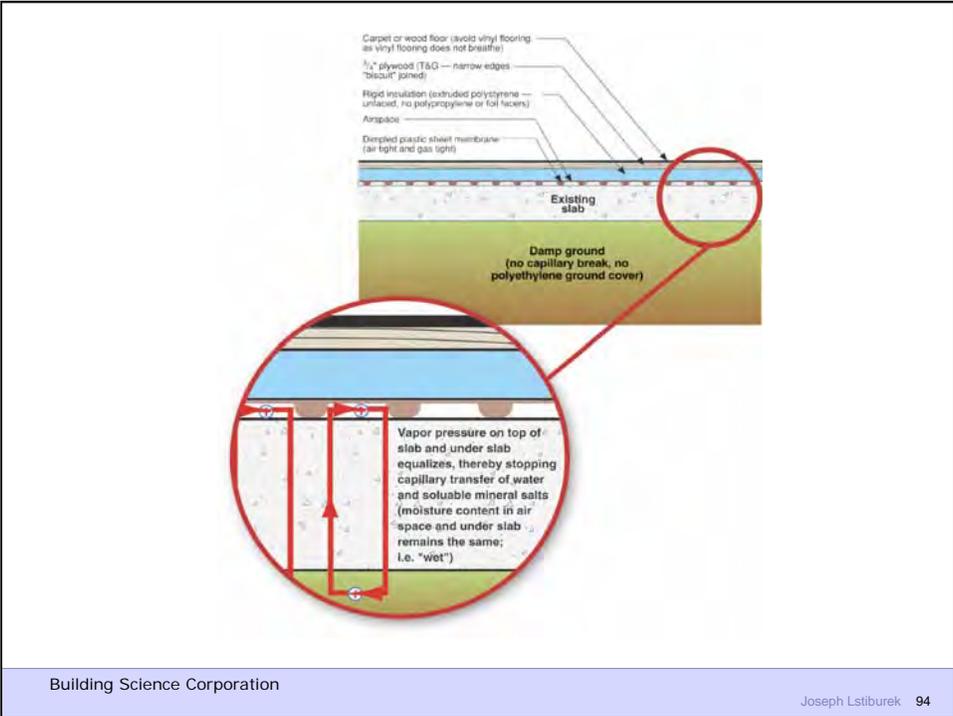
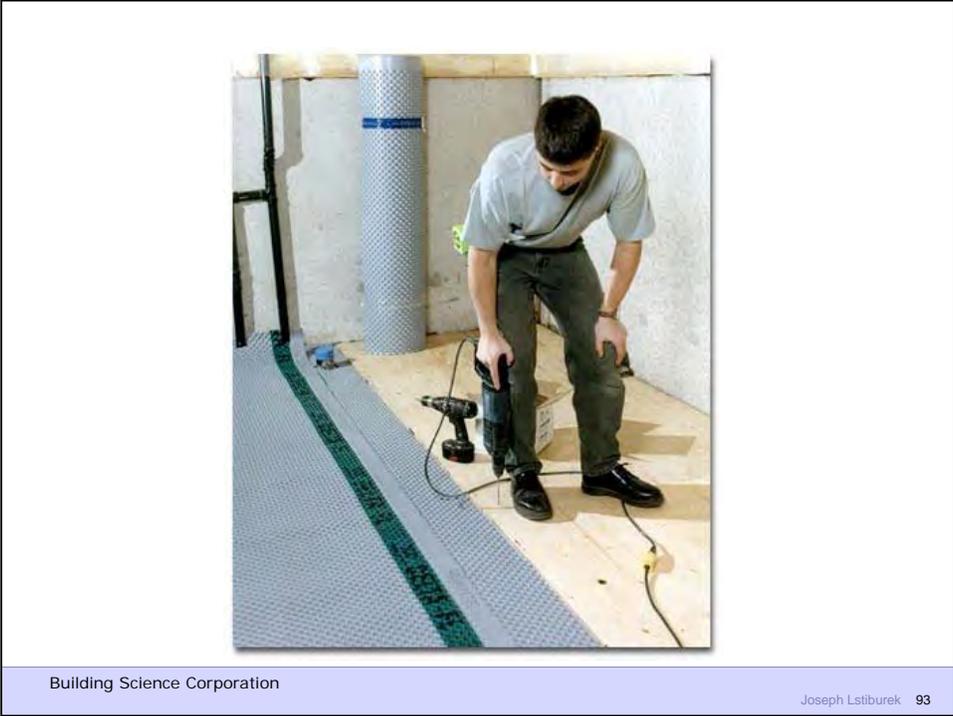
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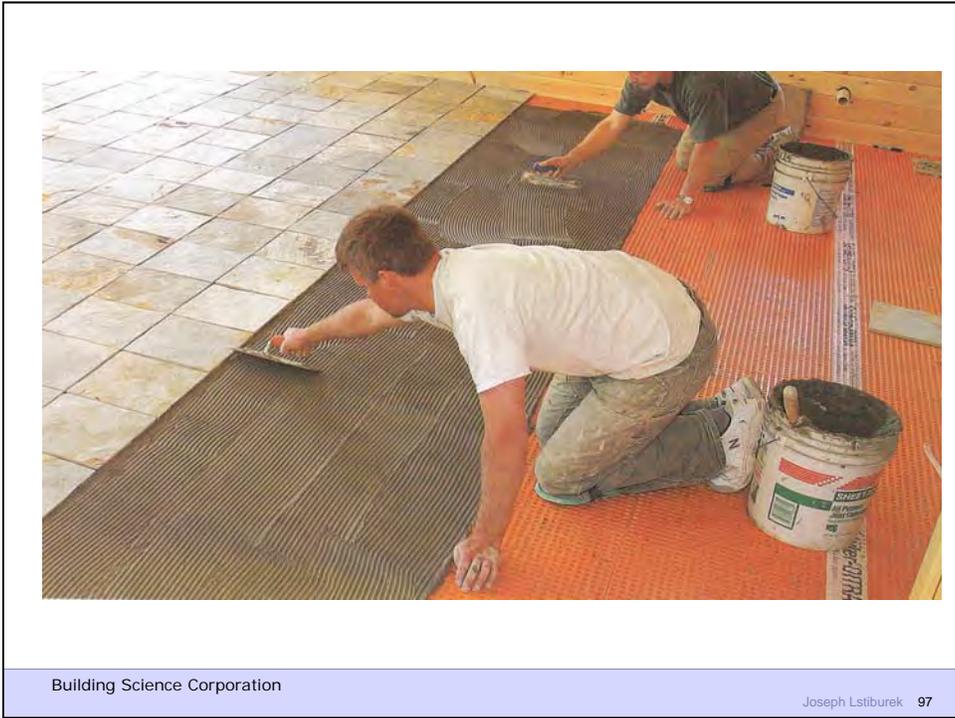




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