

Building Science Corporation

Spray Polyurethane Foam

Building Enclosures

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

Life is Tough Enough as it is

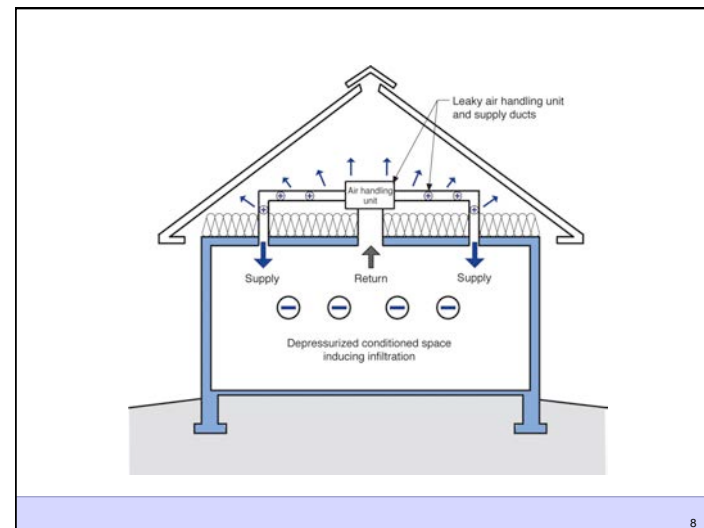
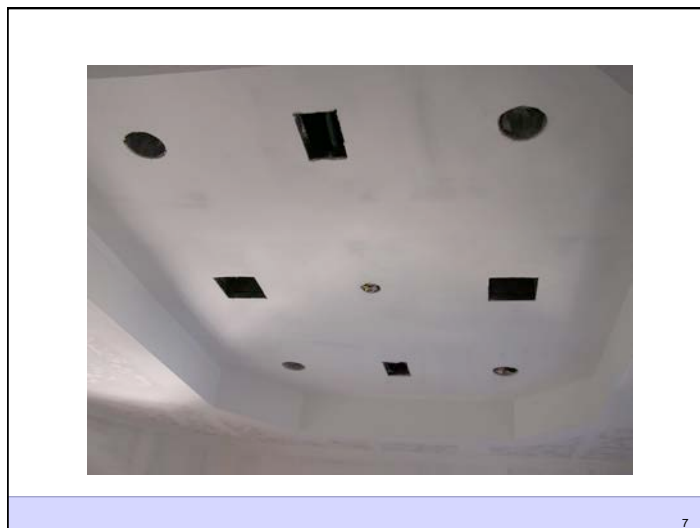
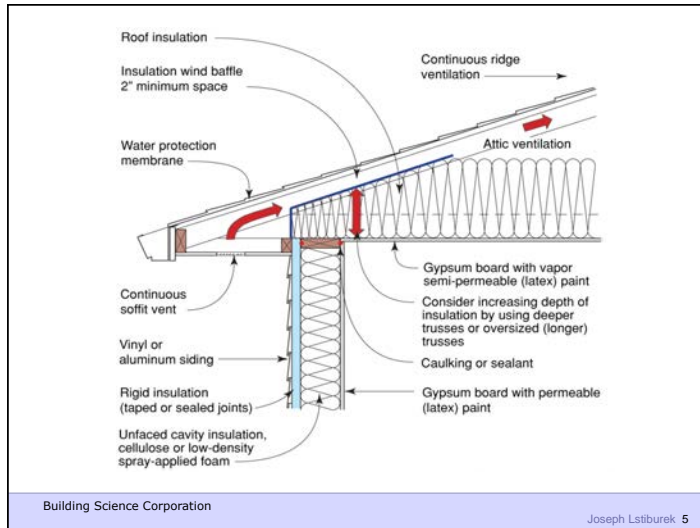
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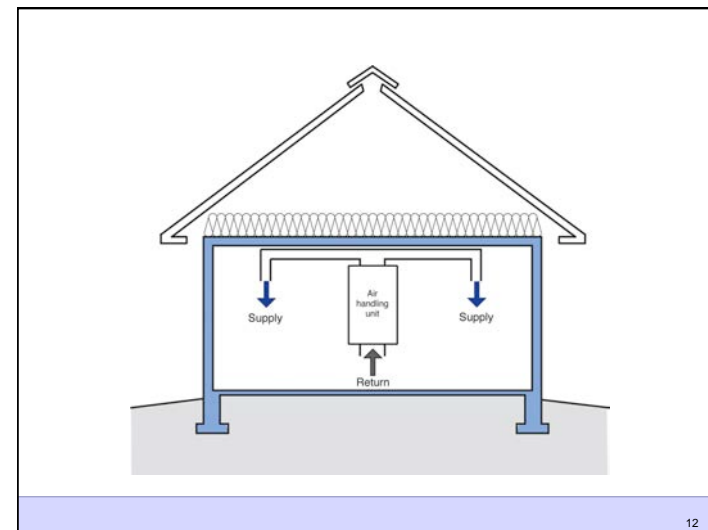
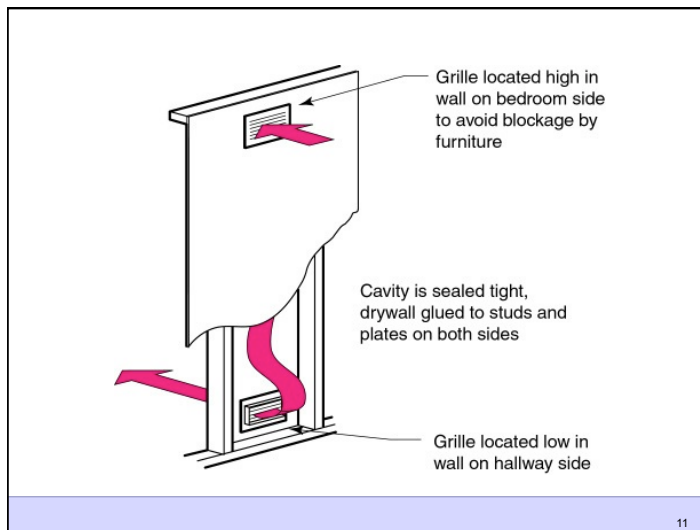
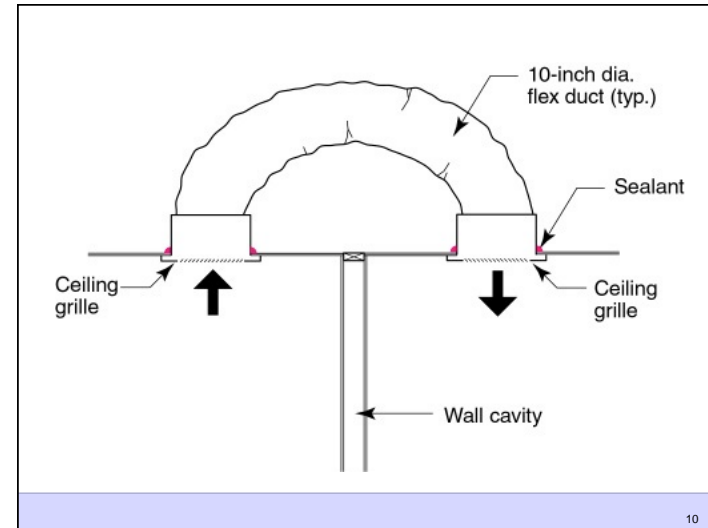
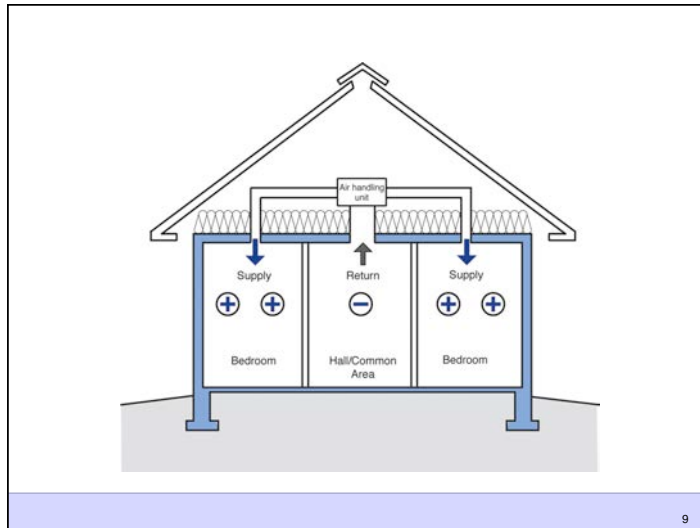
Life is Tough Enough as it is
It is Harder When You Are Stupid

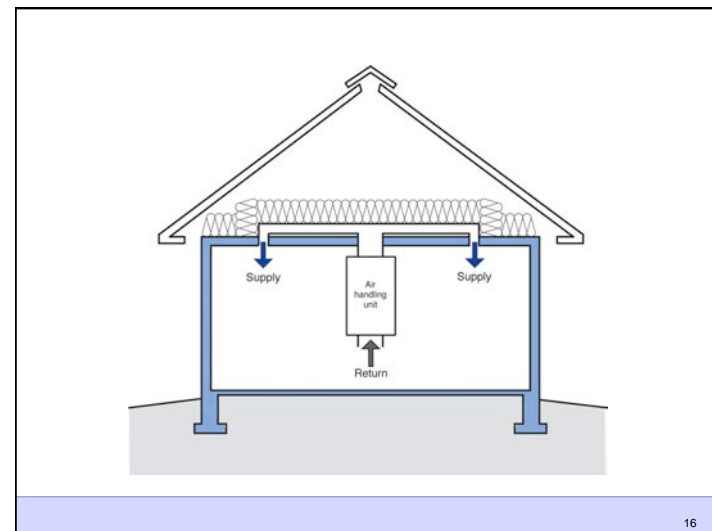
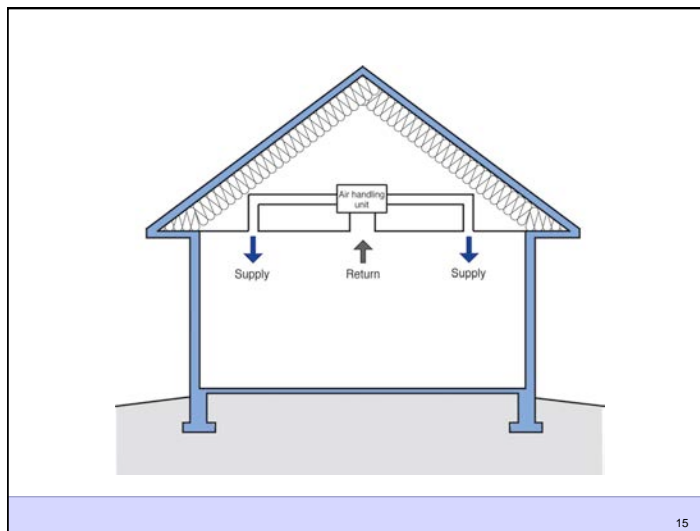
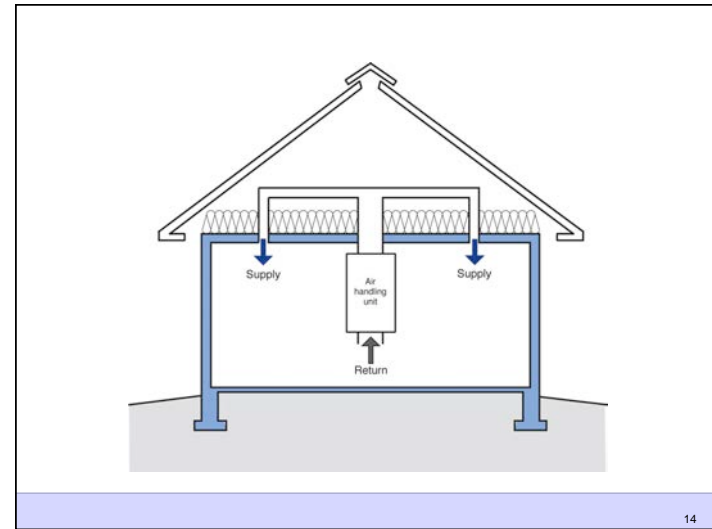
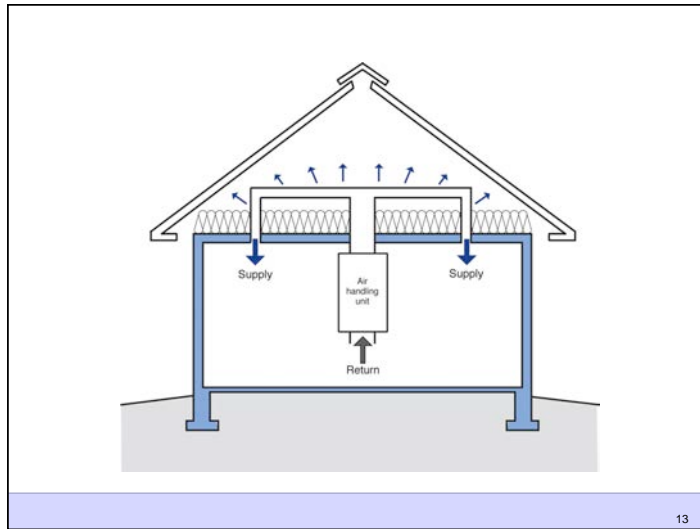
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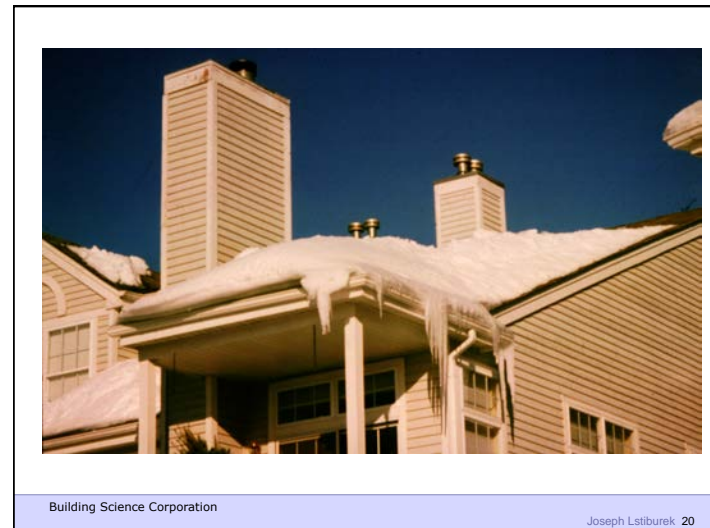
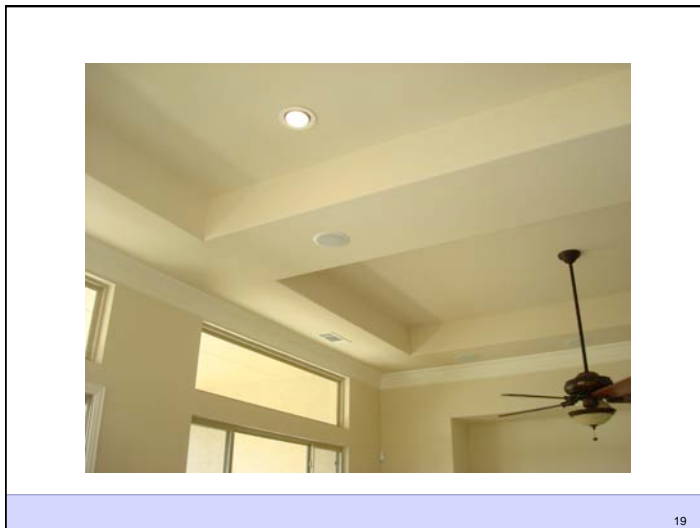
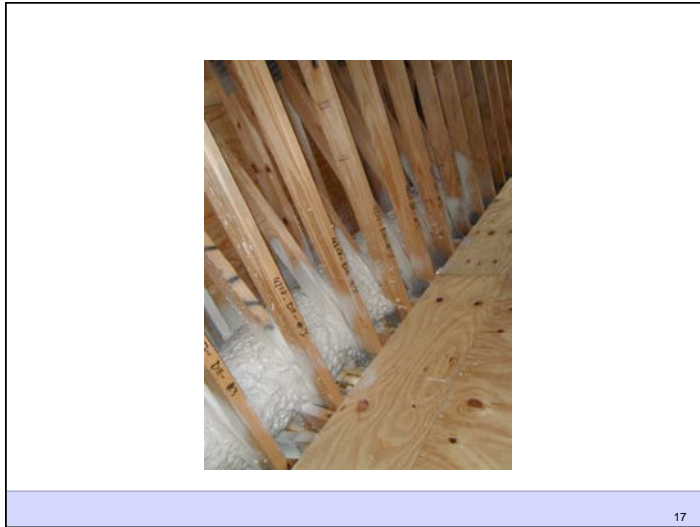
Life is Tough Enough as it is
It is Harder When You Are Stupid
Don't do Stupid Things

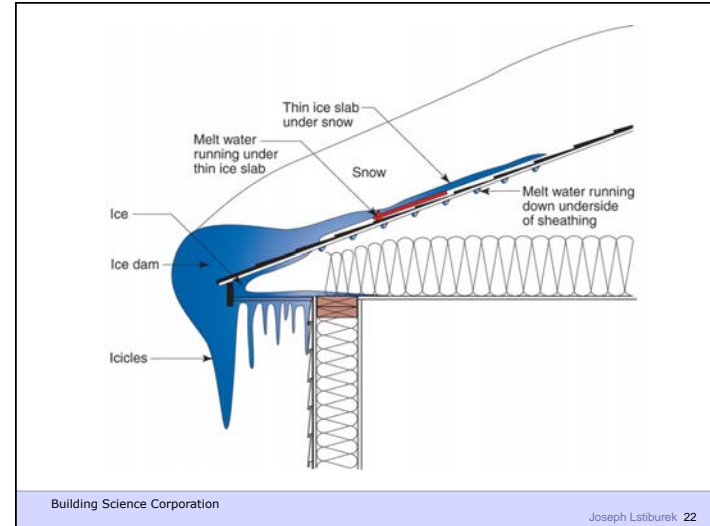
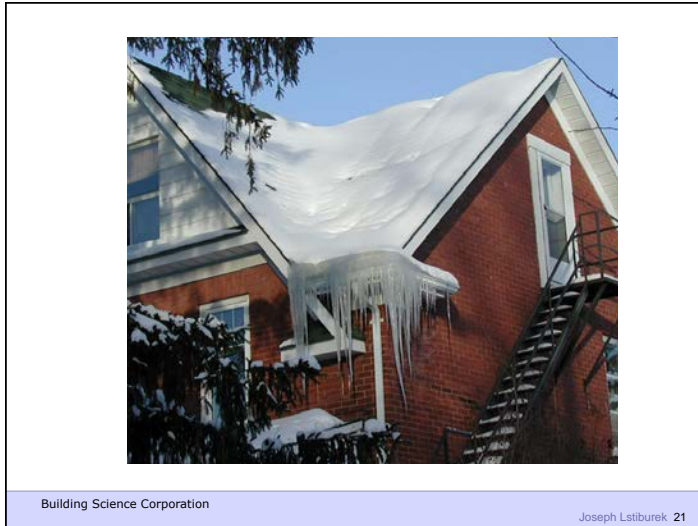
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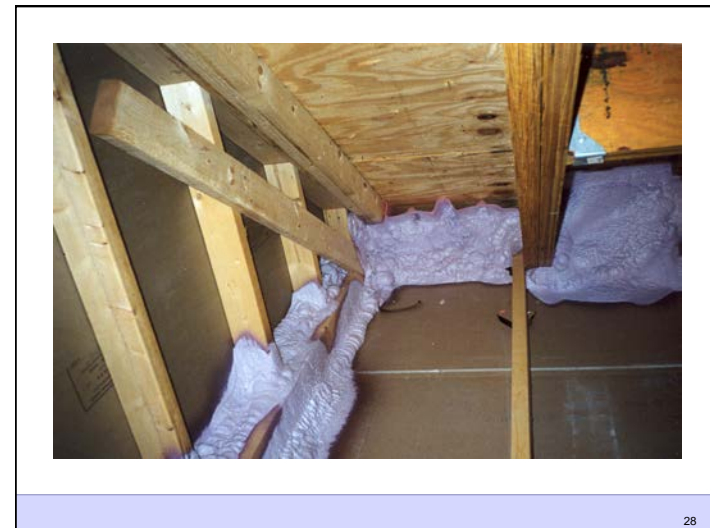
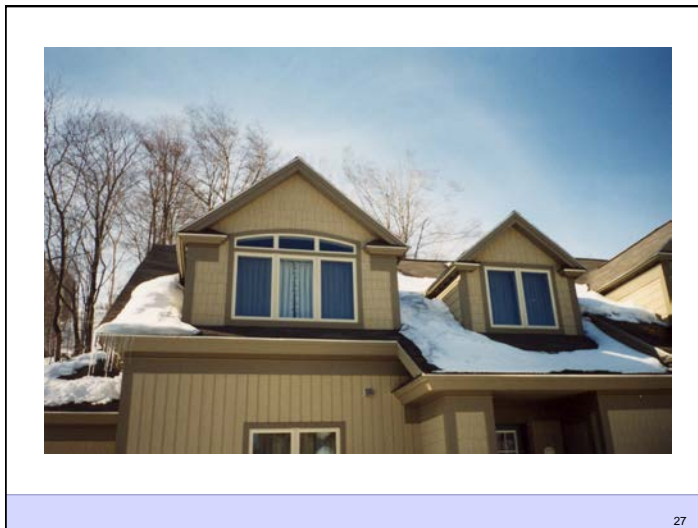
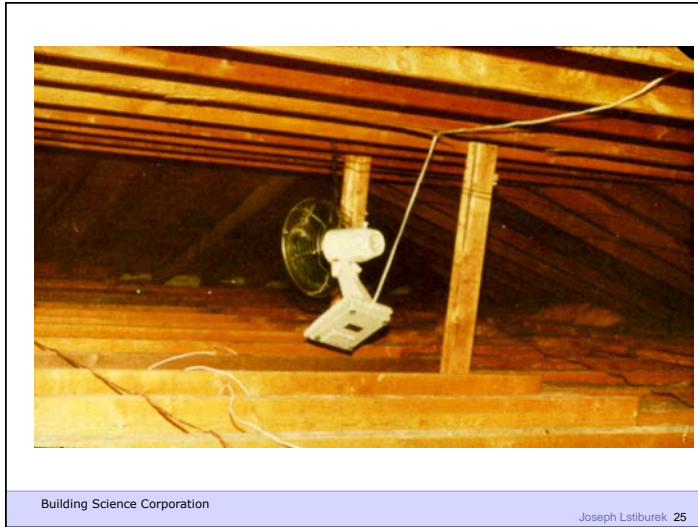


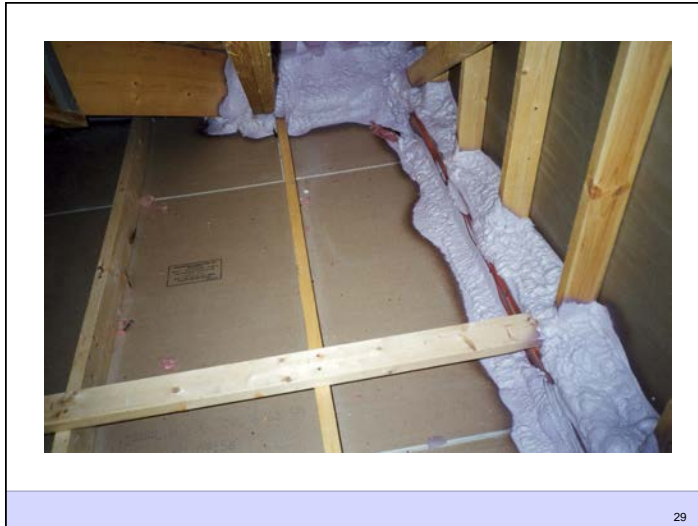




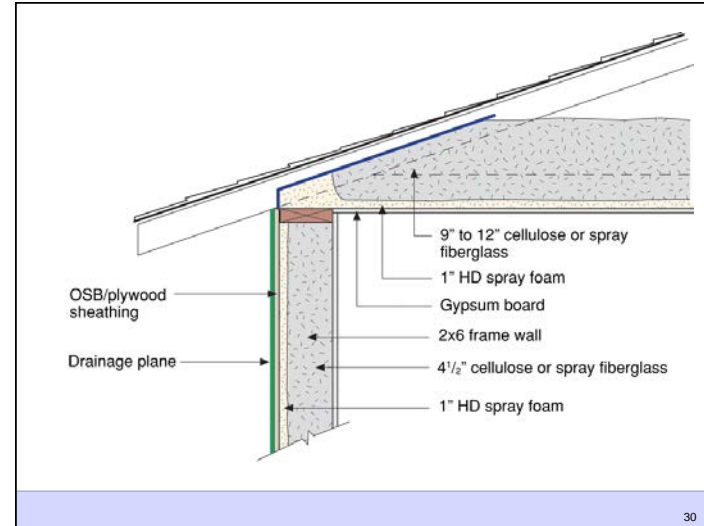




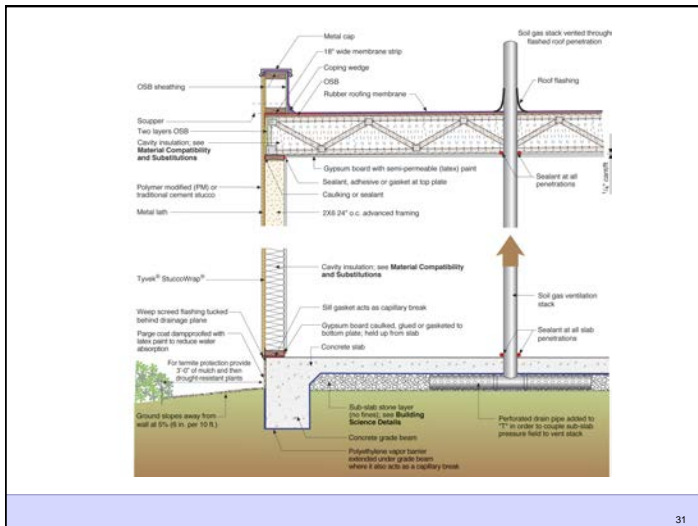




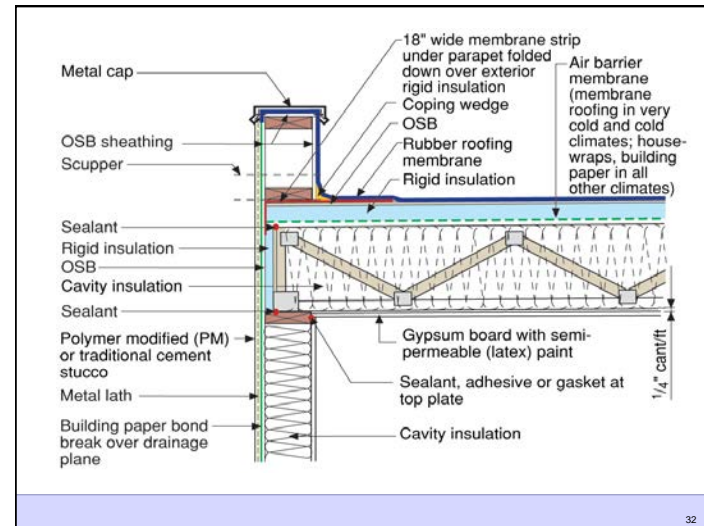
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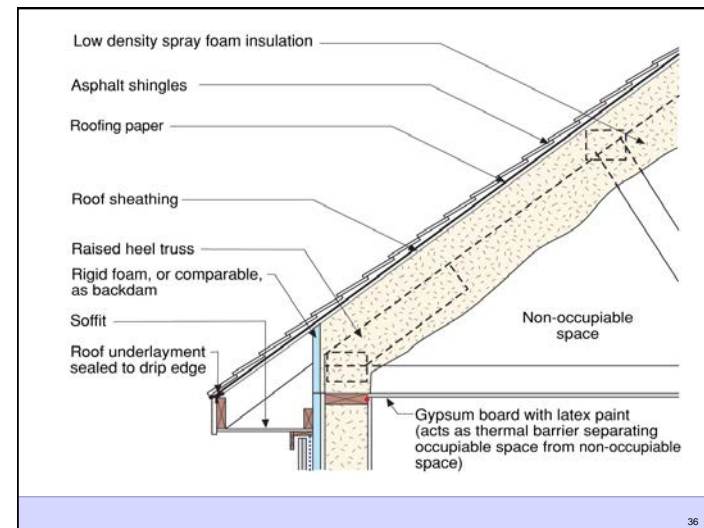
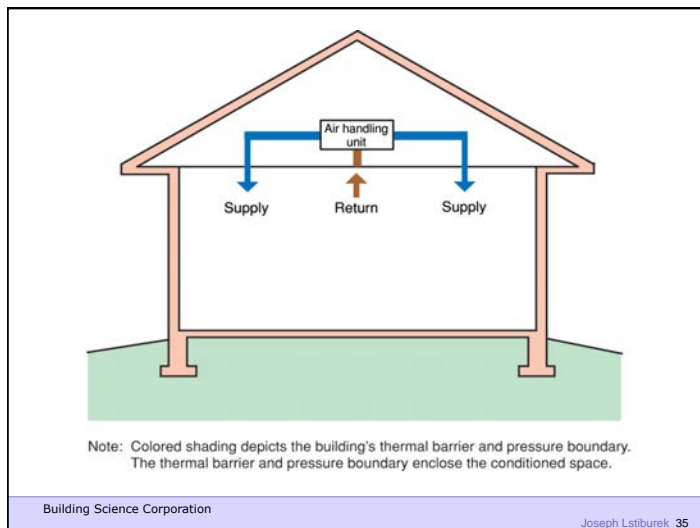
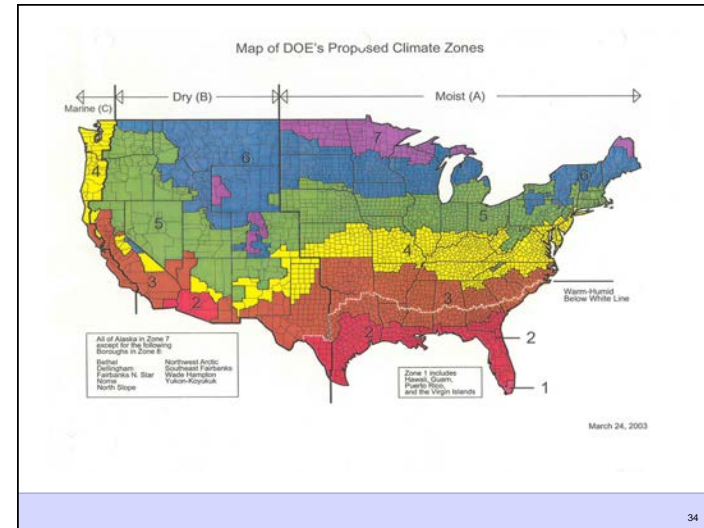
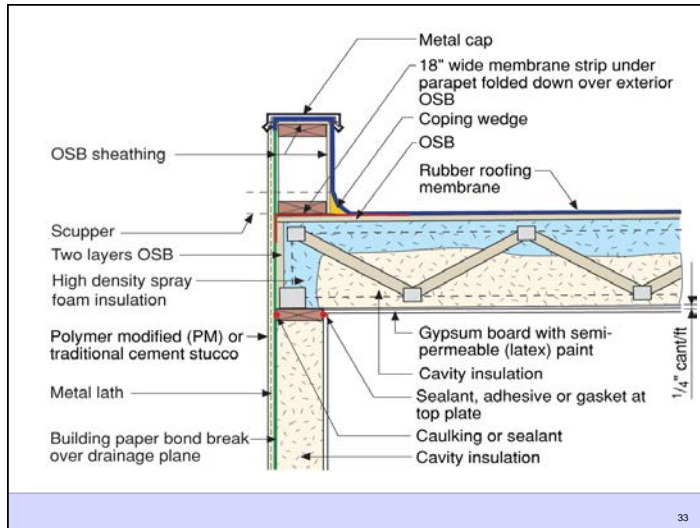
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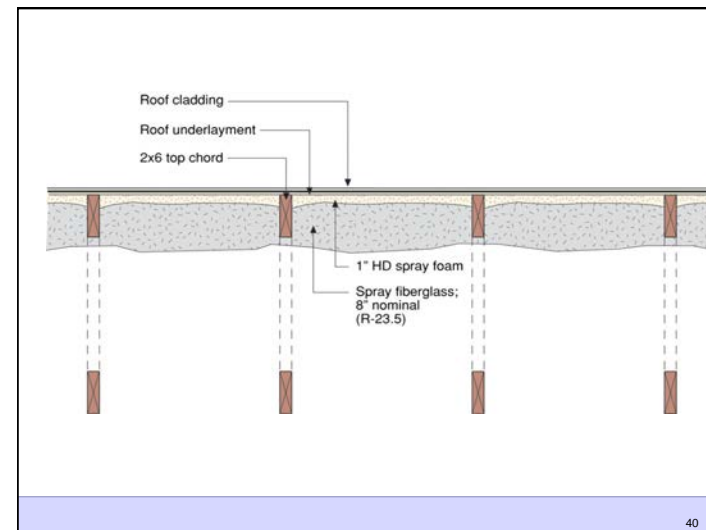
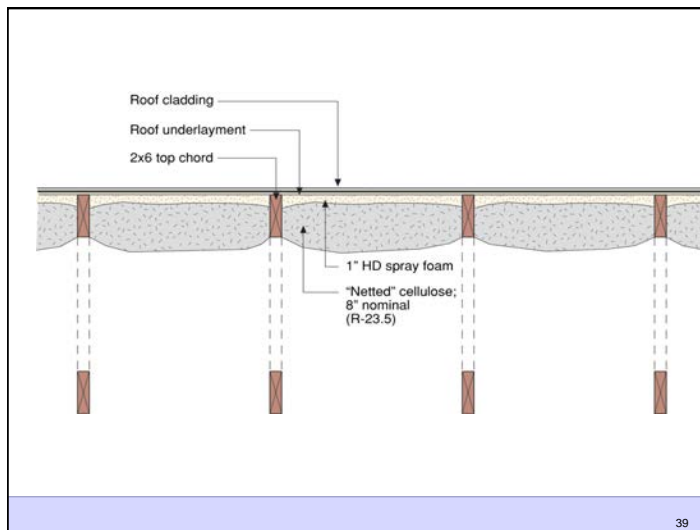
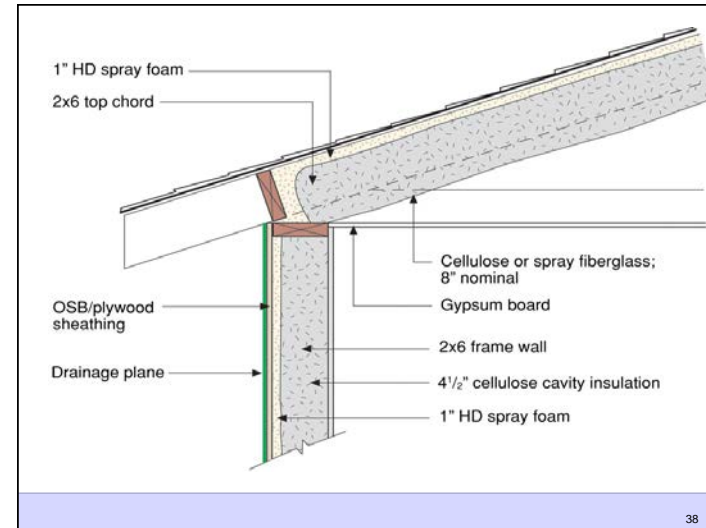
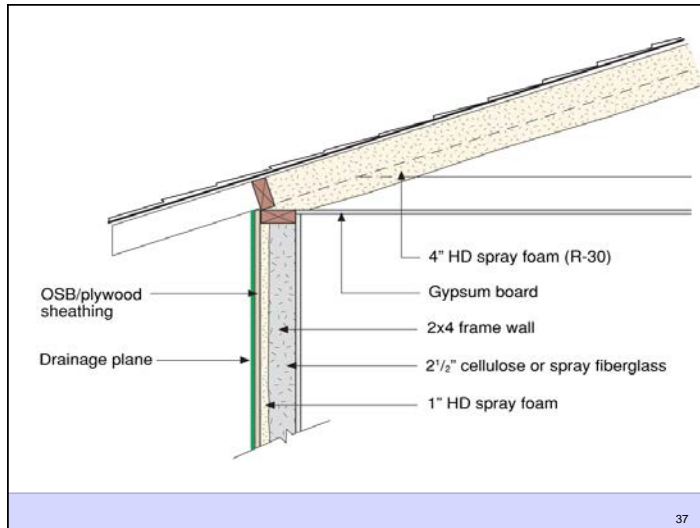


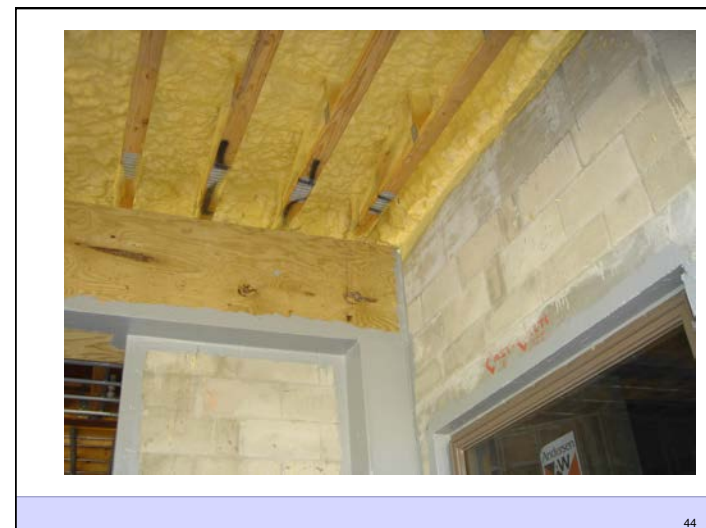
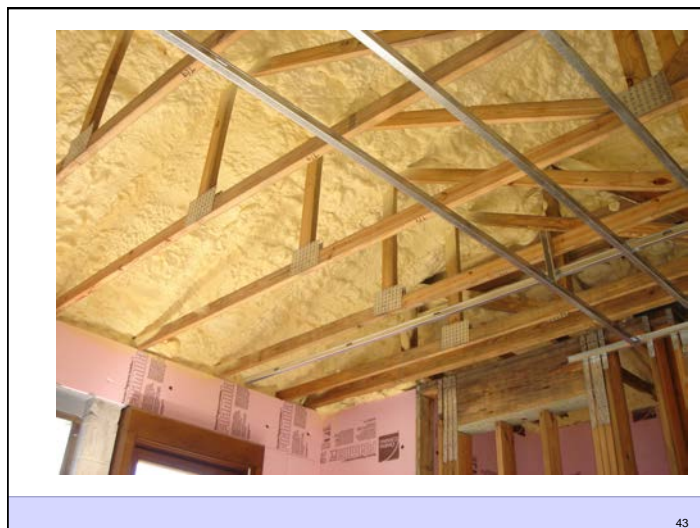
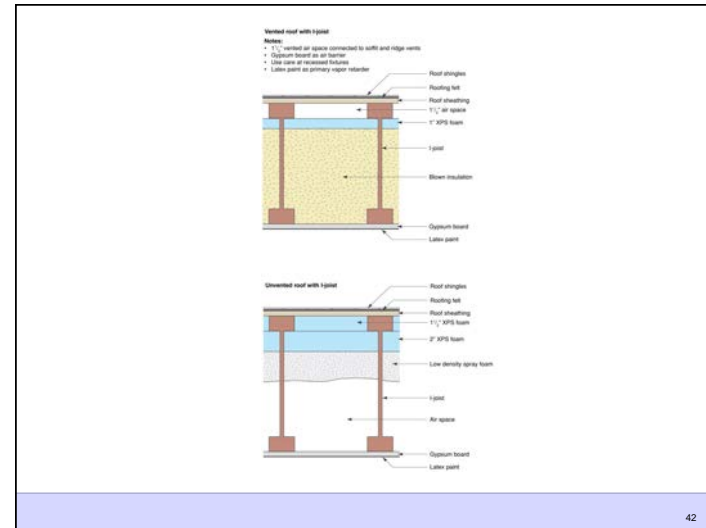
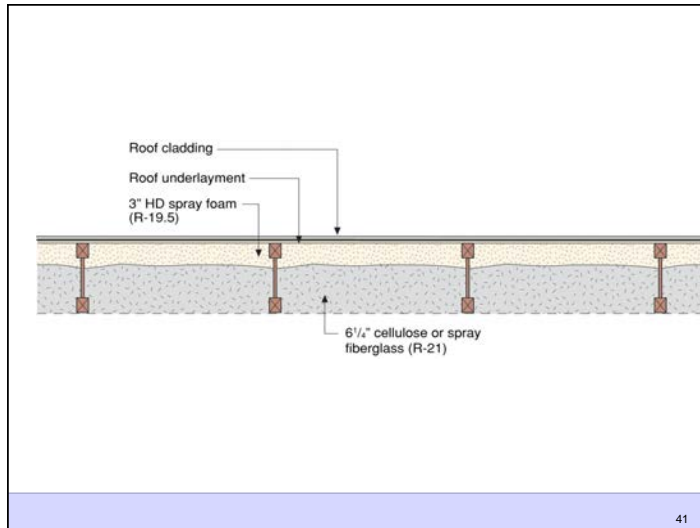
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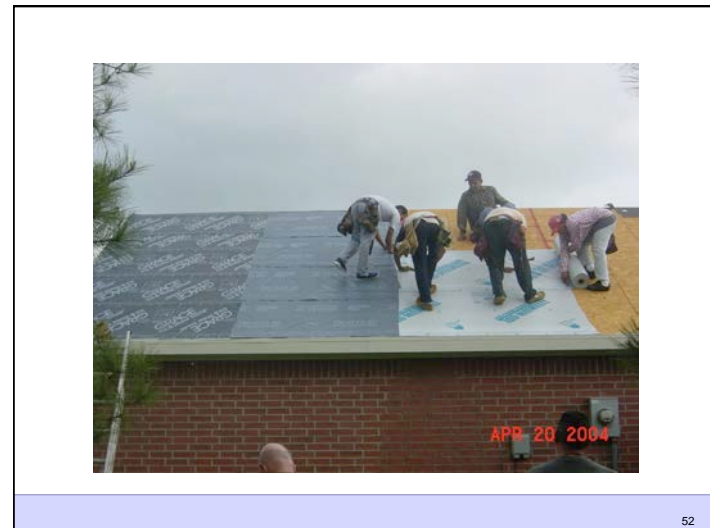
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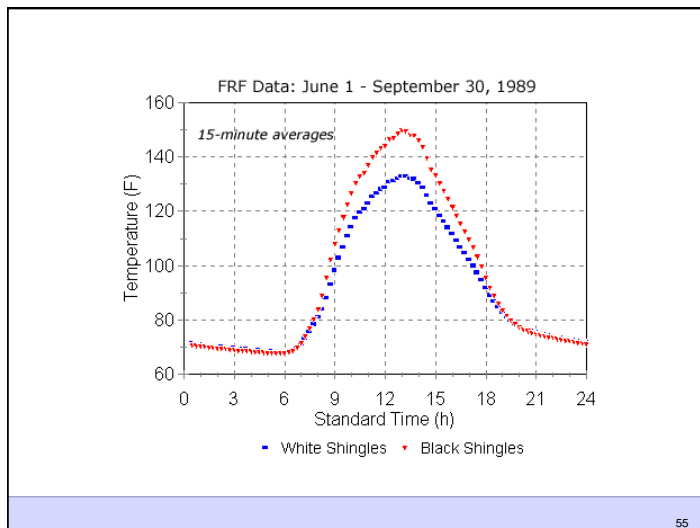




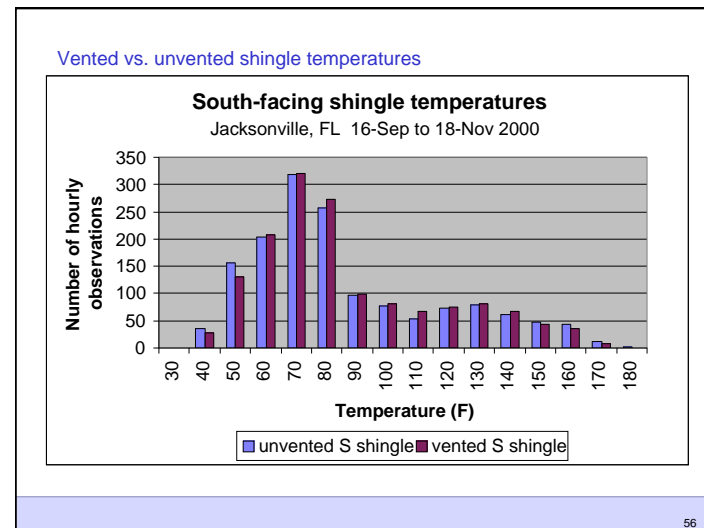
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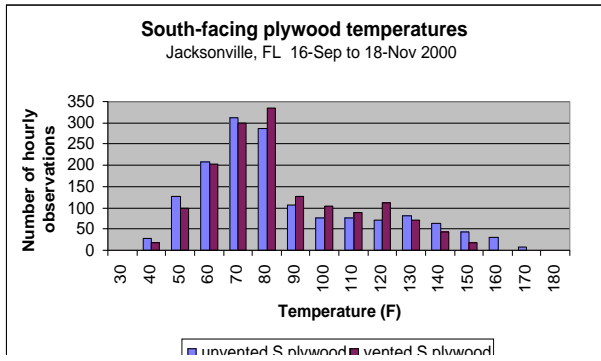


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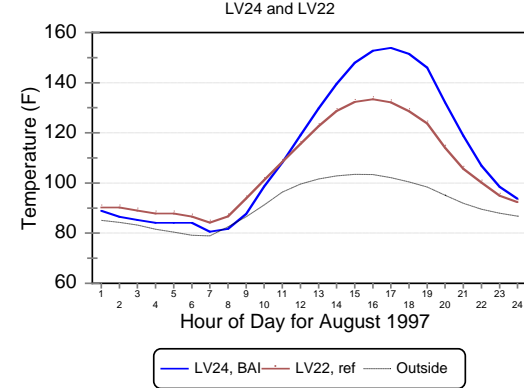
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Vented vs. unvented roof sheathing temperatures

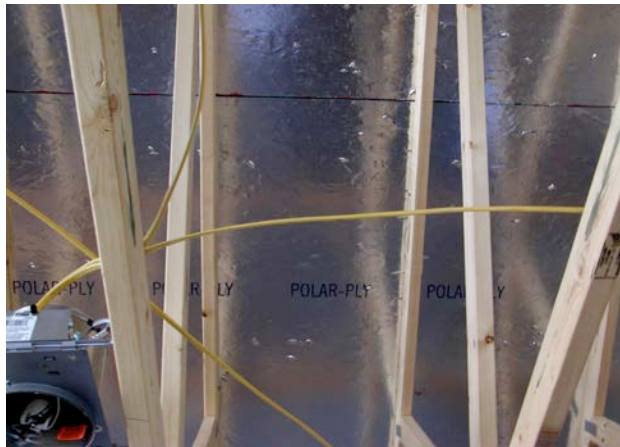


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Hourly Maximim Roof Deck Temperature

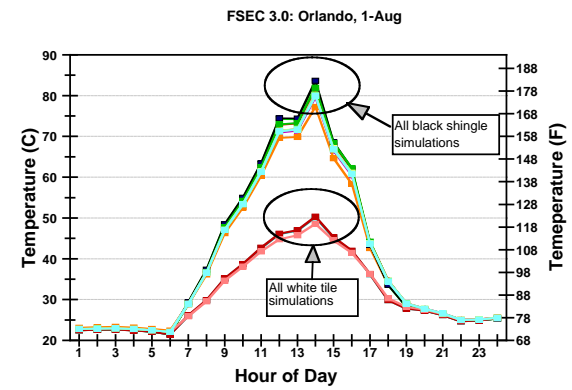


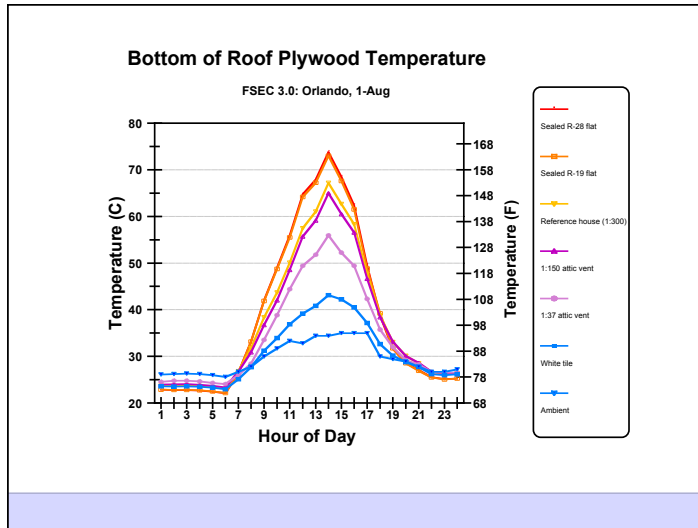
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59

Roof Shingle Temperature





Open Cell vs Closed Cell

Conditioned Attics Not Unvented Attics
Must Have a Supply and a Return Path

Conditioned Attics Not Unvented Attics
Must Have a Supply and a Return Path
In IECC Climate Zone 5 or Higher You Must
Have a Class II Vapor Retarder

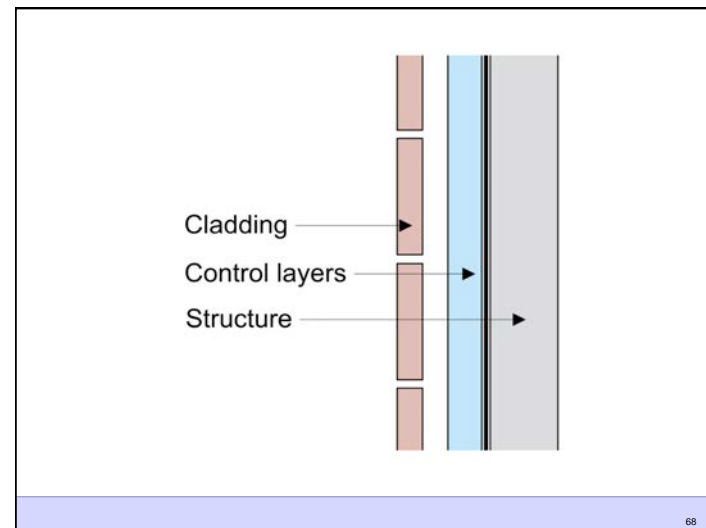
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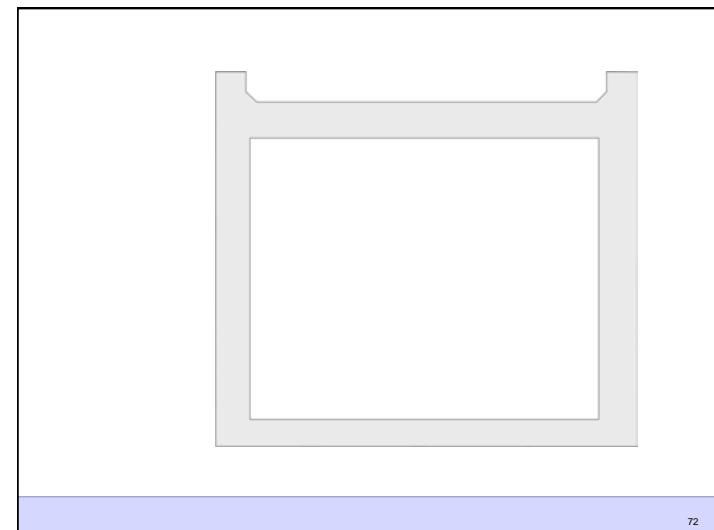
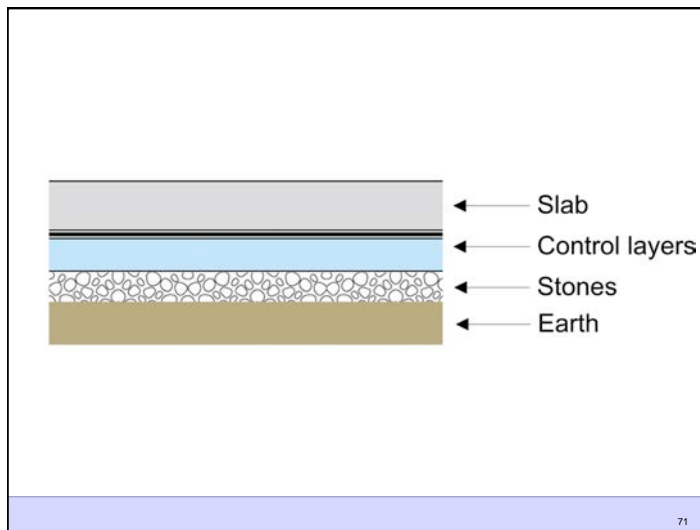
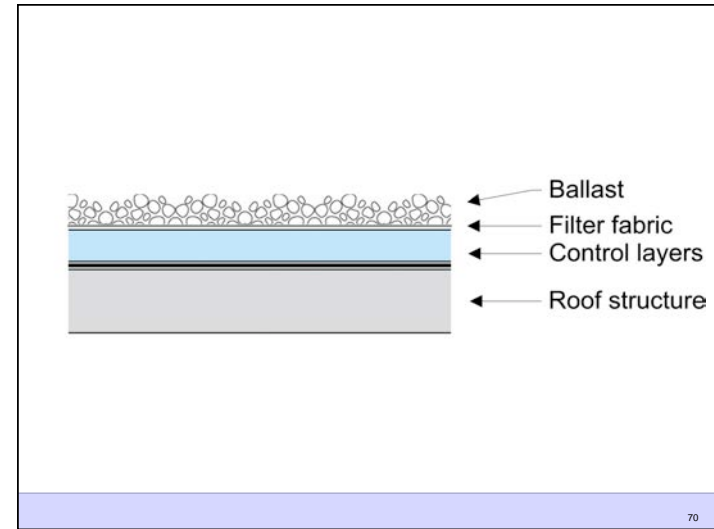
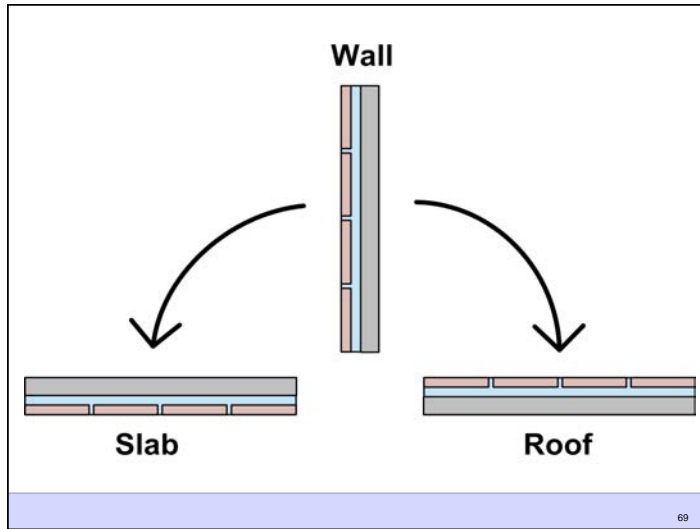
The Perfect Wall

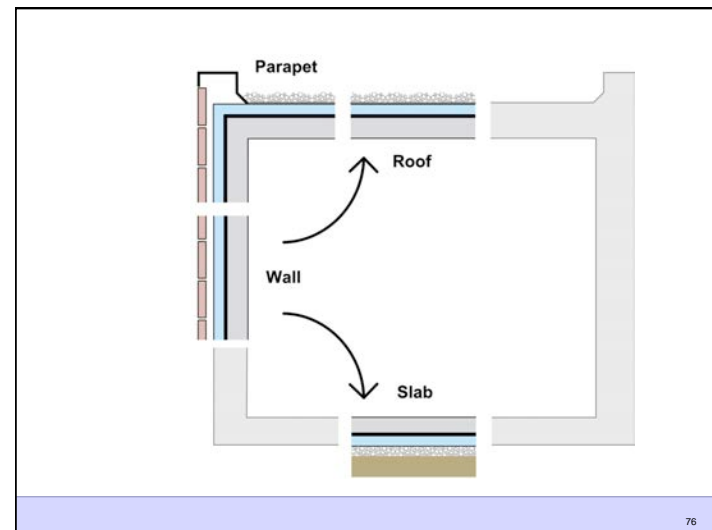
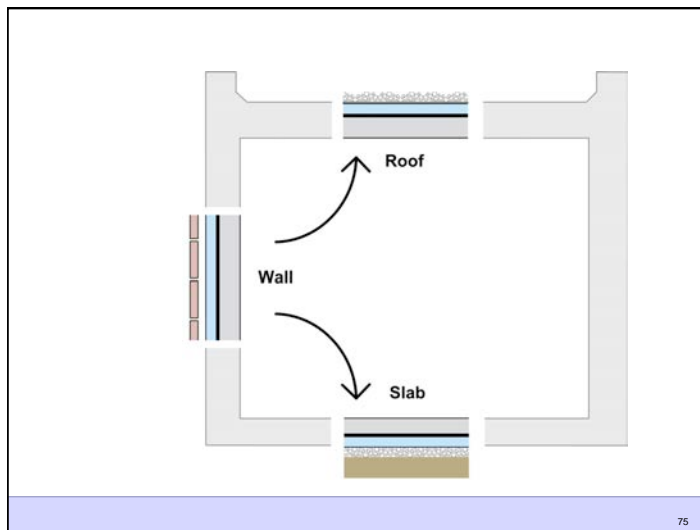
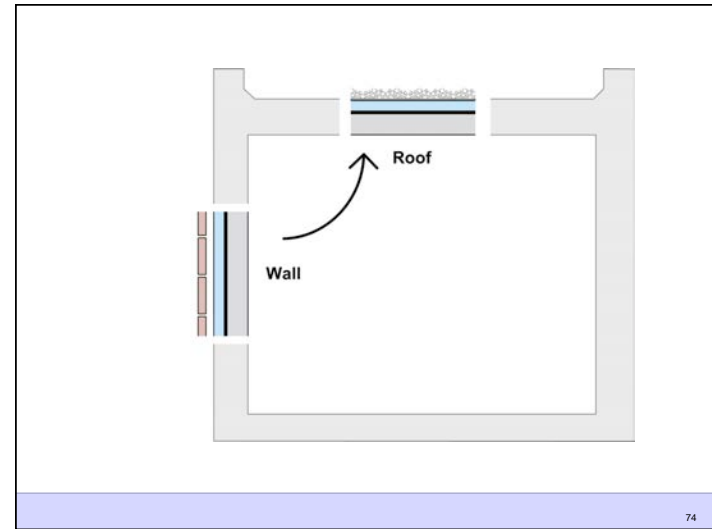
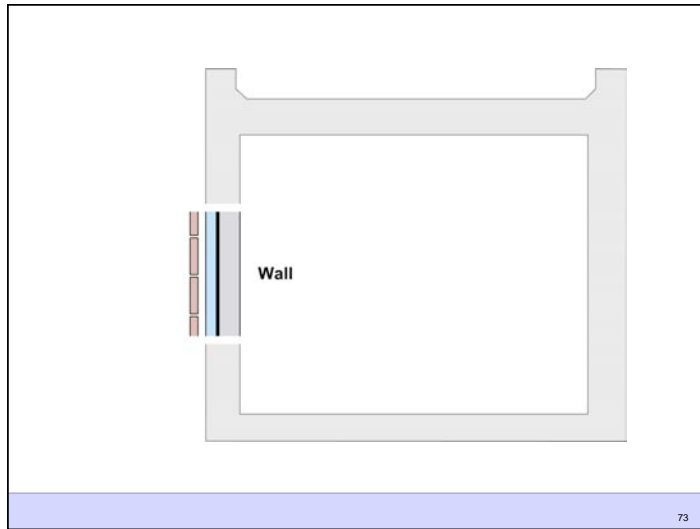
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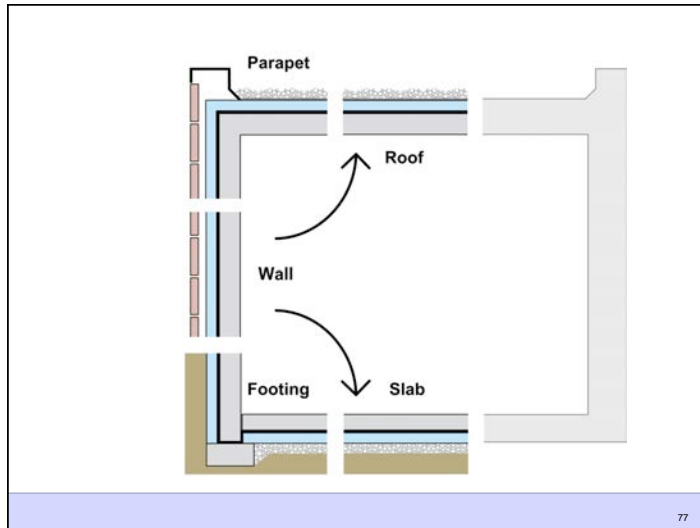
Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

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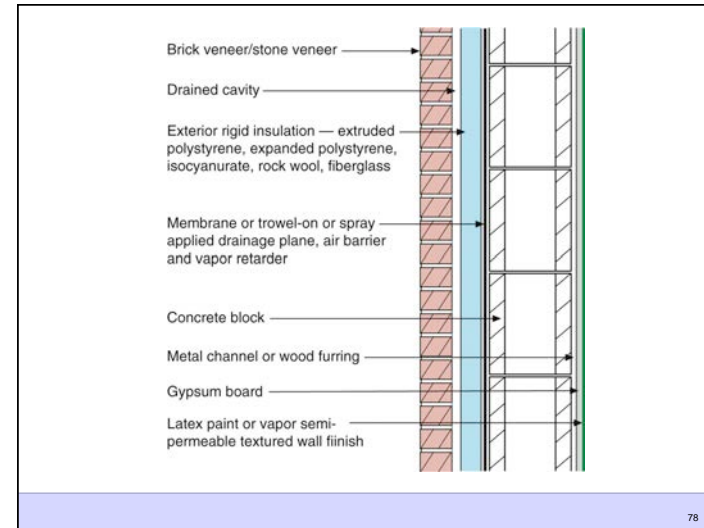




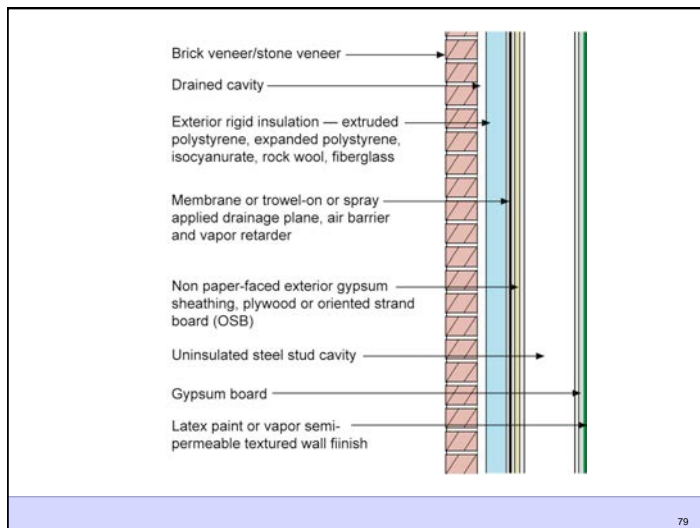




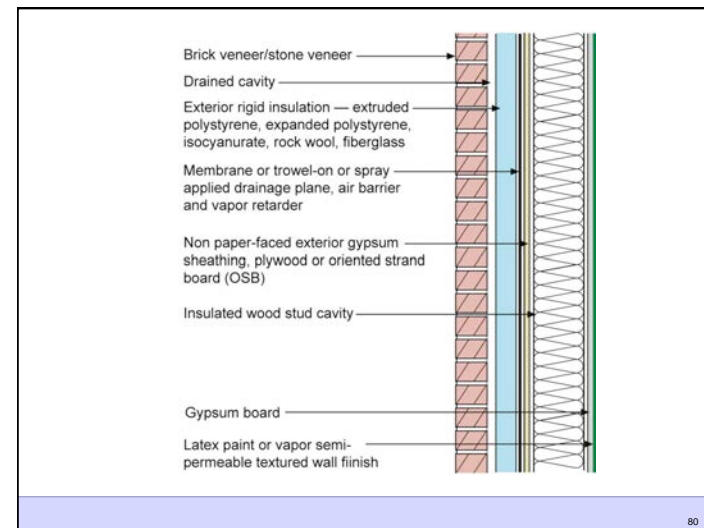
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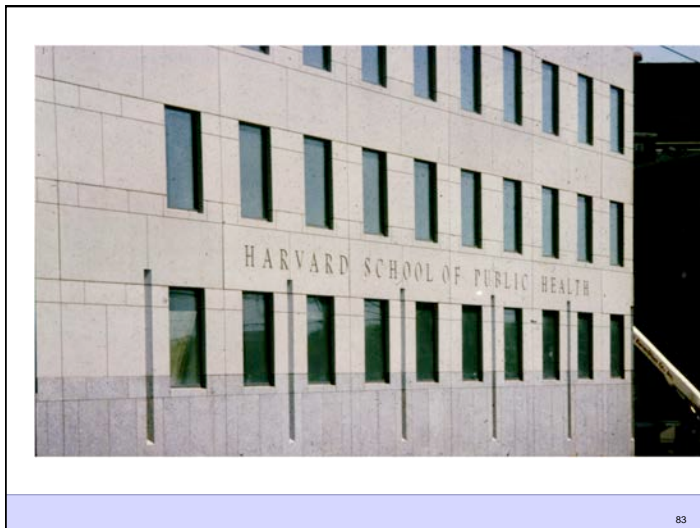
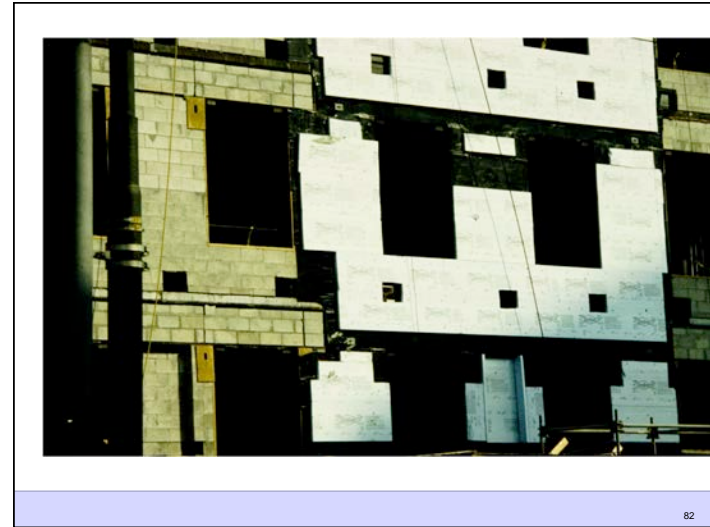
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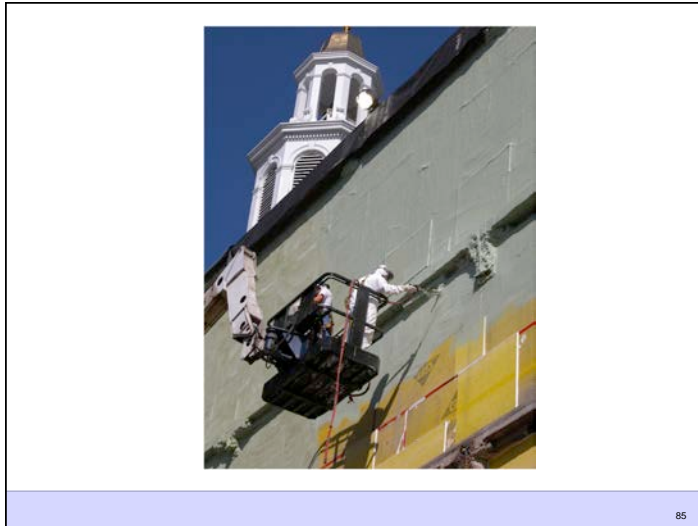


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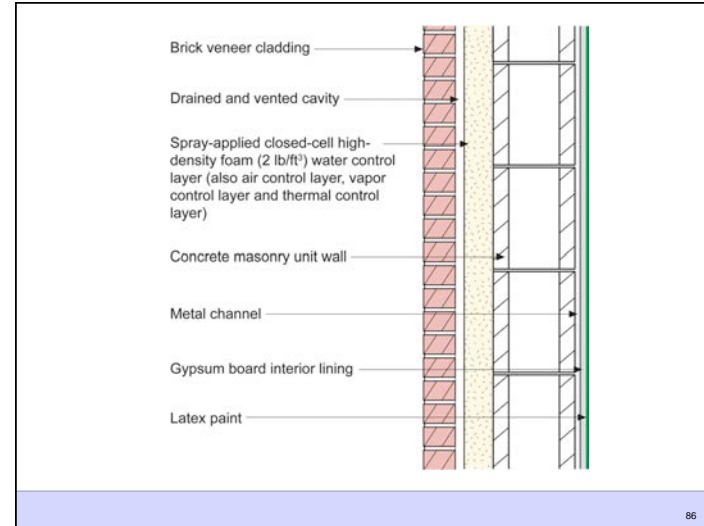


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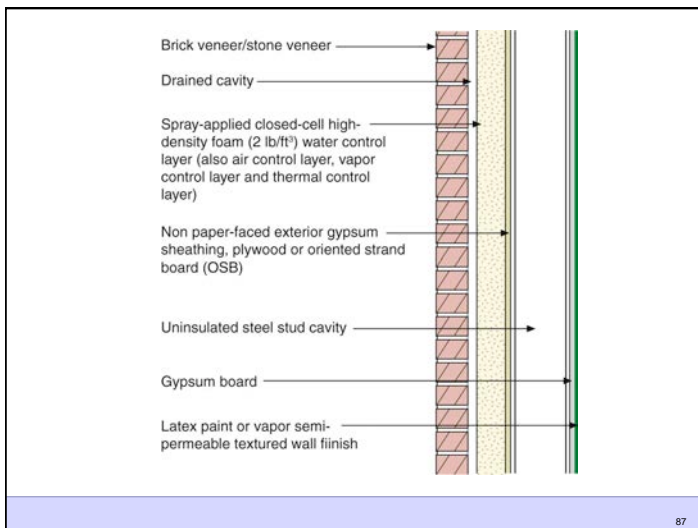




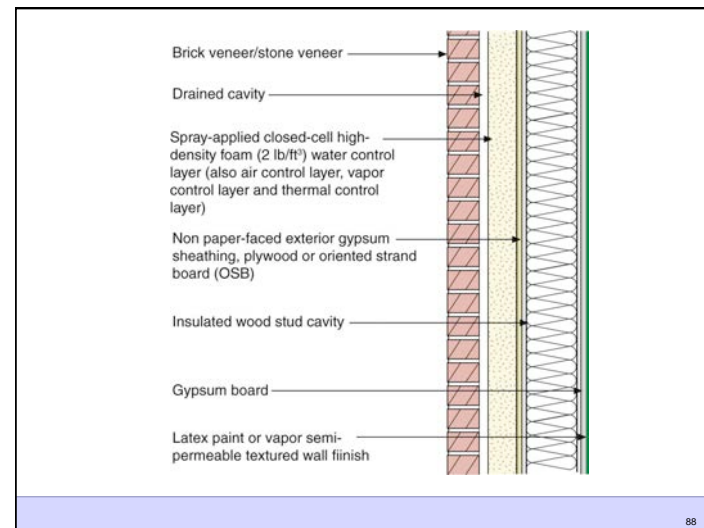
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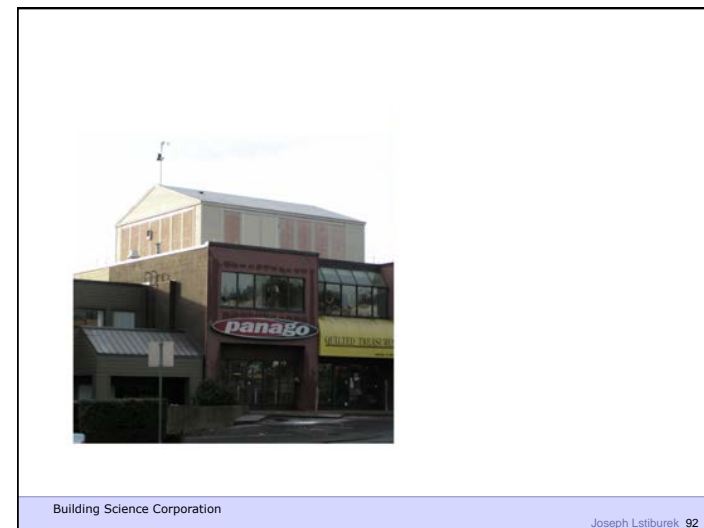
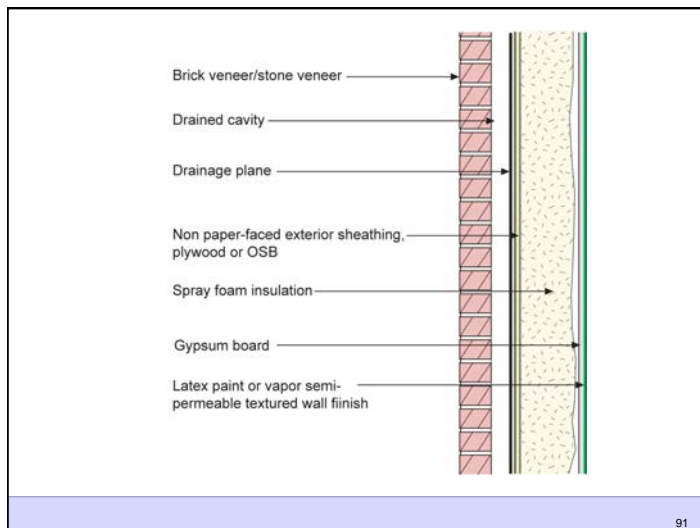
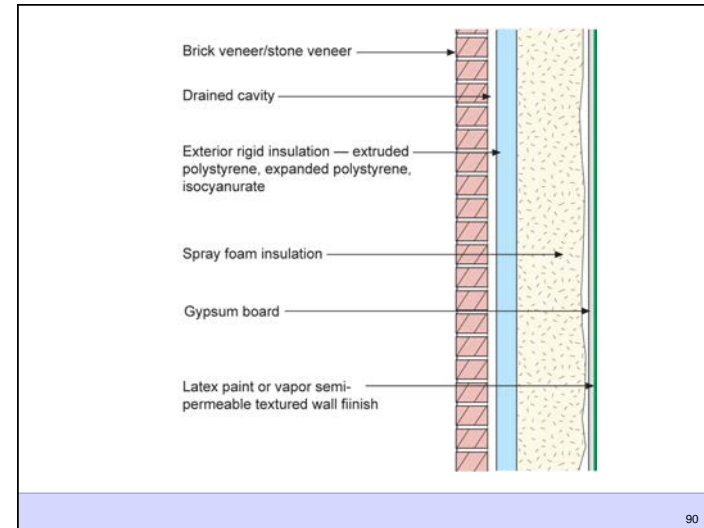
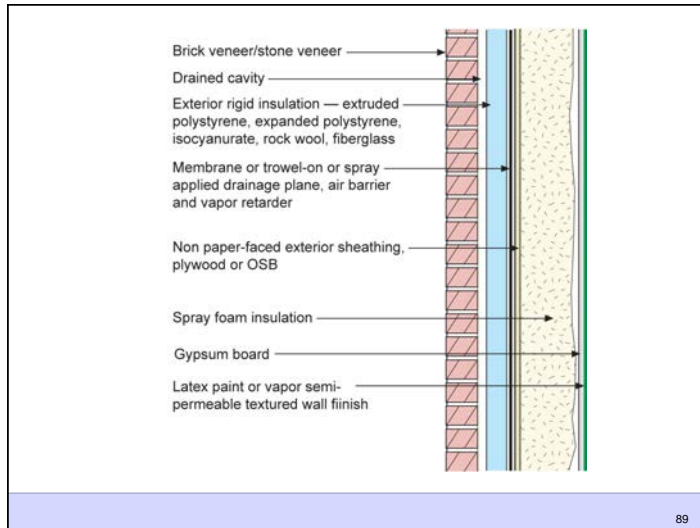
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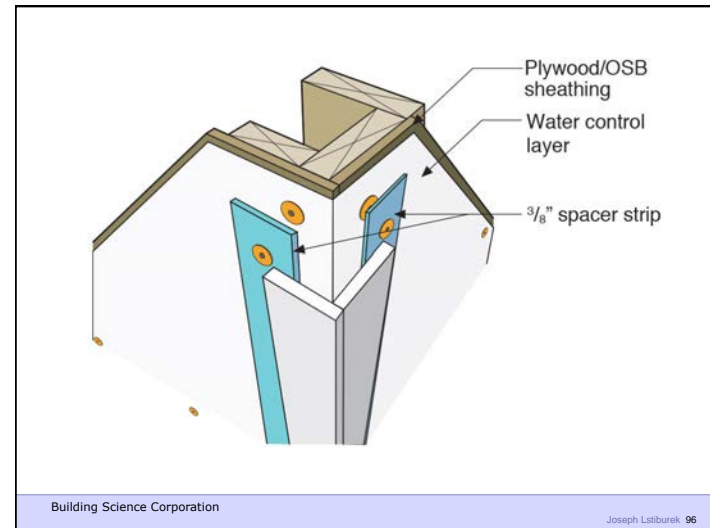
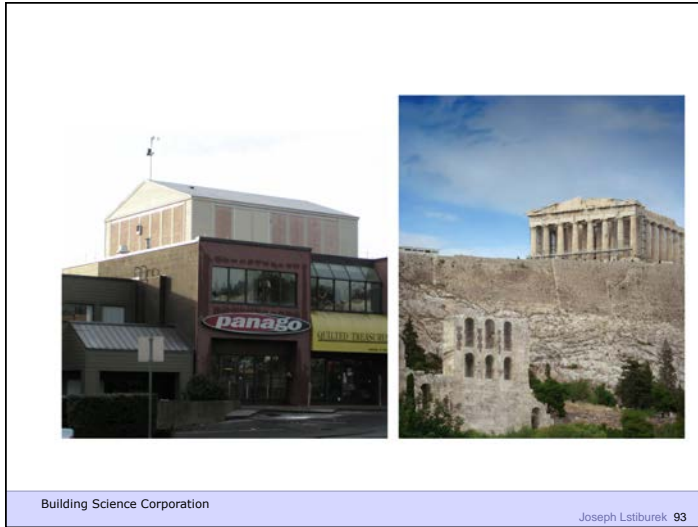


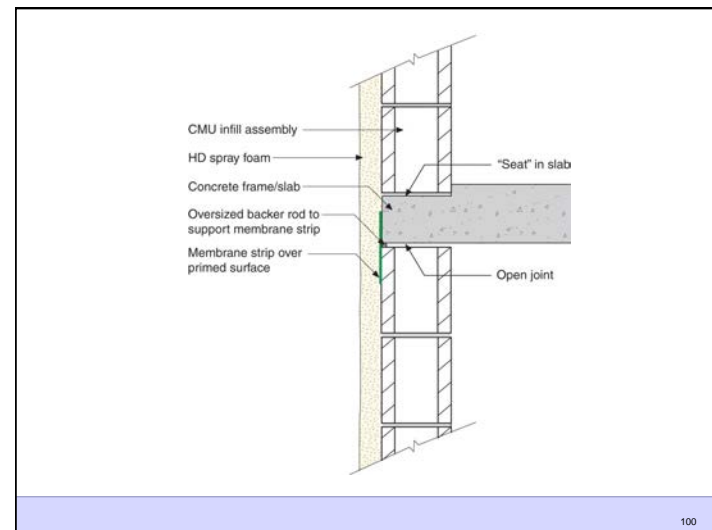
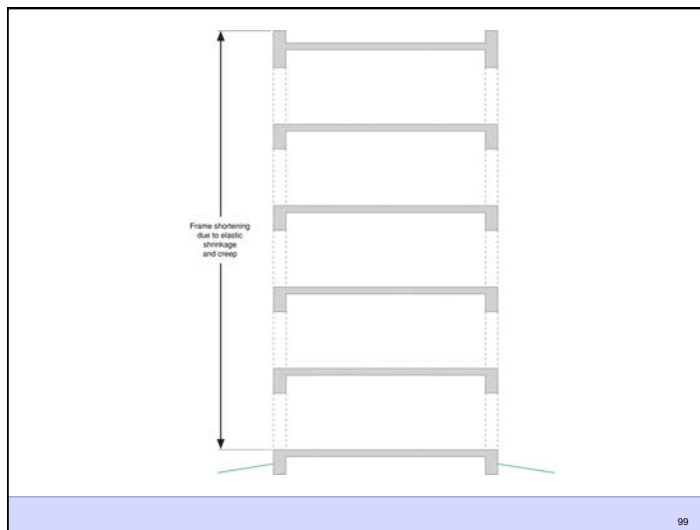
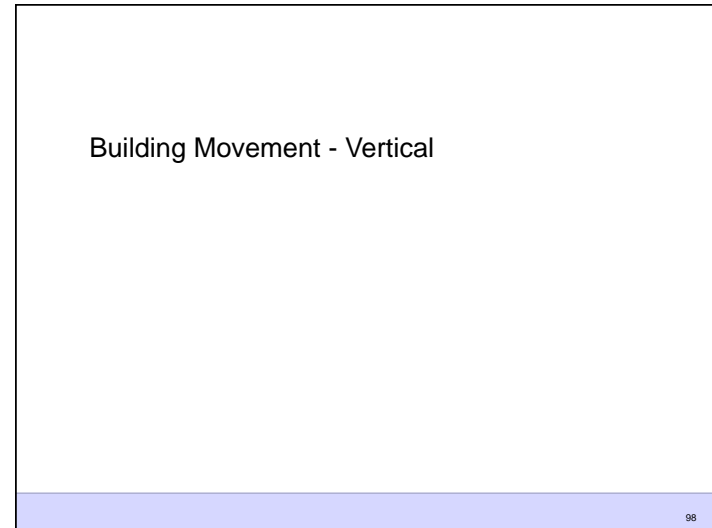
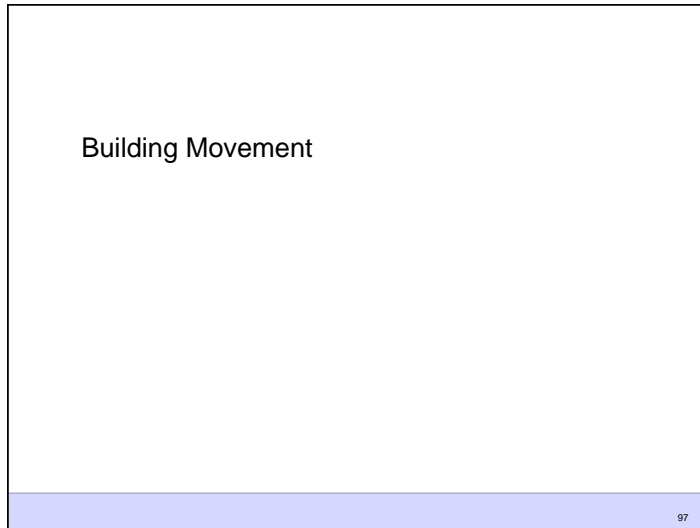
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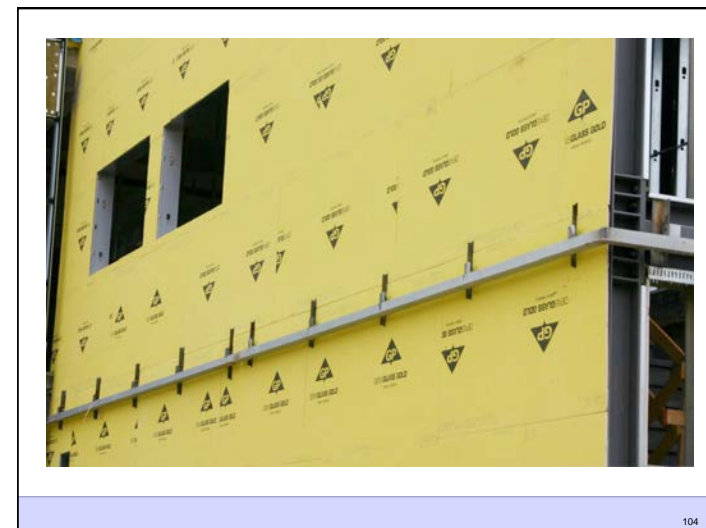
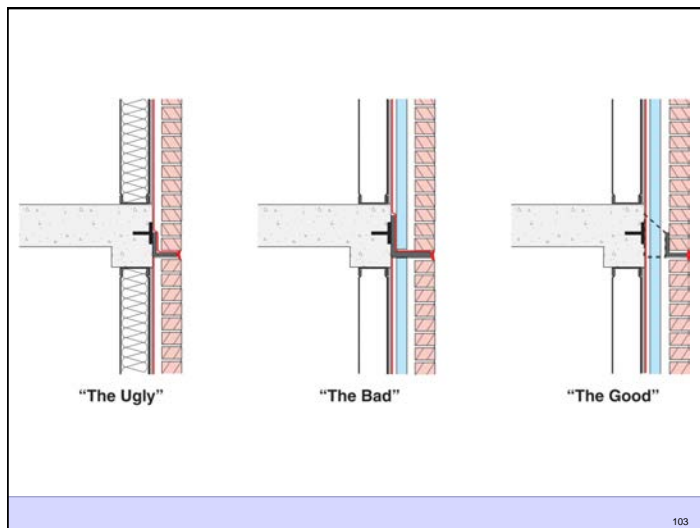
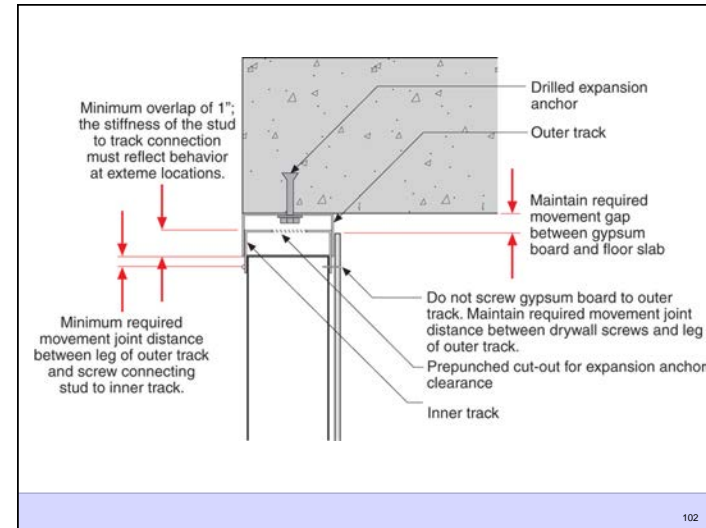
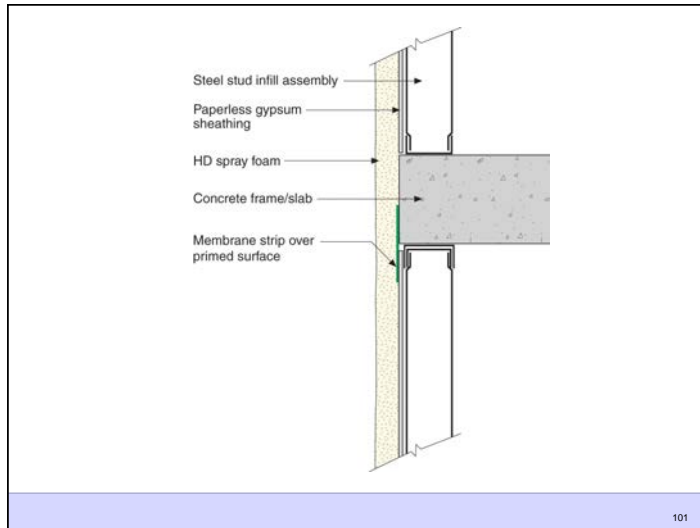


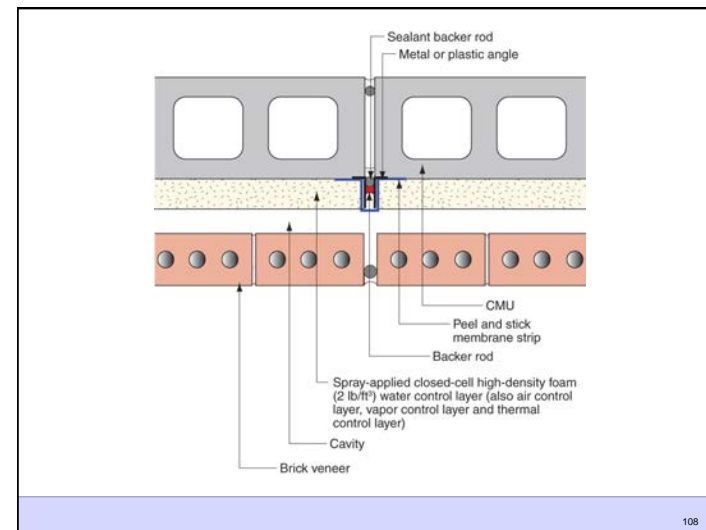
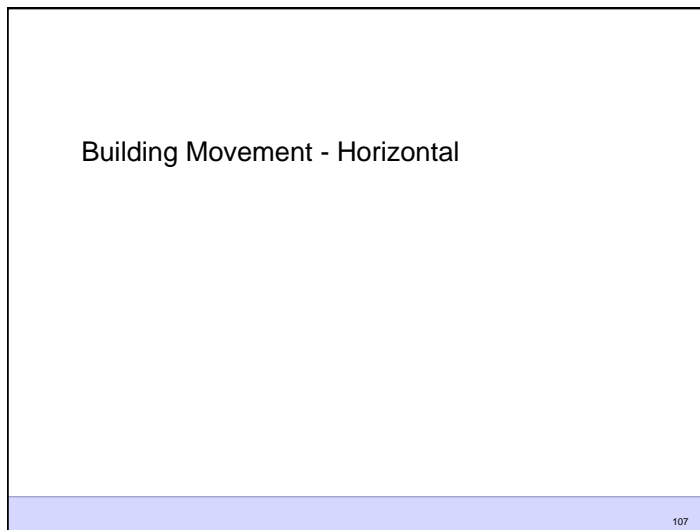
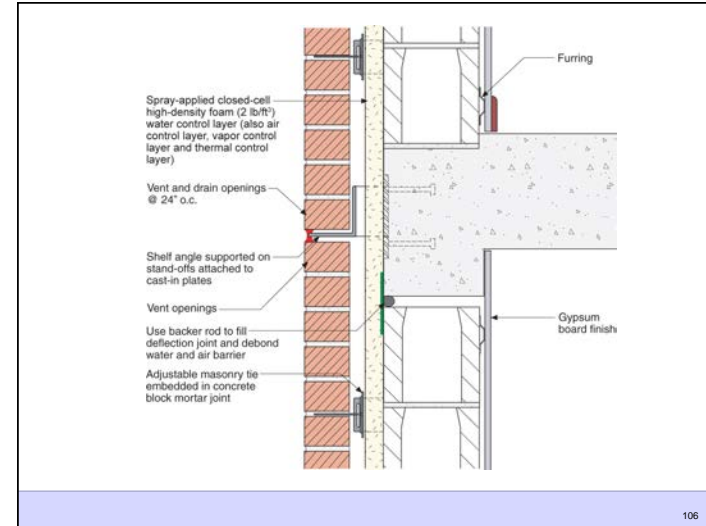
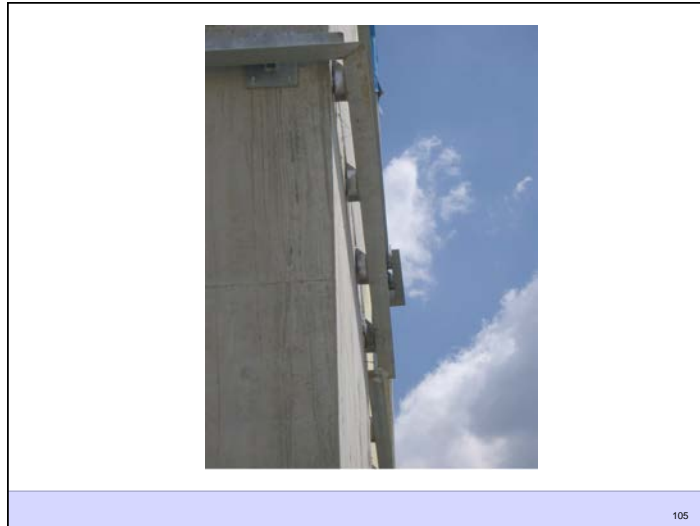
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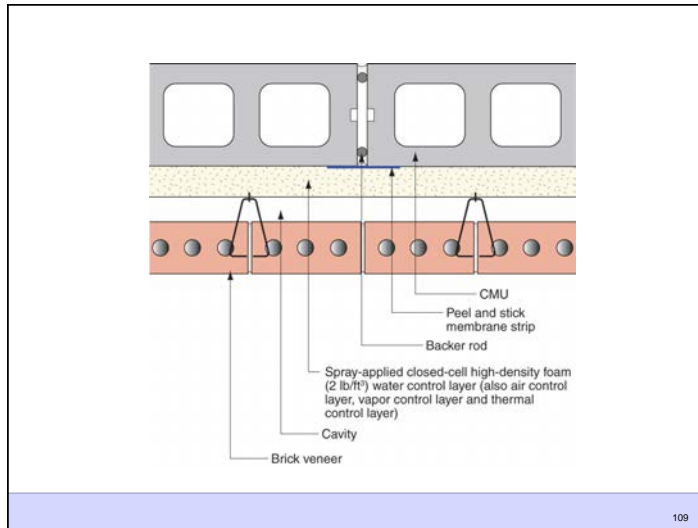






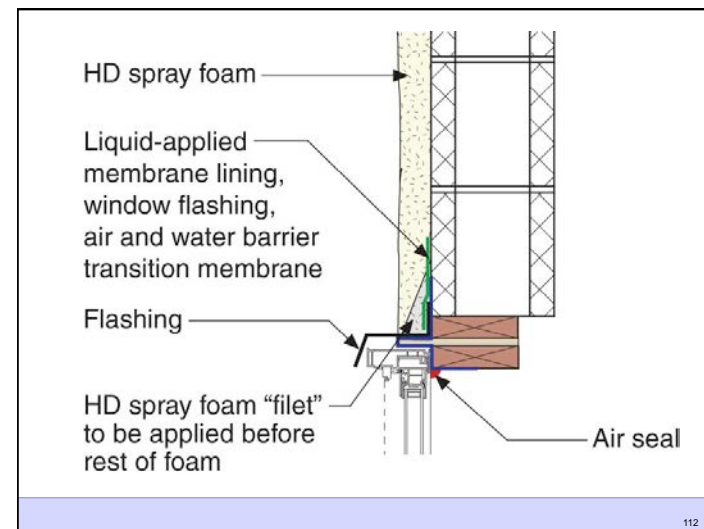
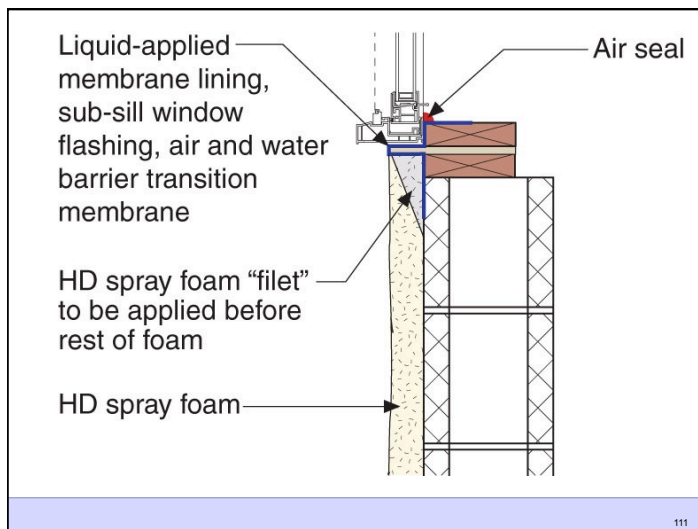


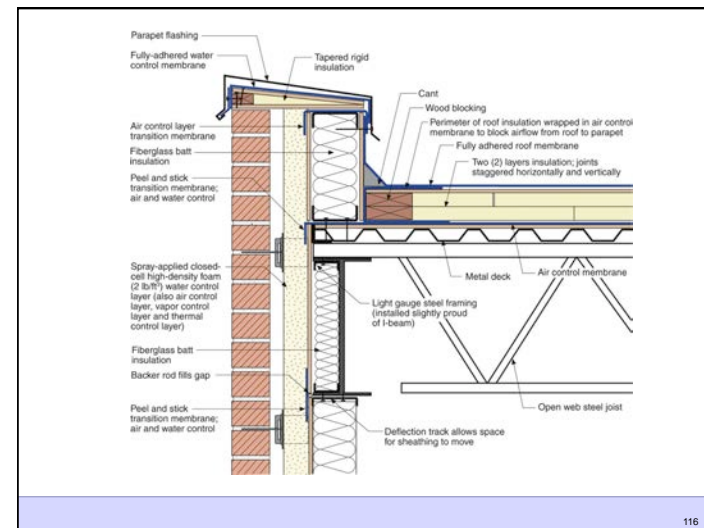
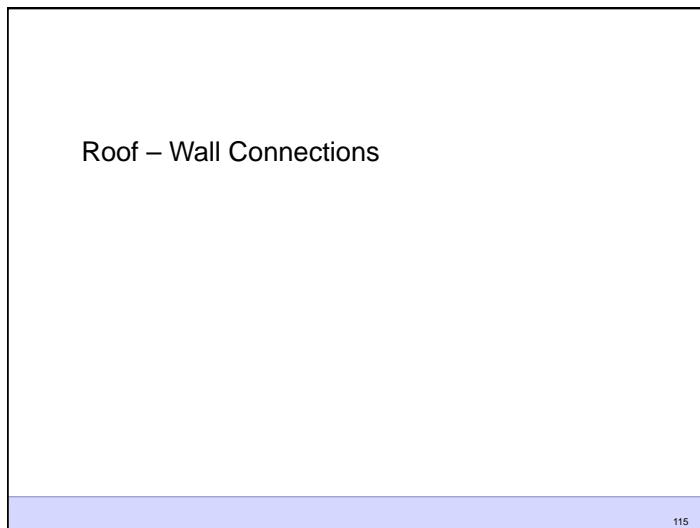
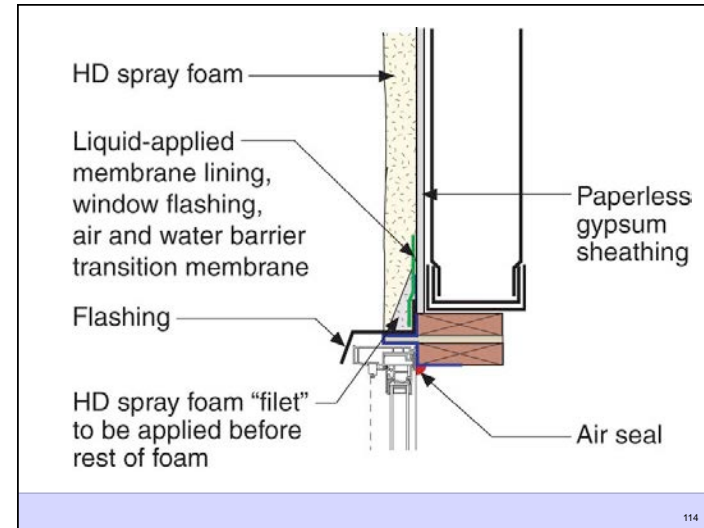
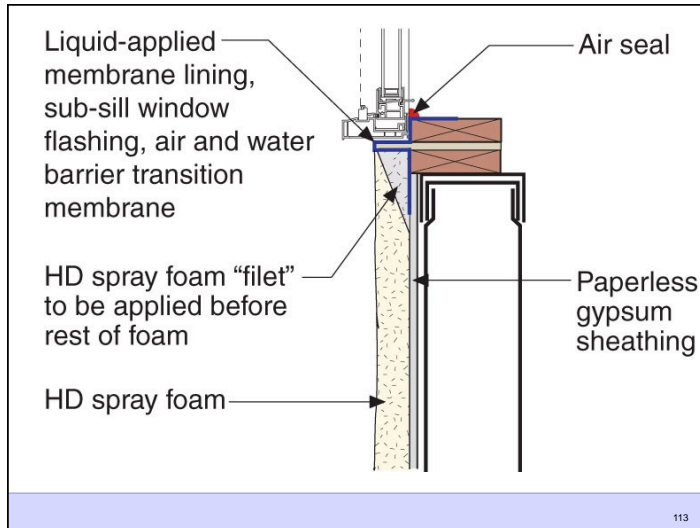


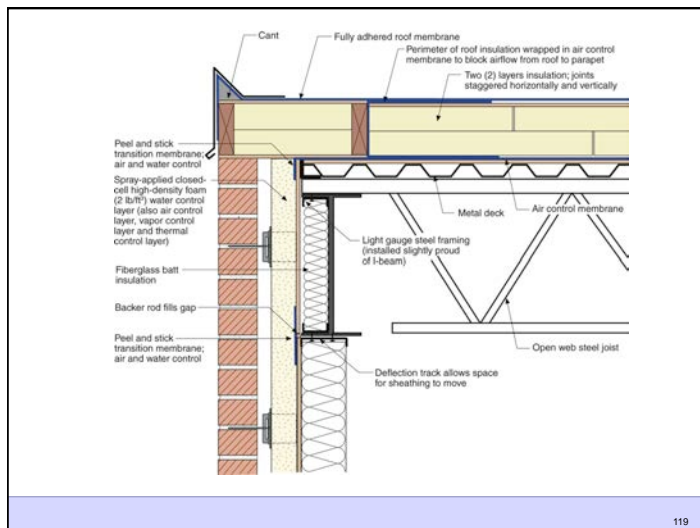
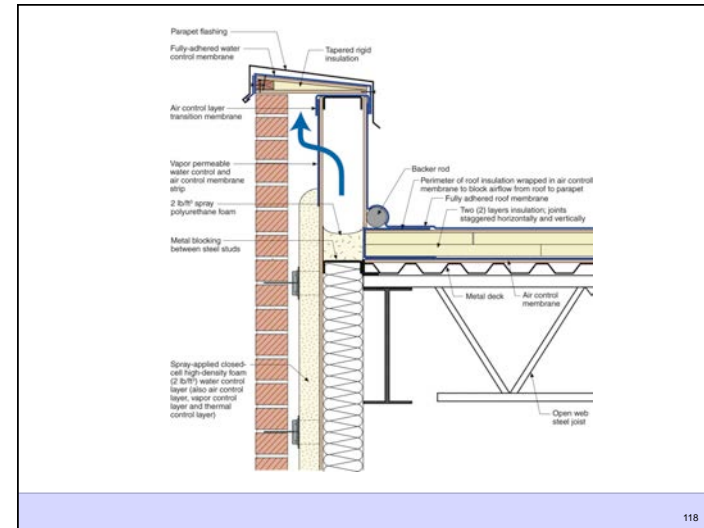
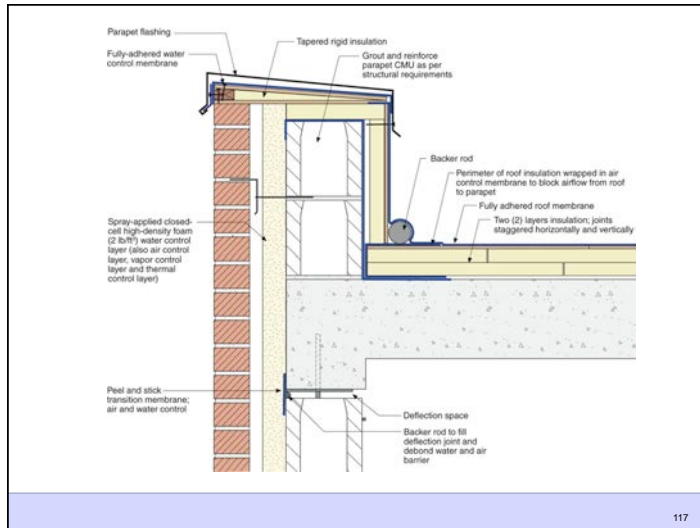


“Punched” Openings

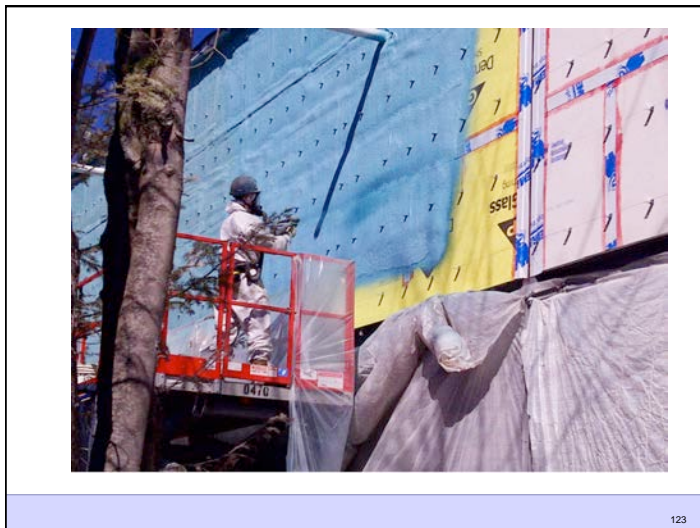
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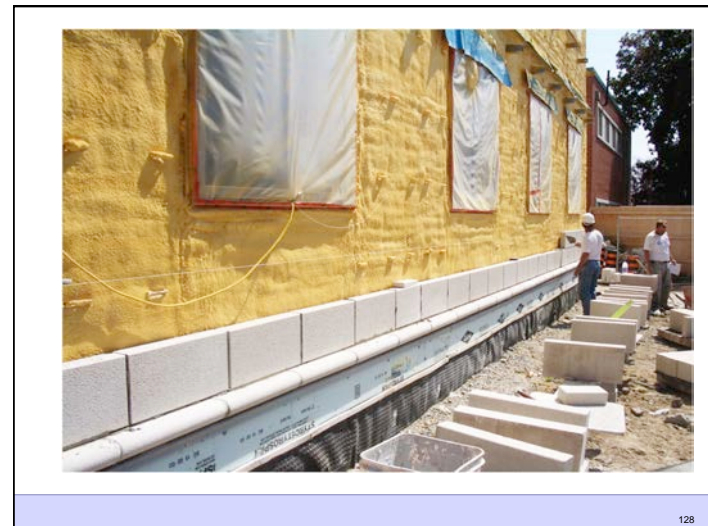
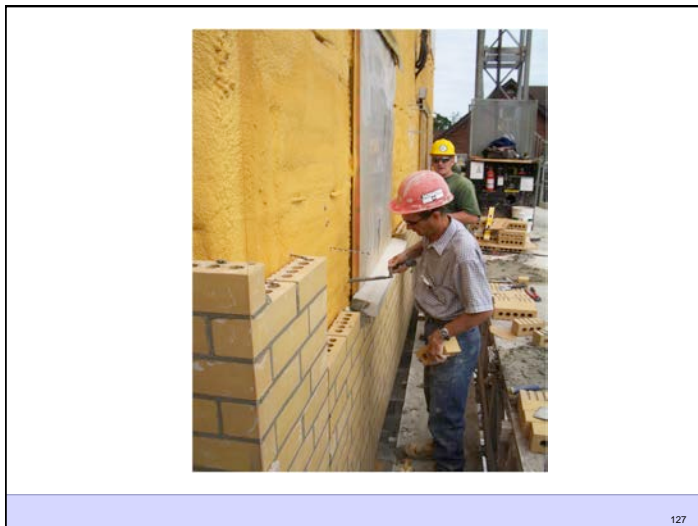
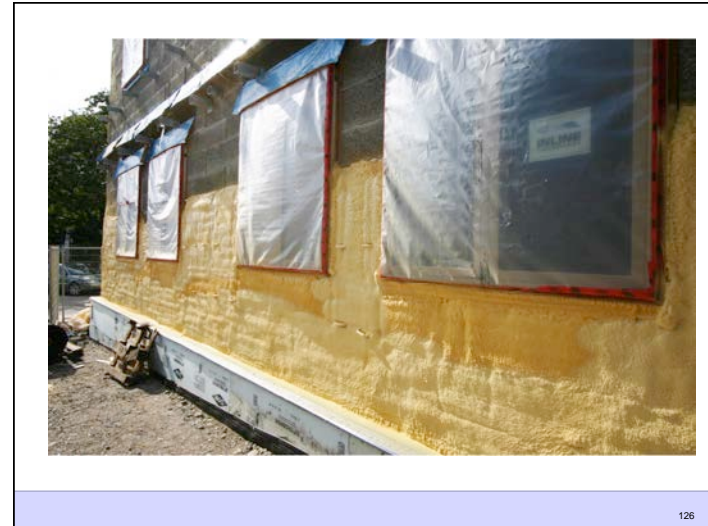


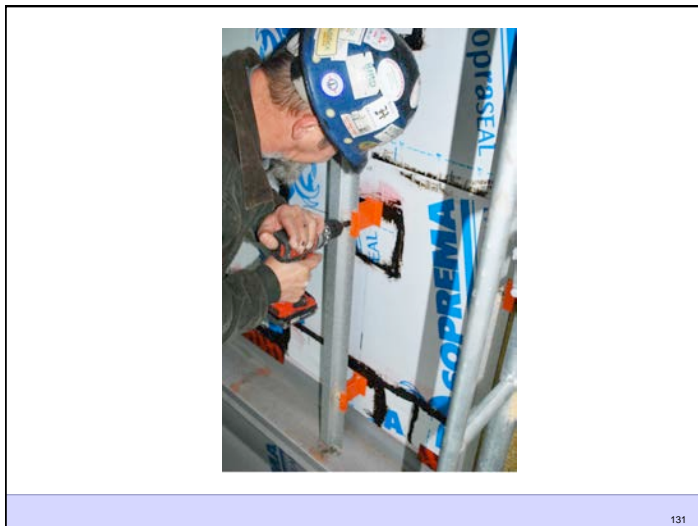


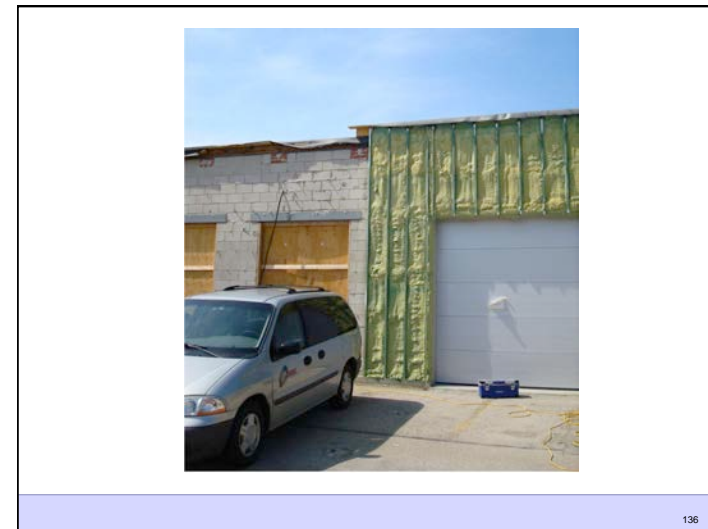
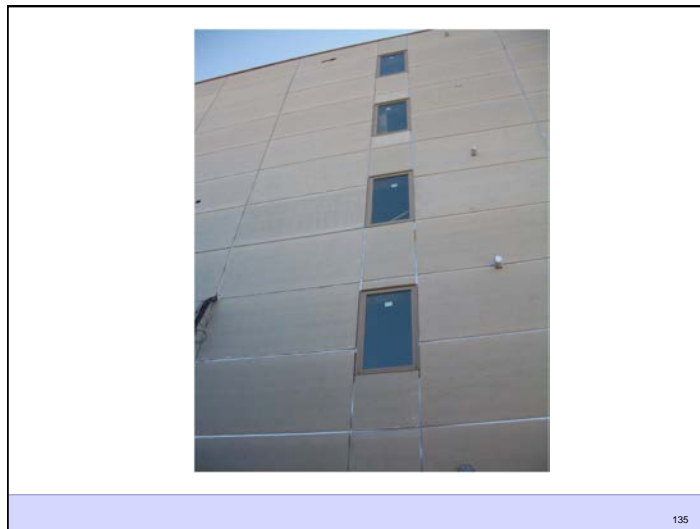
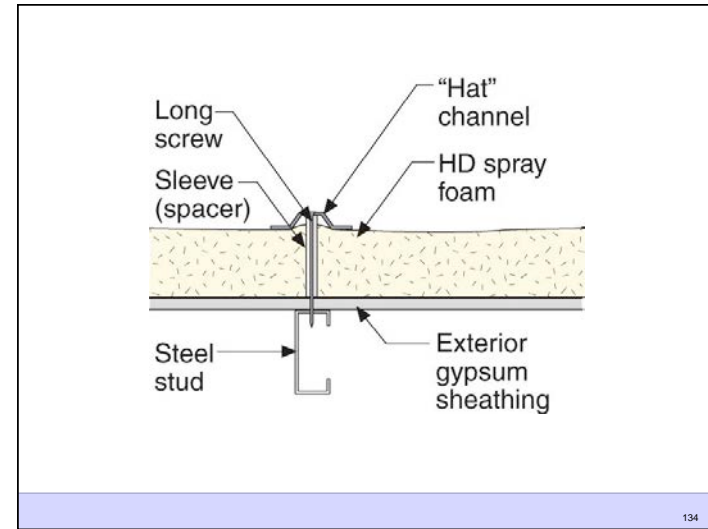
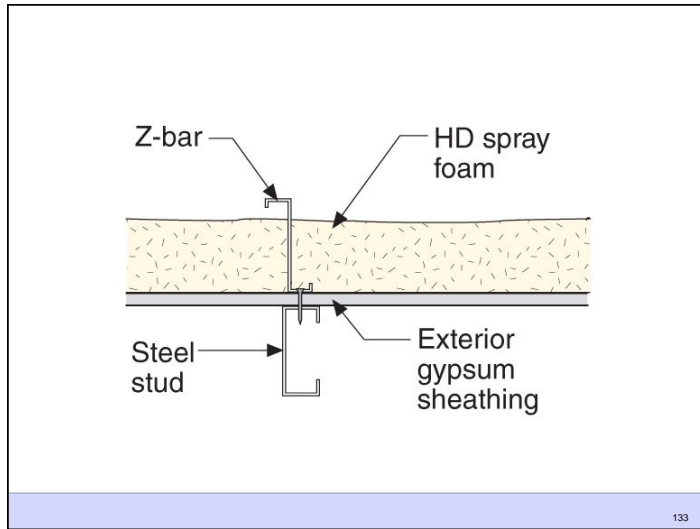


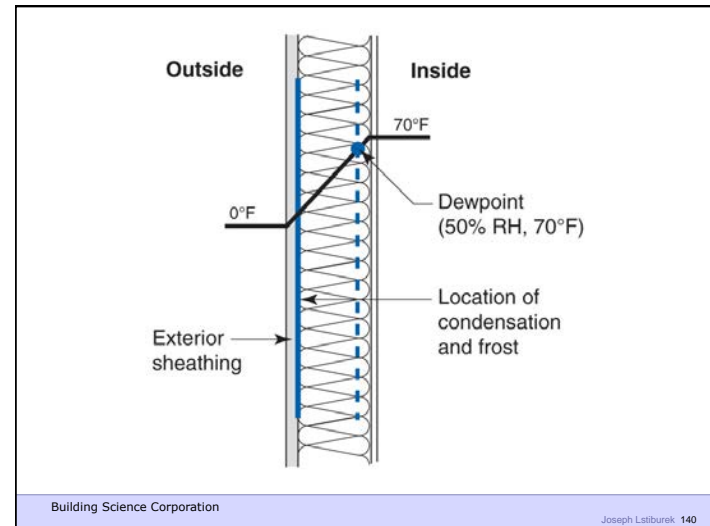
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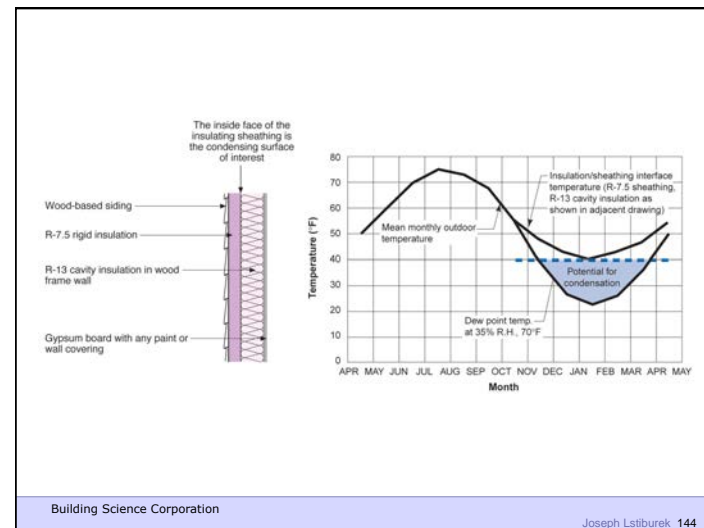
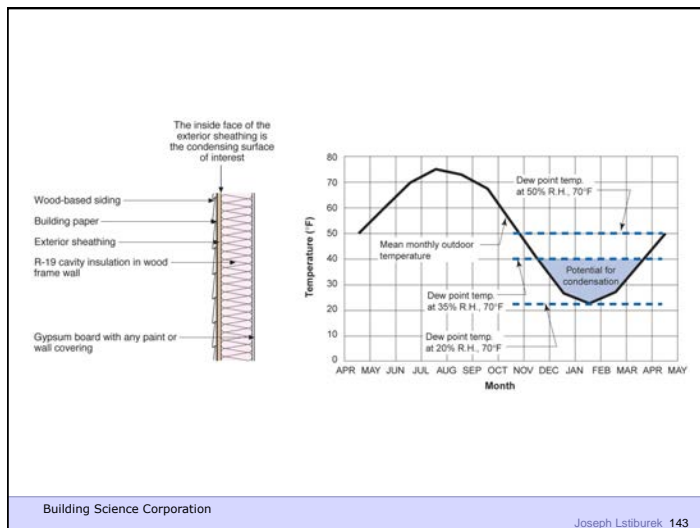
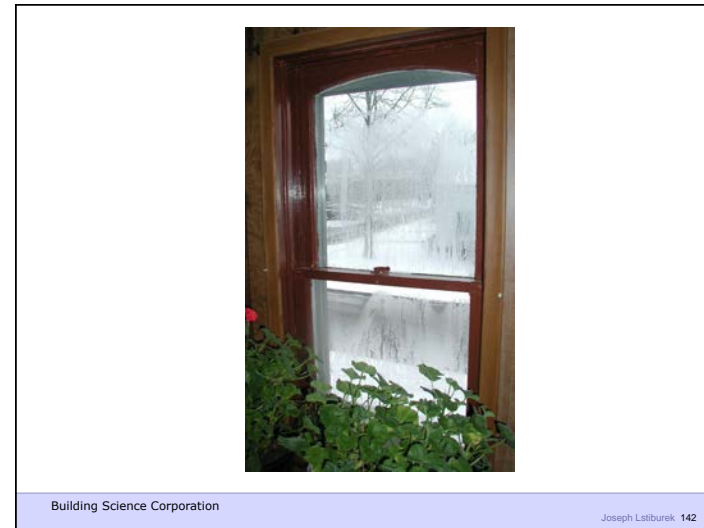


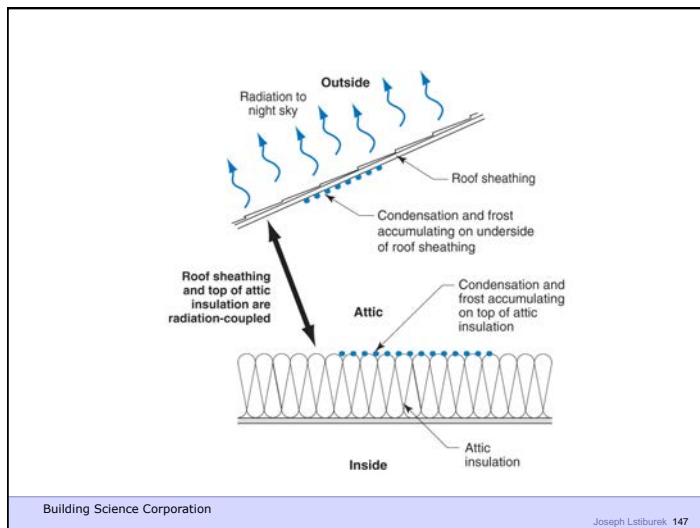
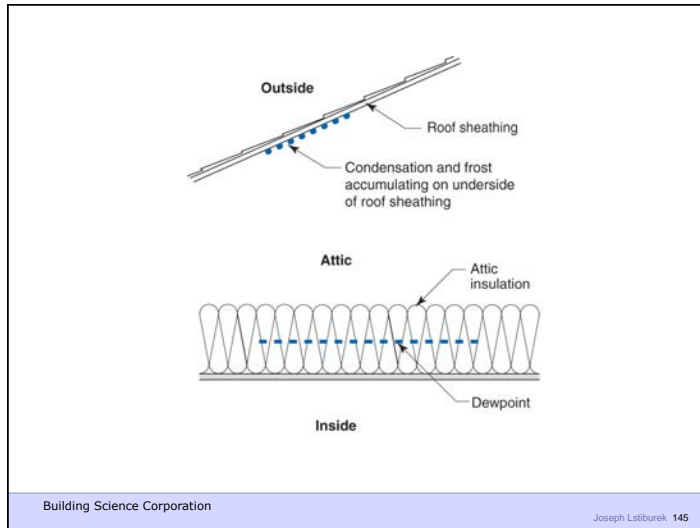


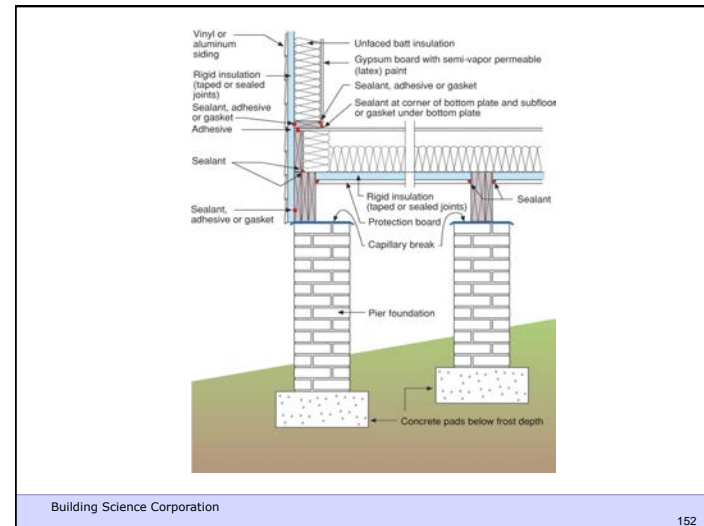
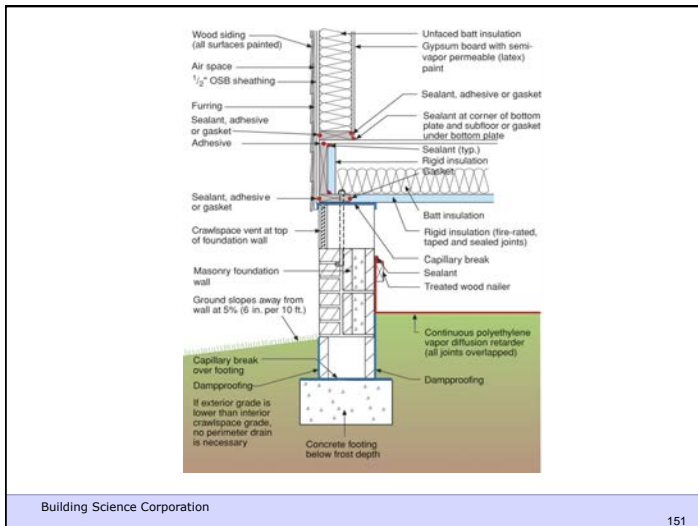
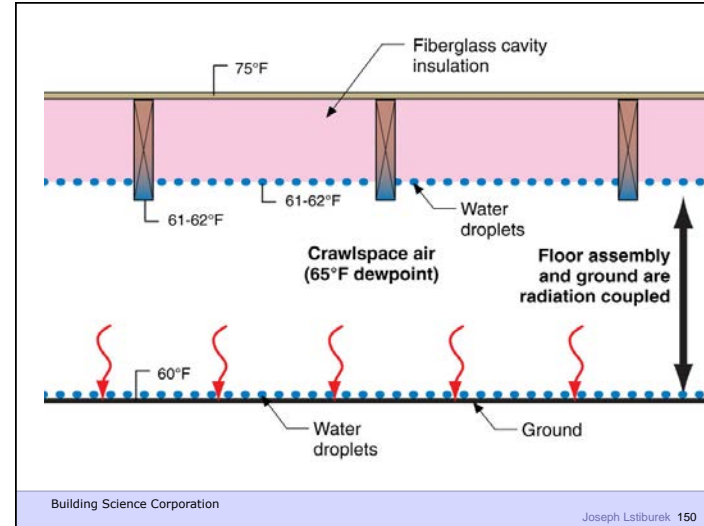


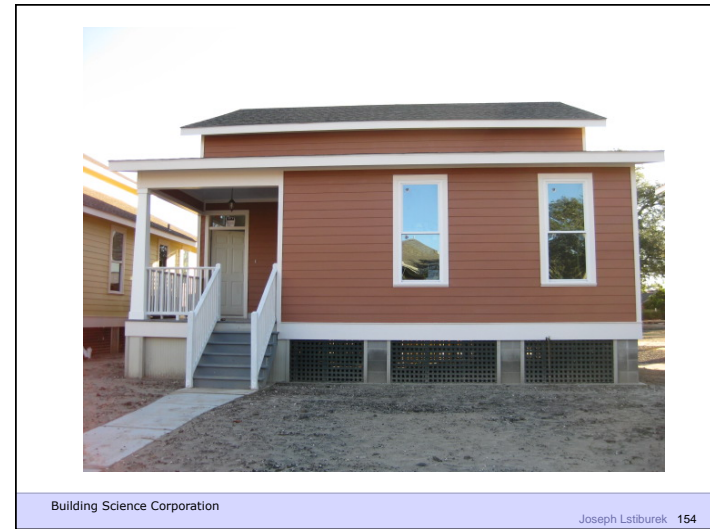
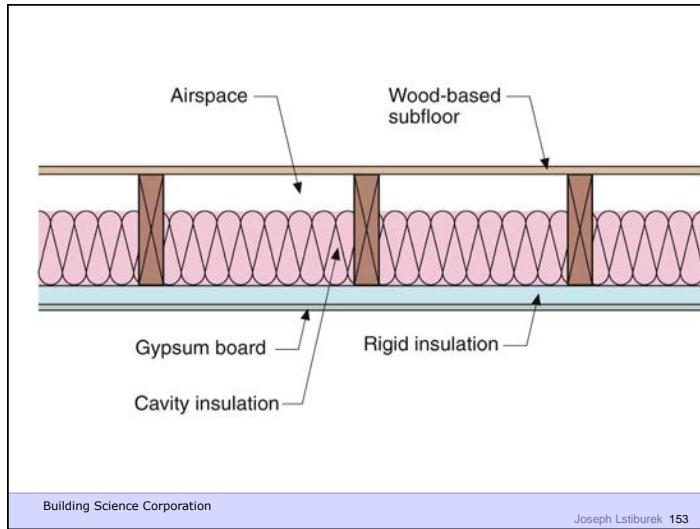


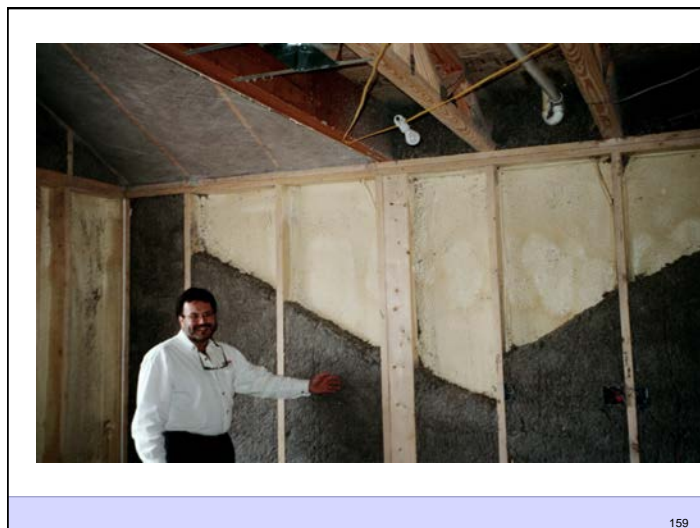
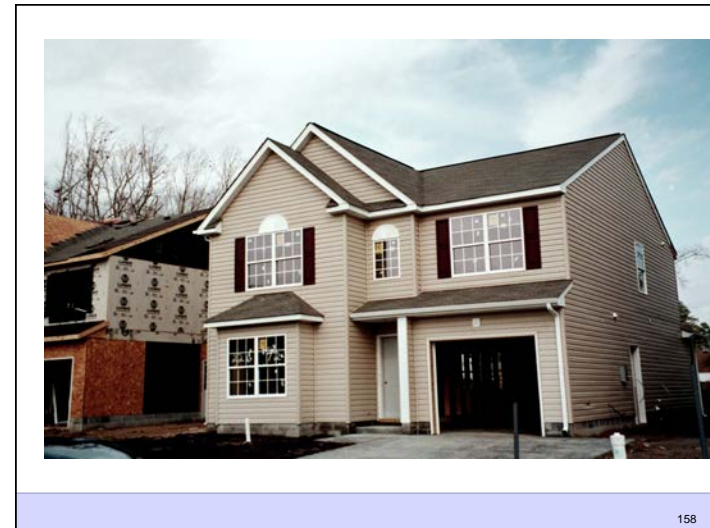
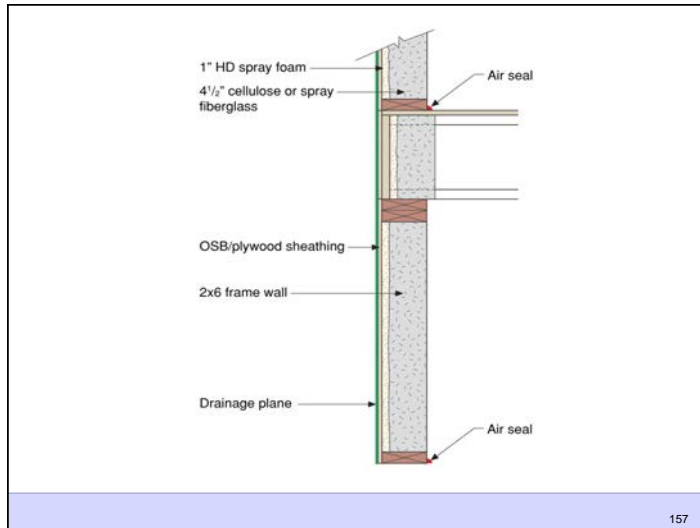


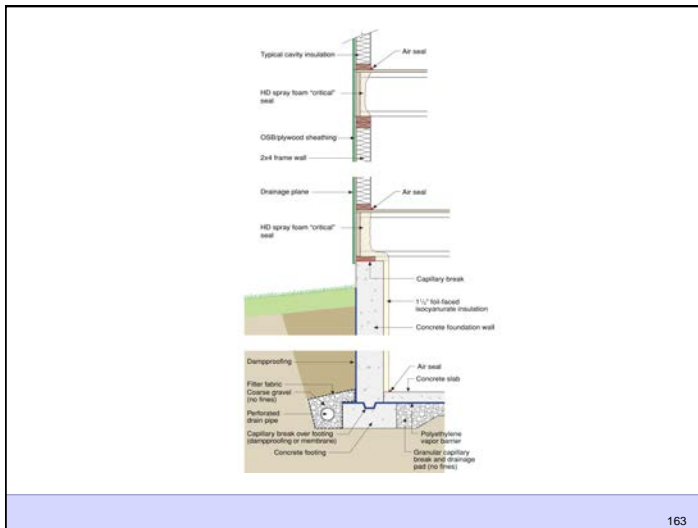


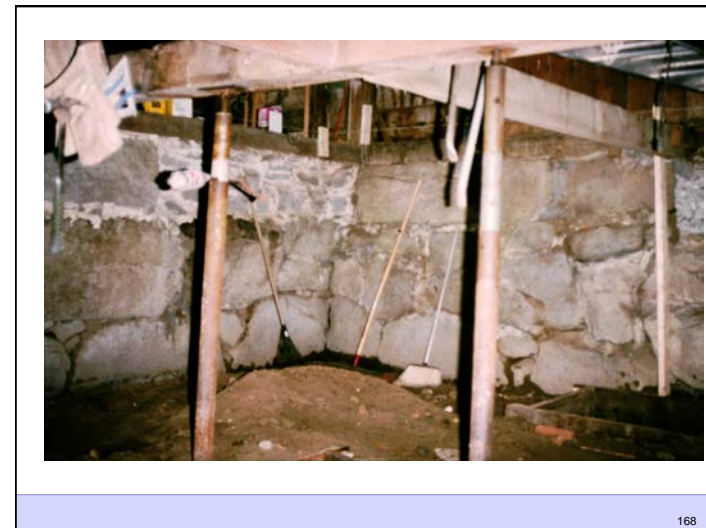
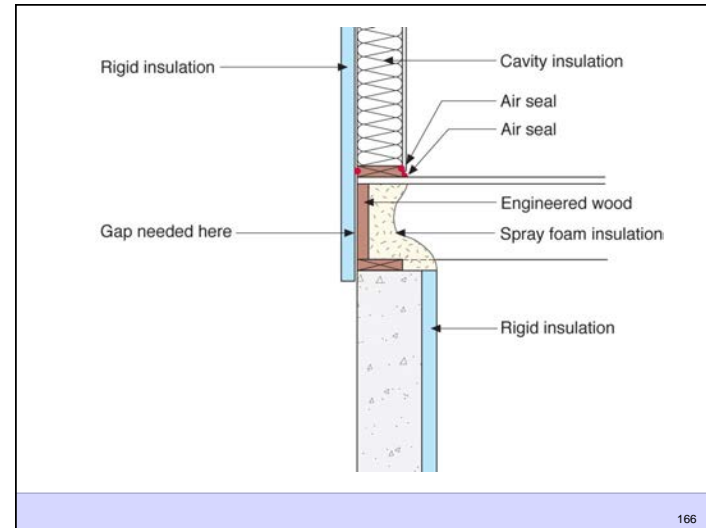
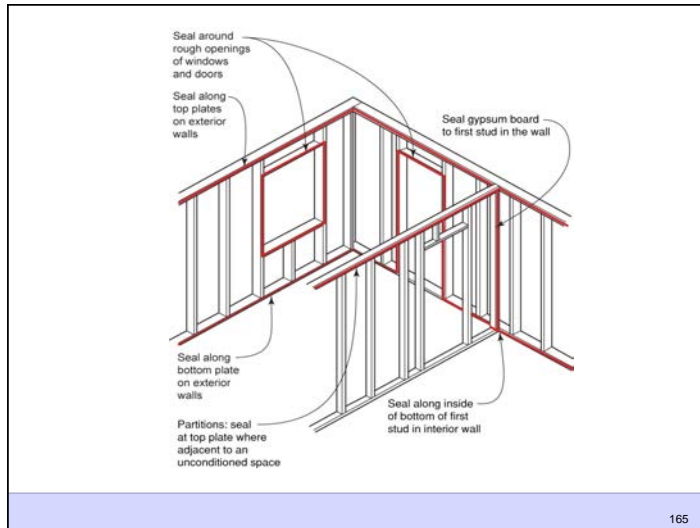


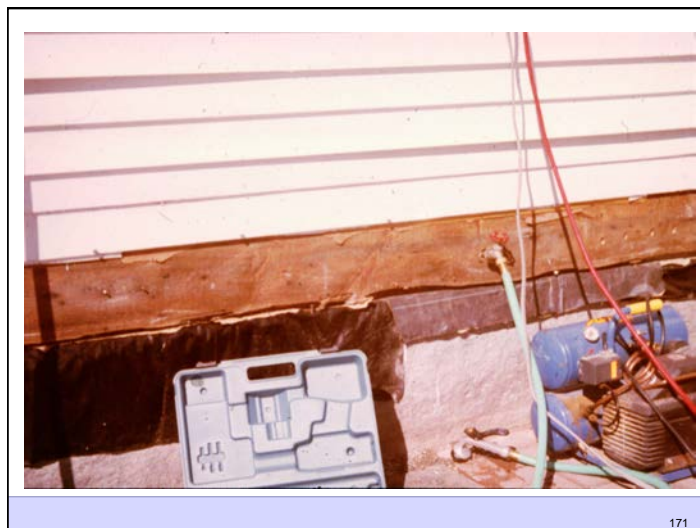
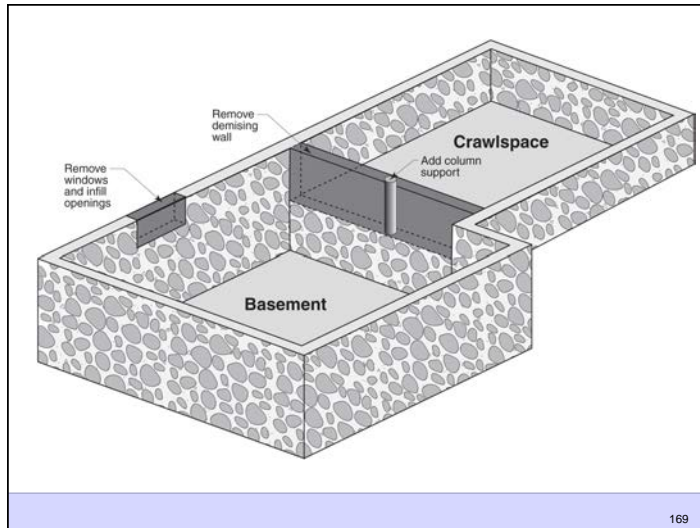


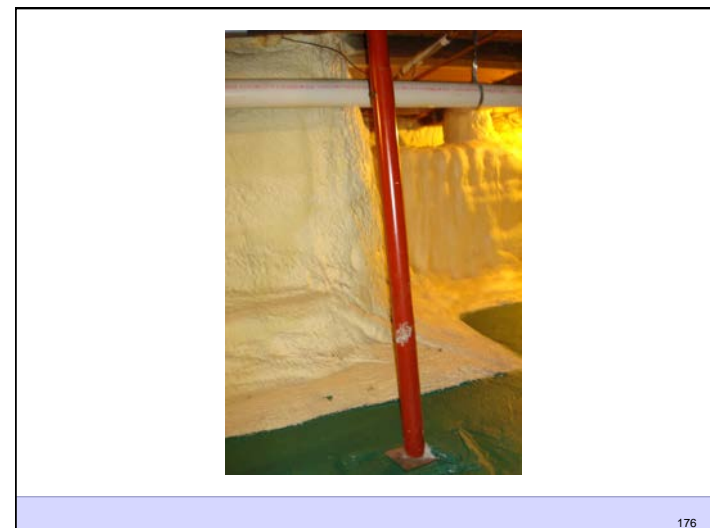
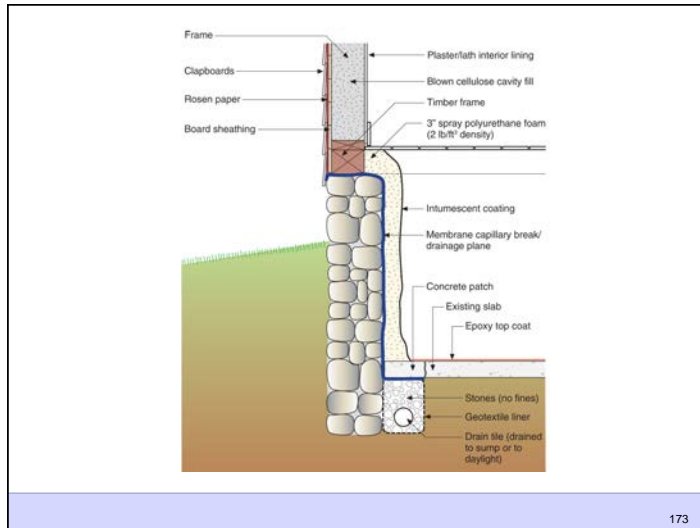


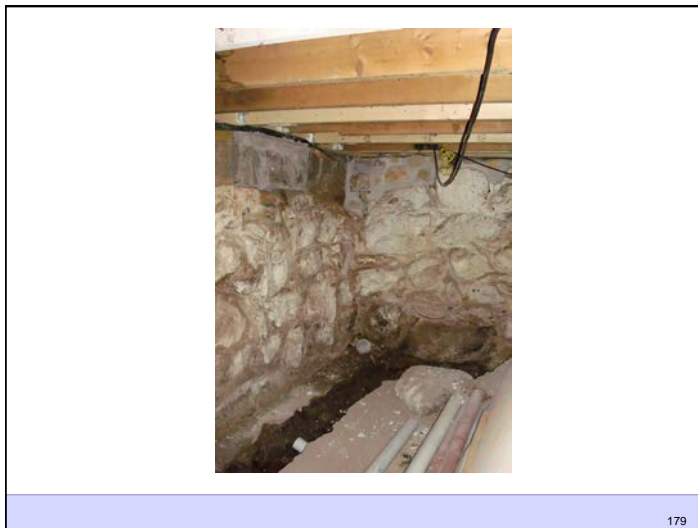
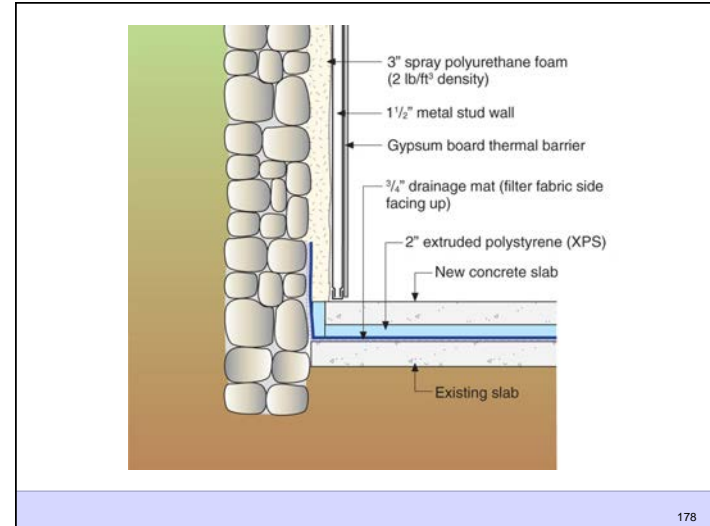


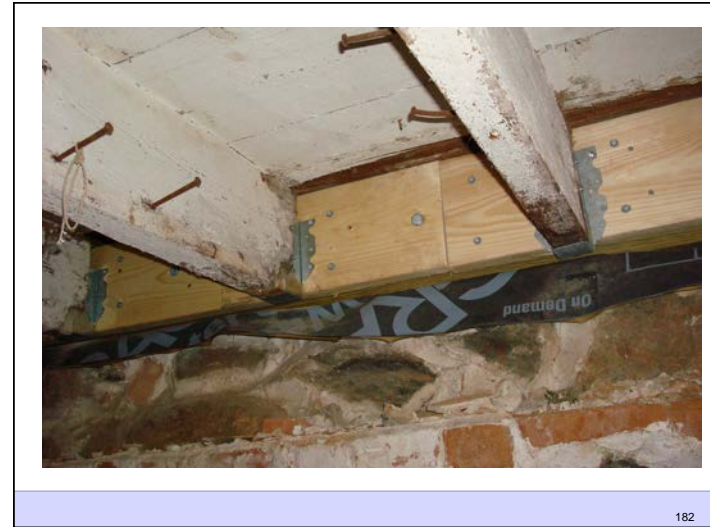
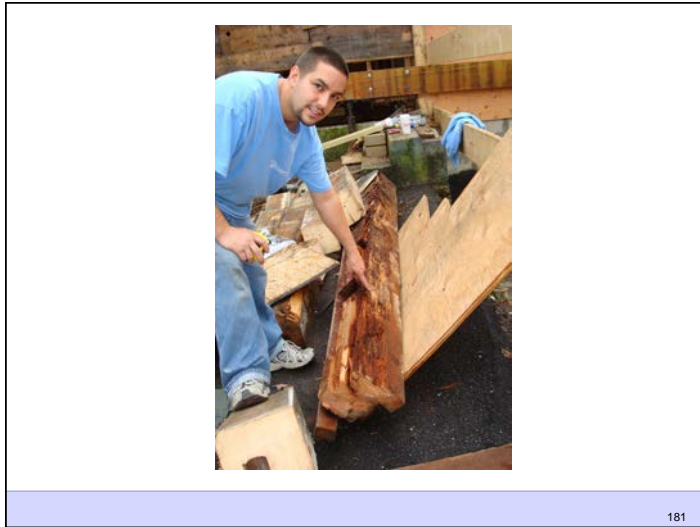




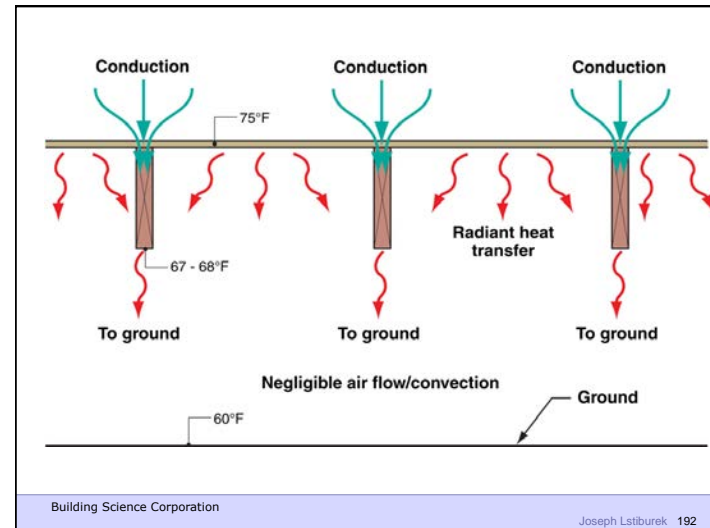
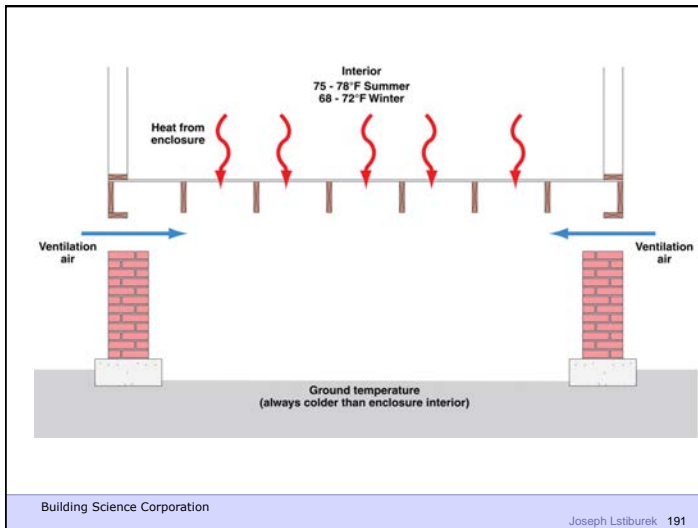
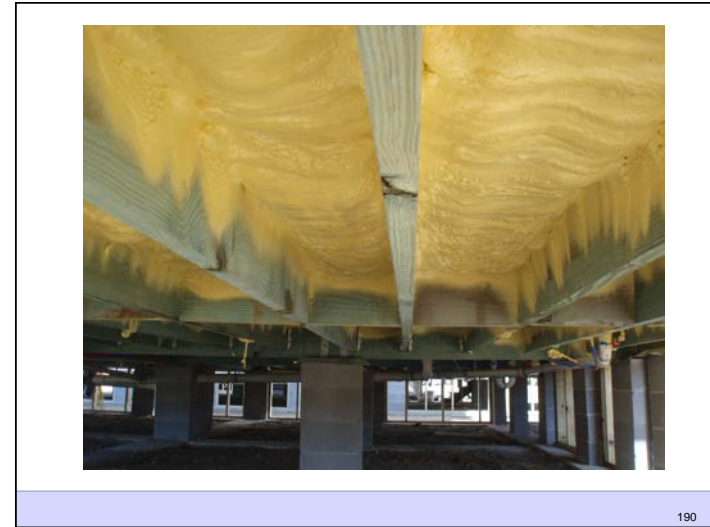


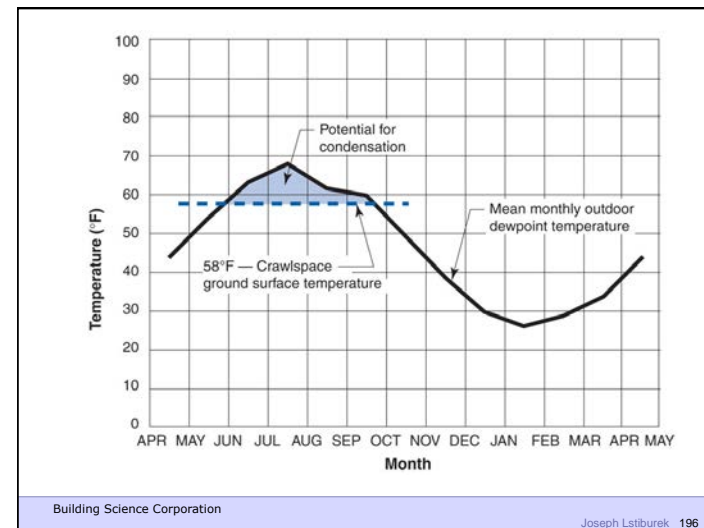
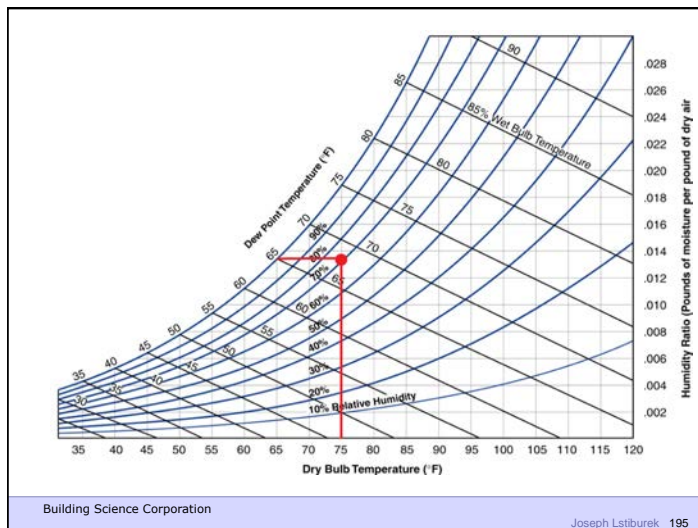
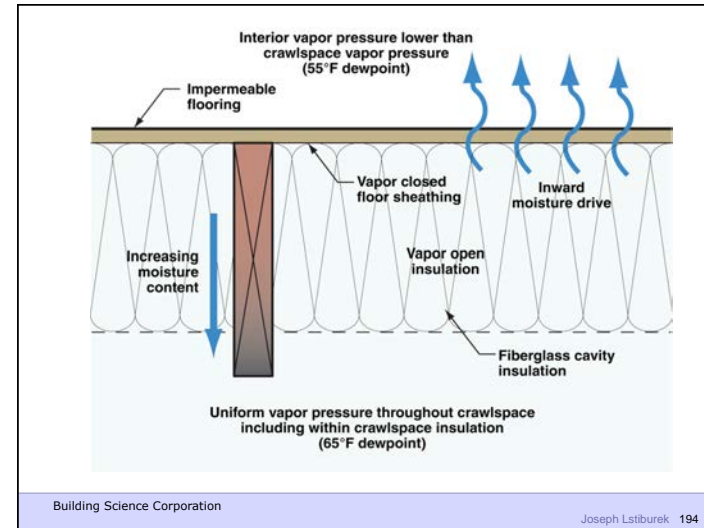
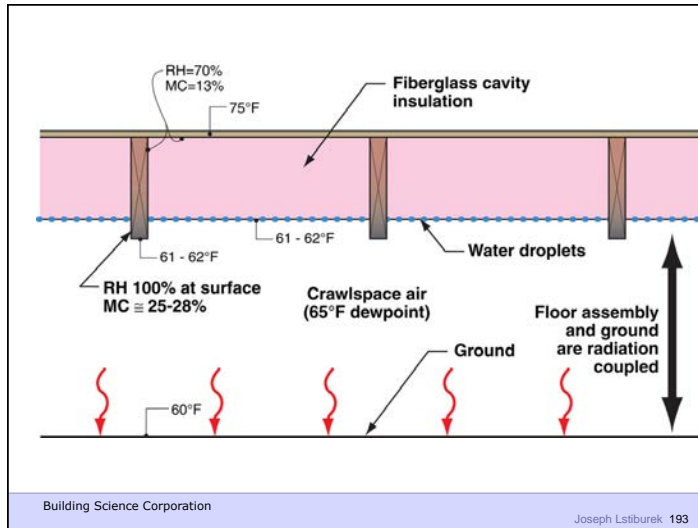


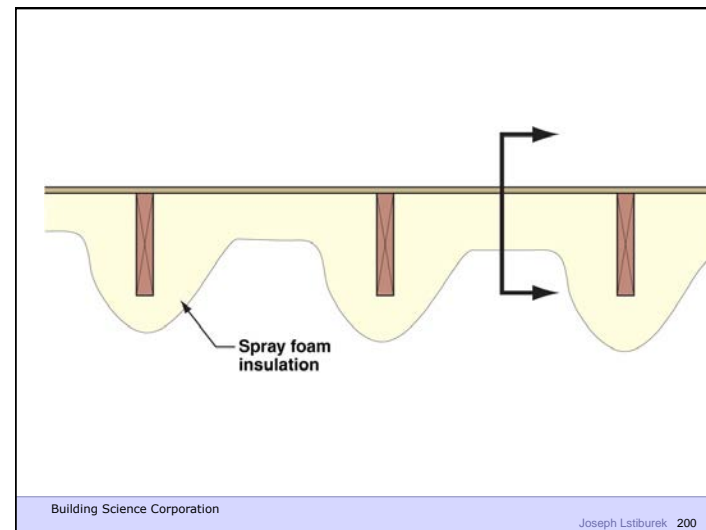
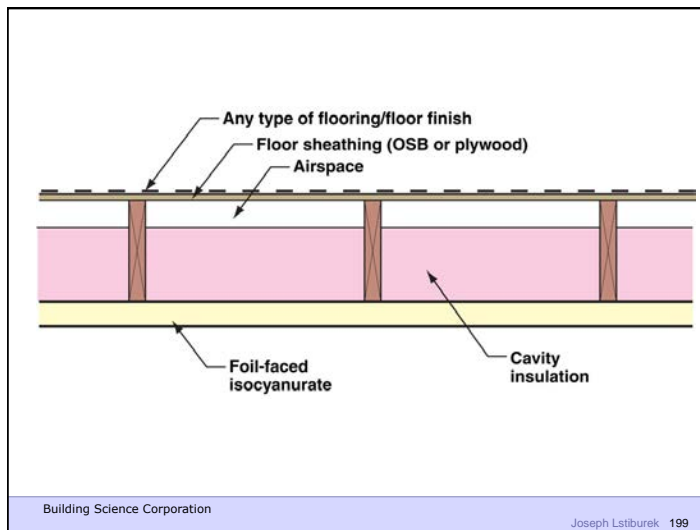
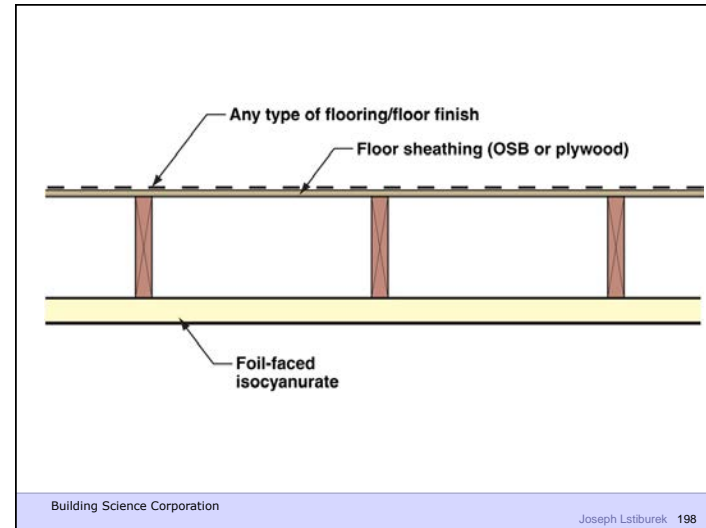
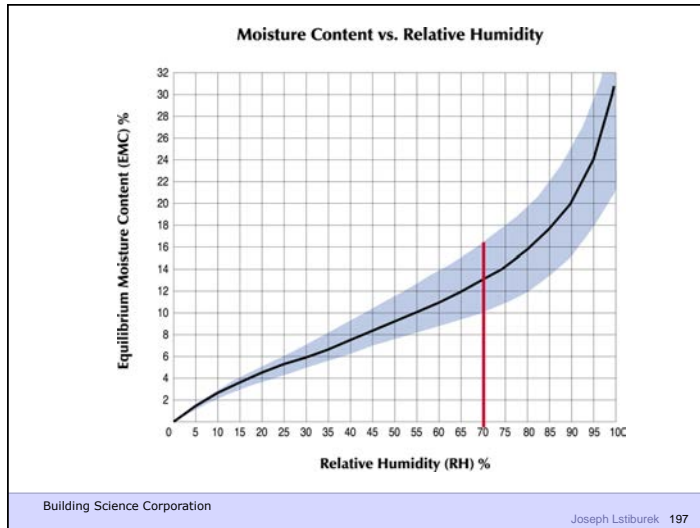


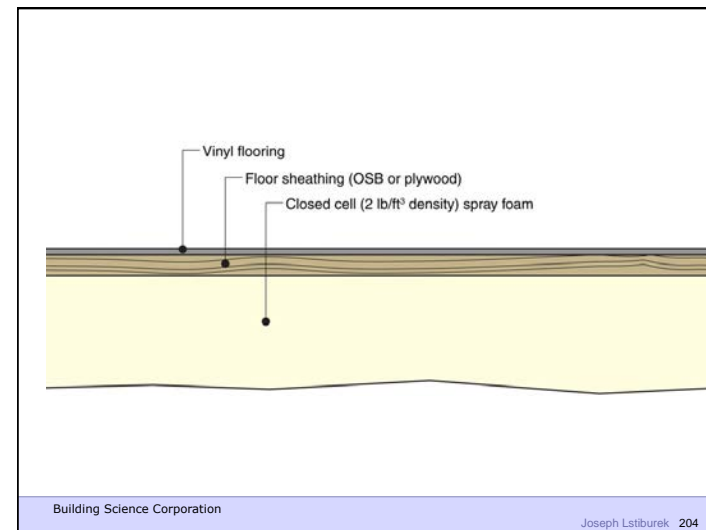
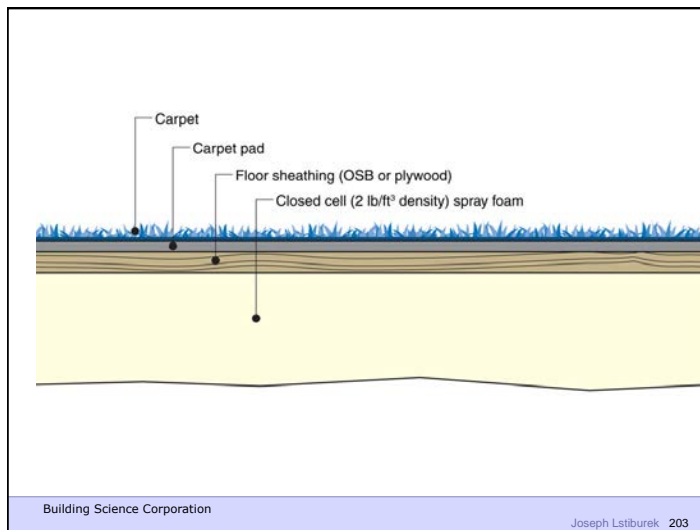
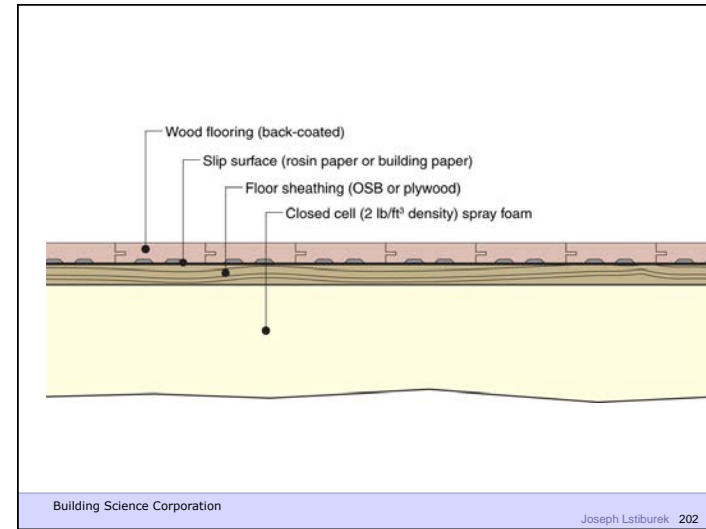
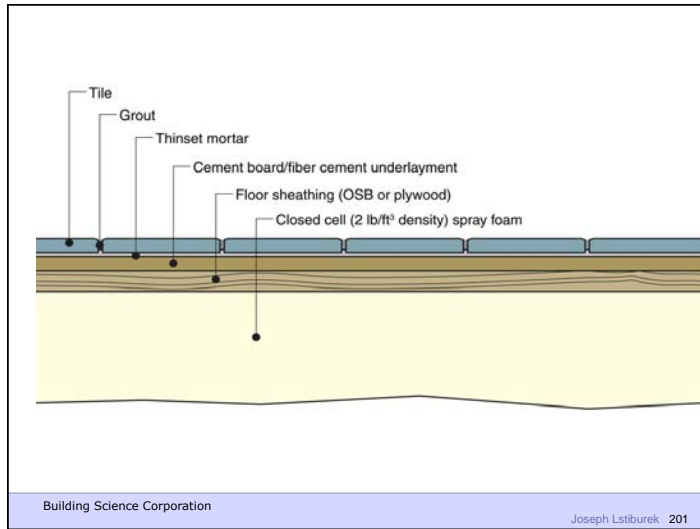


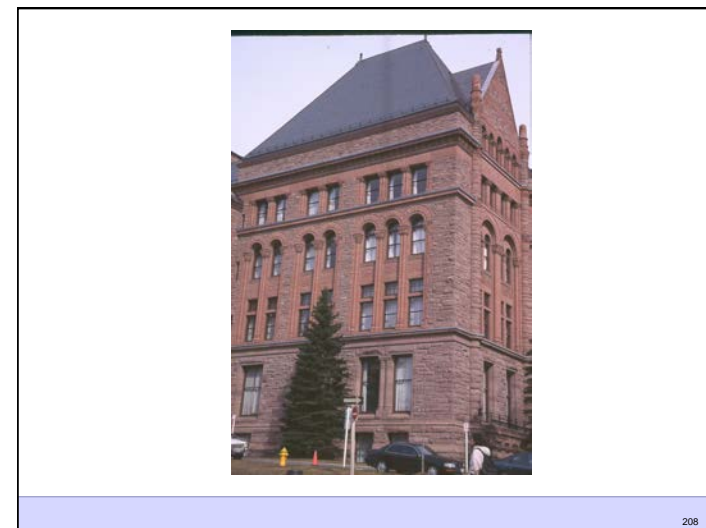
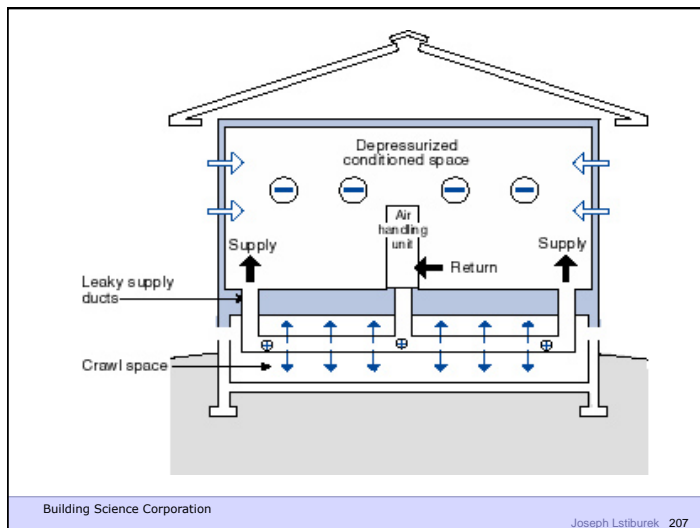
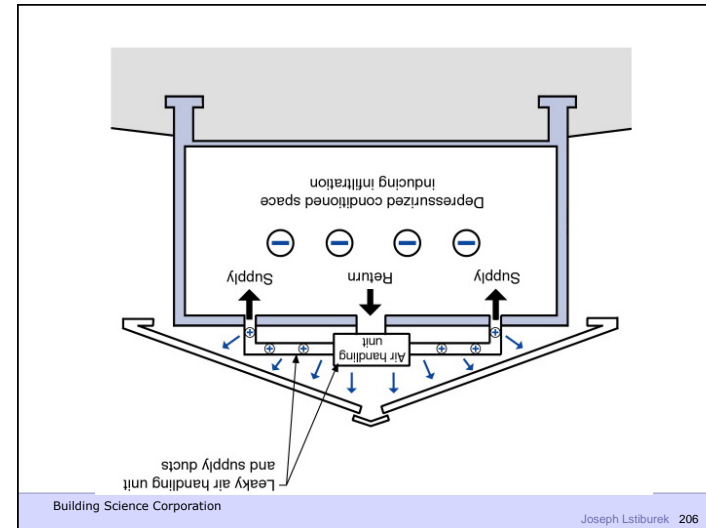
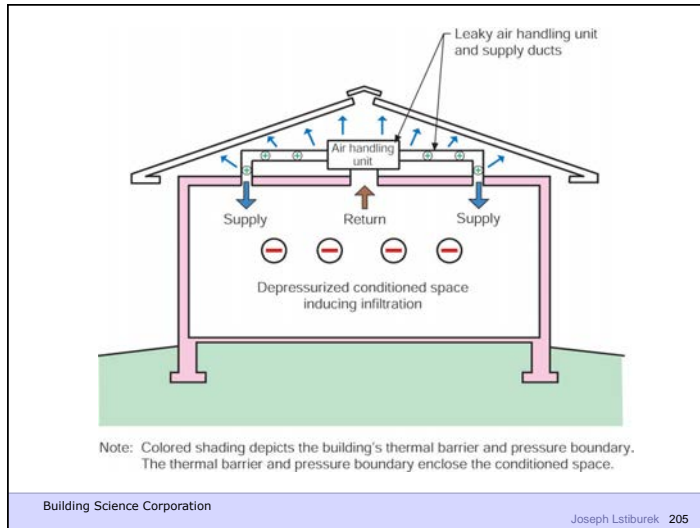


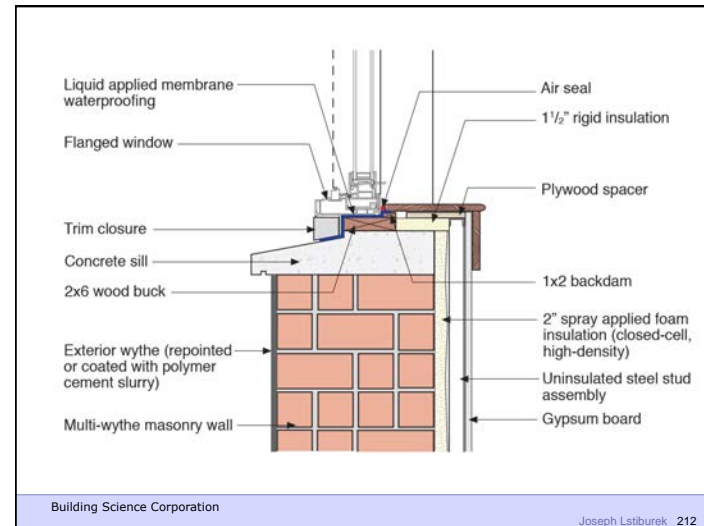
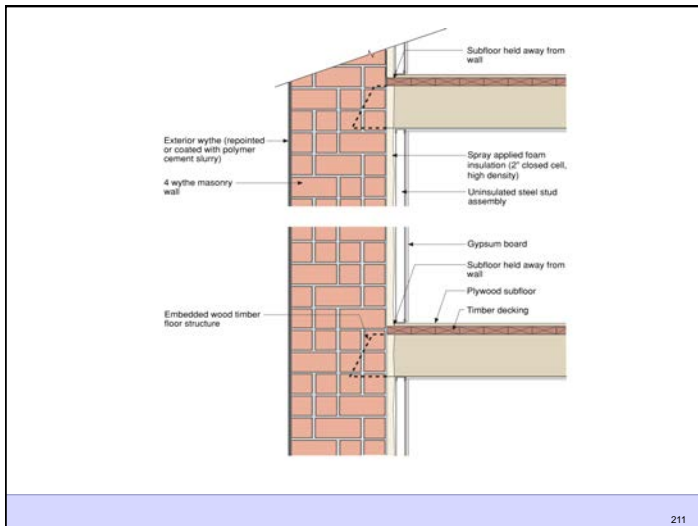
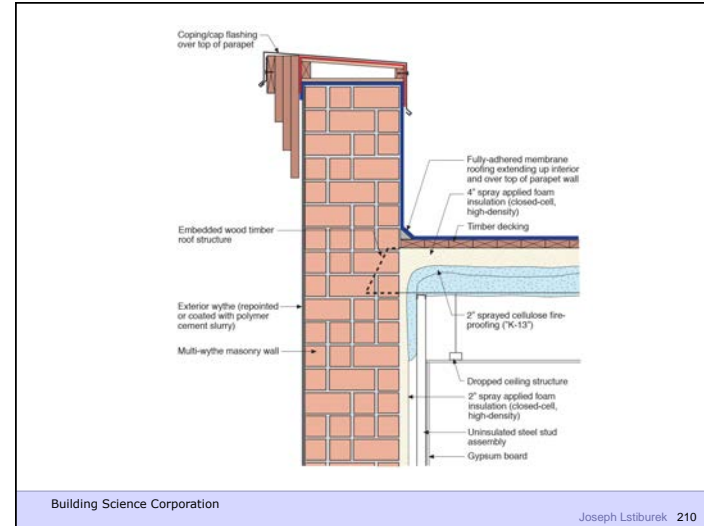
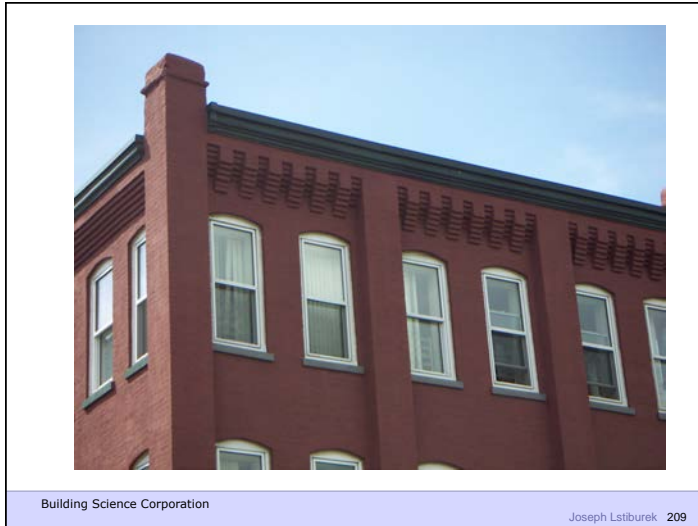


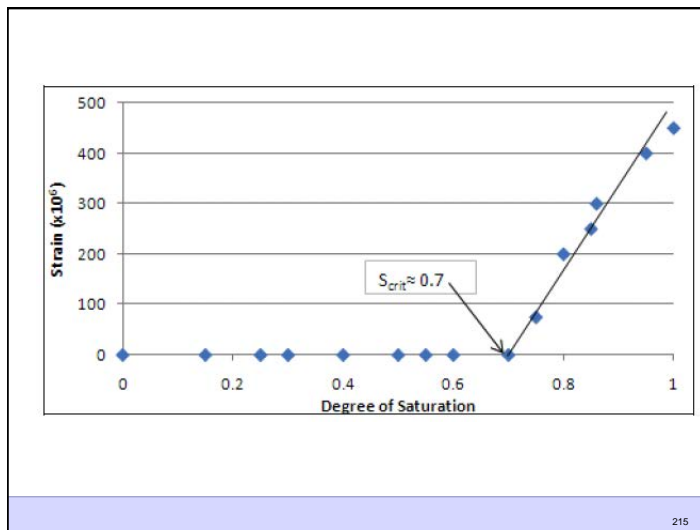
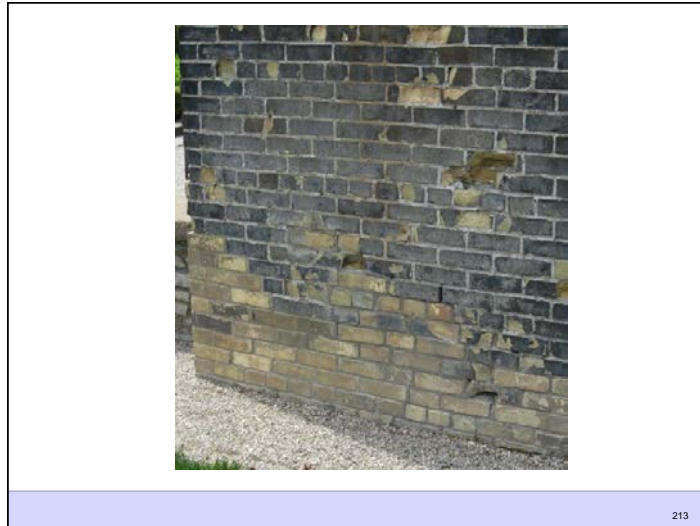


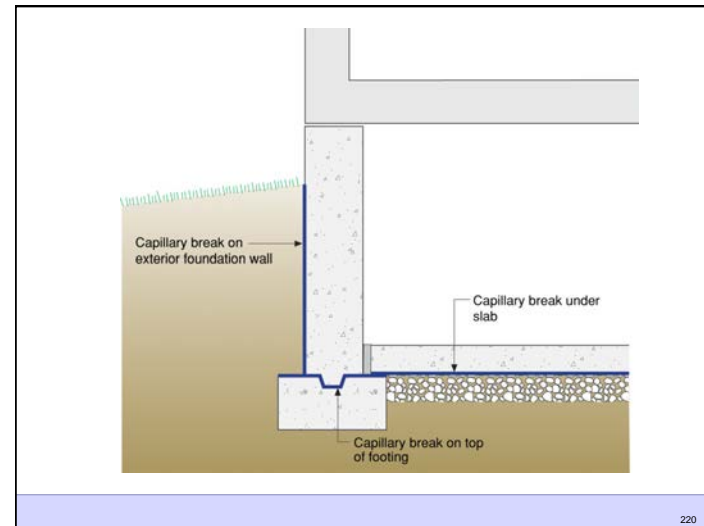
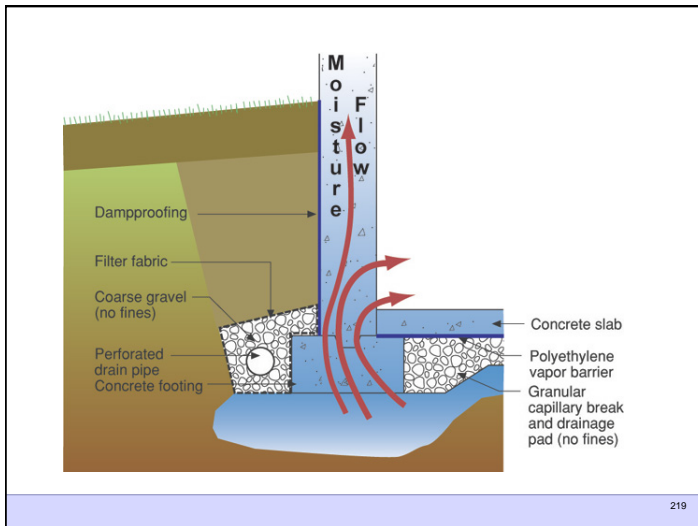
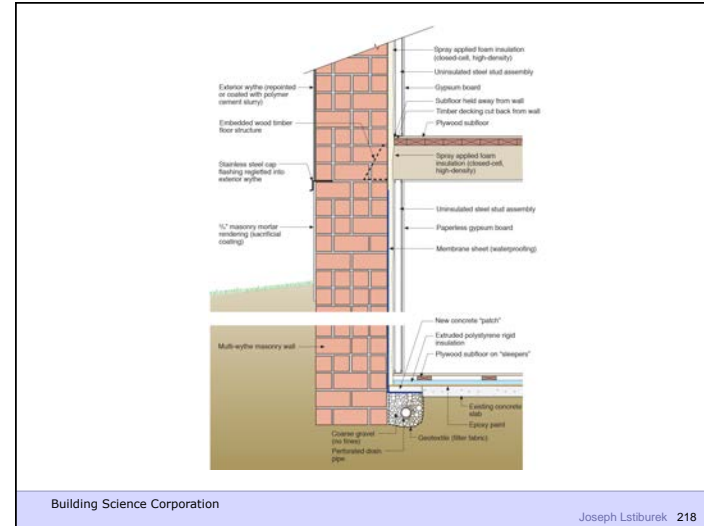








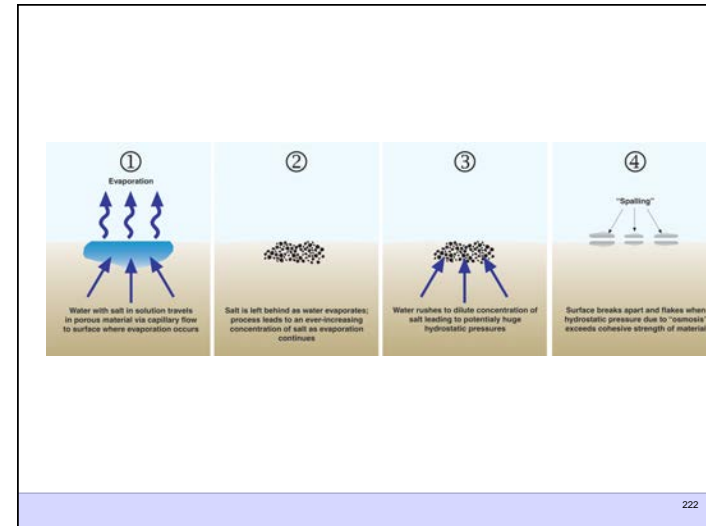




Capillarity + Salt = Osmosis

- 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

221



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

223



