

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

Building Science

Adventures In Building Science

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2nd Law of Thermodynamics

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In an isolated system, a process can occur only if it increases the total entropy of the system

Rudolf Clausius

Heat Flow Is From Warm To Cold
Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less
Air Flow Is From A Higher Pressure to a
Lower Pressure
Gravity Acts Down

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

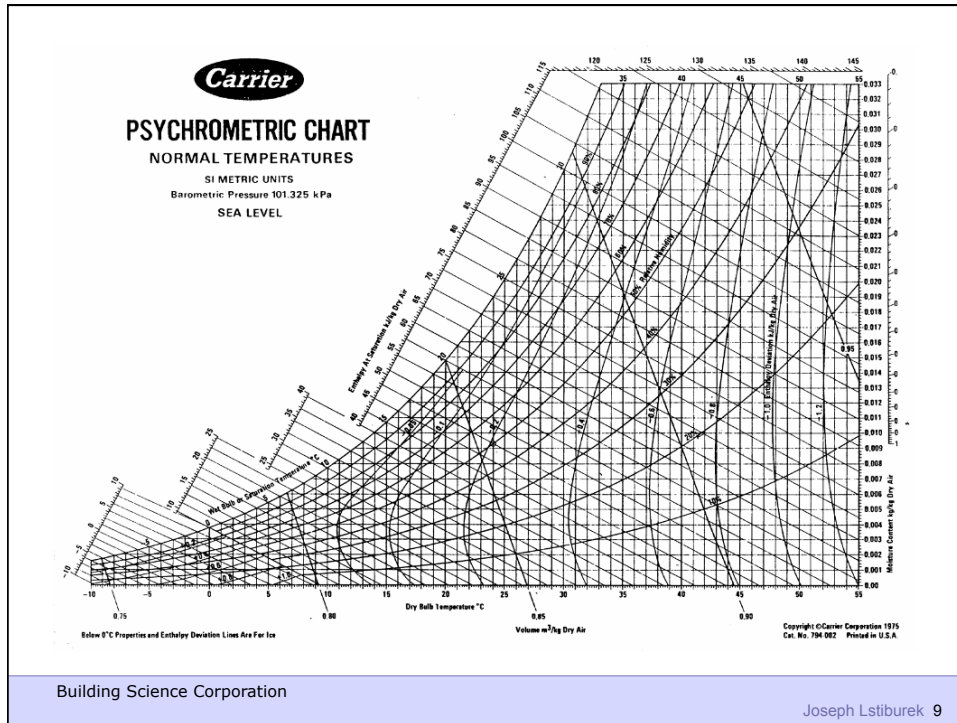
Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Vapor Diffusion

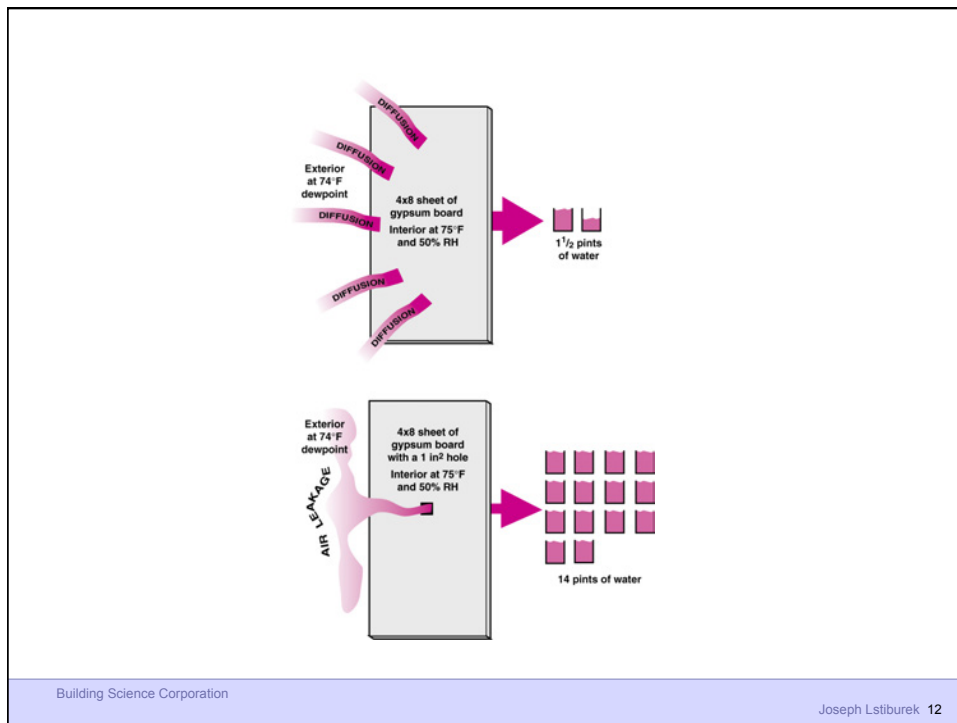
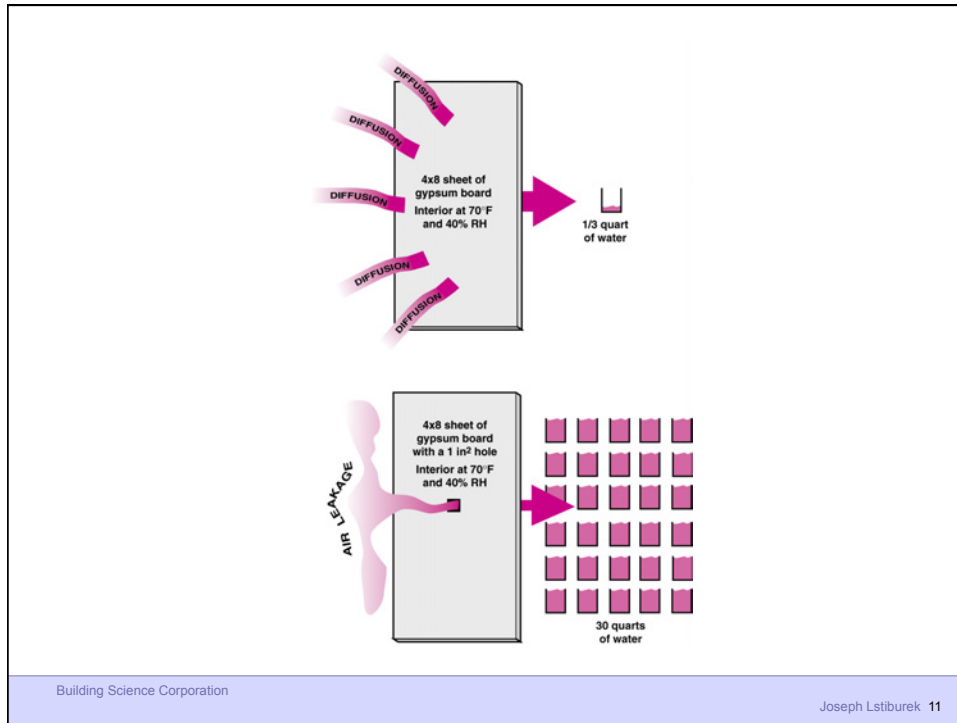
Thermodynamic Potential



Vapor Barriers – Air Barriers

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Damage Functions

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Damage Functions
Water
Heat
Ultra Violet Radiation

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The Three Biggest Problems In Buildings Are Water, Water and Water...

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80 Percent of all Construction Problems are Related to Water

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Heat
Air
Moisture

HAM

Hygrothermal Analysis

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What is a Building?

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A Building is an Environmental Separator

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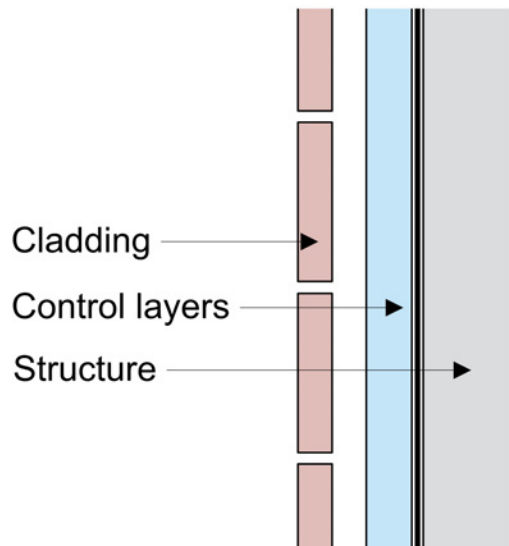
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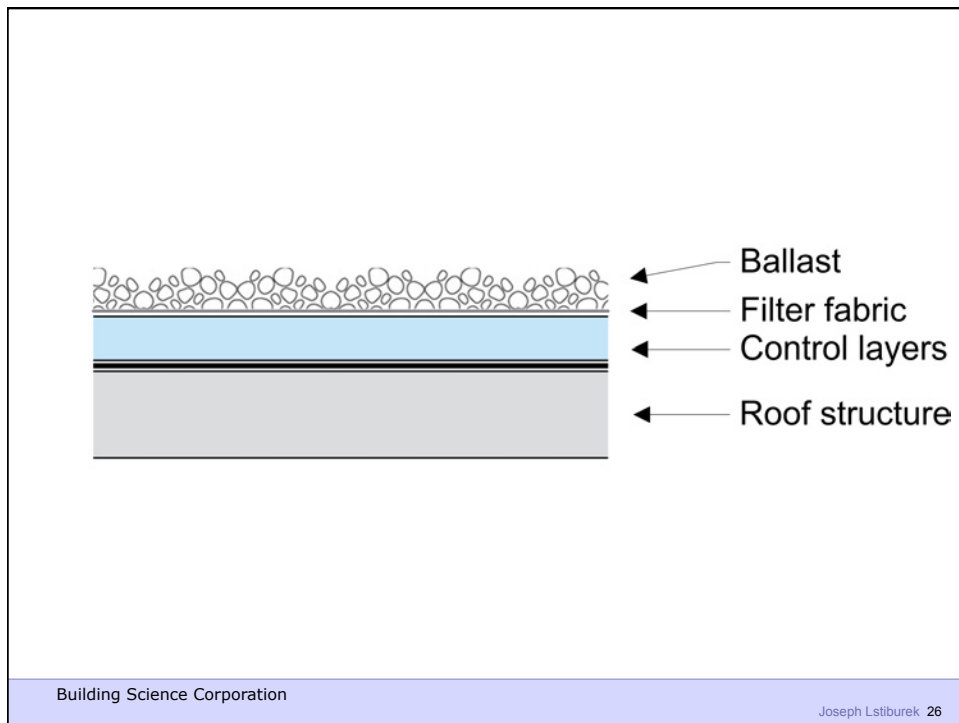
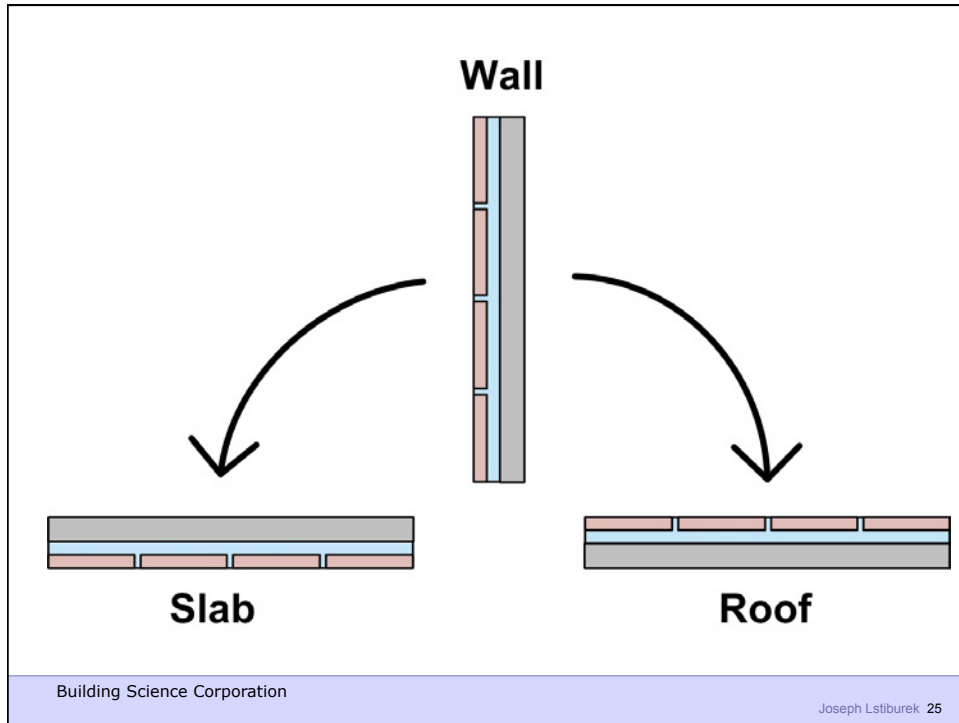
- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and rigidity
- Be durable
- Be aesthetically pleasing
- Be economical

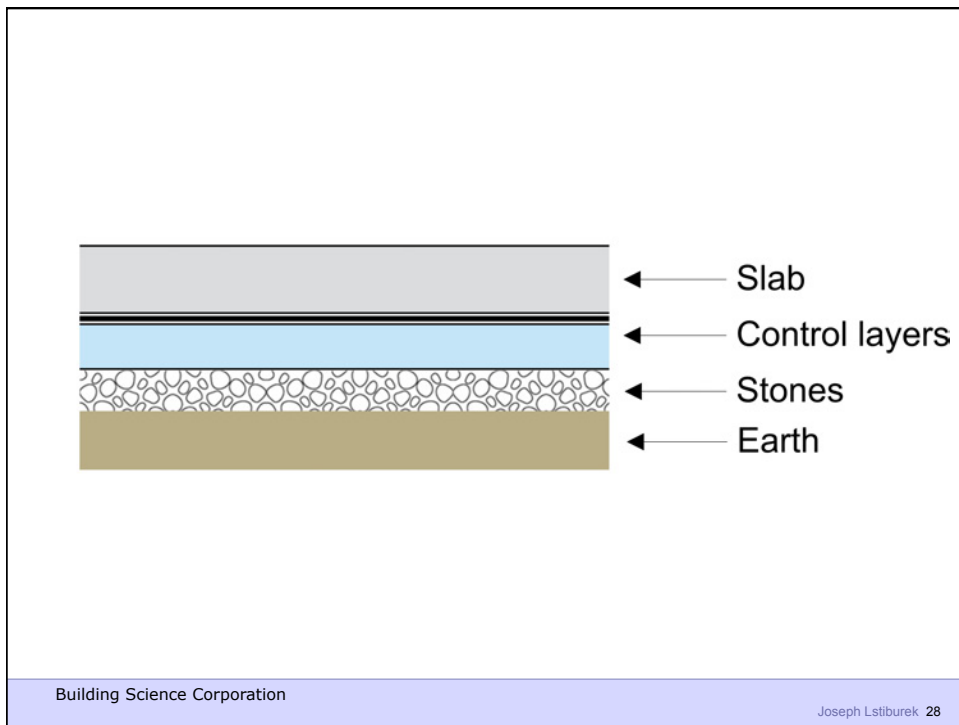
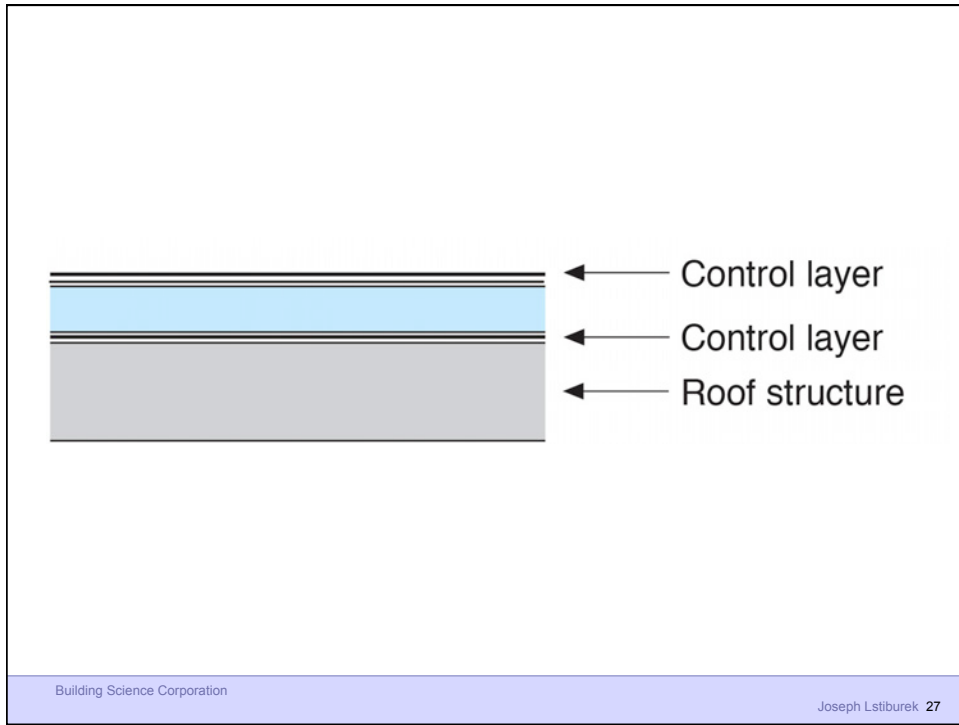
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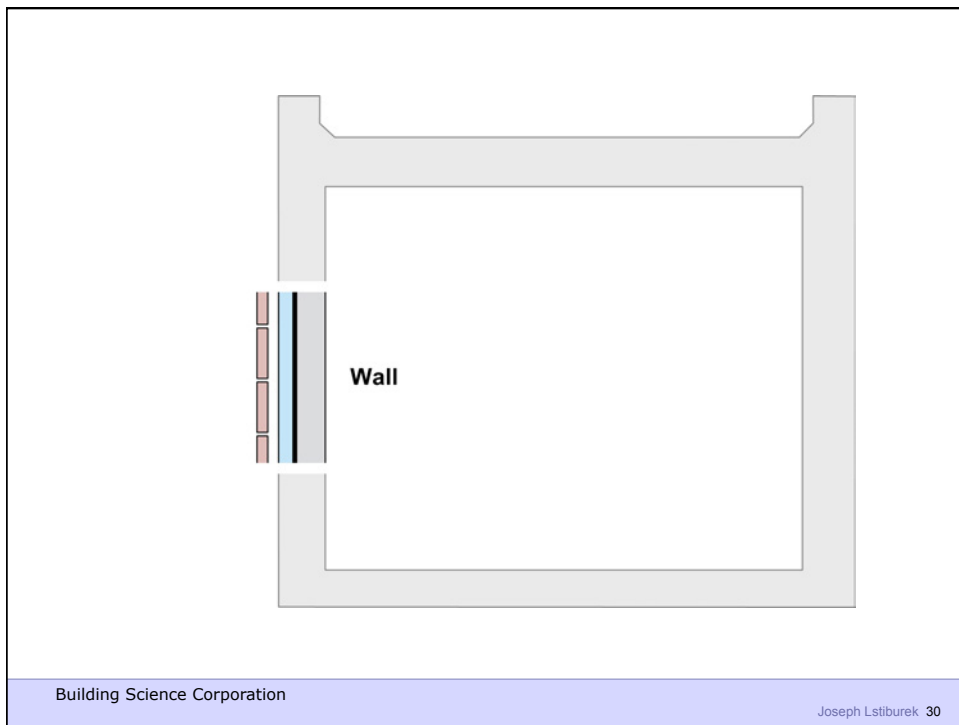
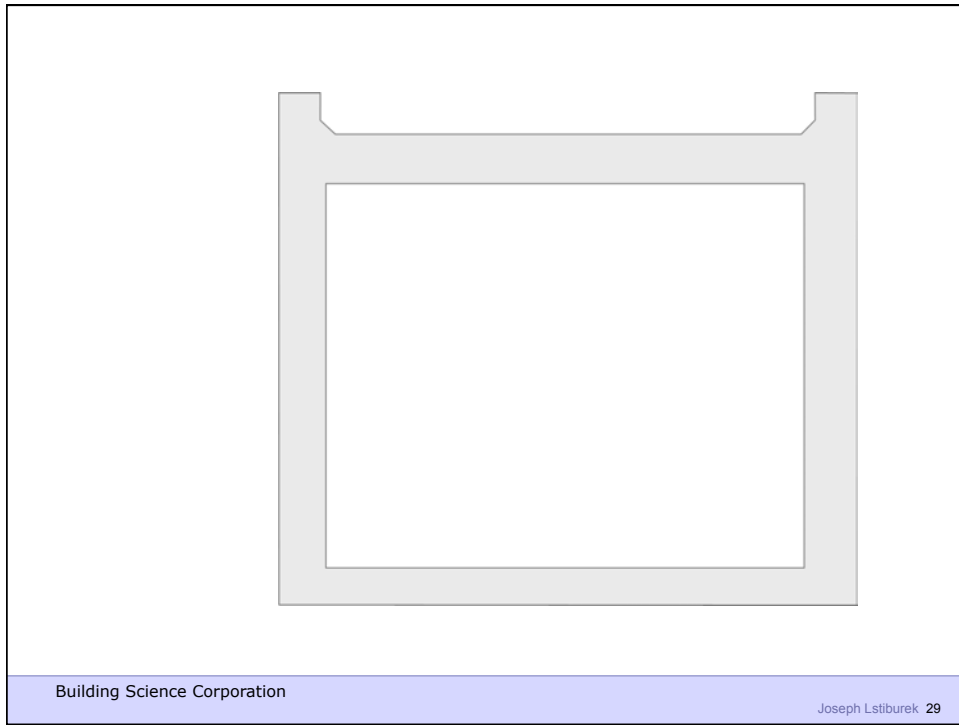
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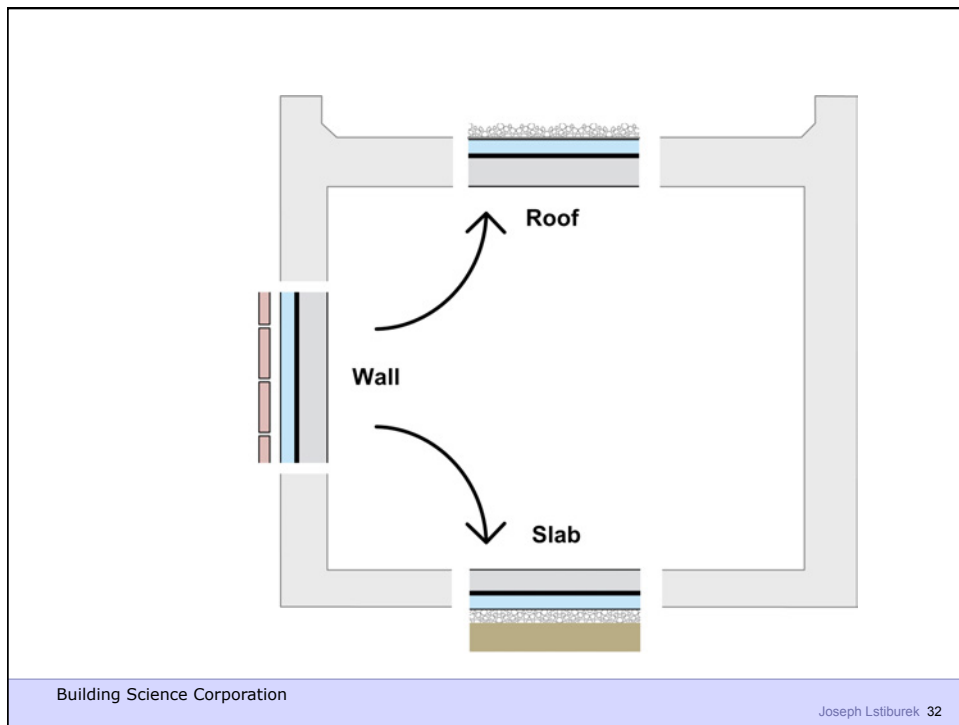
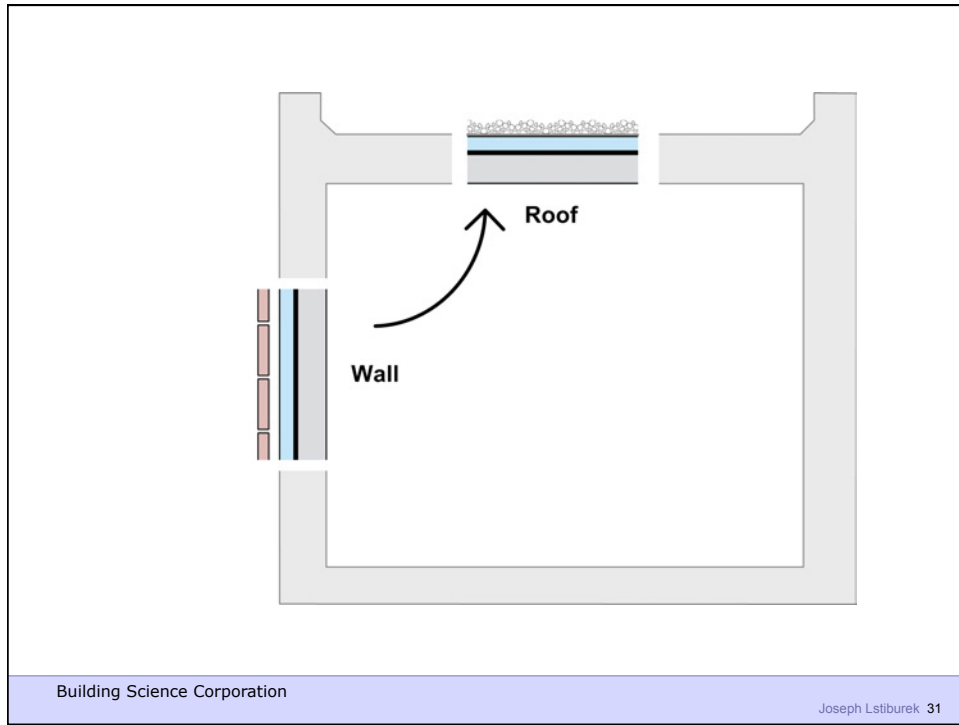
Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

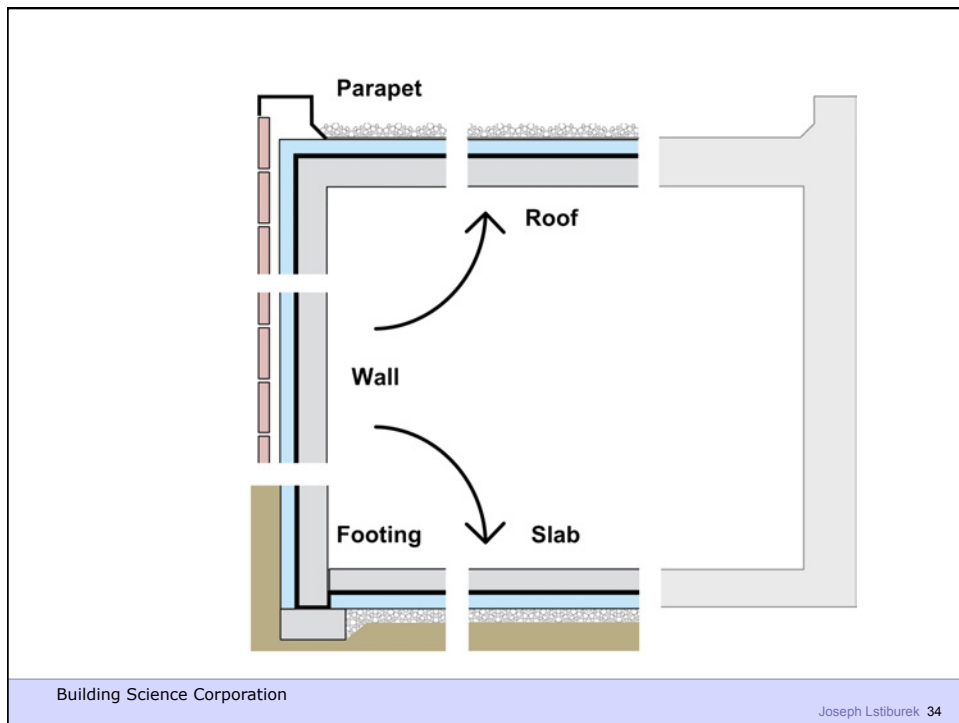
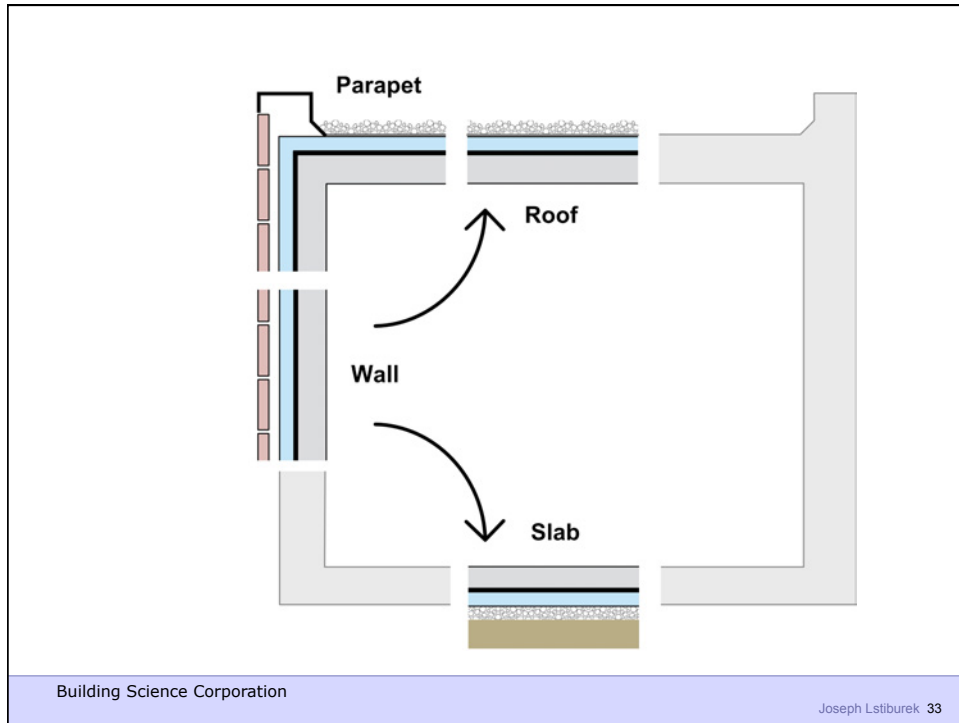


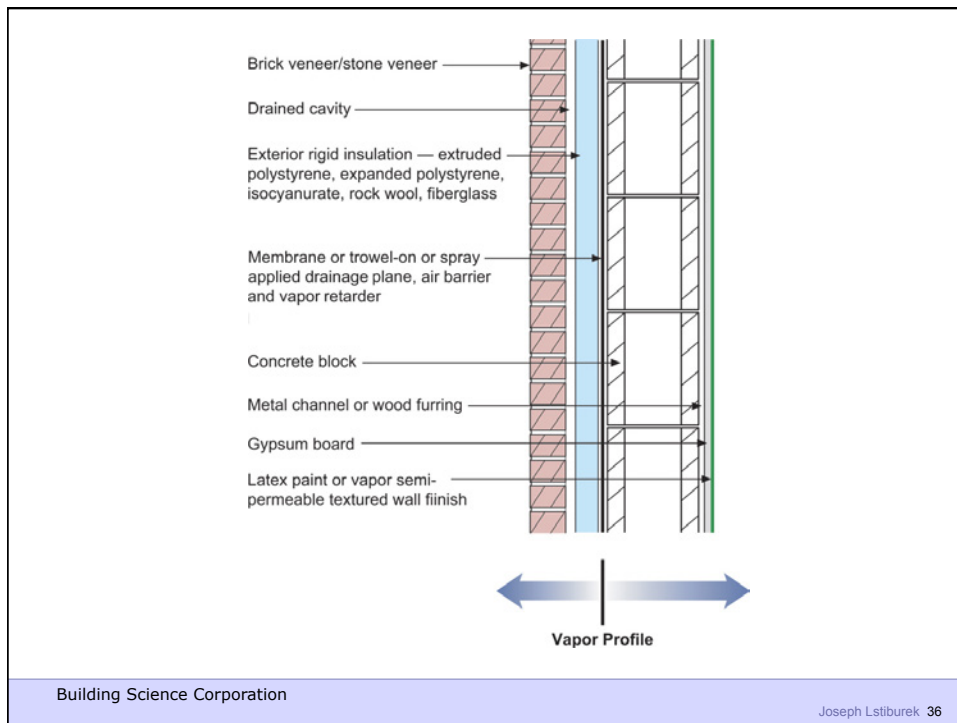
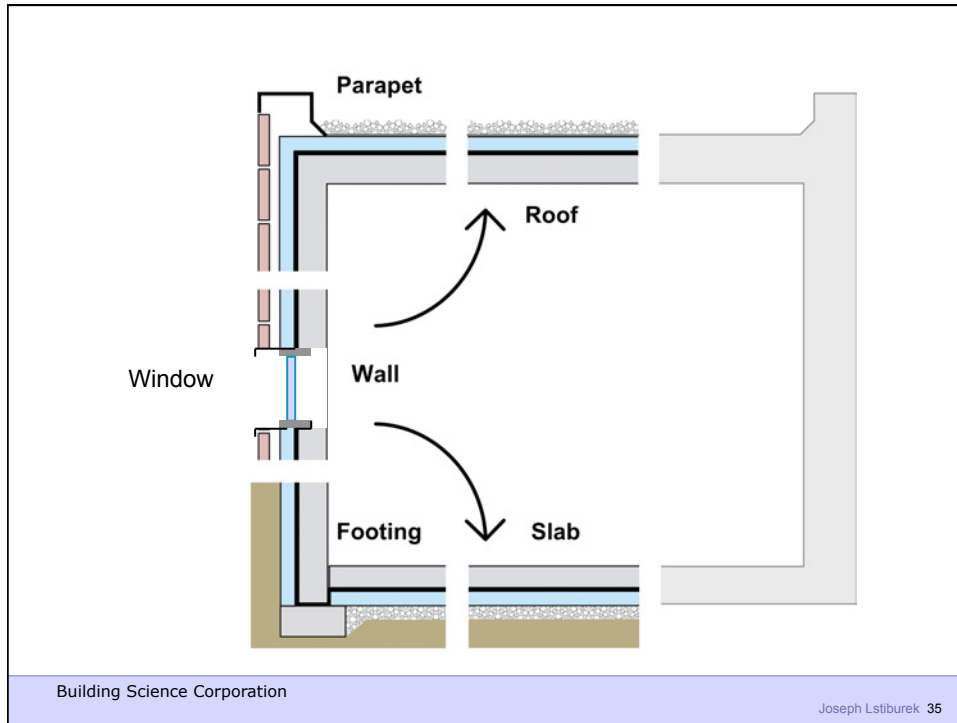


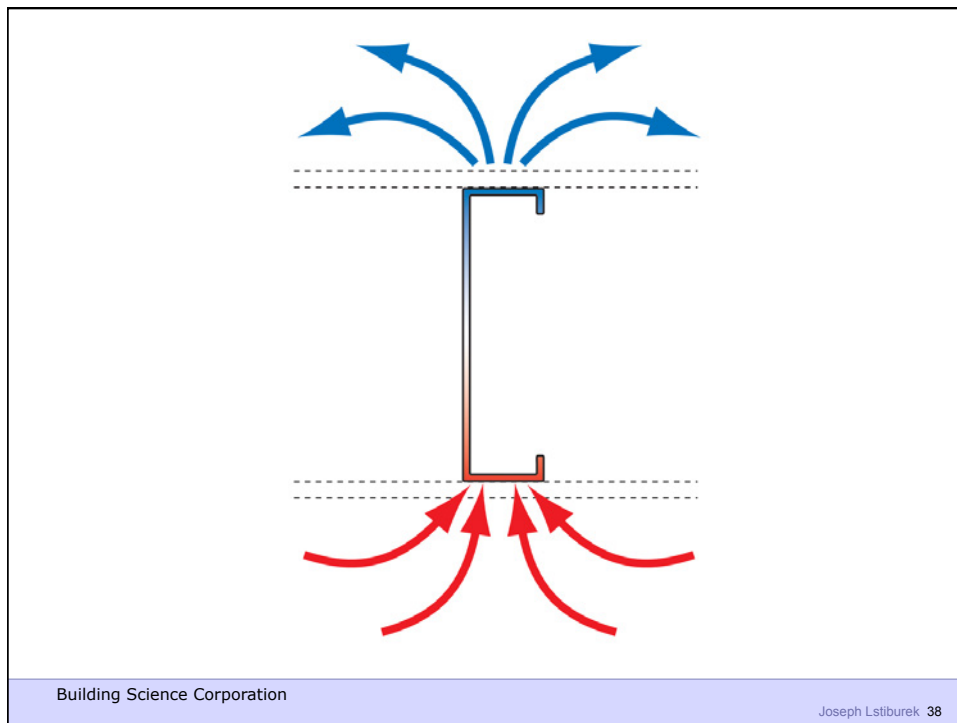
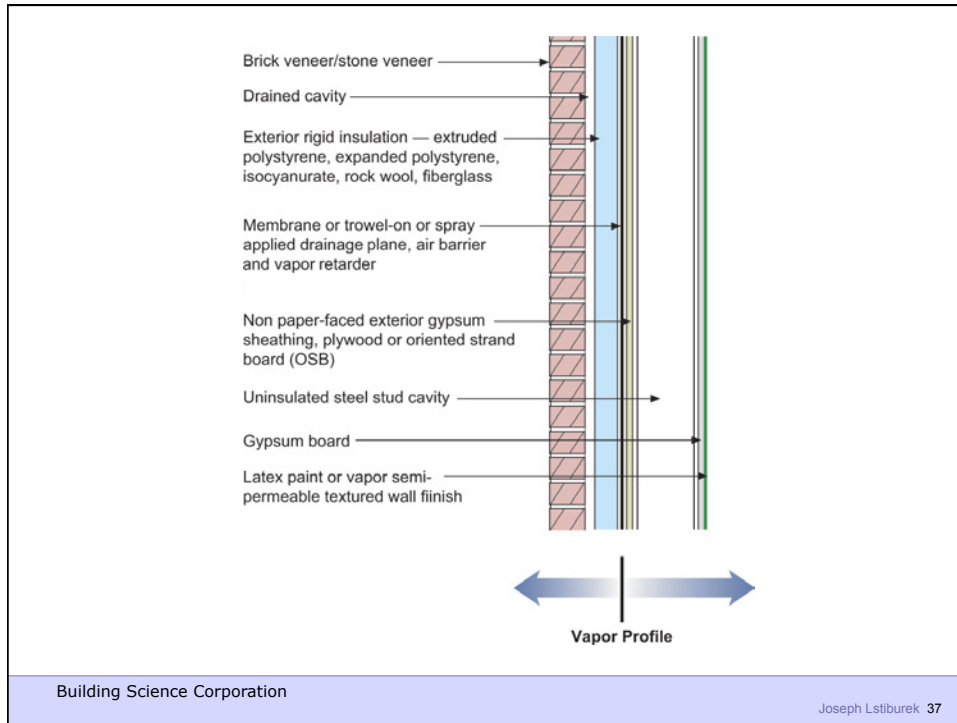


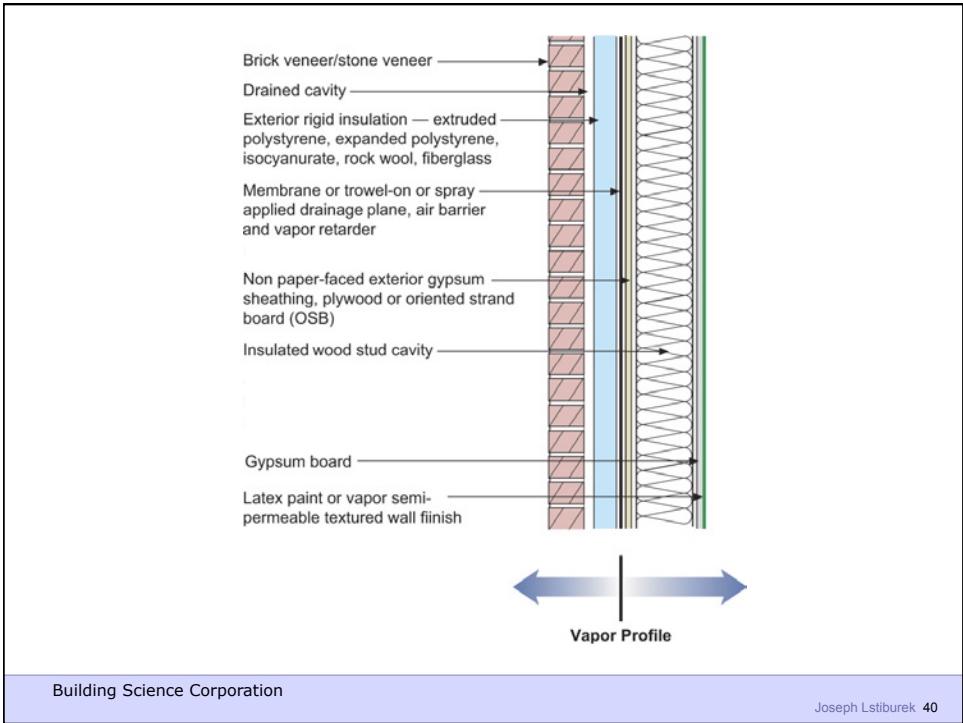




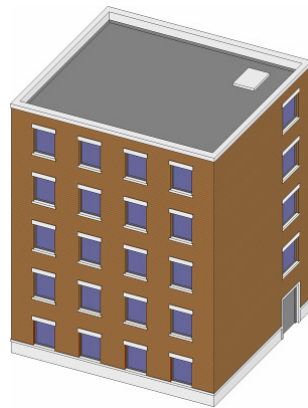




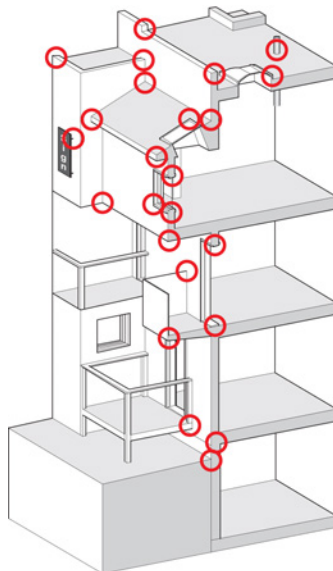




Commercial Enclosure: Simple Layers



- Structure
- Rain/Air/Vapor
- Insulation
- Finish







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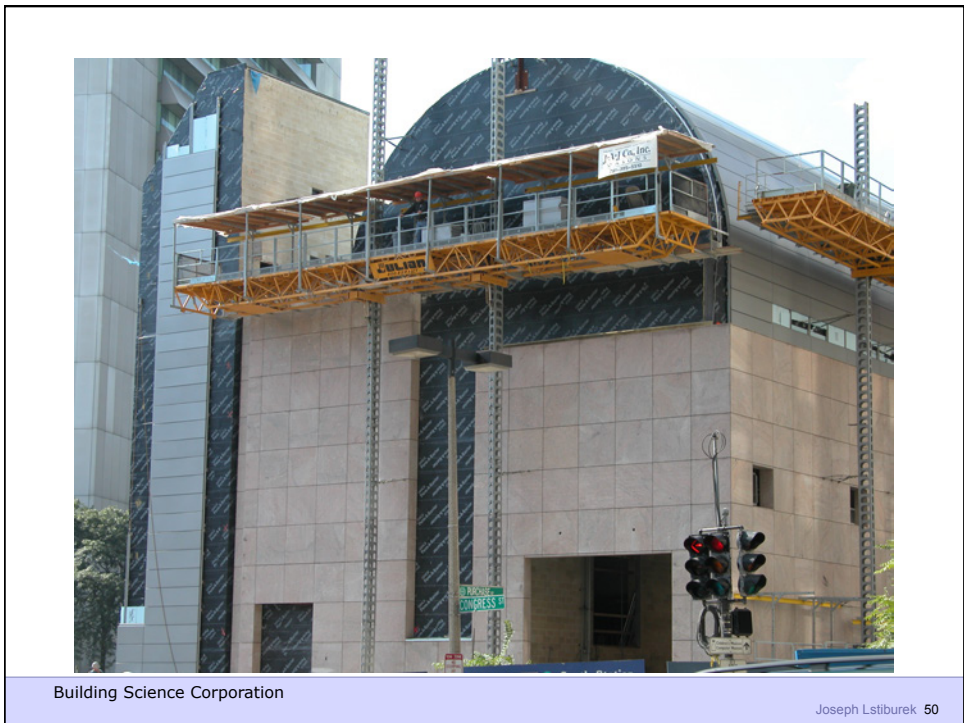
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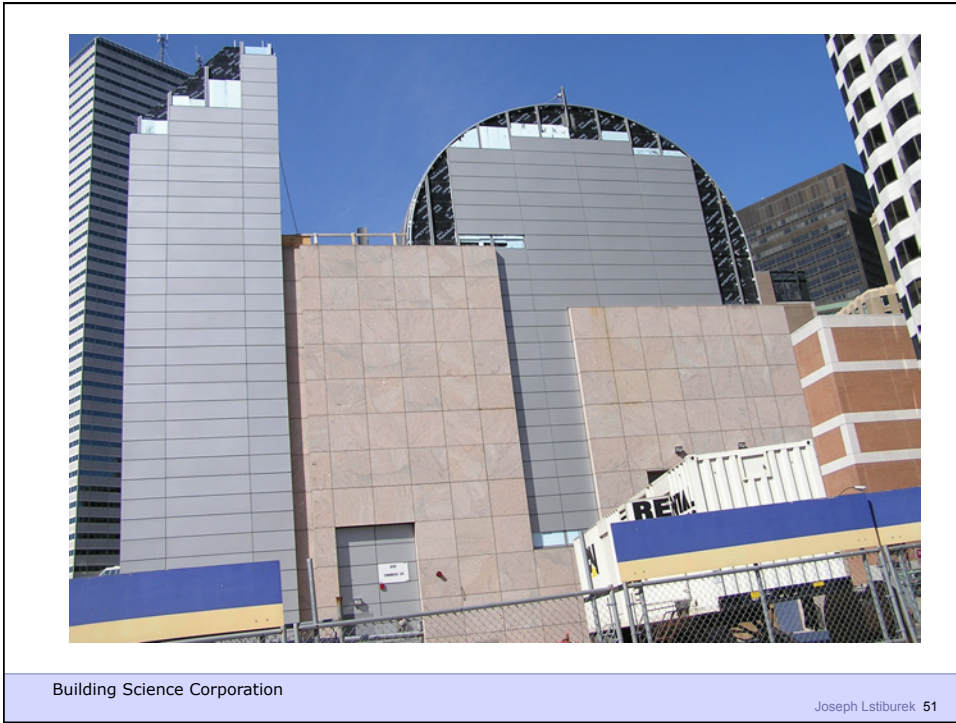
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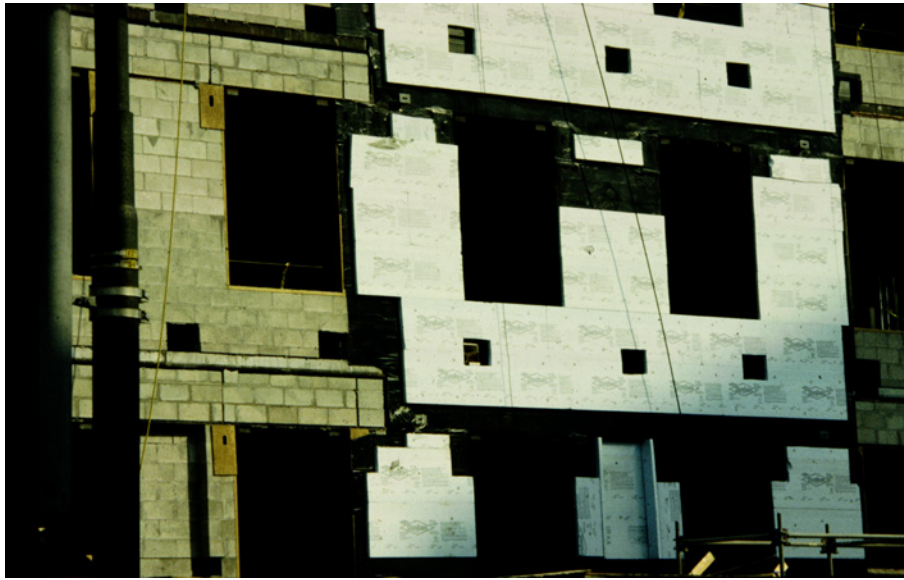


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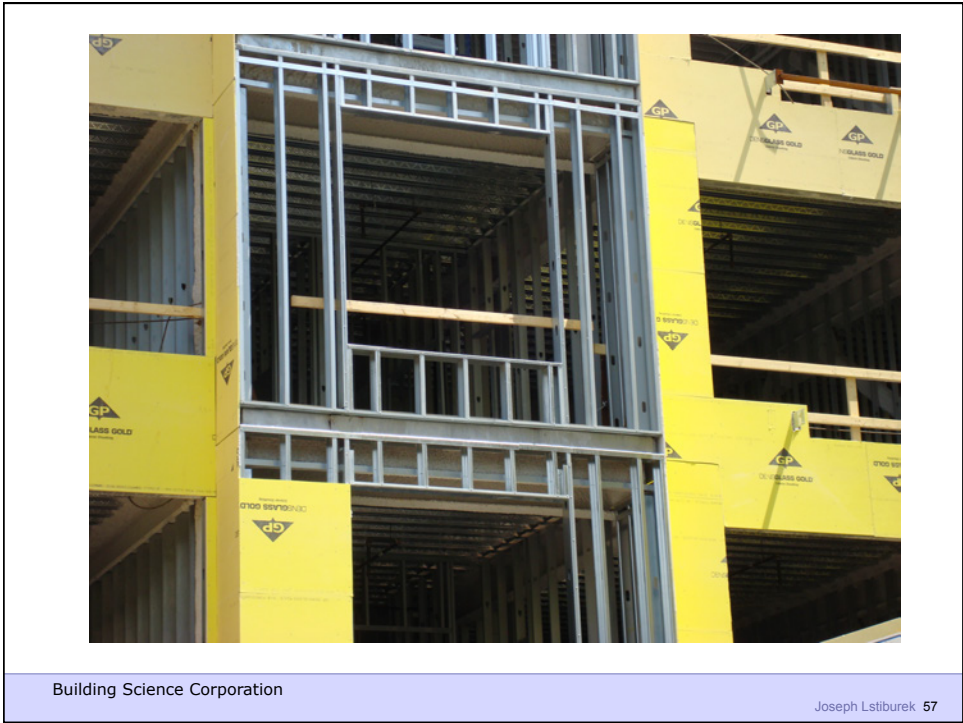
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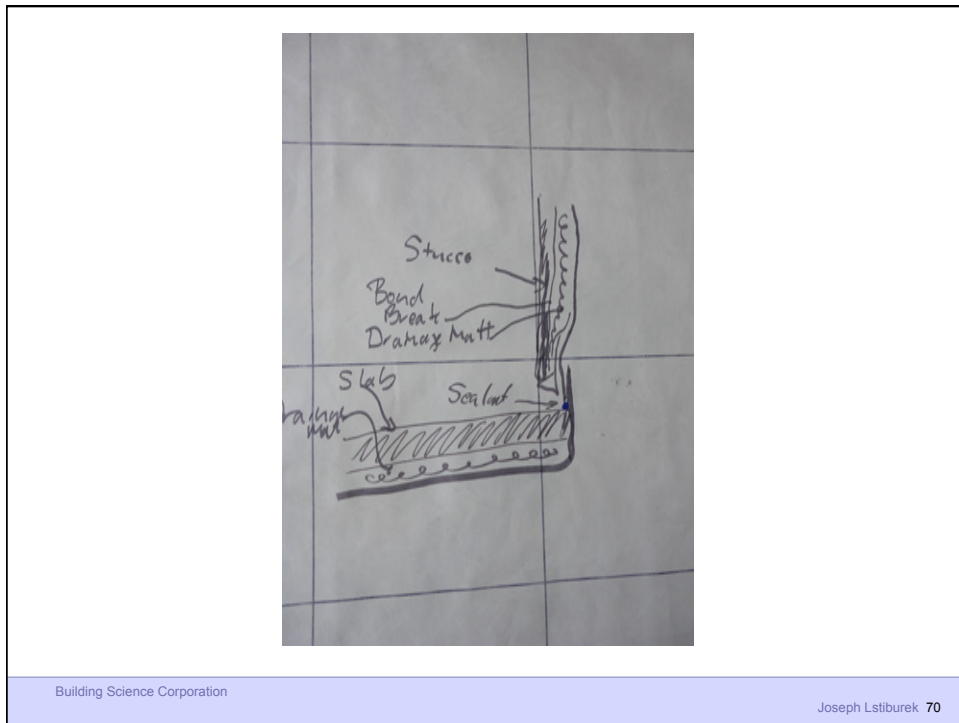
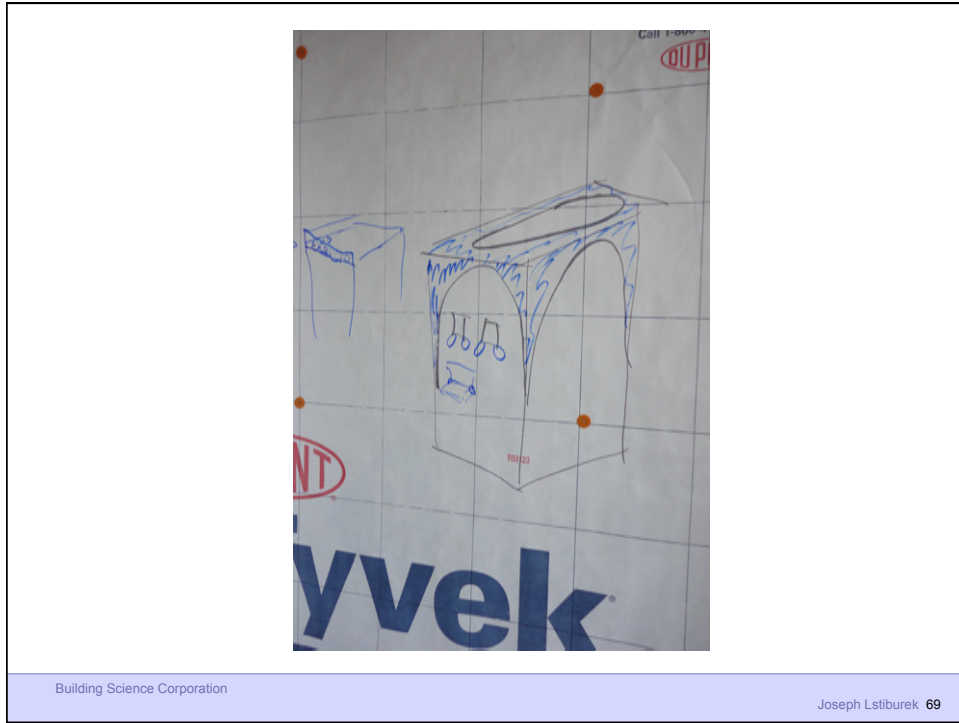
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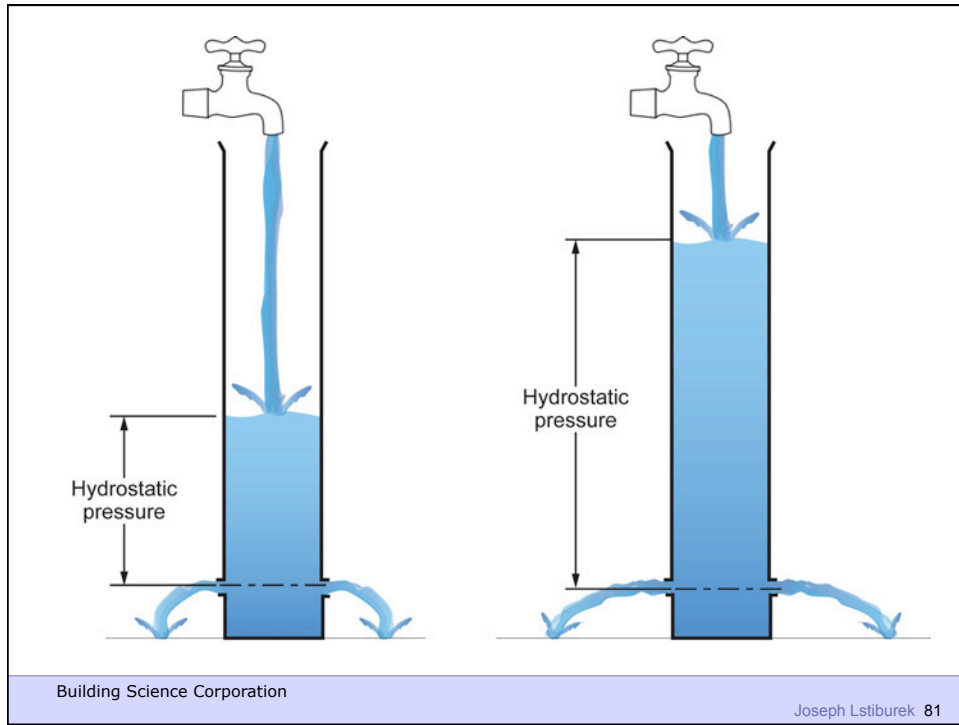
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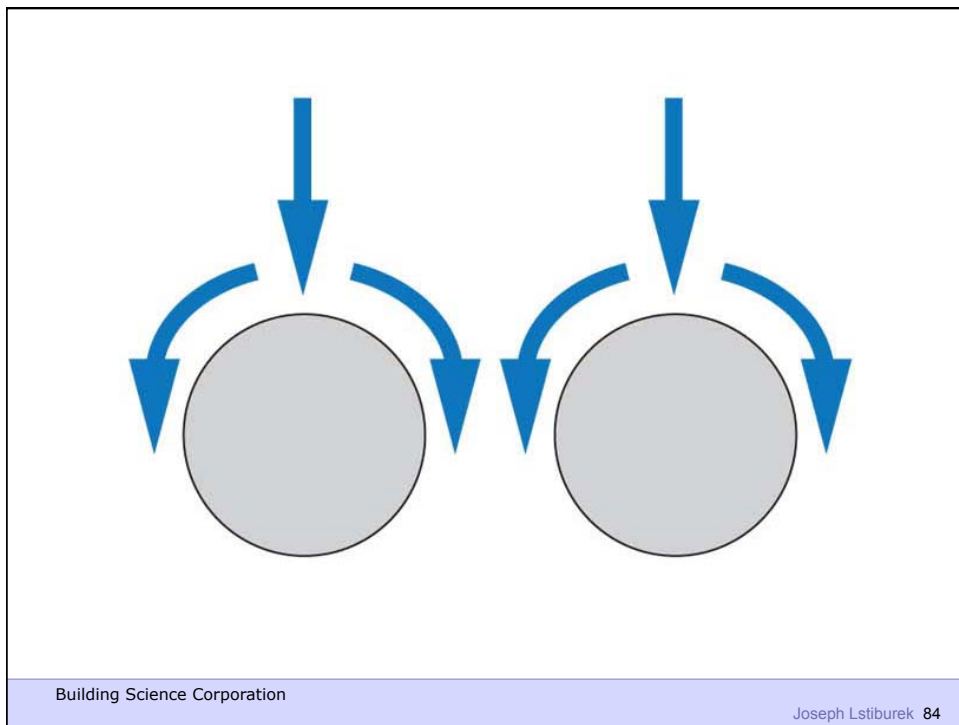
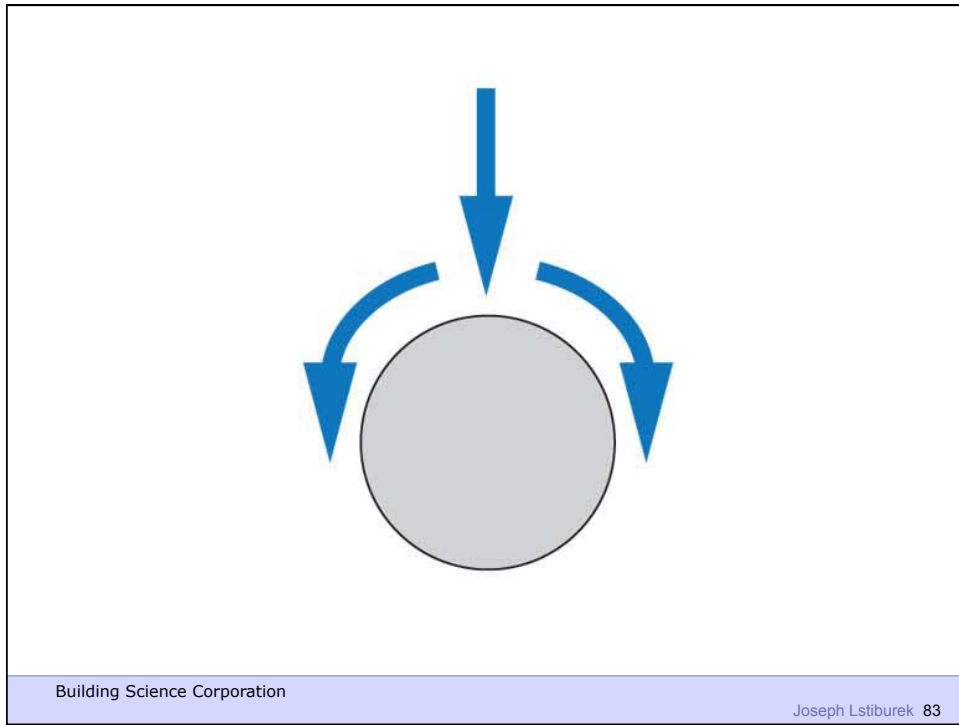
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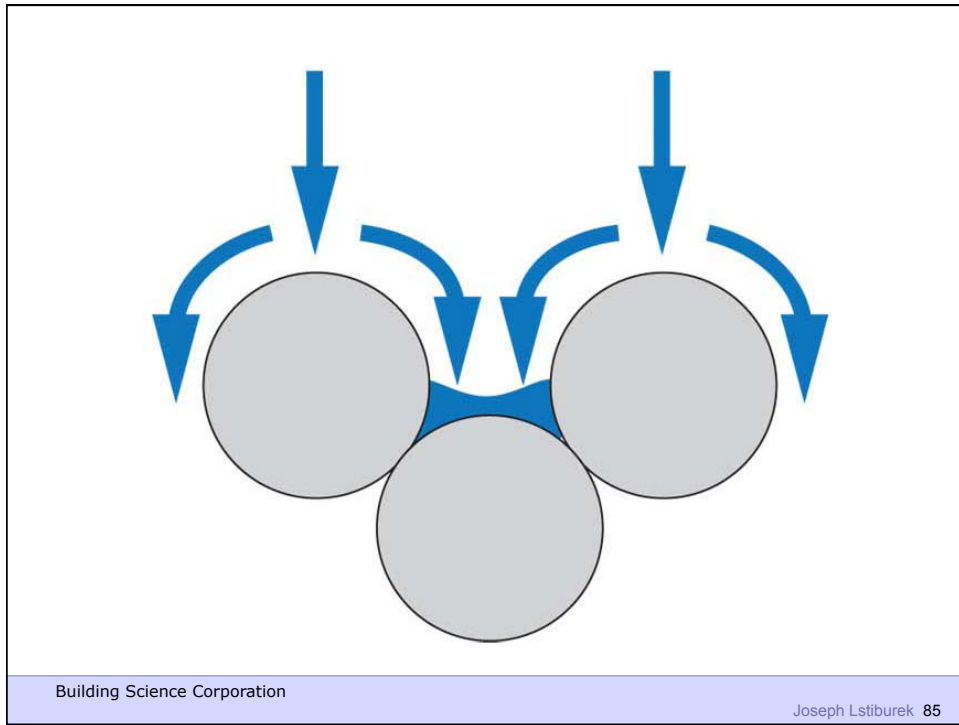


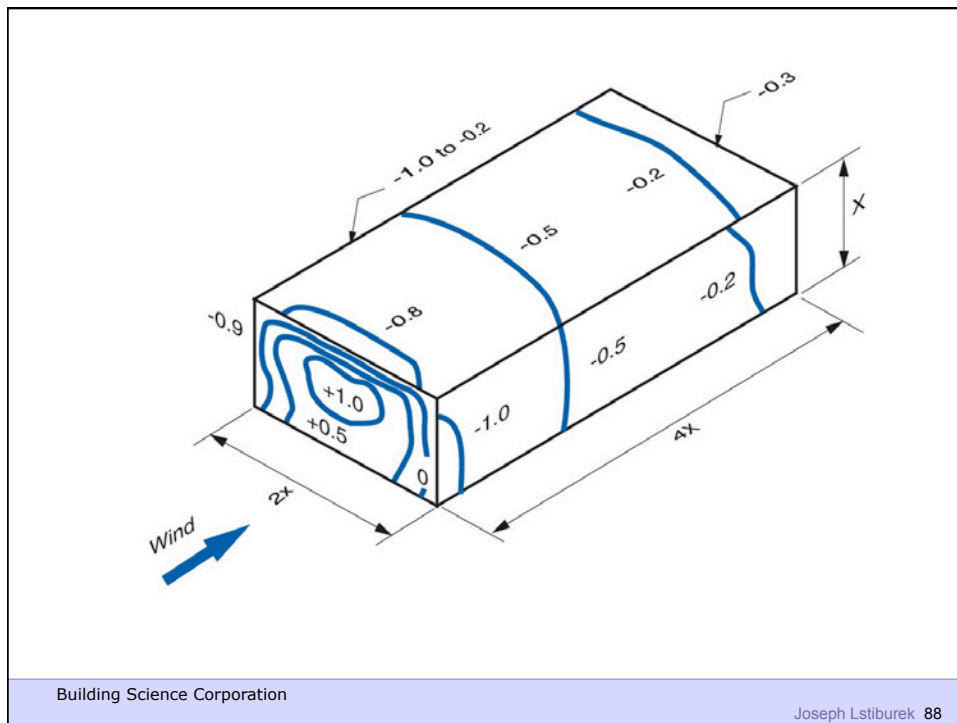
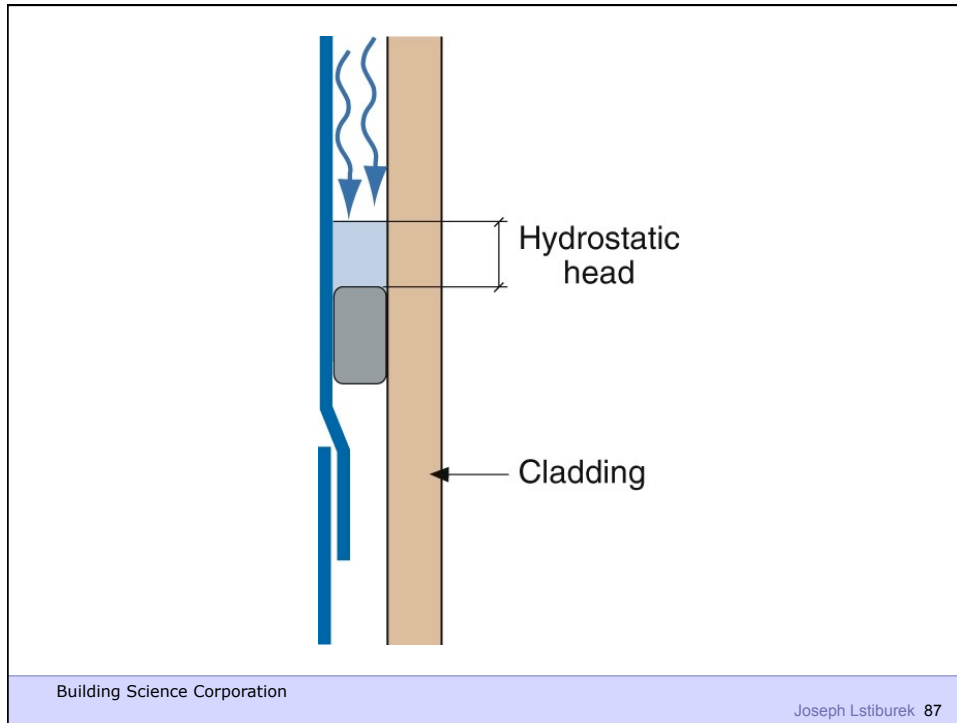
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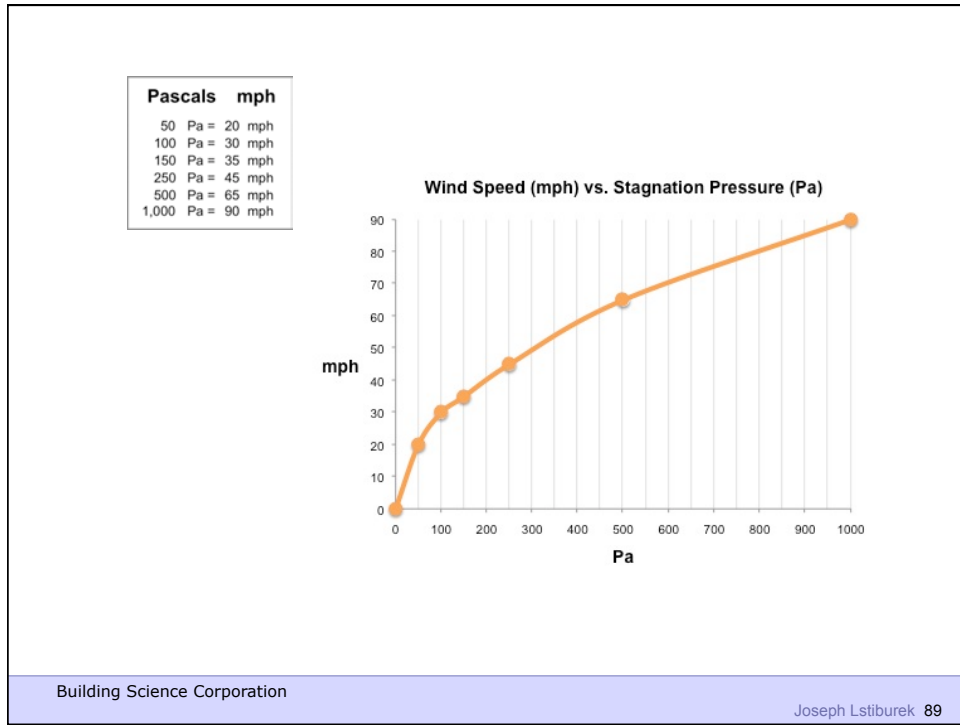
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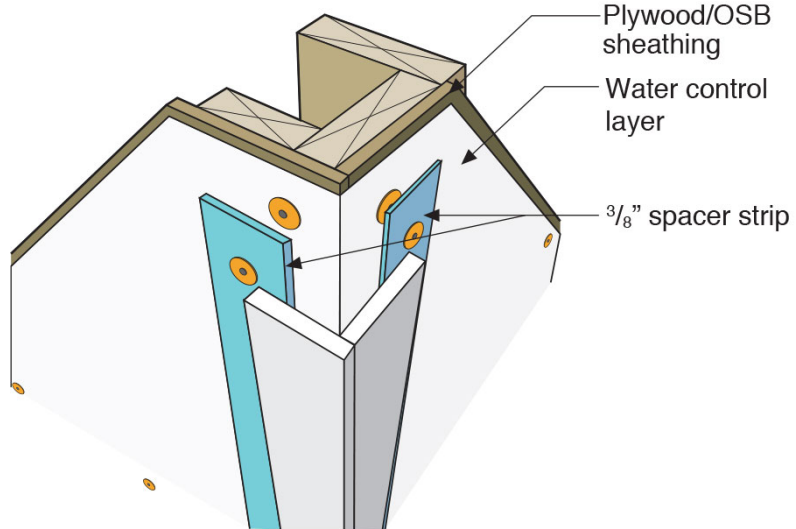






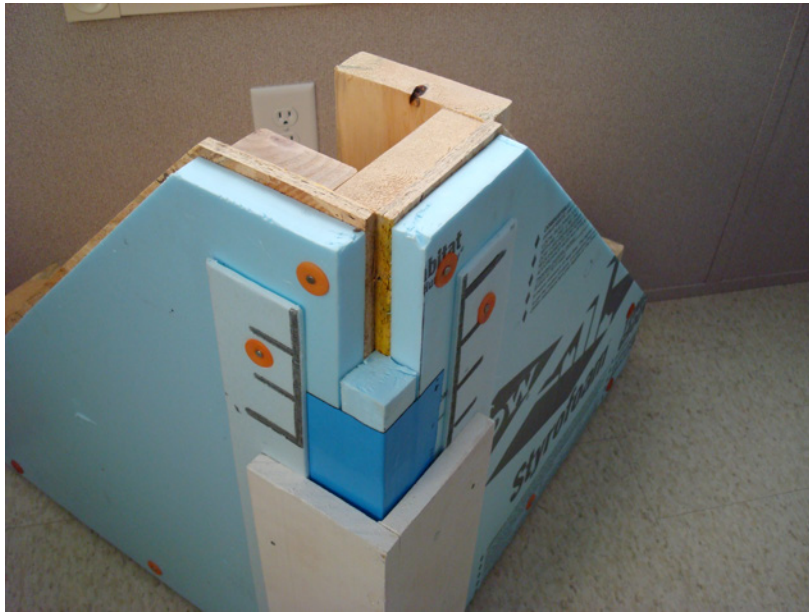
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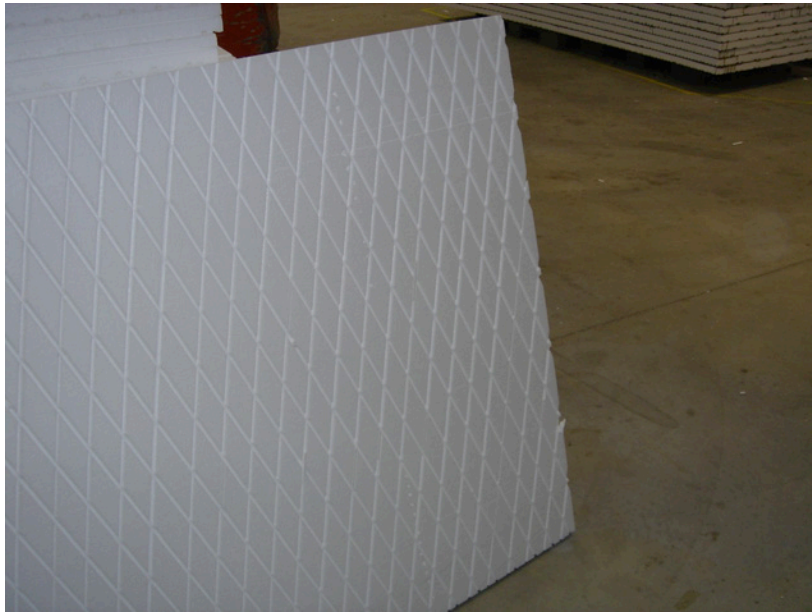
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Joseph Lstiburek 94



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Joseph Lstiburek 95



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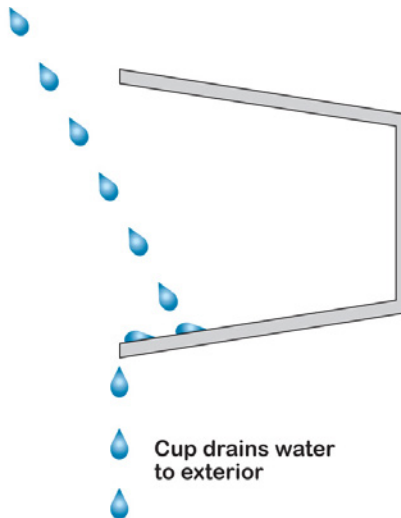
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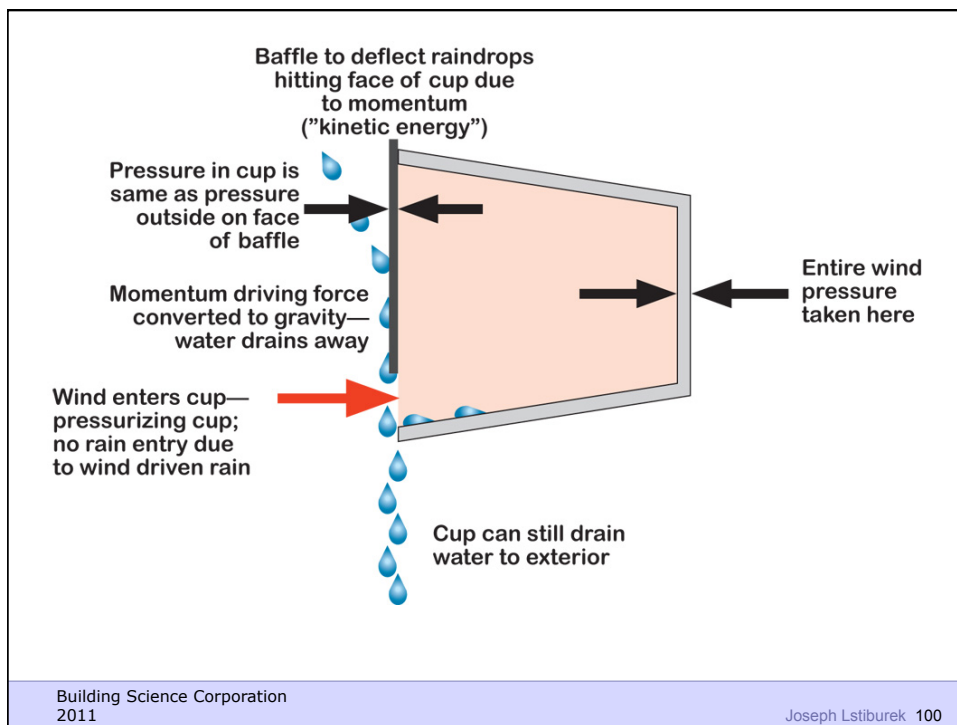
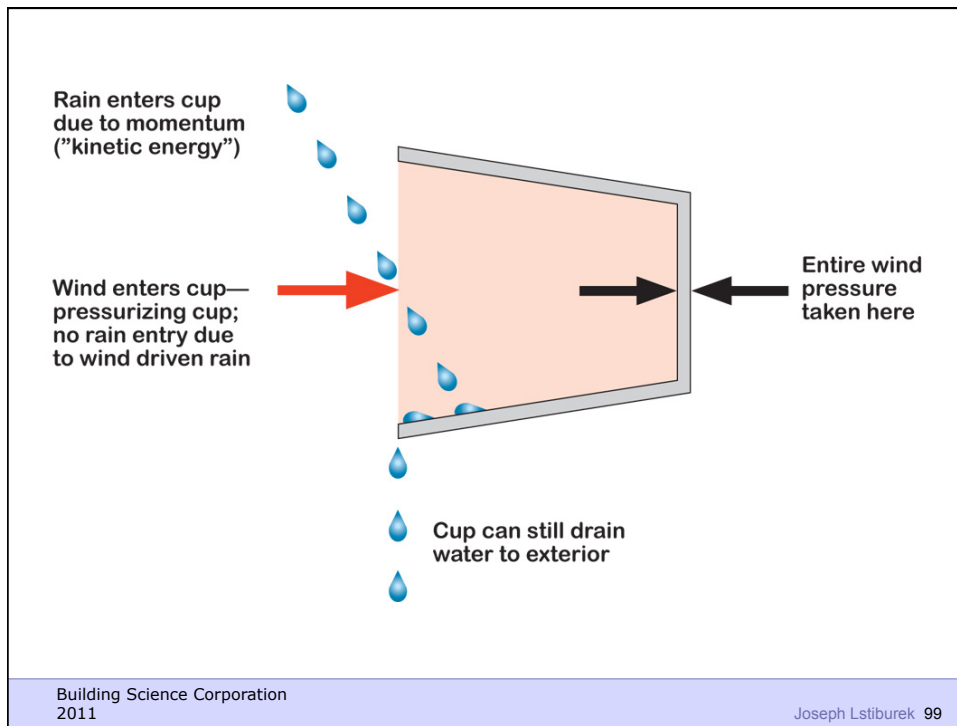
Rain enters cup
due to momentum
("kinetic energy")

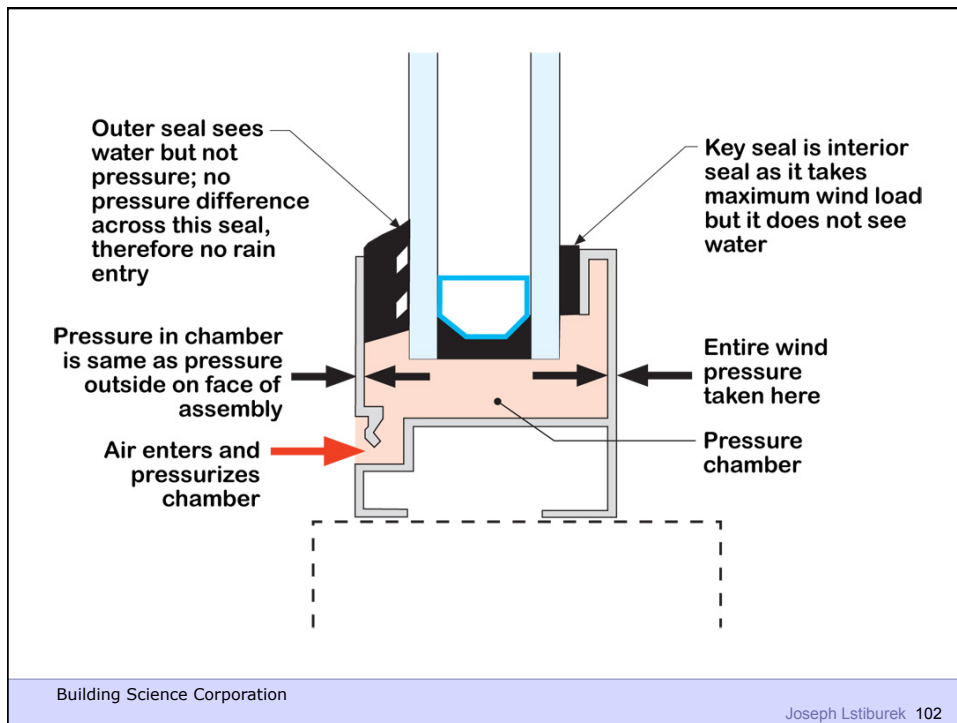
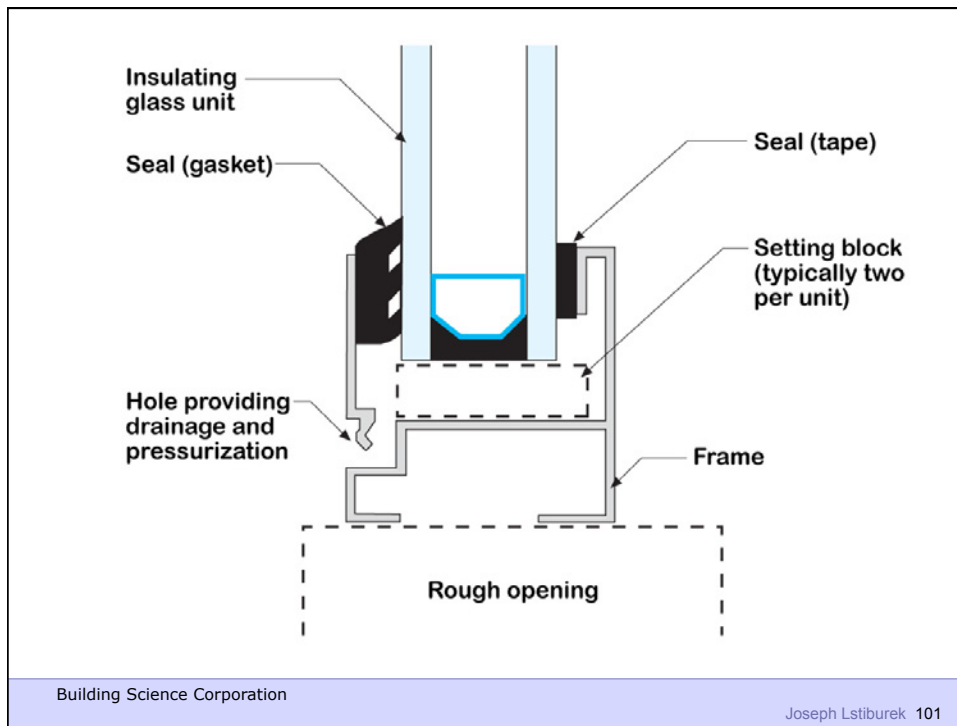


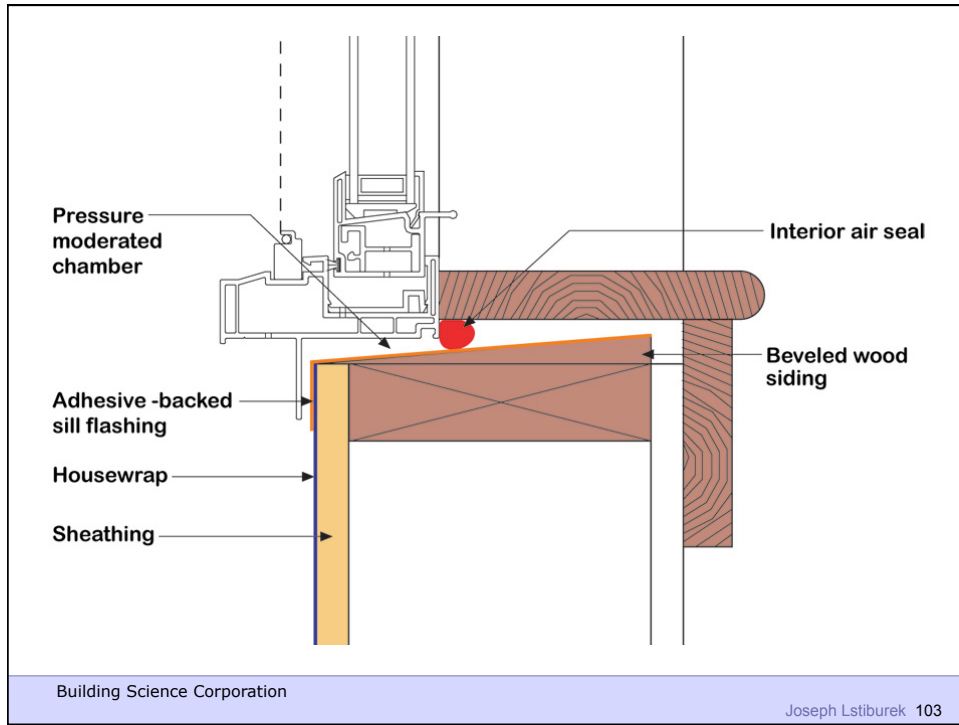
Cup drains water
to exterior

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2011

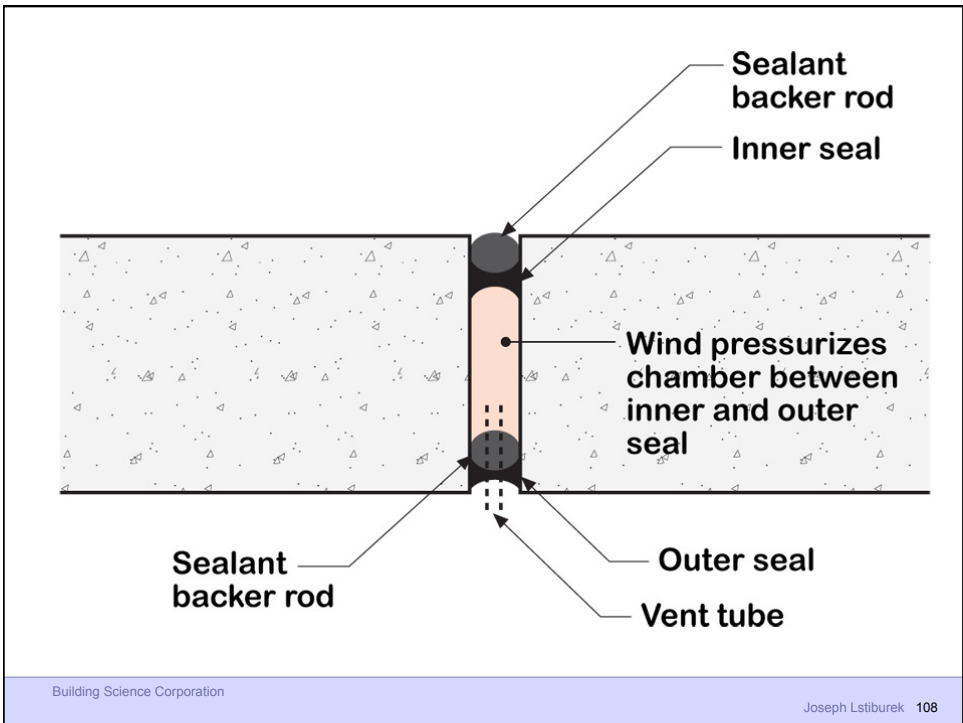
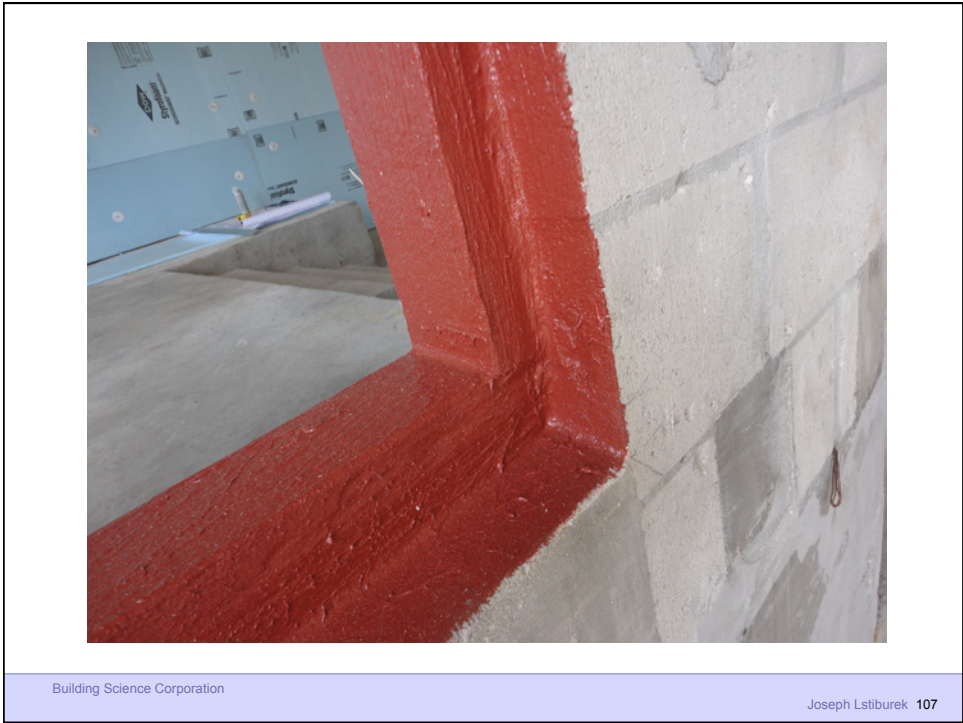
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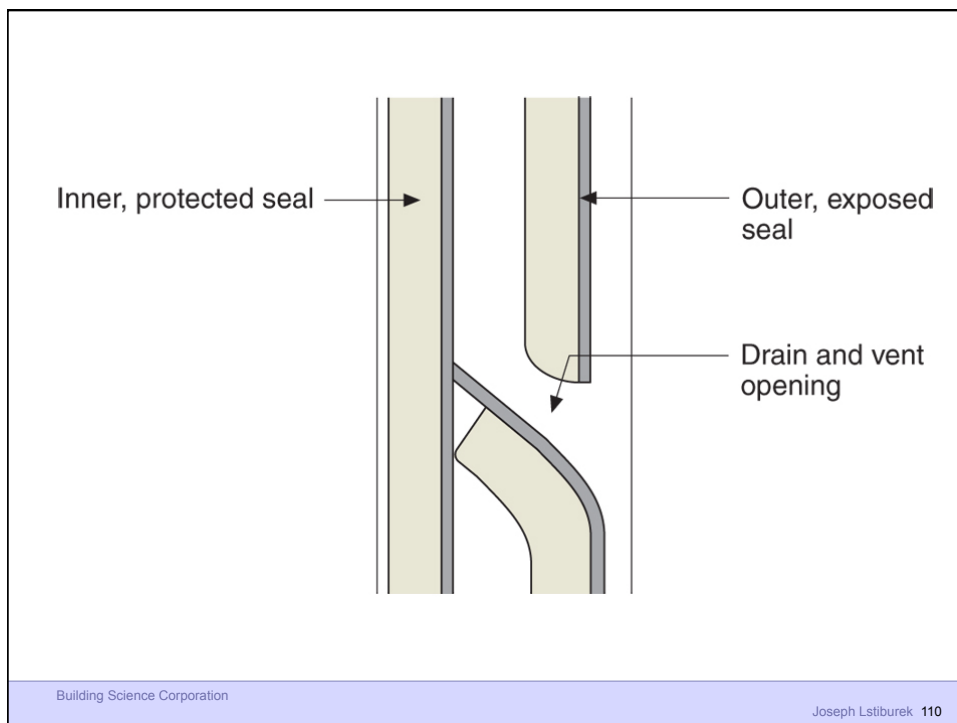
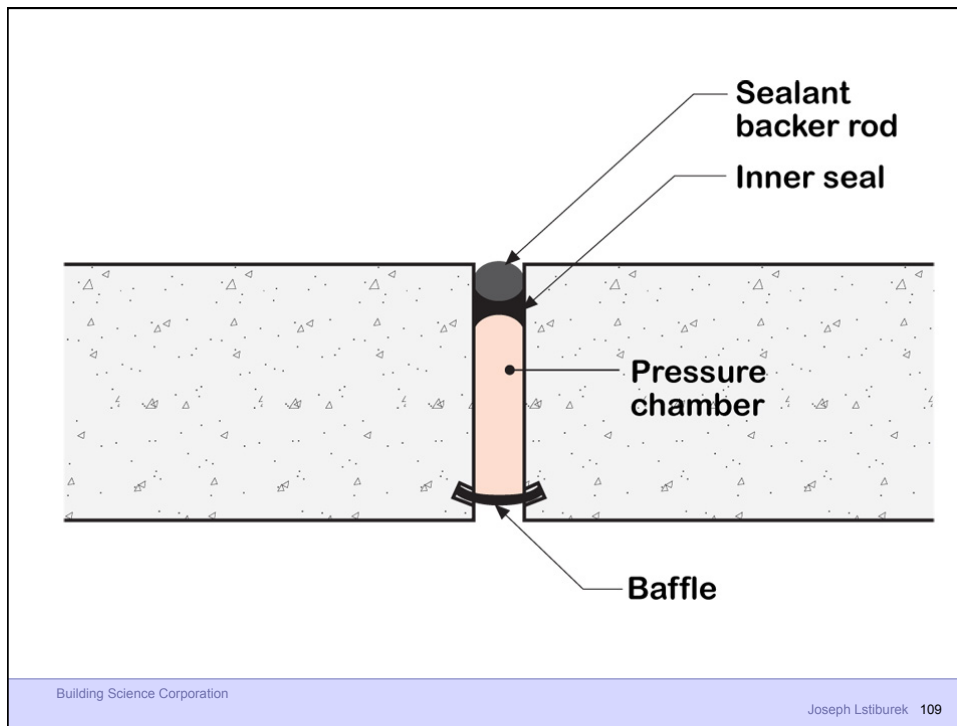


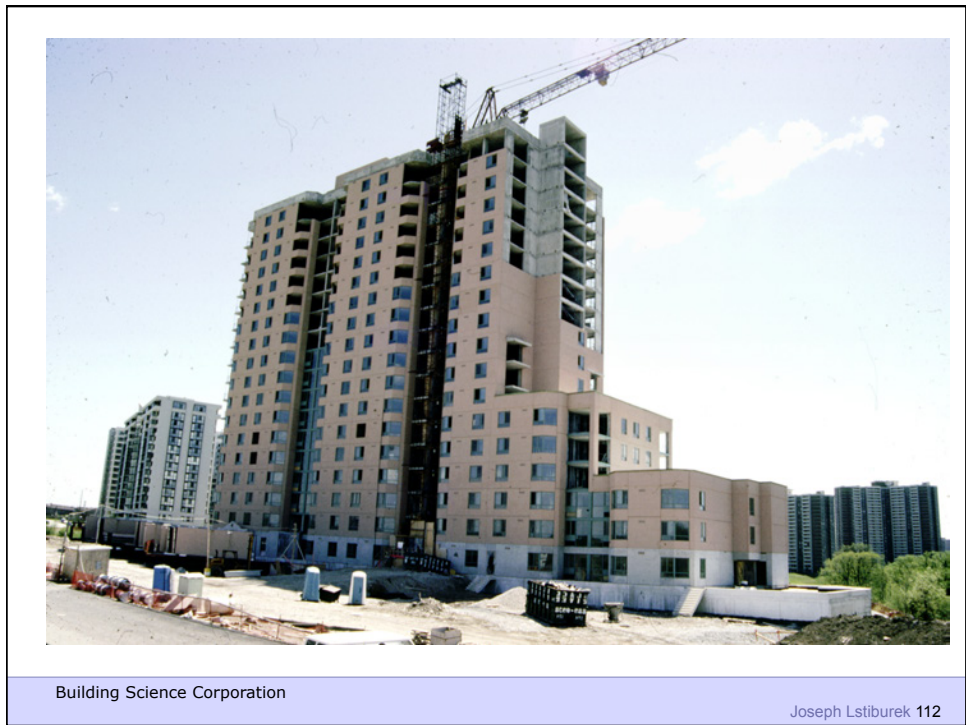
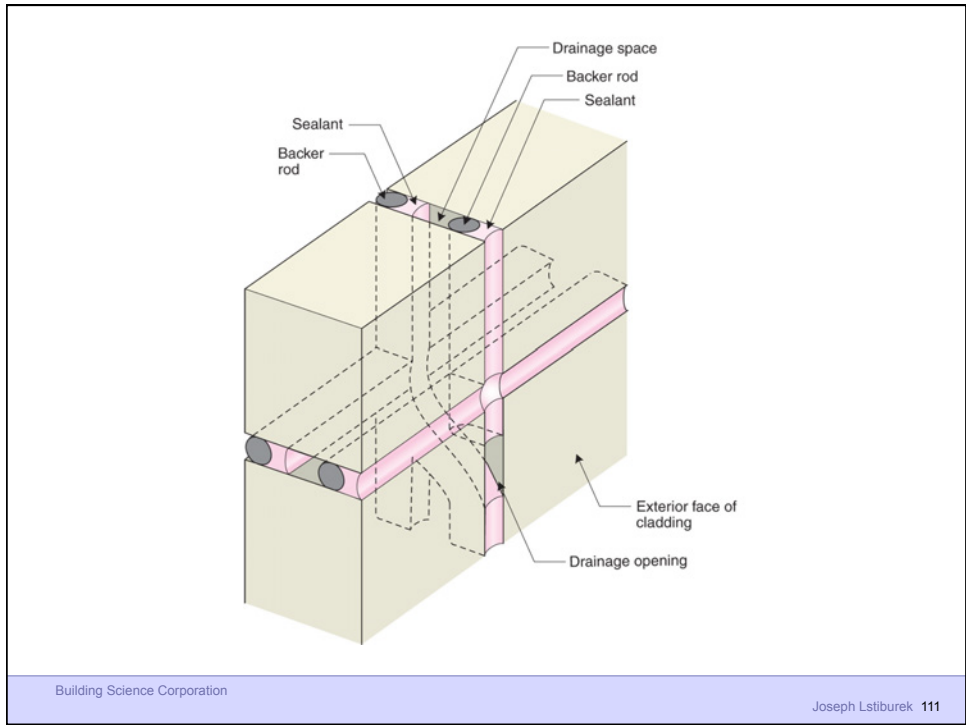




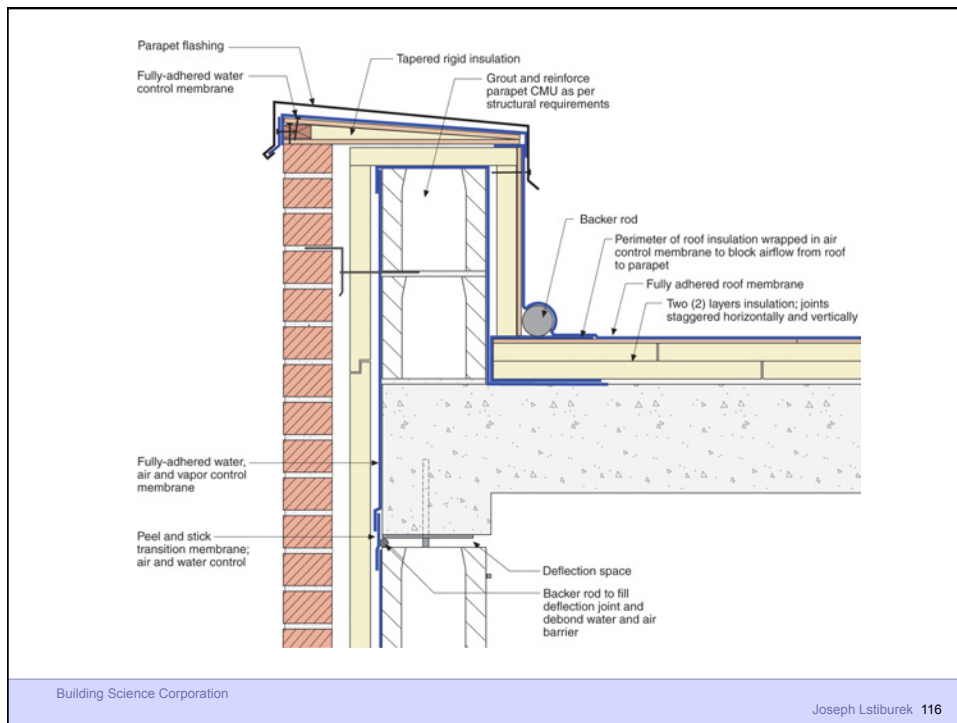
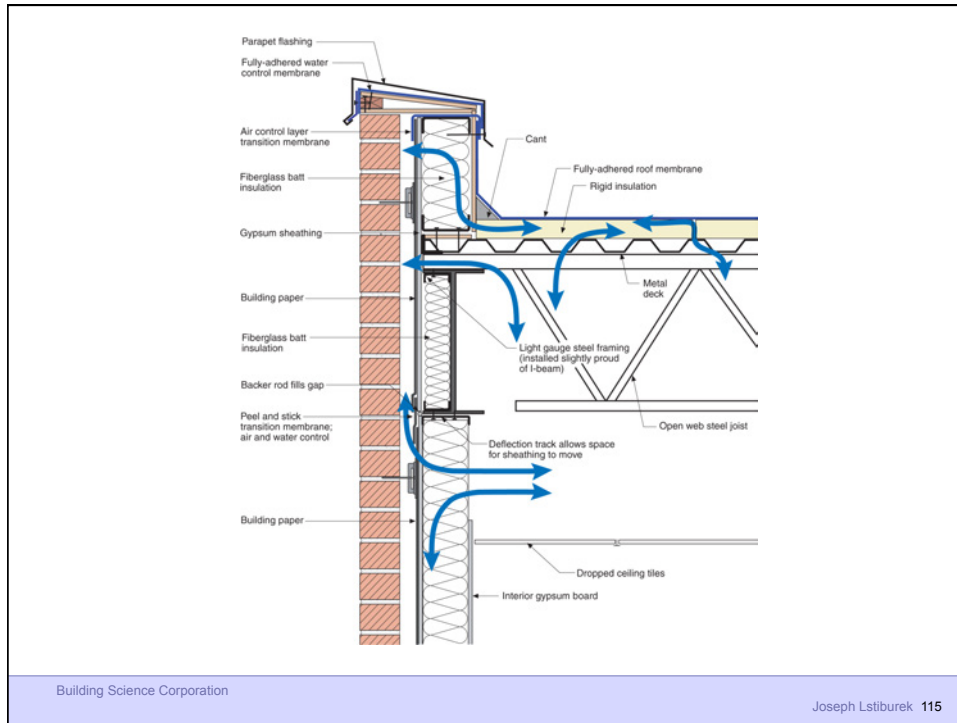


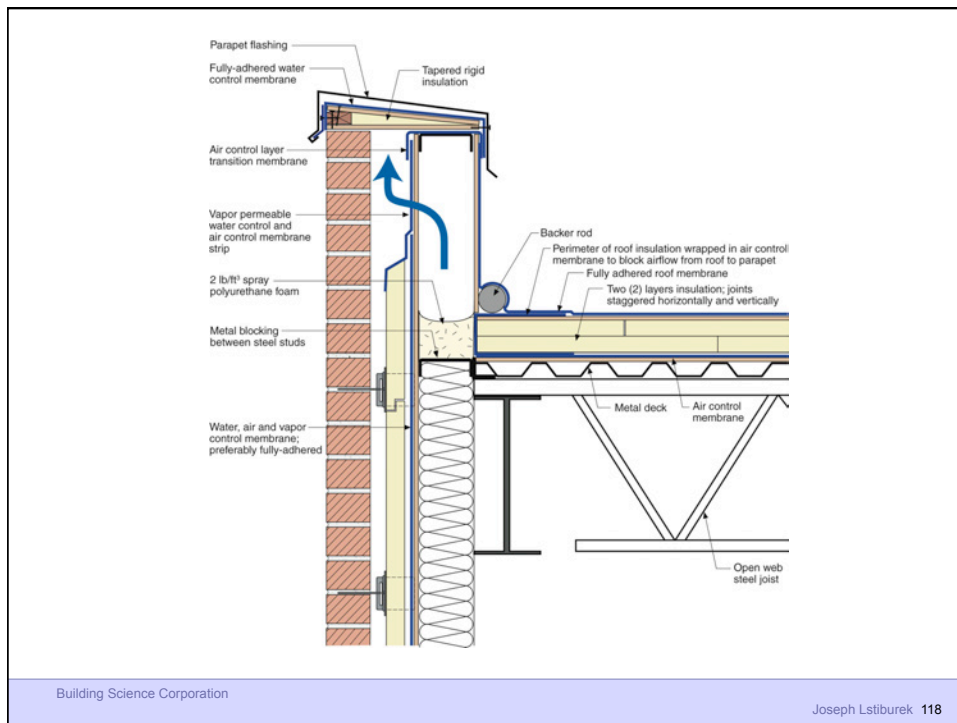
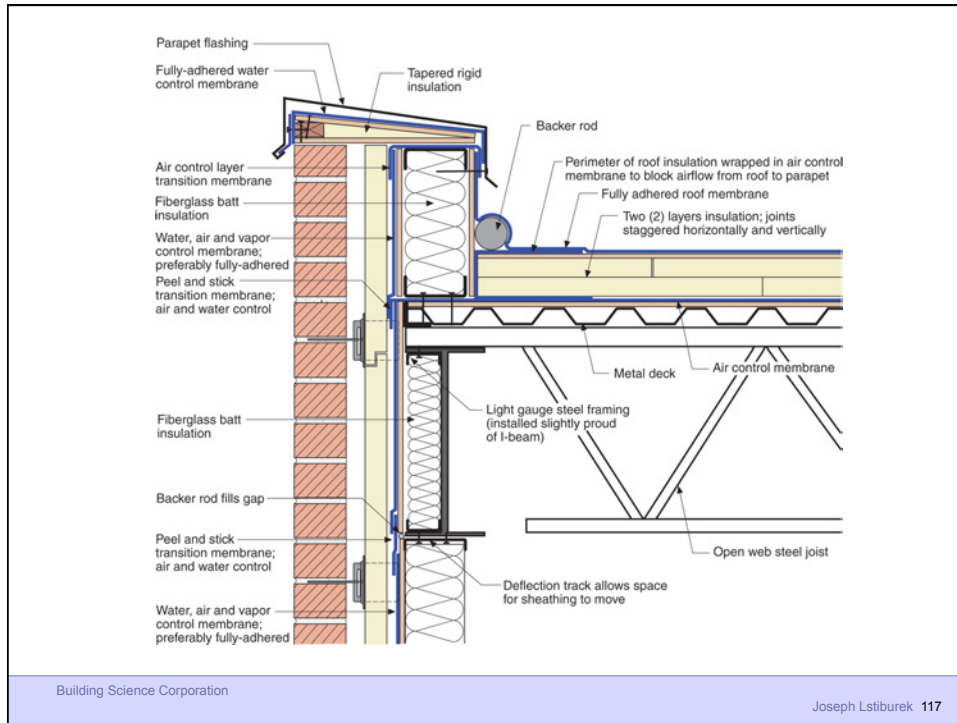


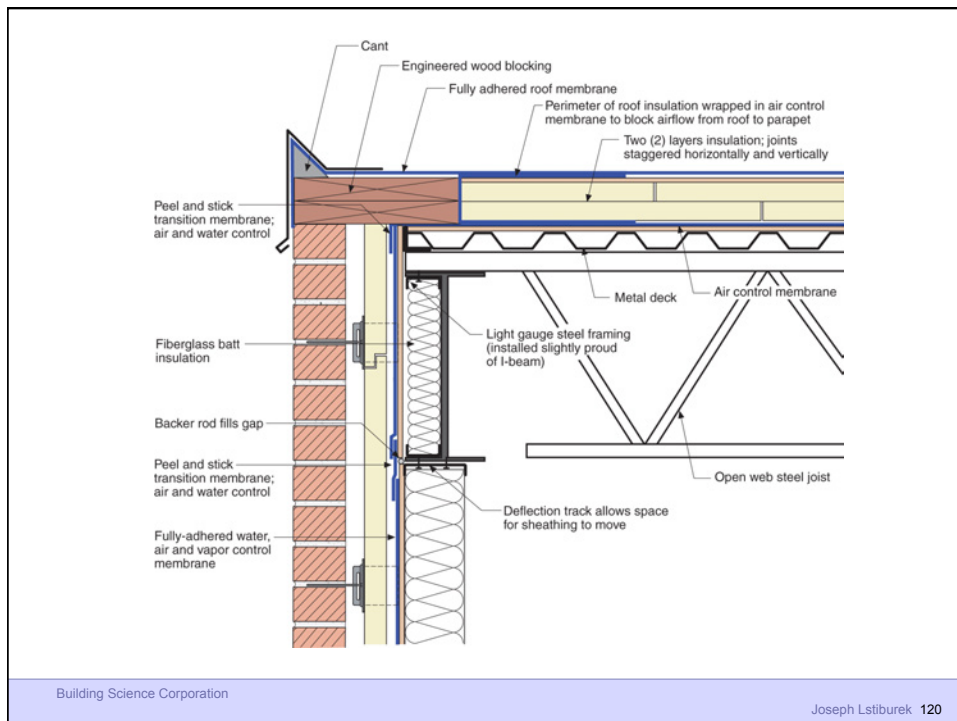
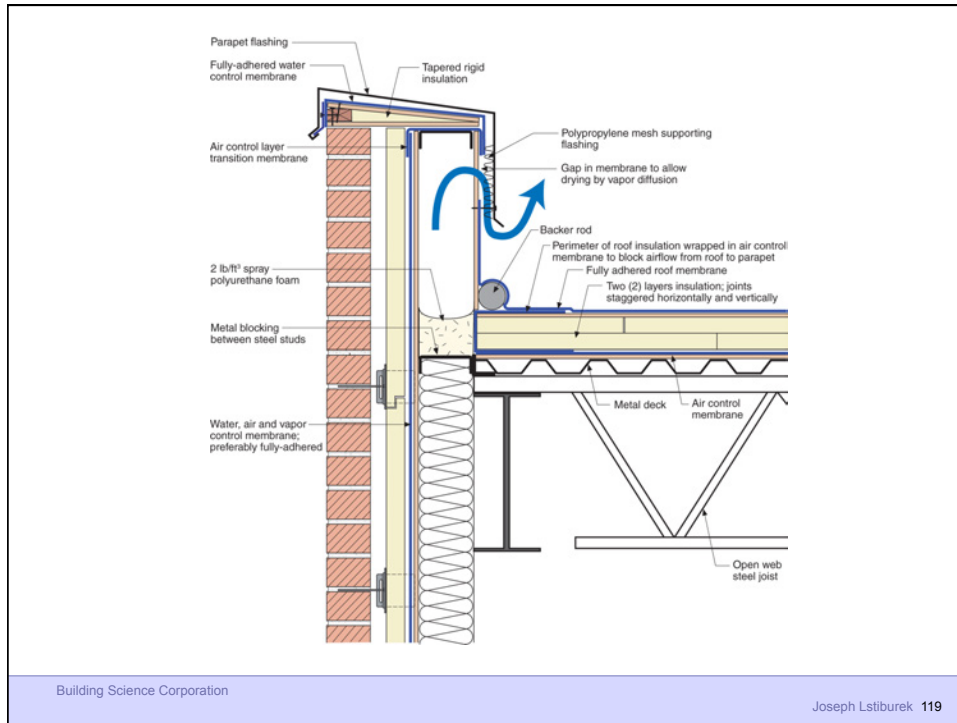


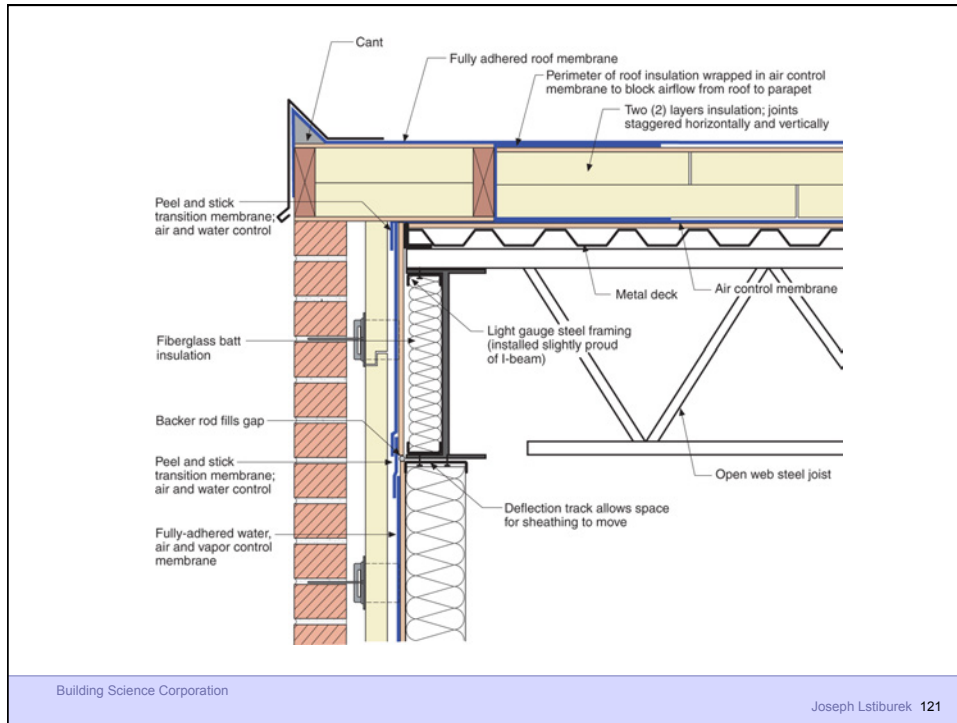




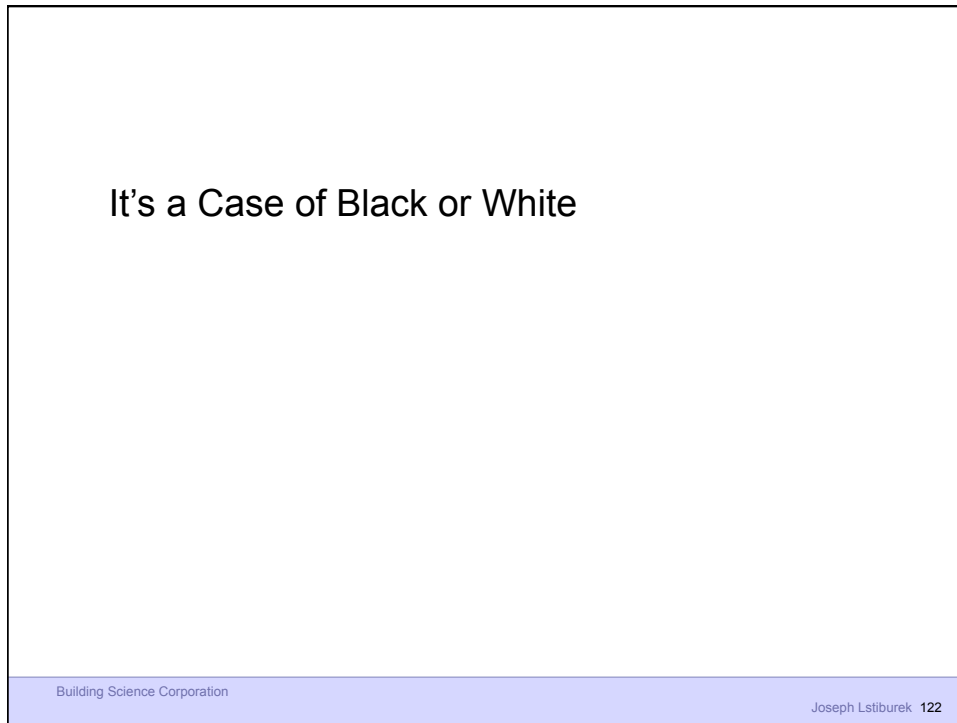








It's a Case of Black or White



It's a Case of Black or White Arrhenius

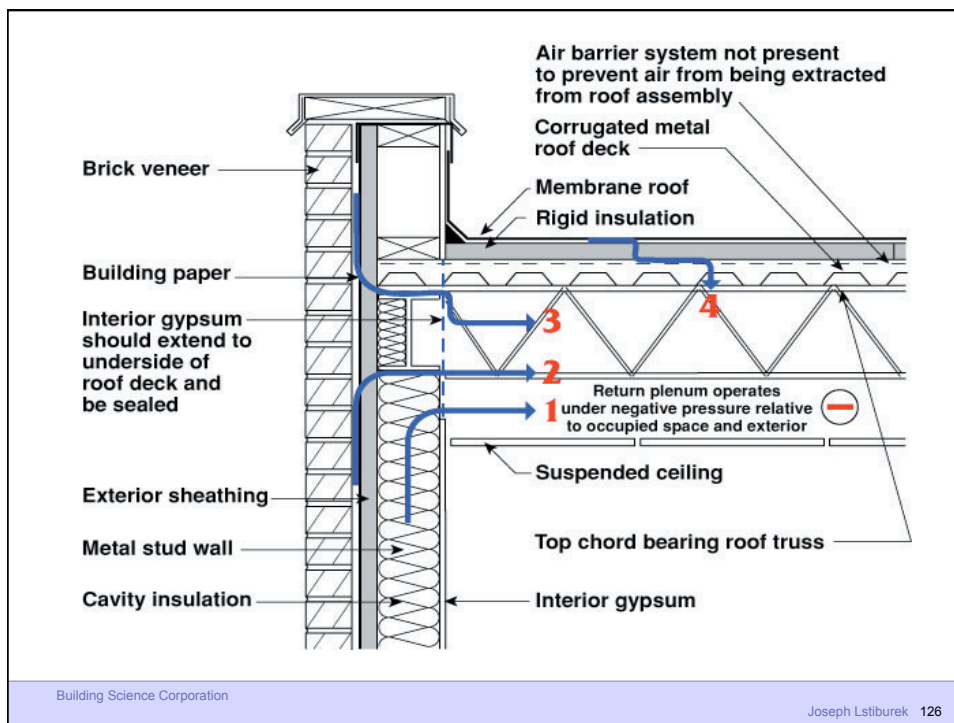
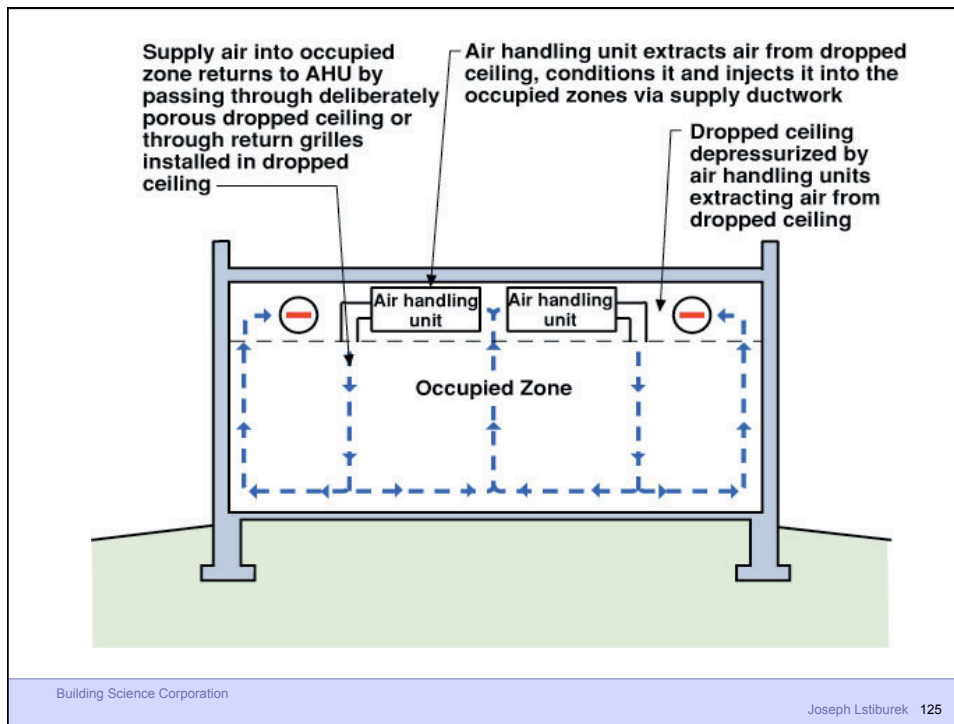
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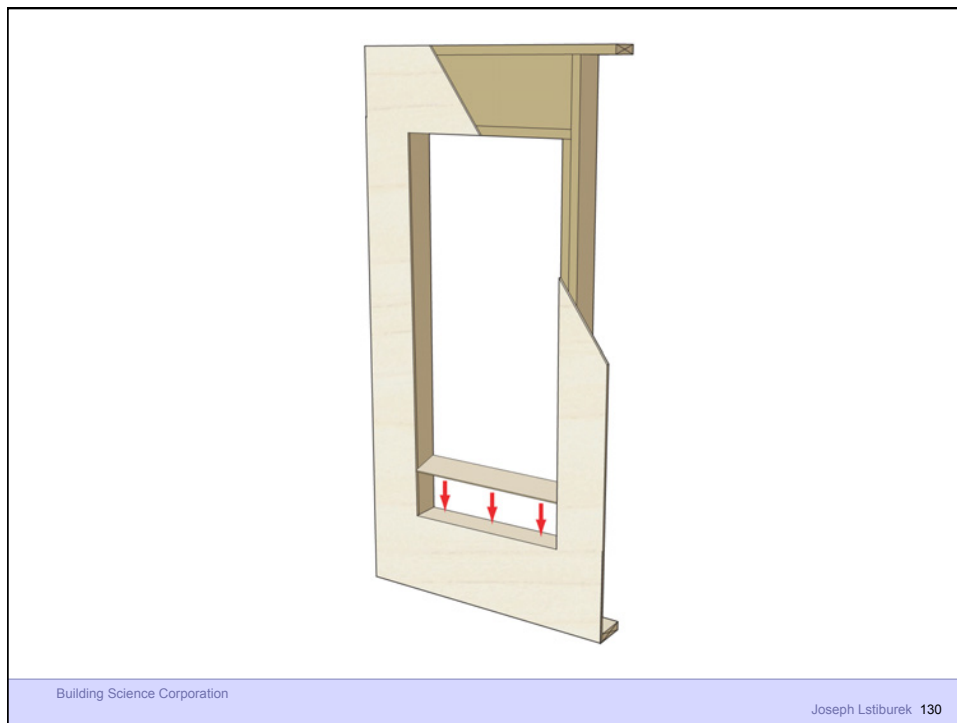
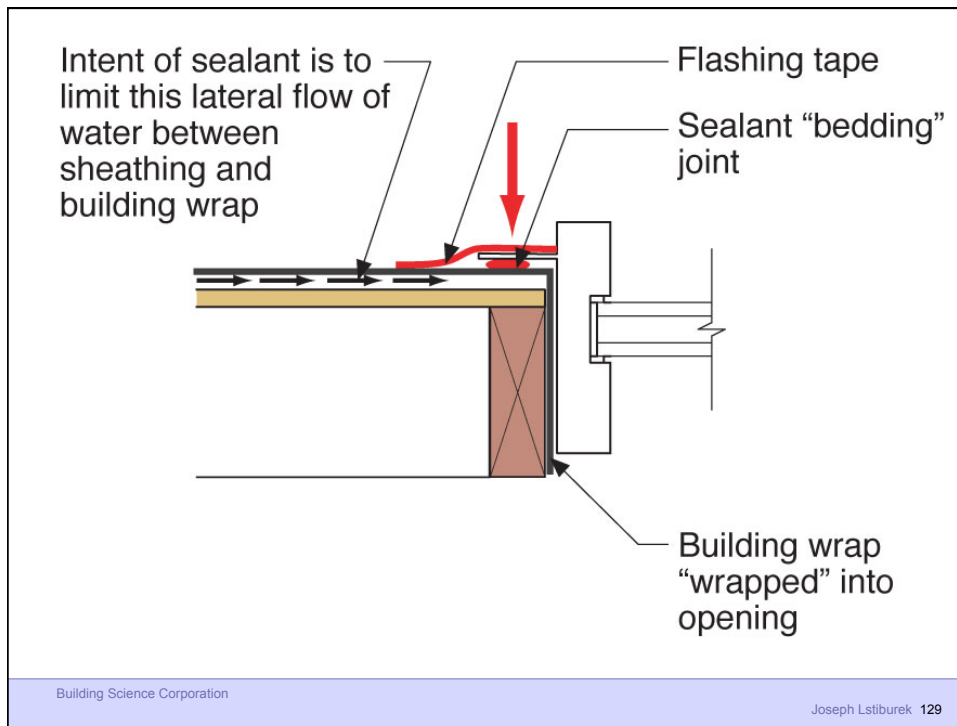
It's a Case of Black or White
Arrhenius
Every 10 degrees C – double the “badness”

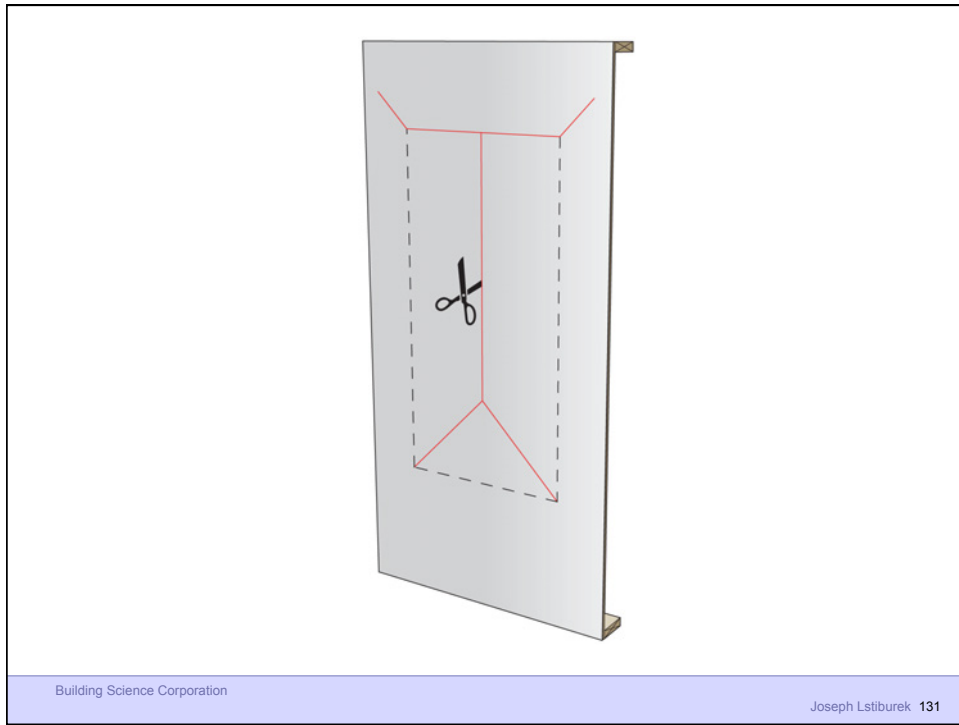
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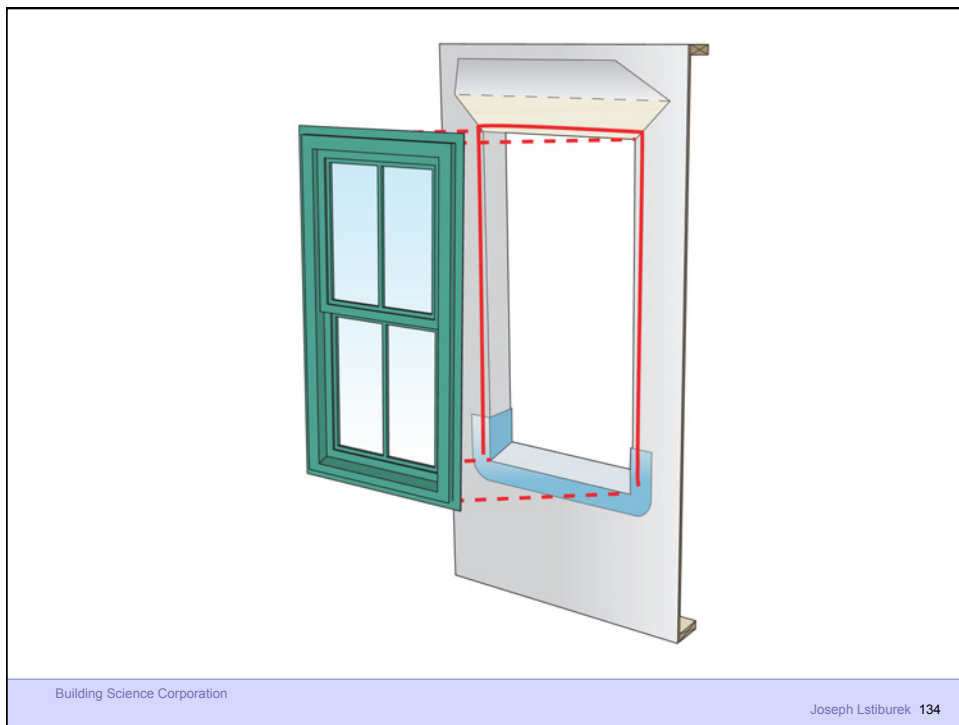
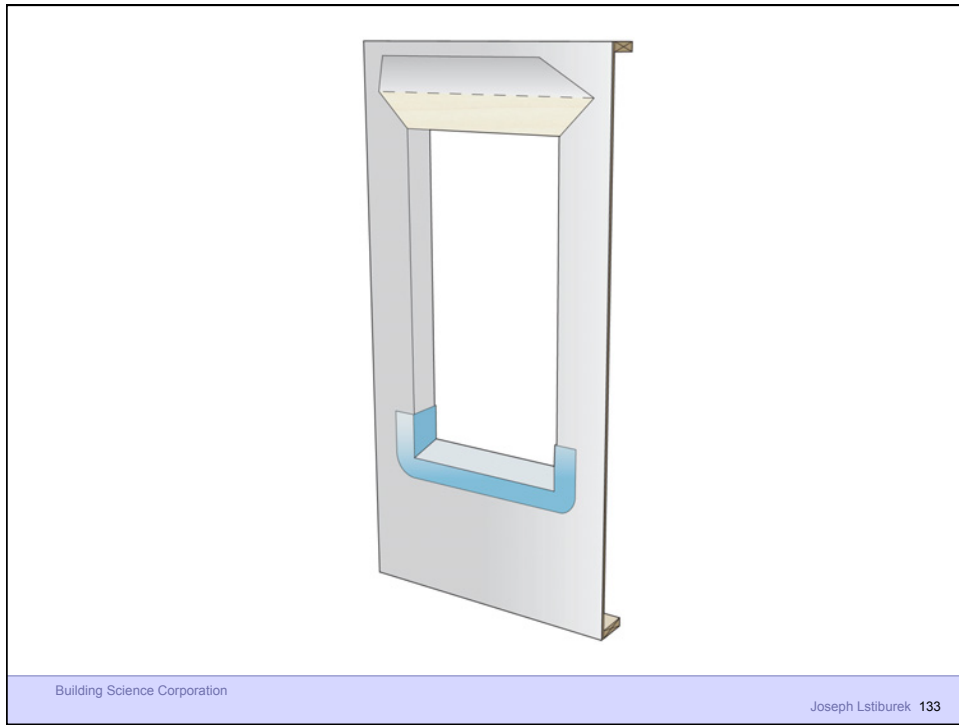
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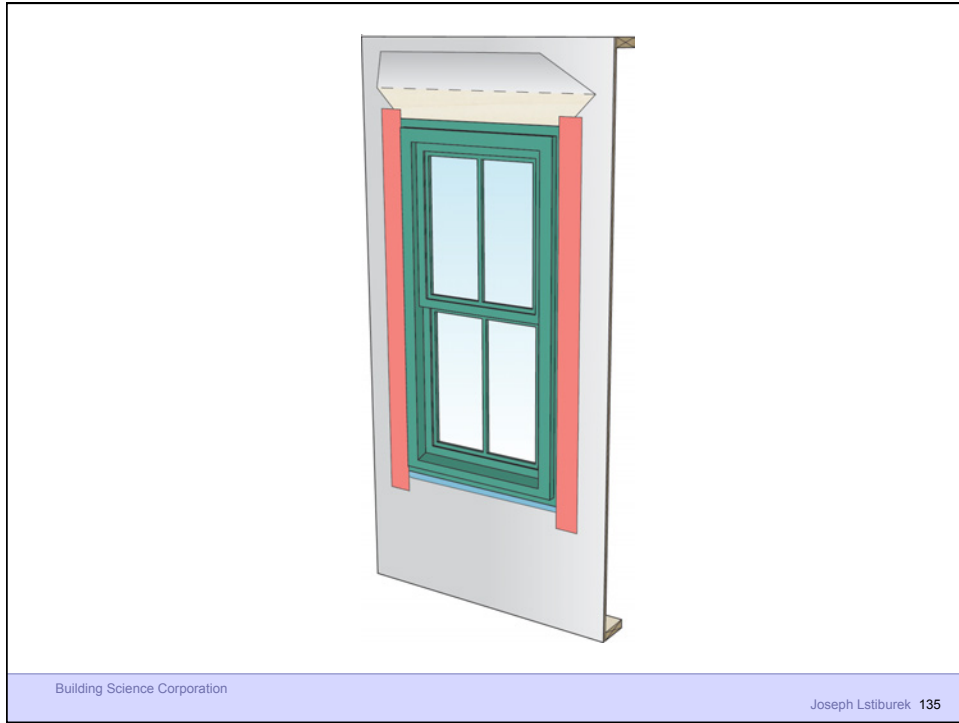


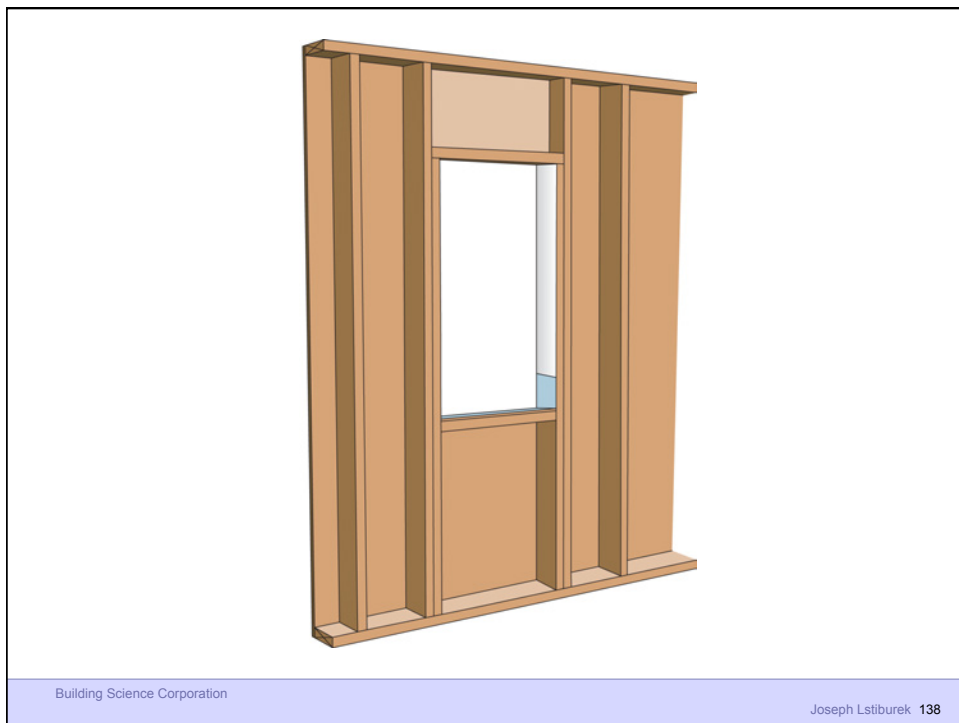
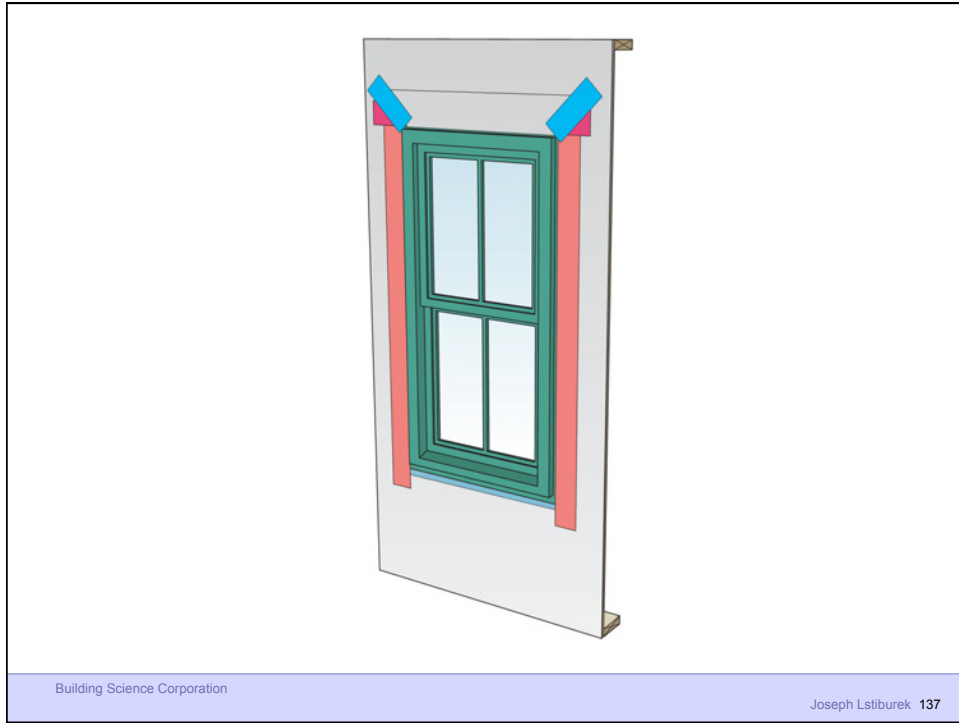


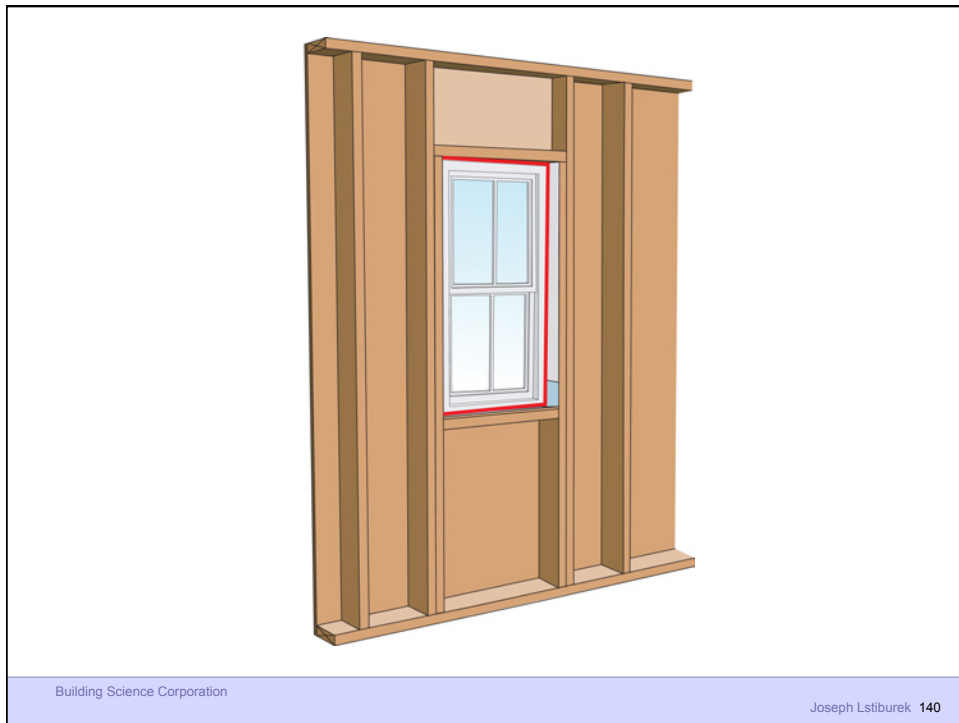
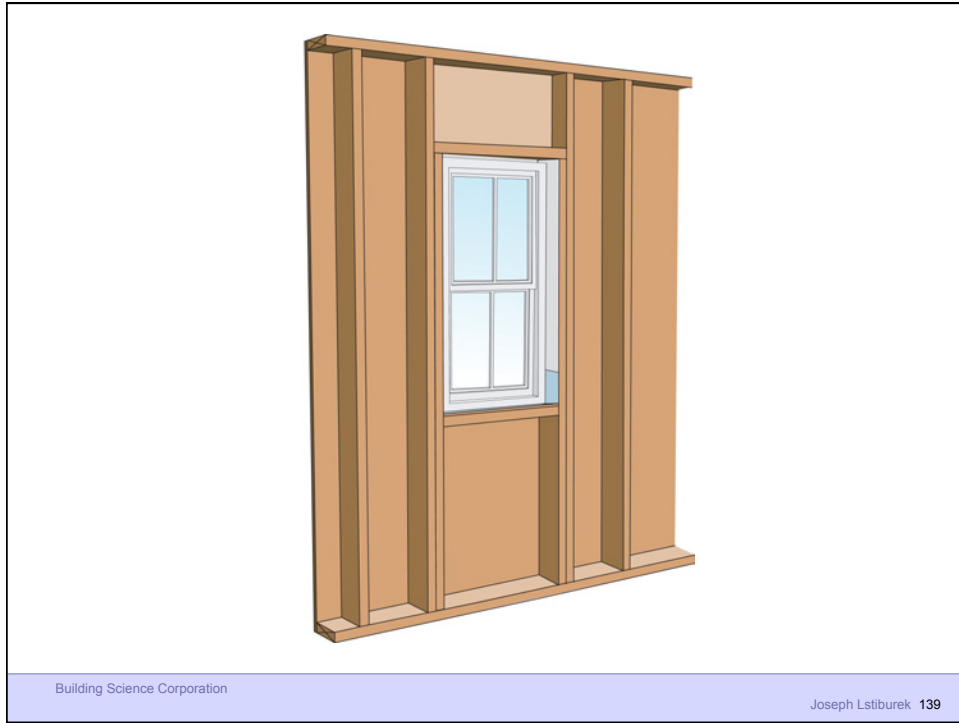














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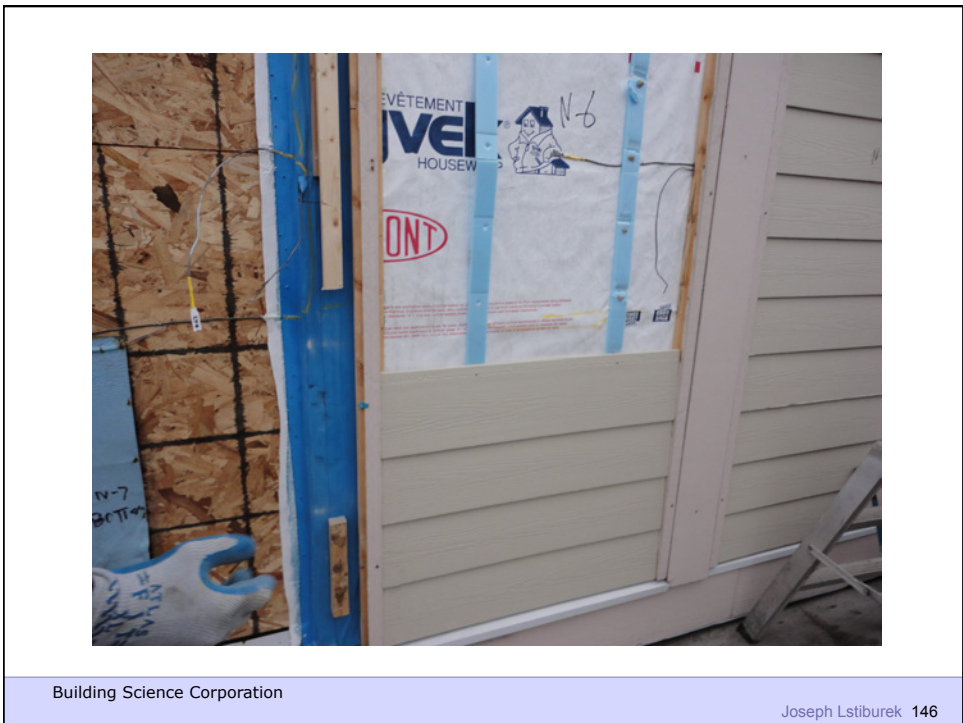
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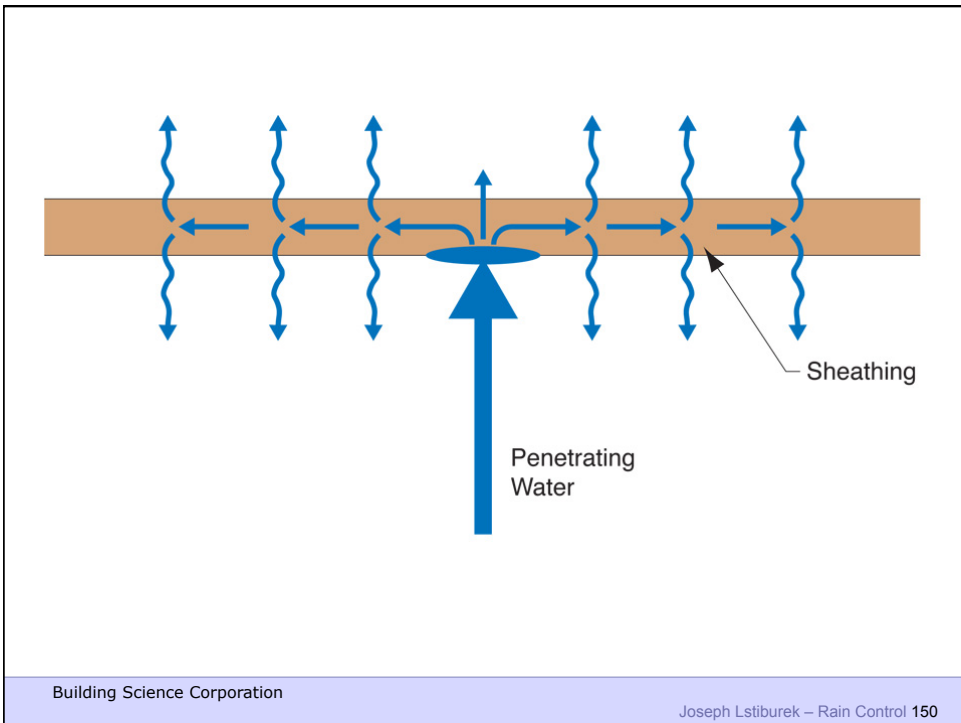


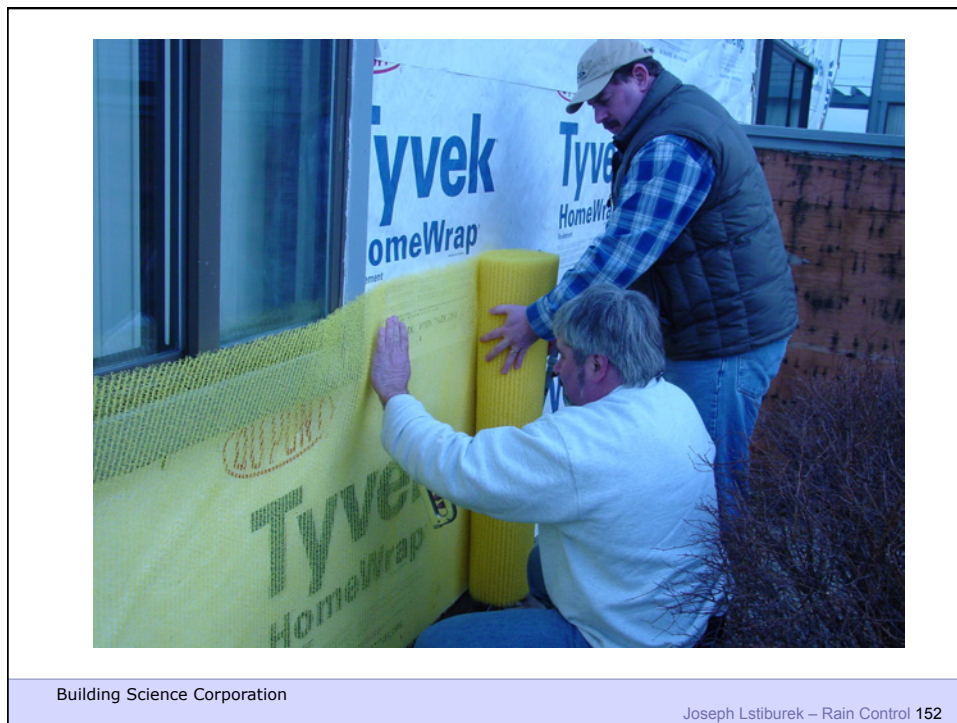
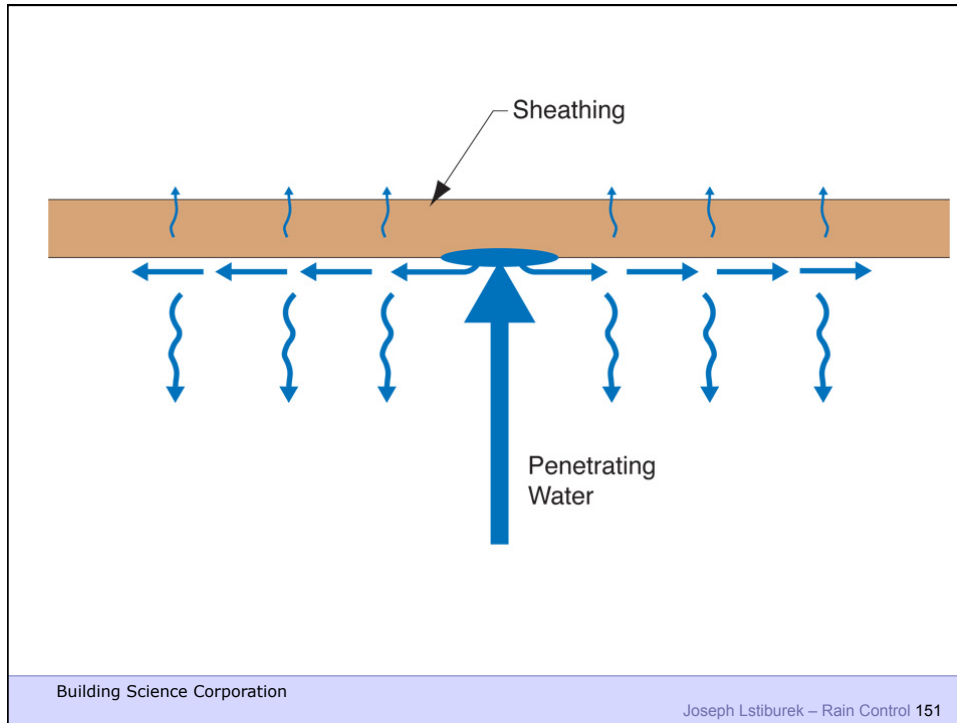
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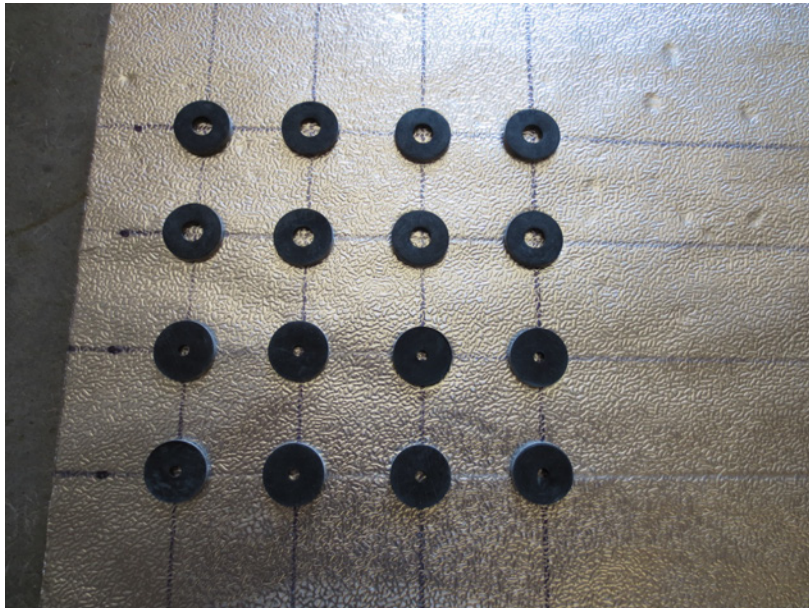




Rain Screen

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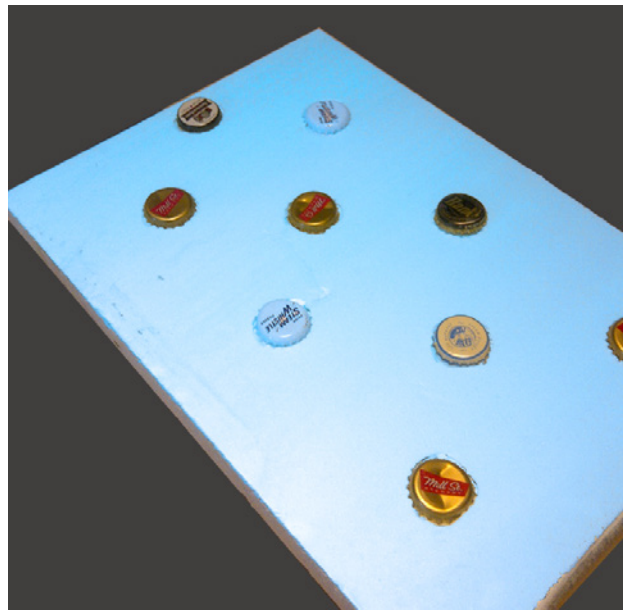
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Beer Screen?

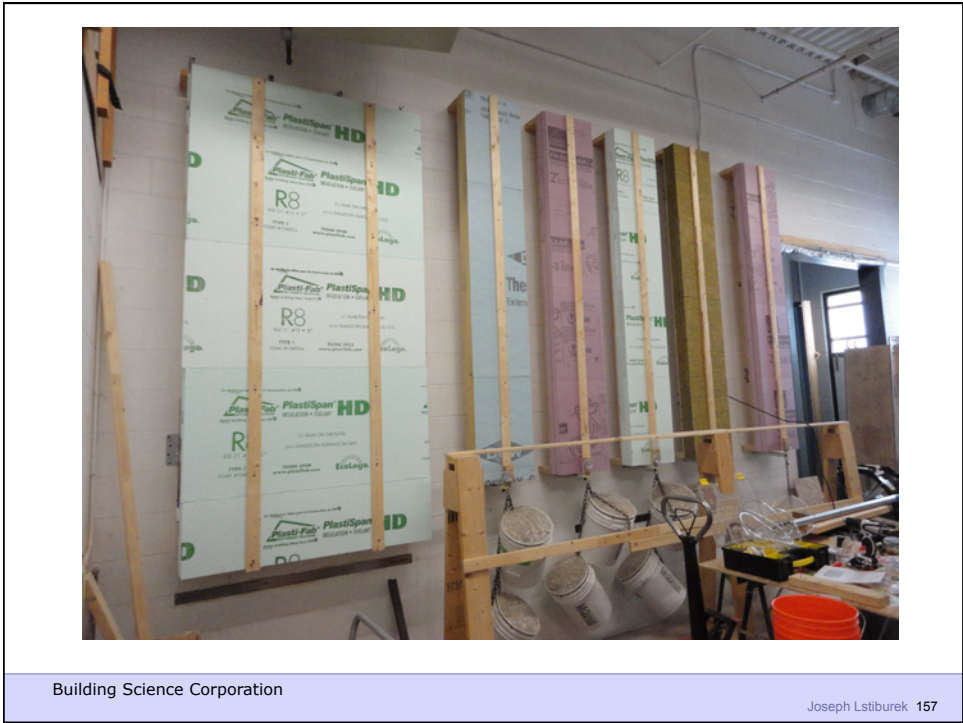
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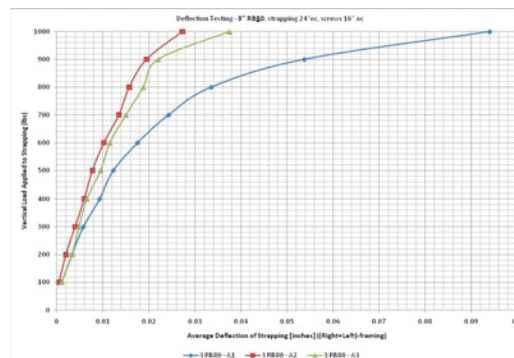
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Rockwool

1x3 furring @ 24" o.c.
 #10 screws @ 16" o.c. vertically
 Result: 20 psf cladding weight
 with < 2/100" deflection



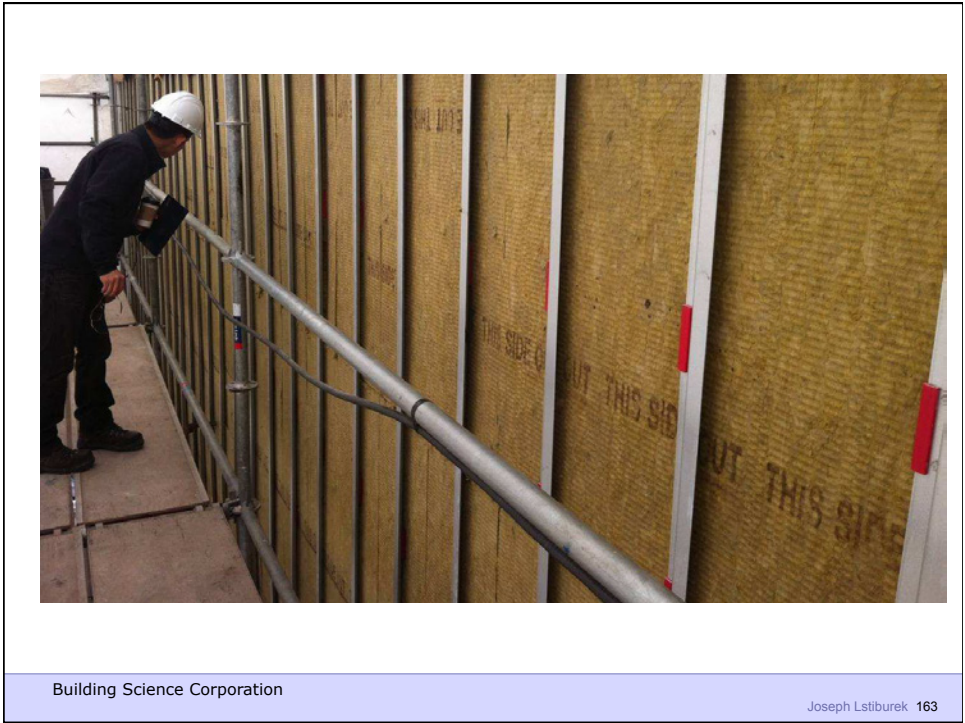


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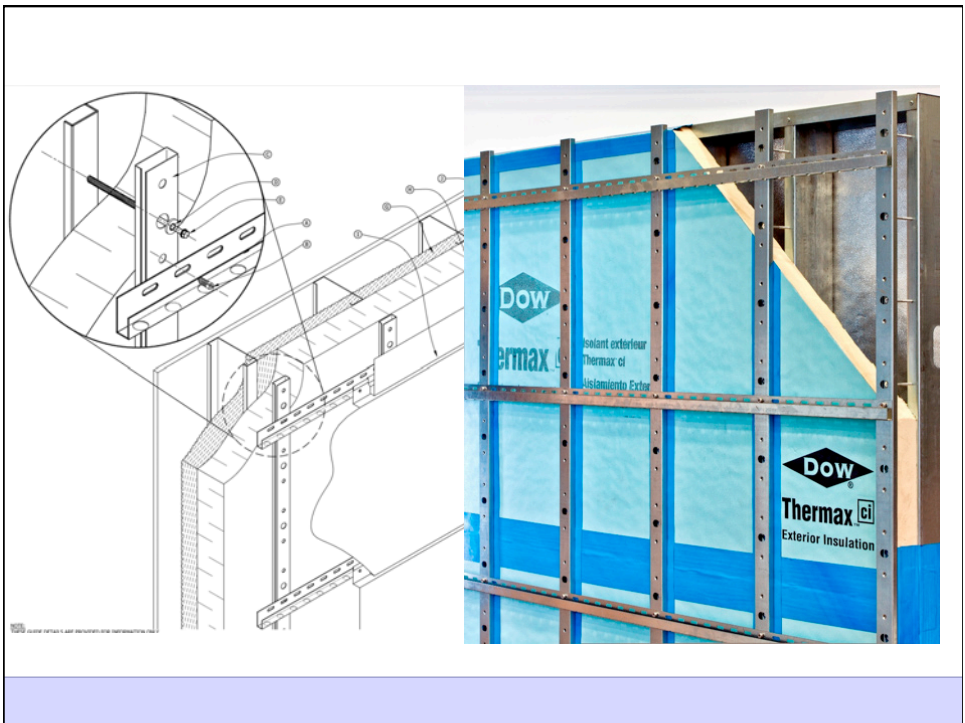


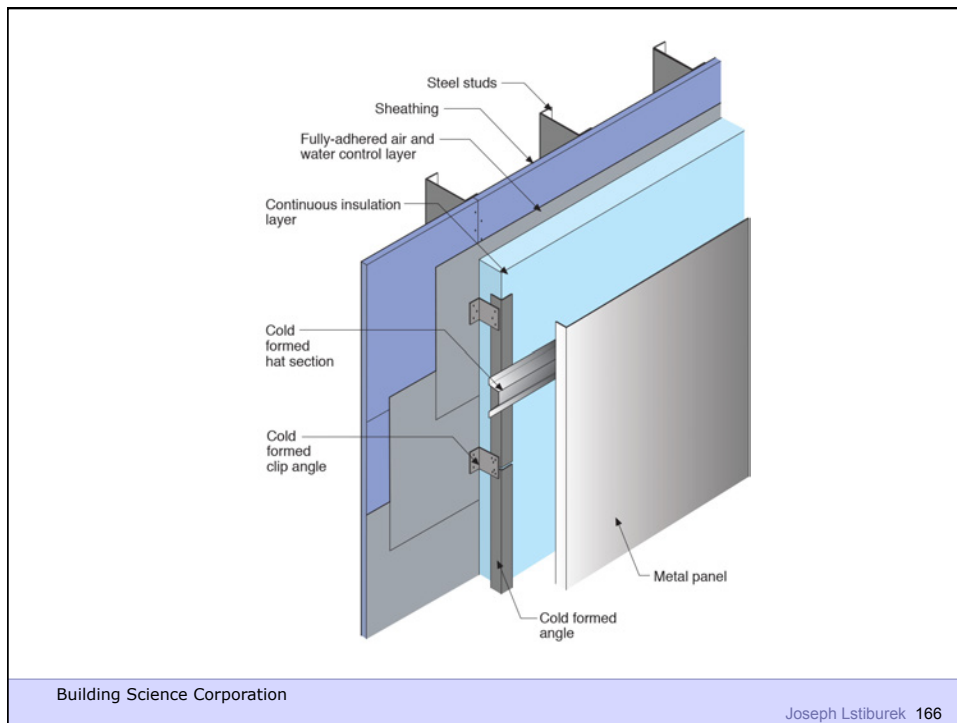
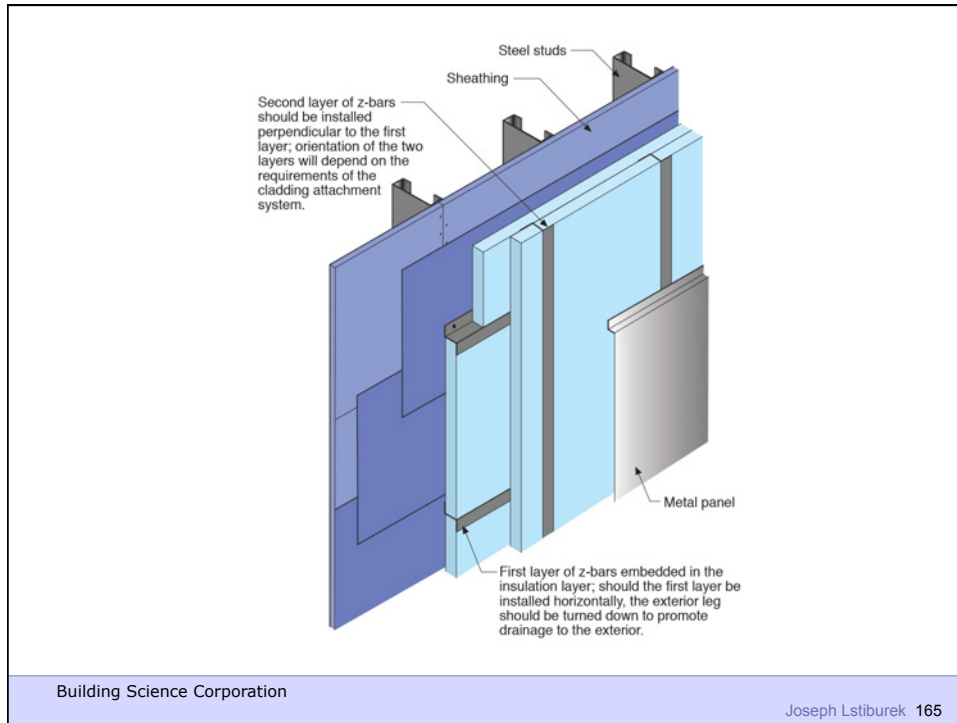
162

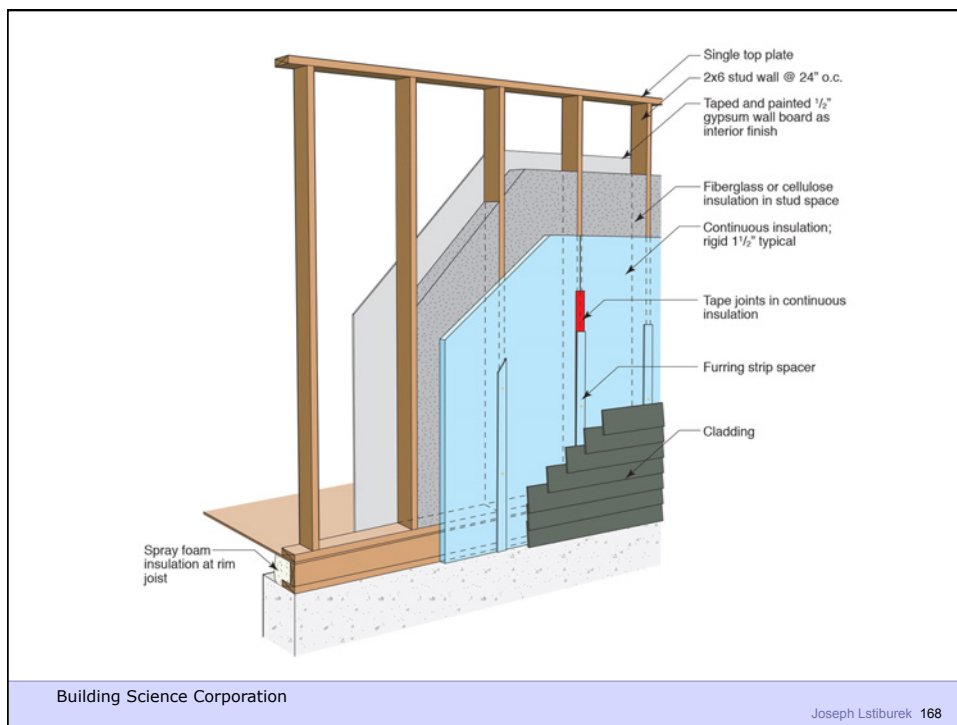
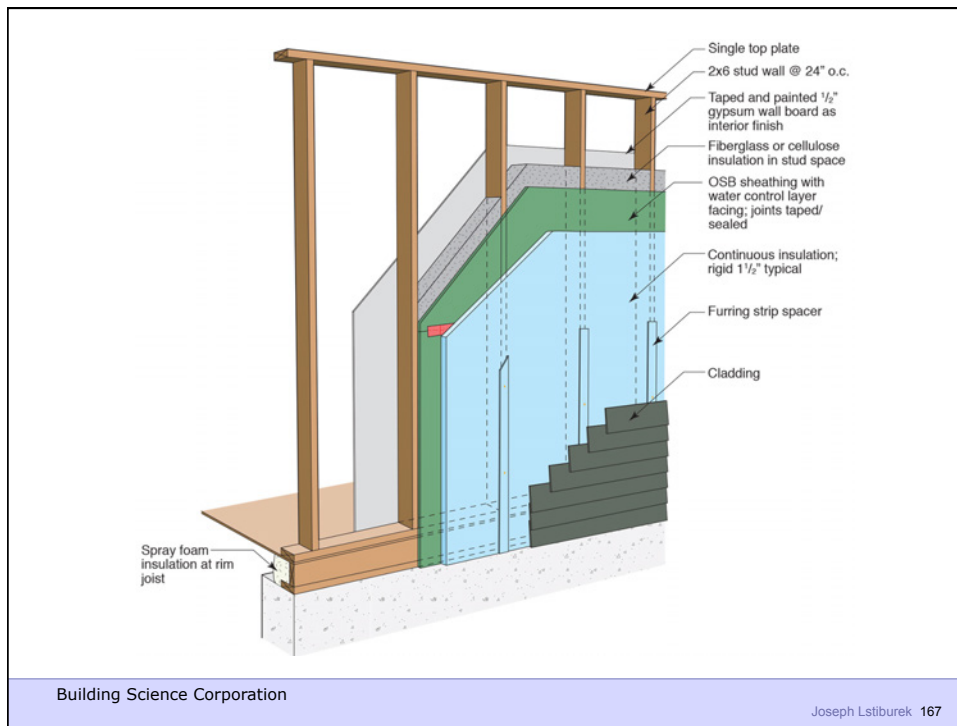


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Joseph Lstiburek 163



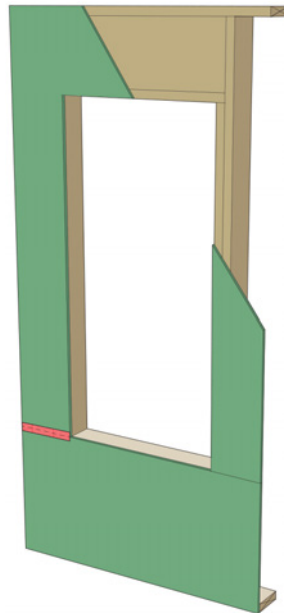




Innies and Outies

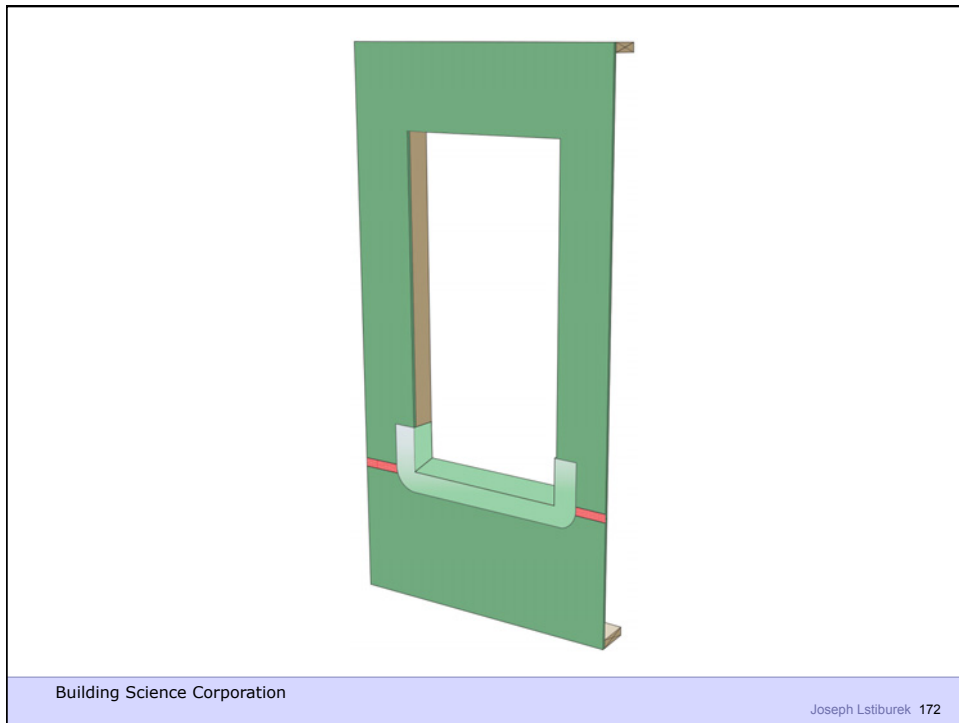
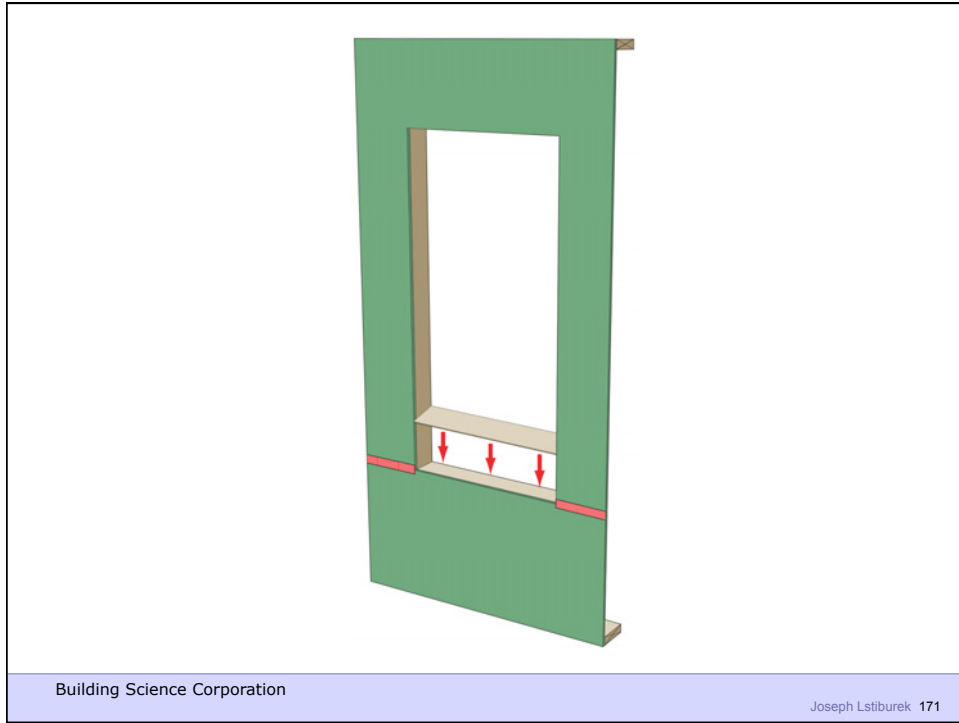
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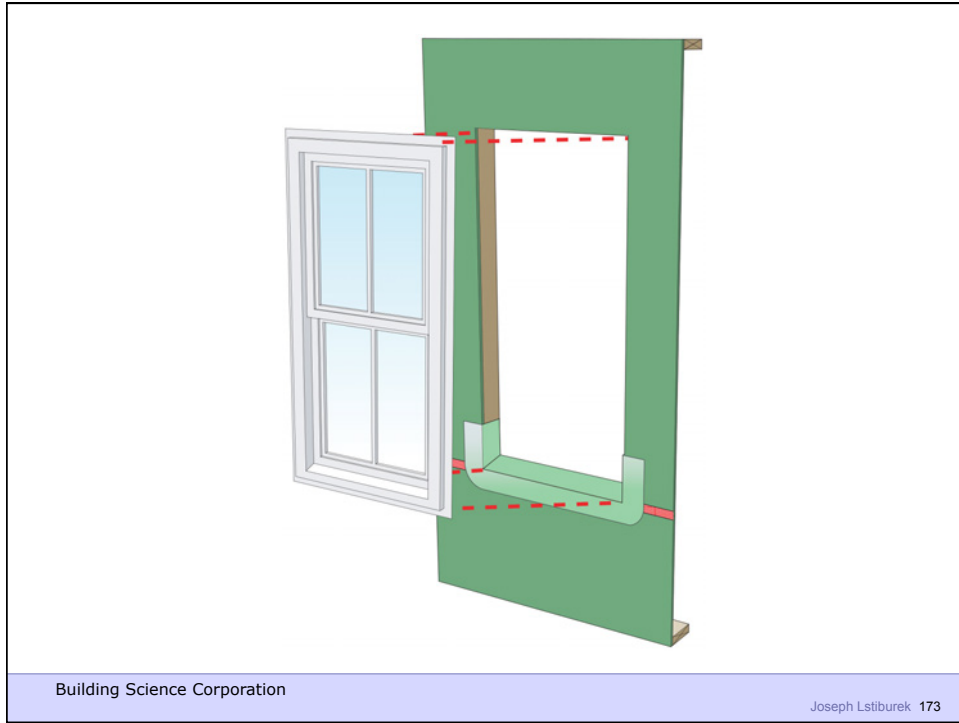
Joseph Lstiburek 169

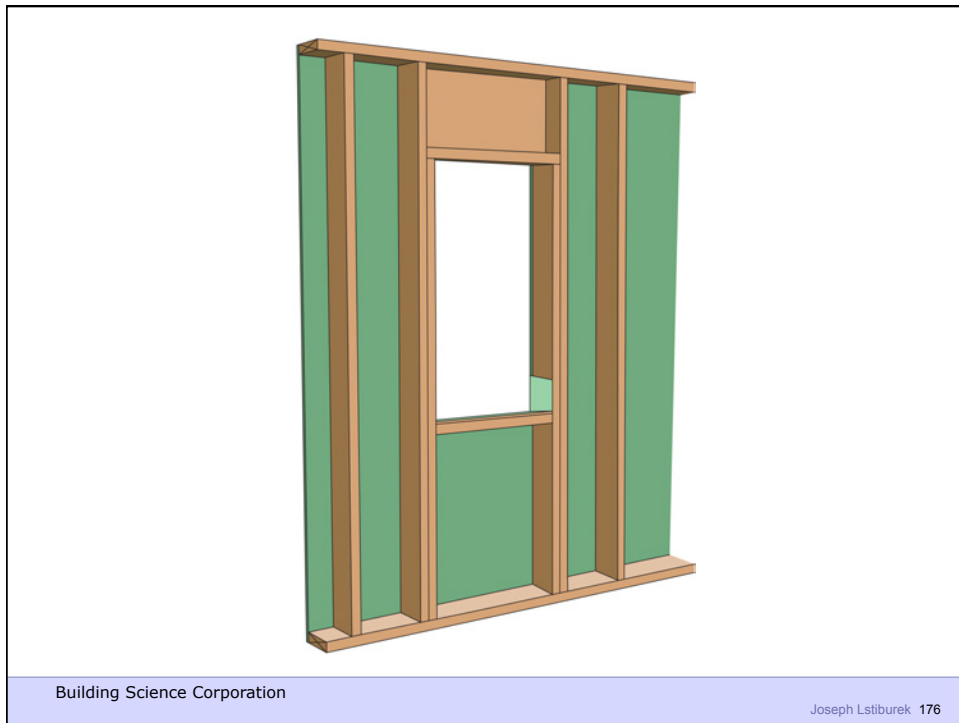
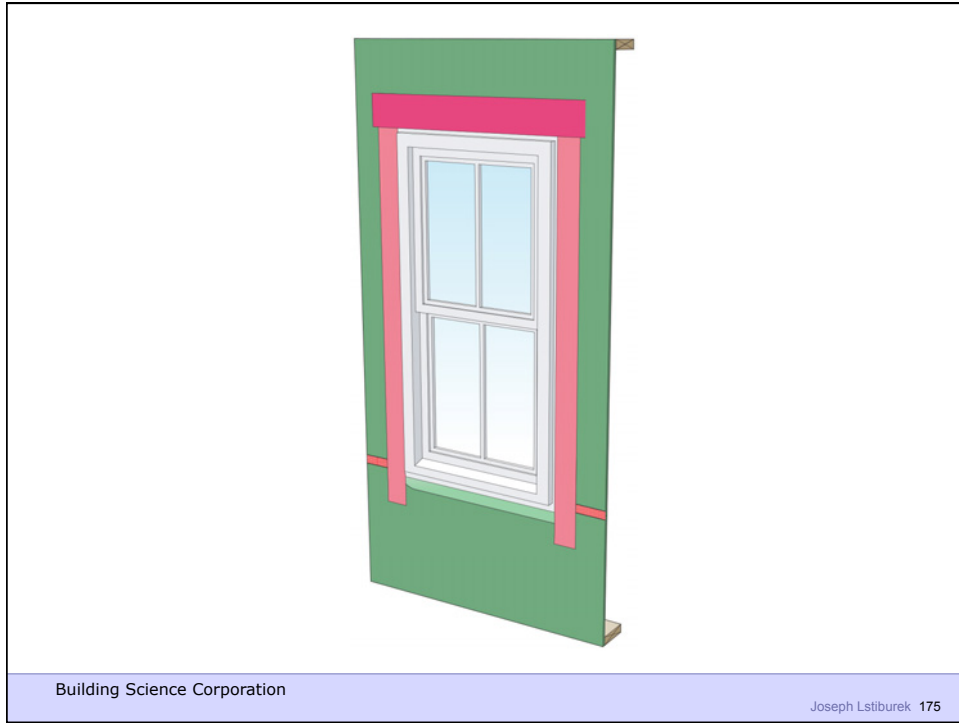


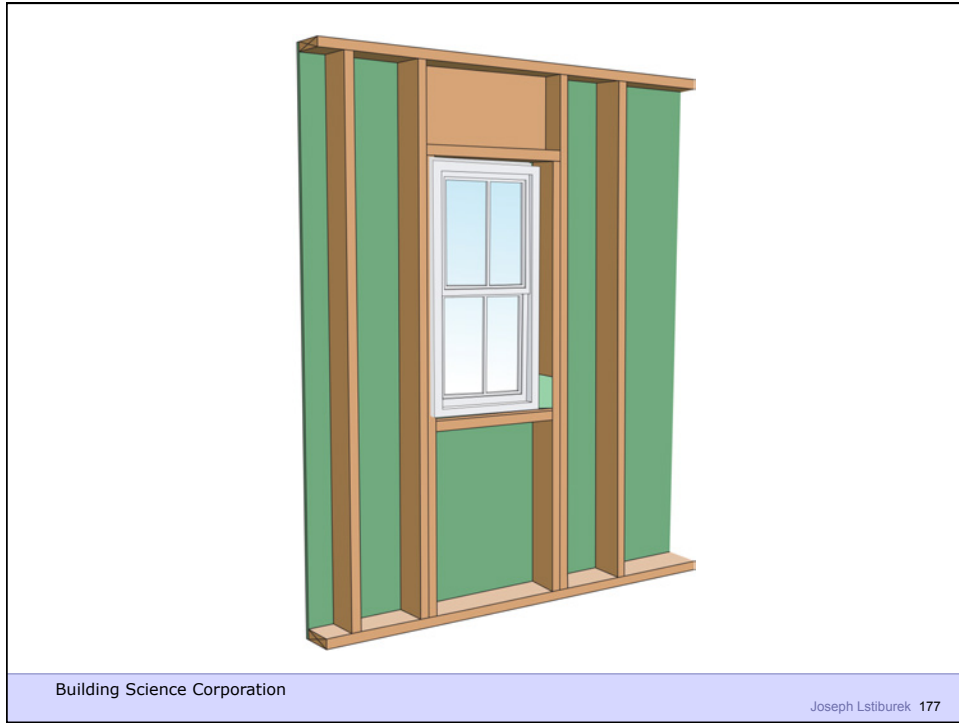
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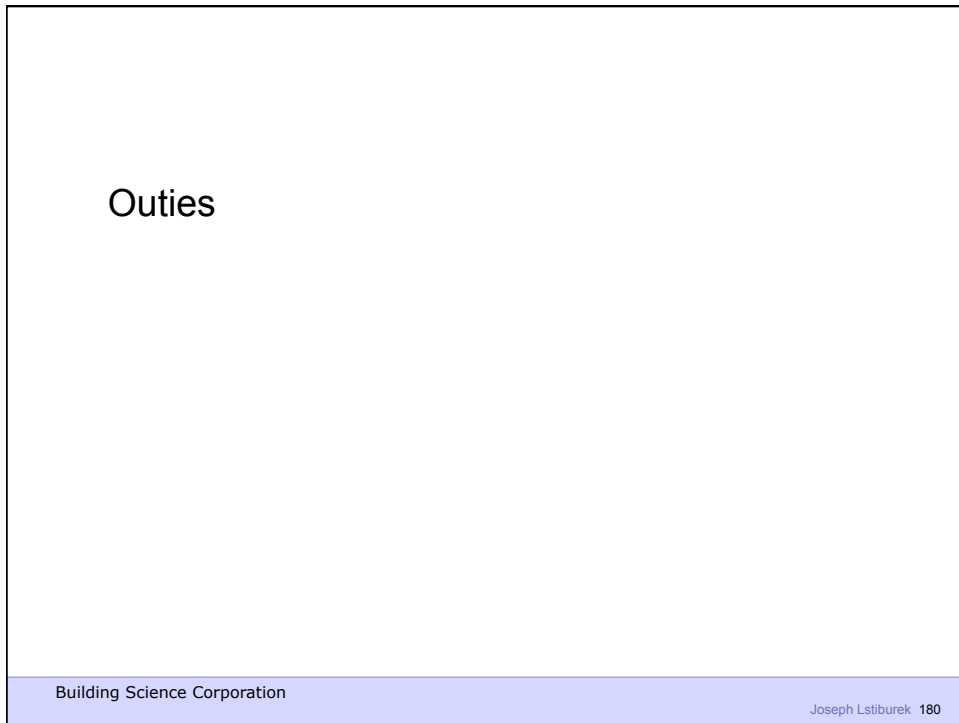
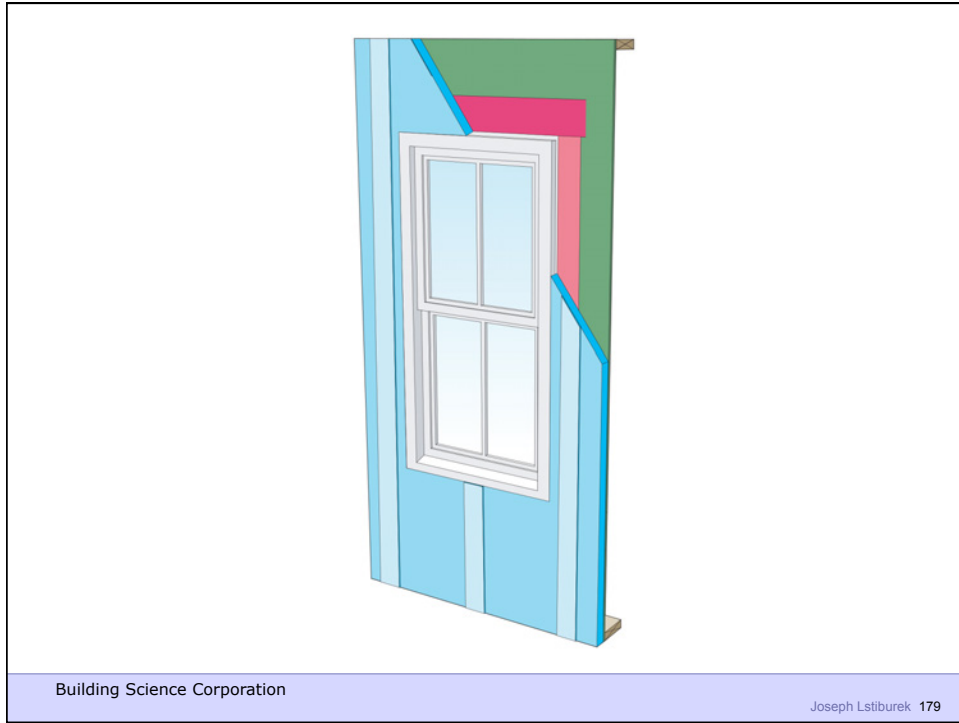
Joseph Lstiburek 170

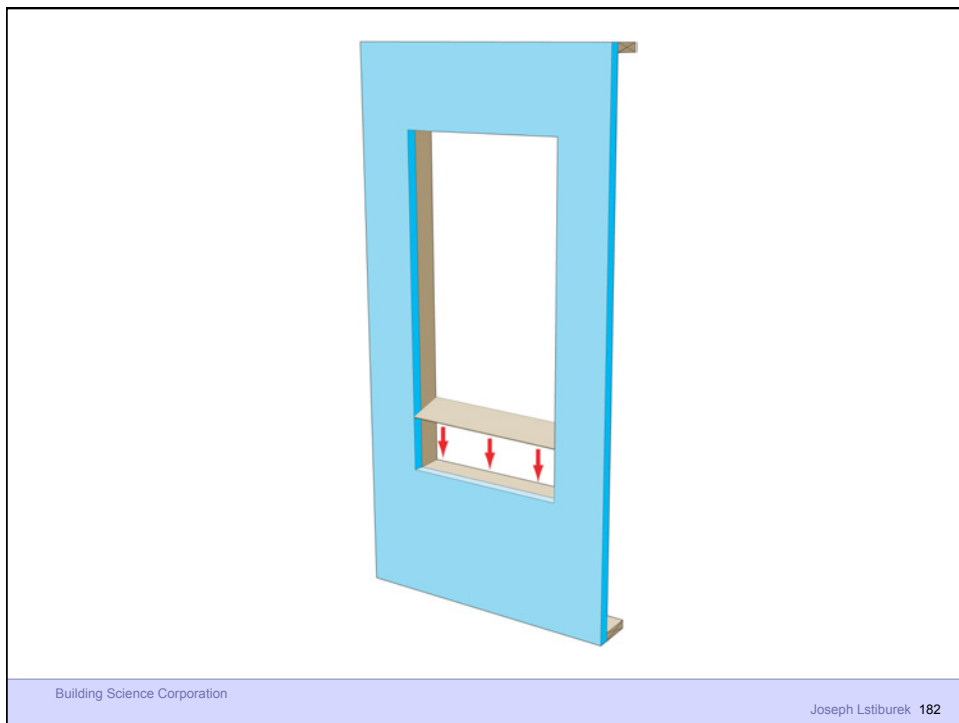
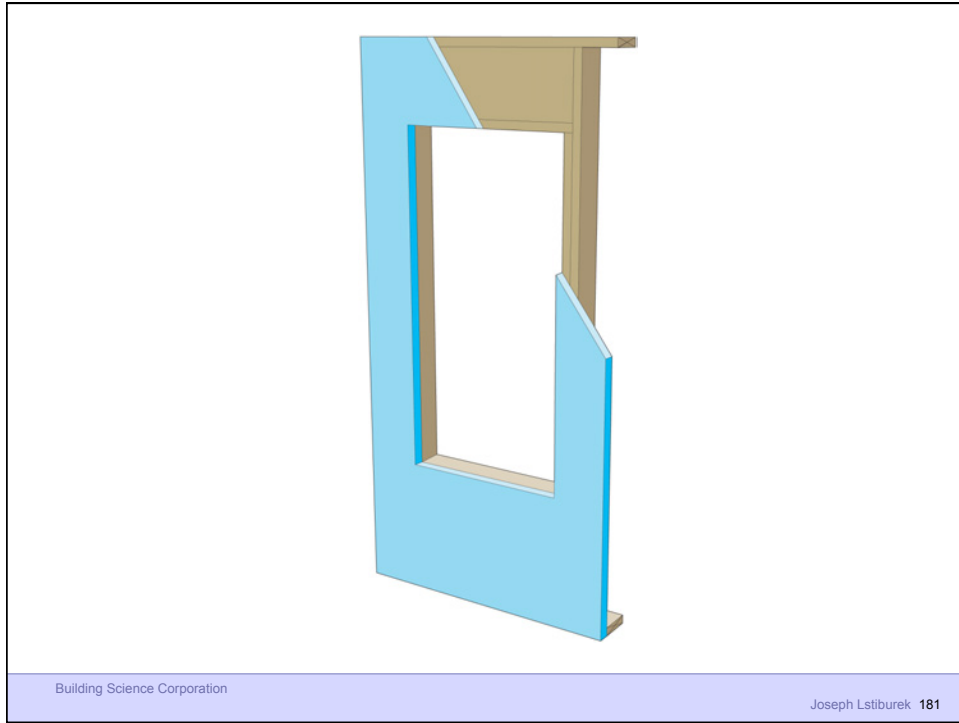


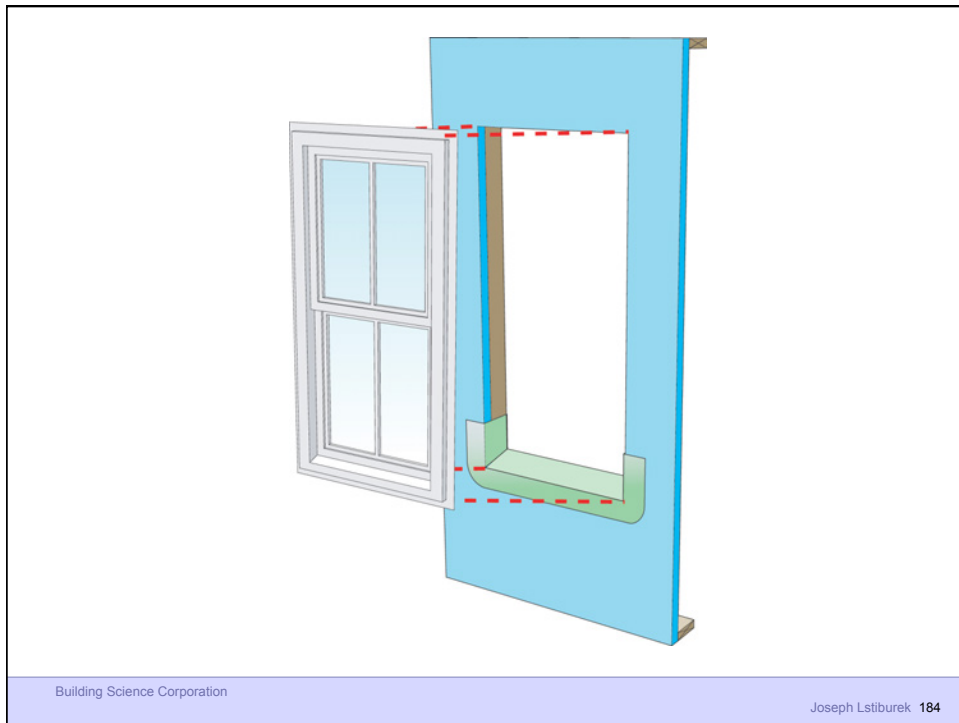
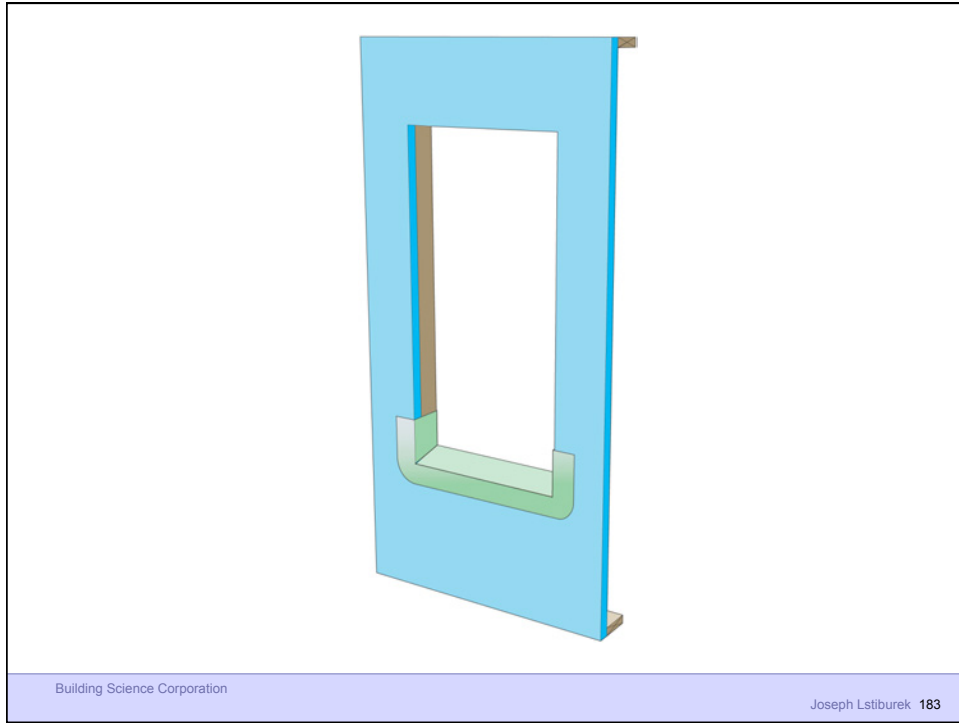


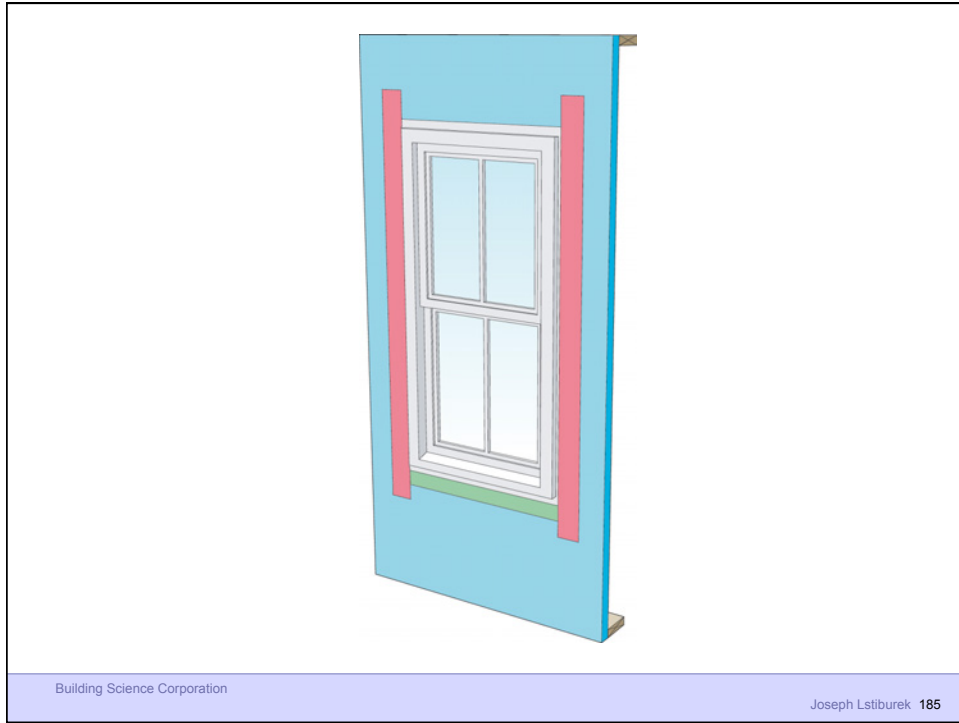


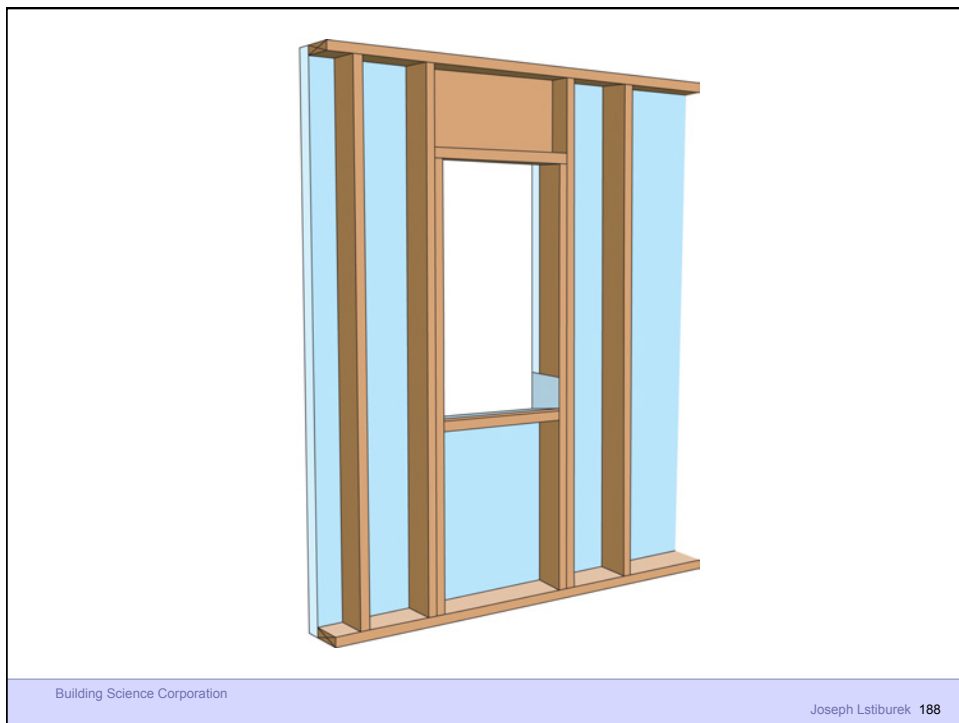
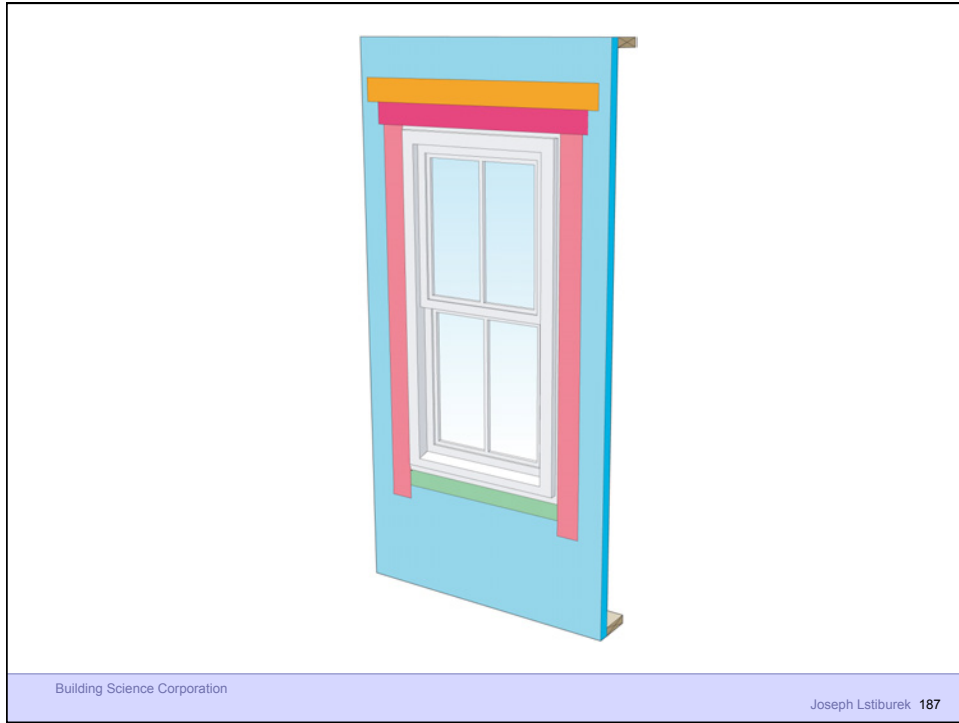










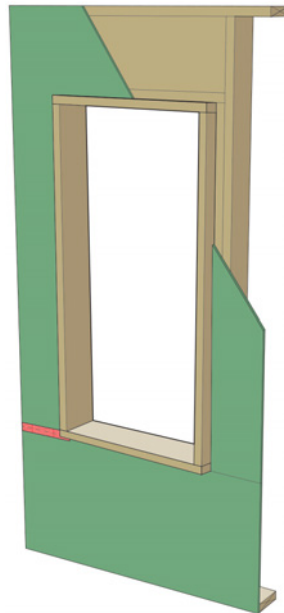




Outies with Fluffy Rocks

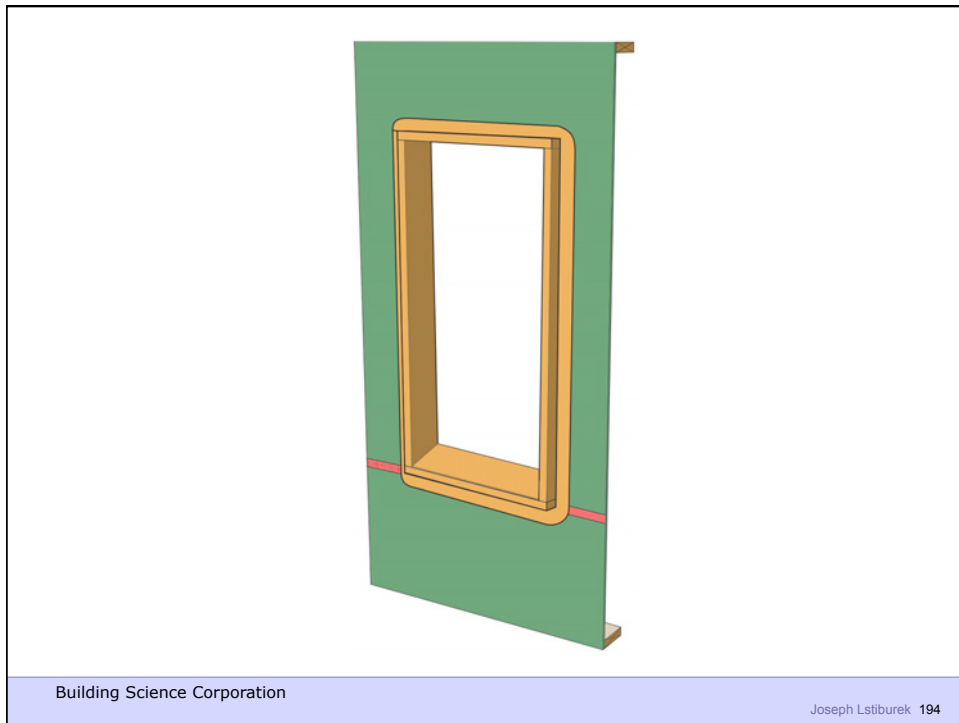
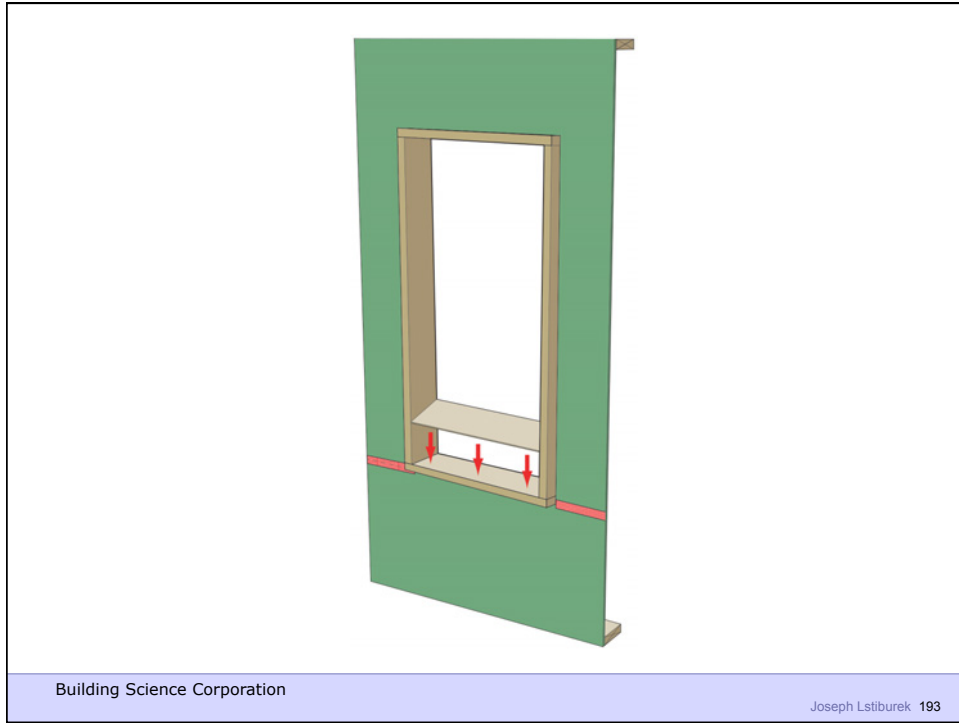
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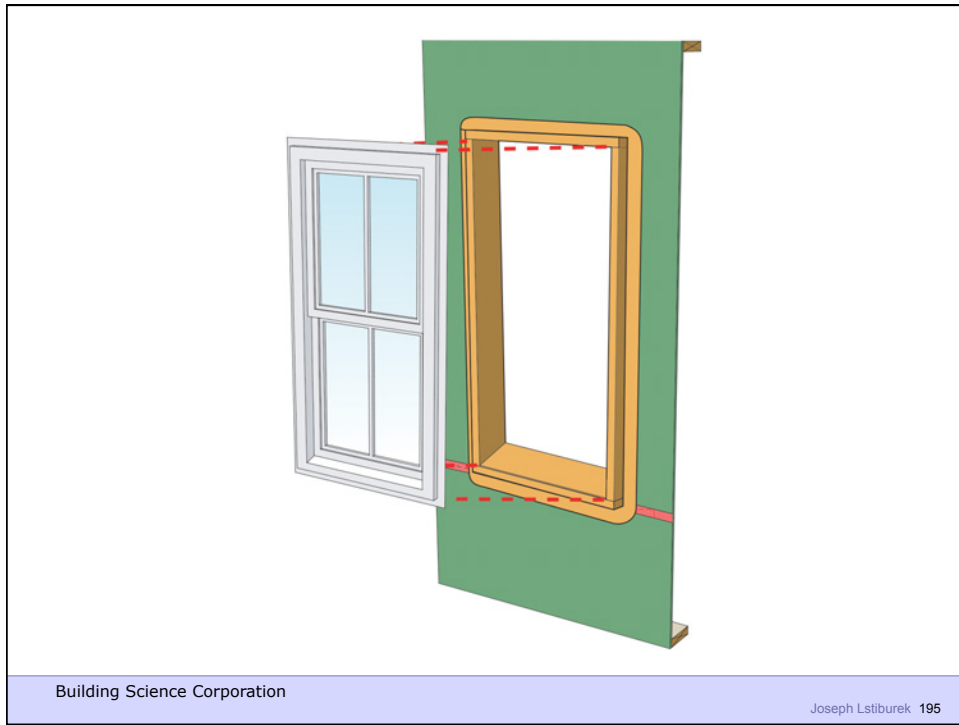
Joseph Lstiburek 191



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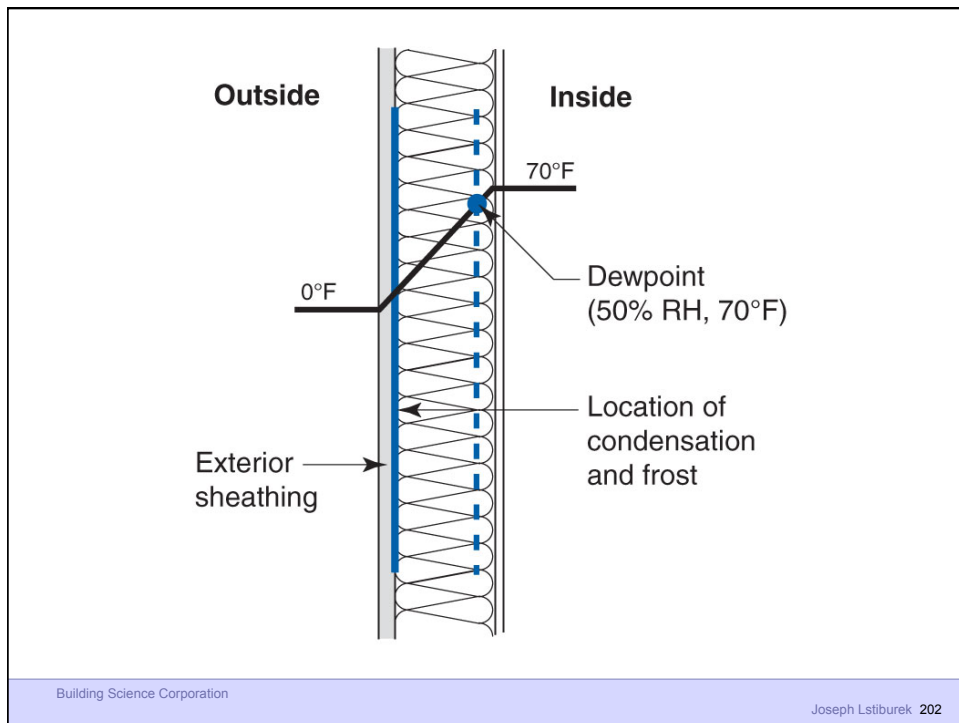
Joseph Lstiburek 192







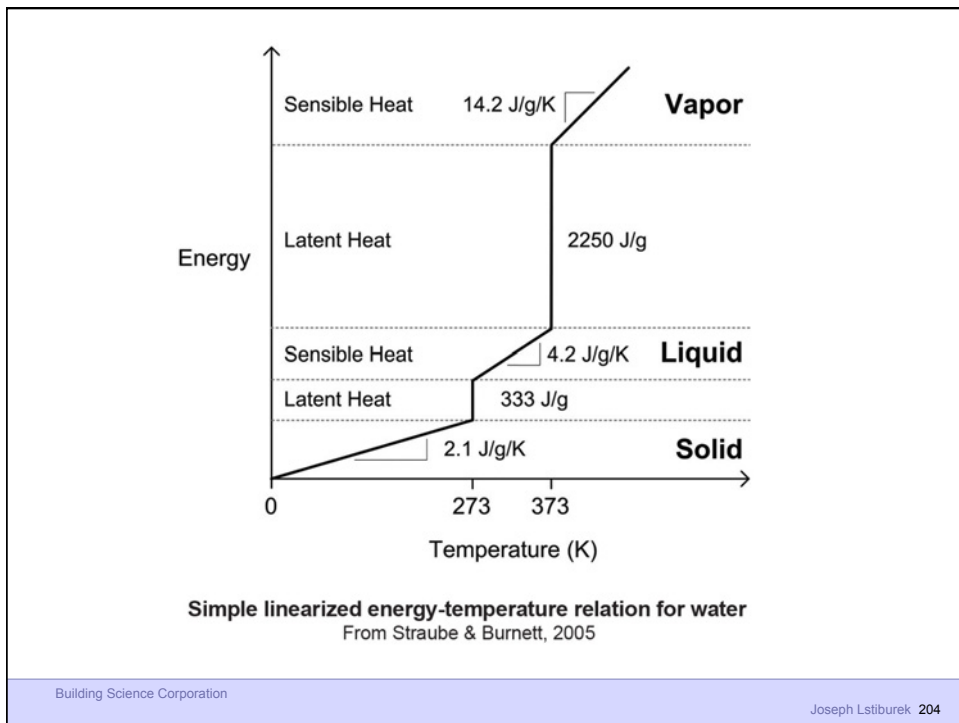






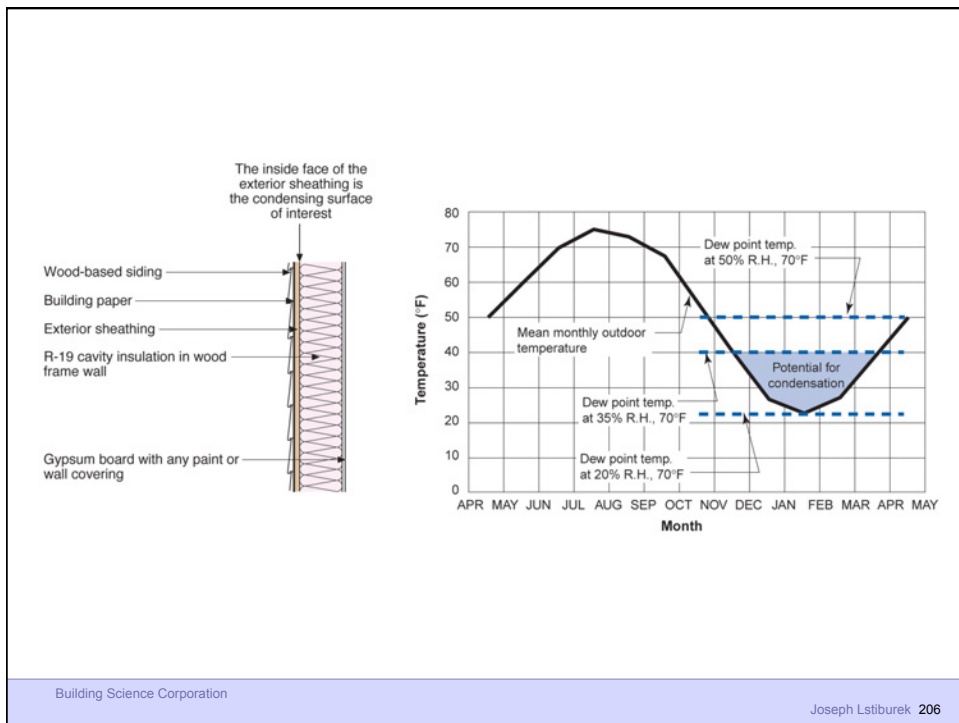
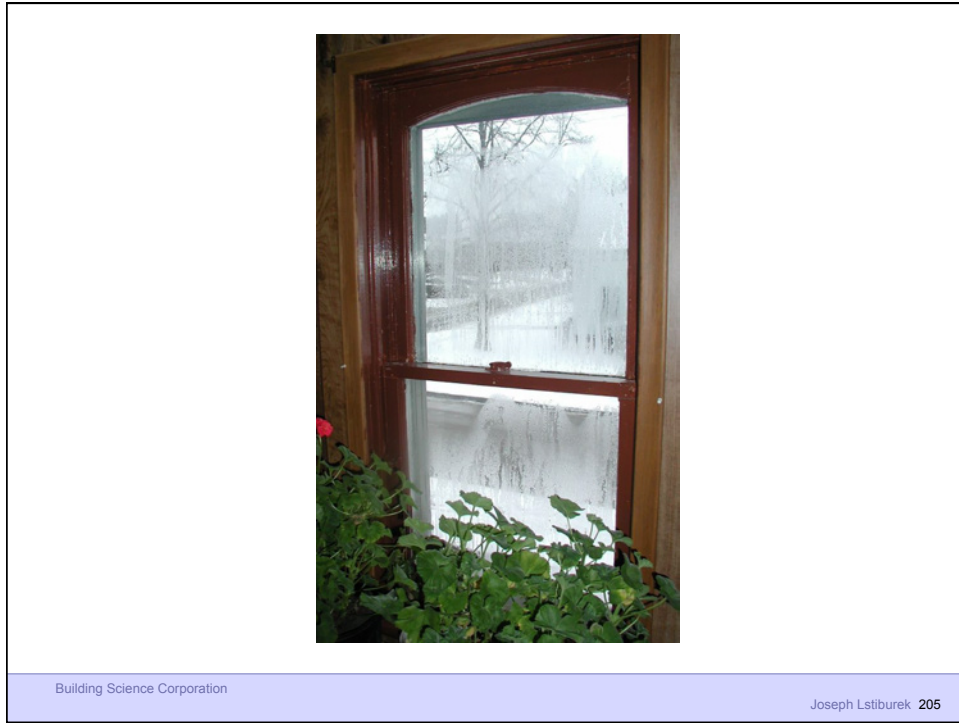
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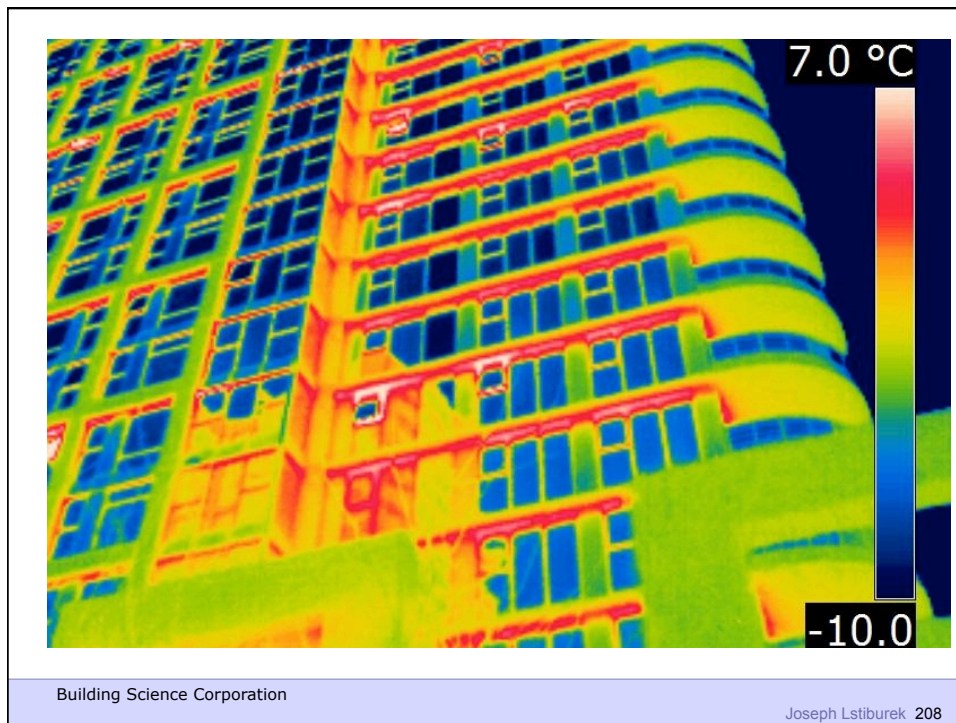
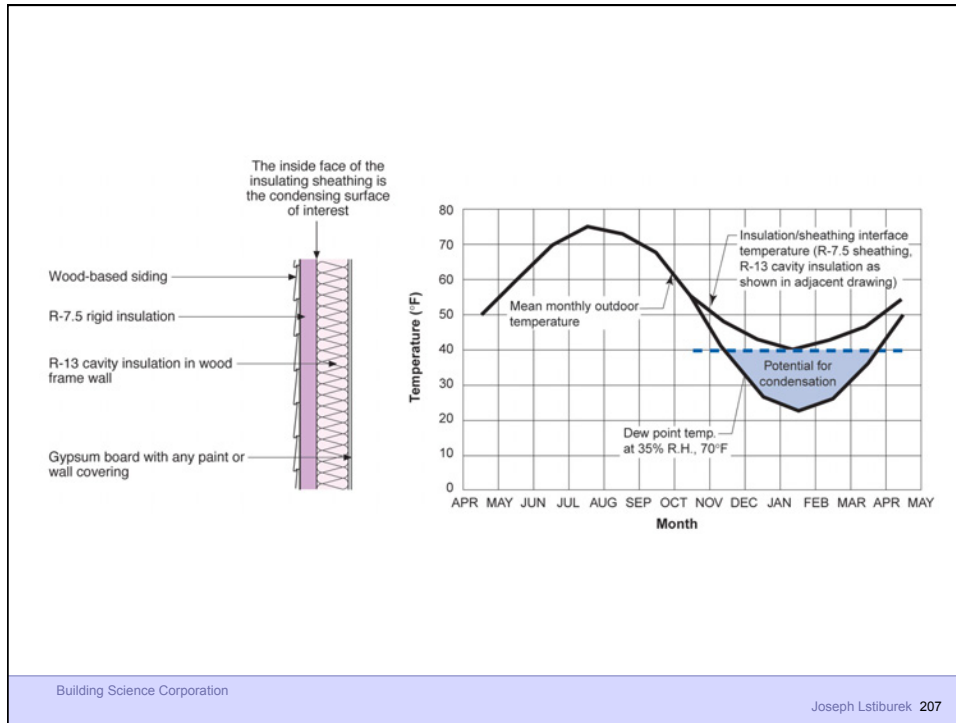
Joseph Lstiburek 203

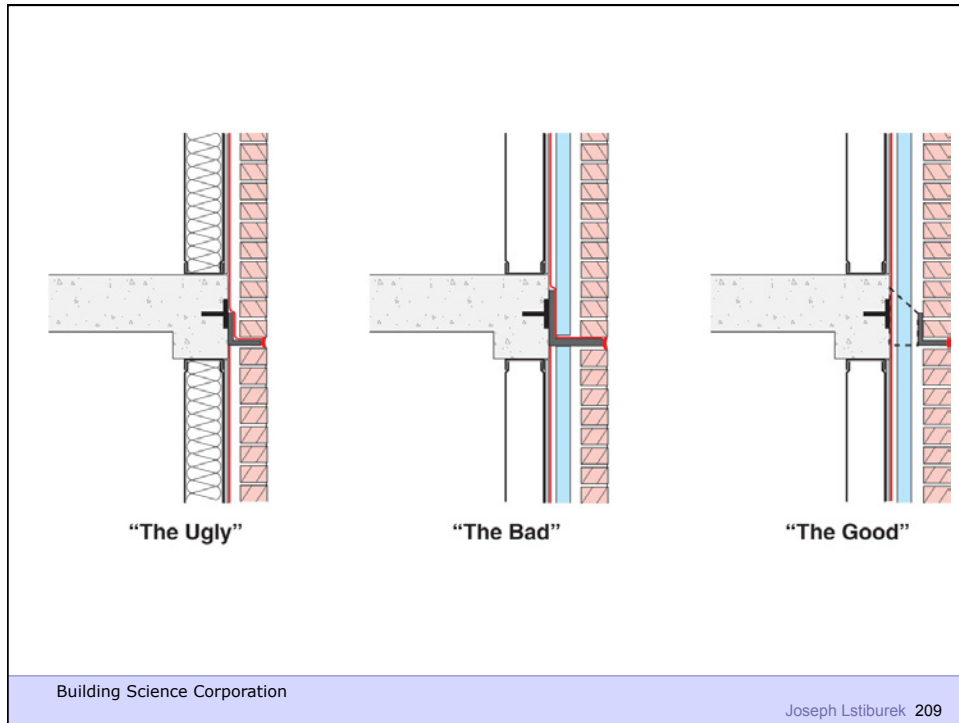


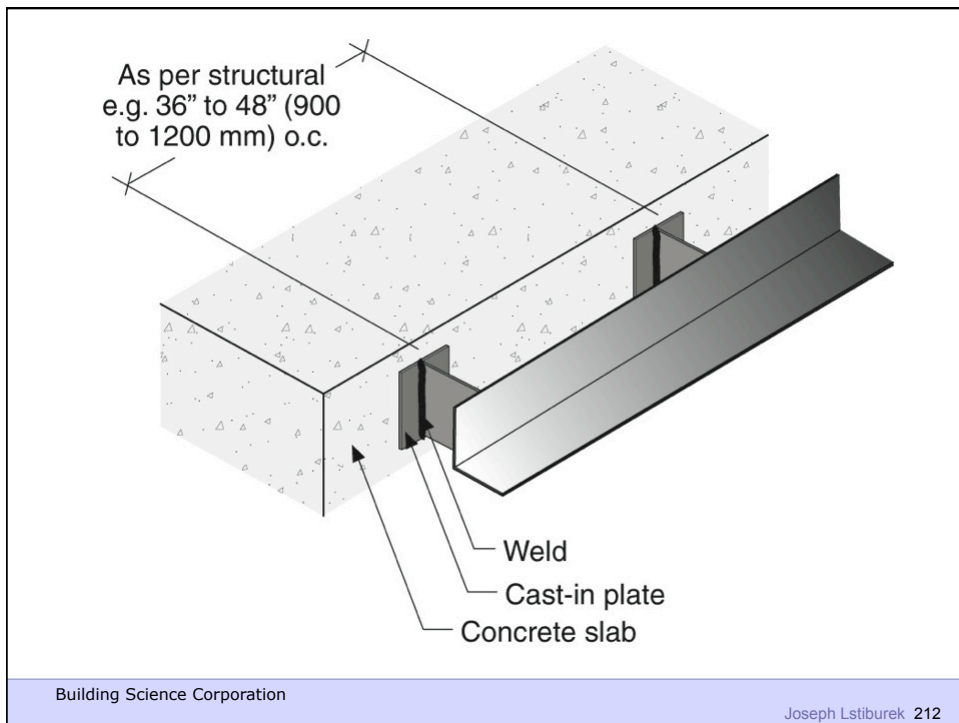
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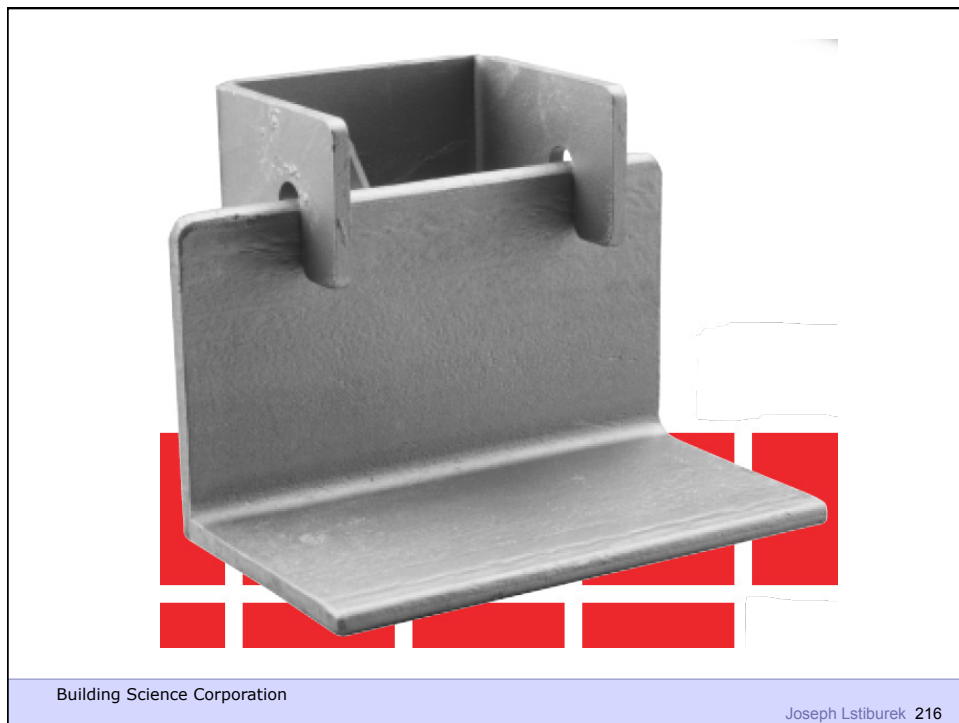
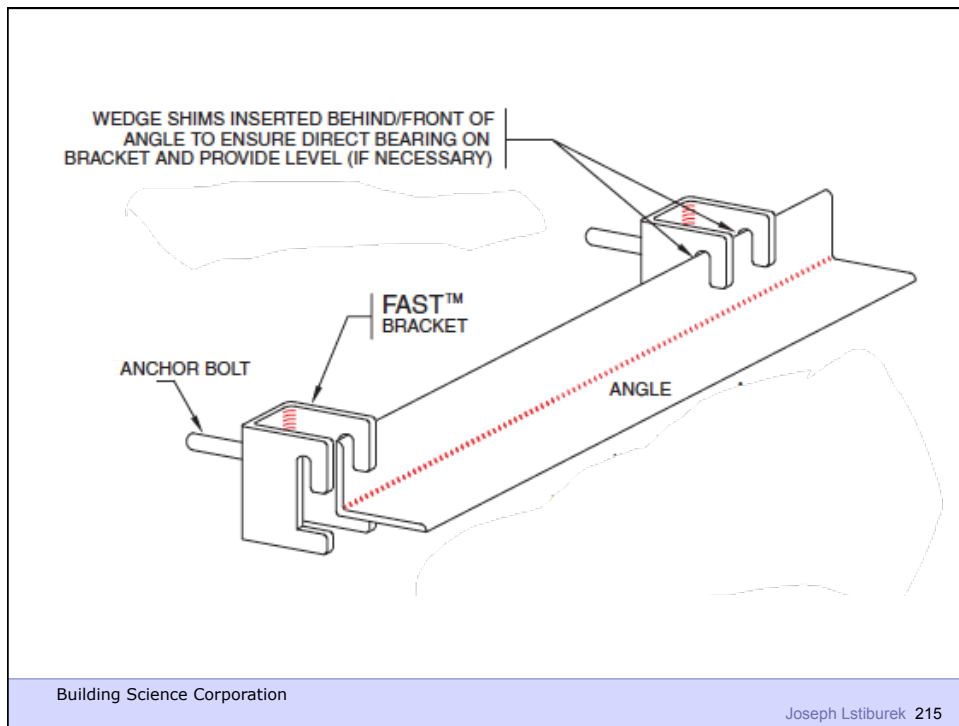
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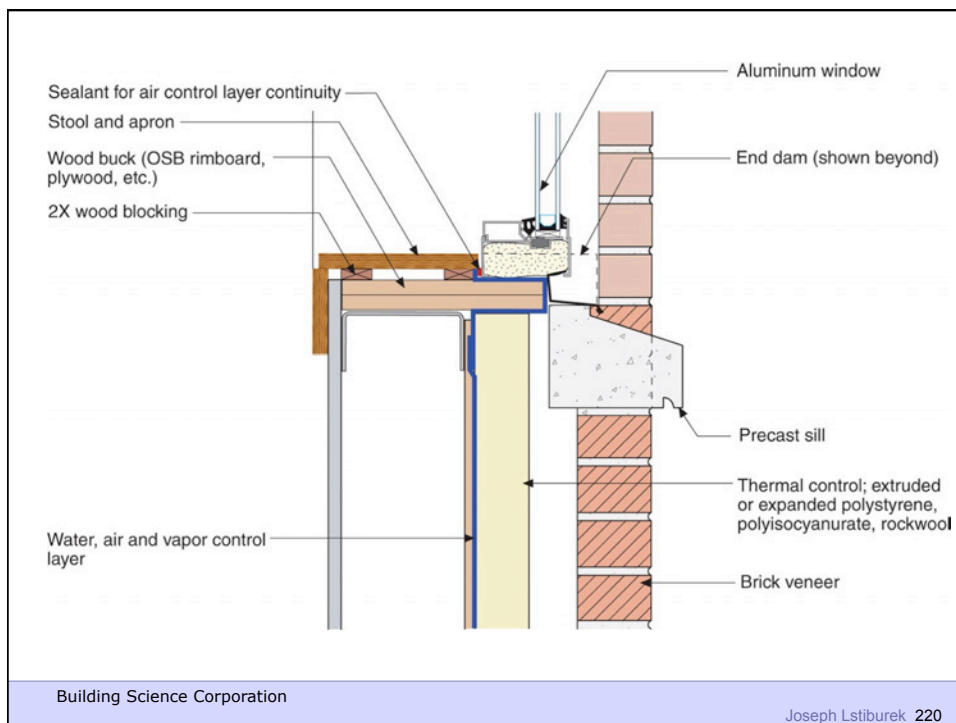
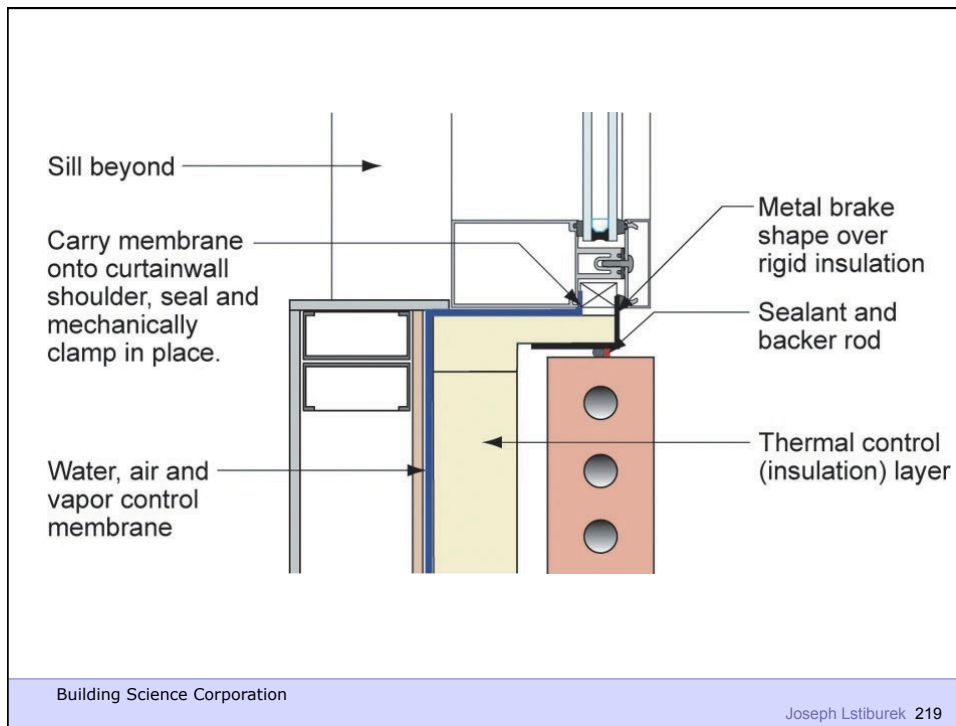


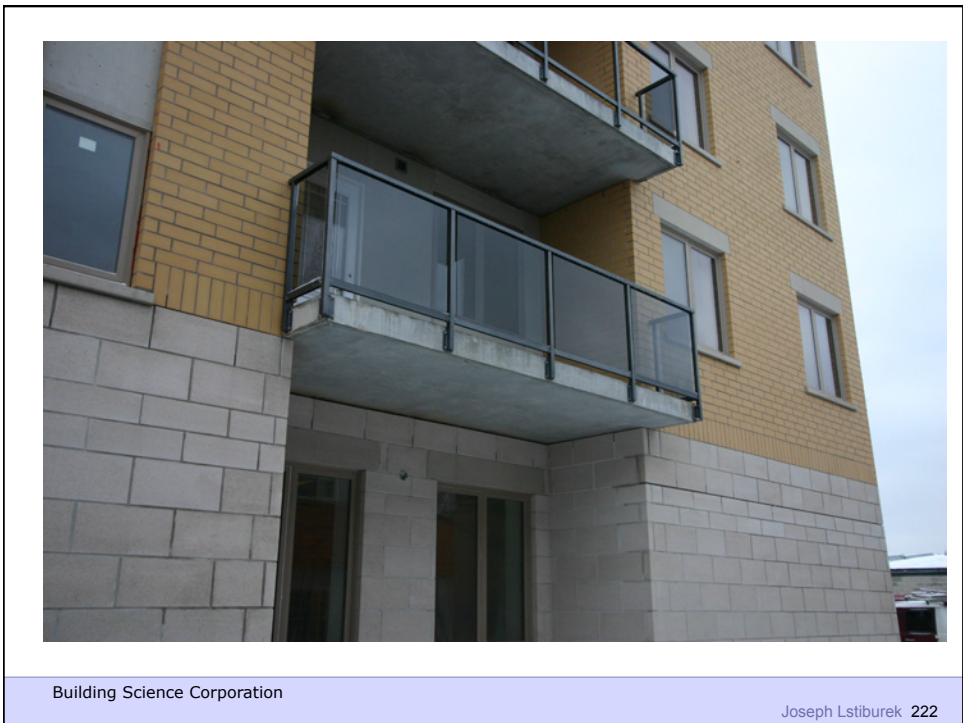
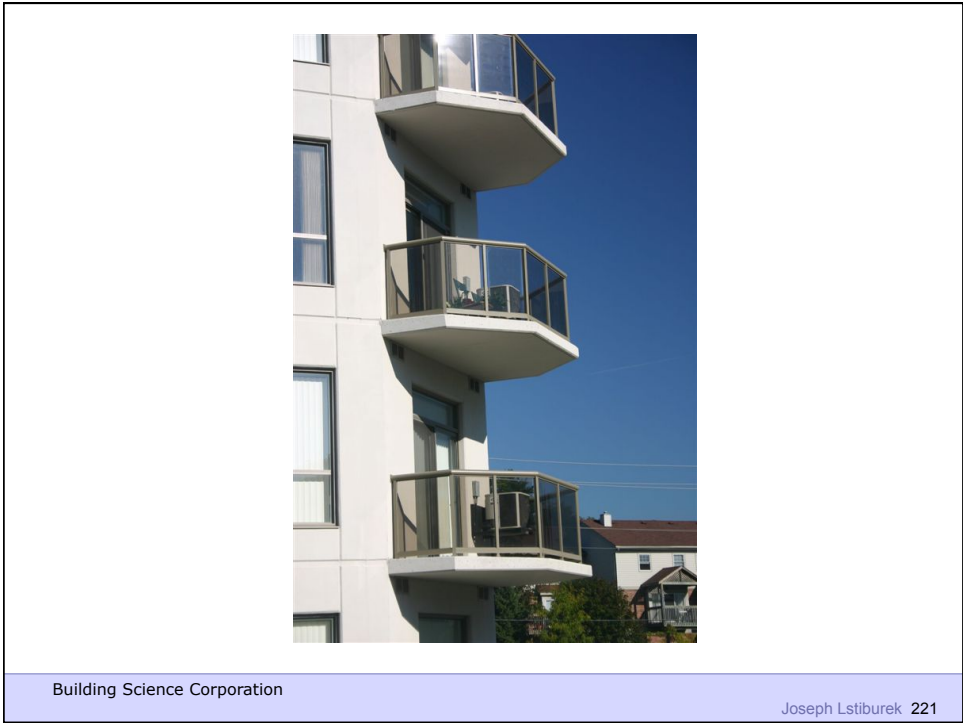
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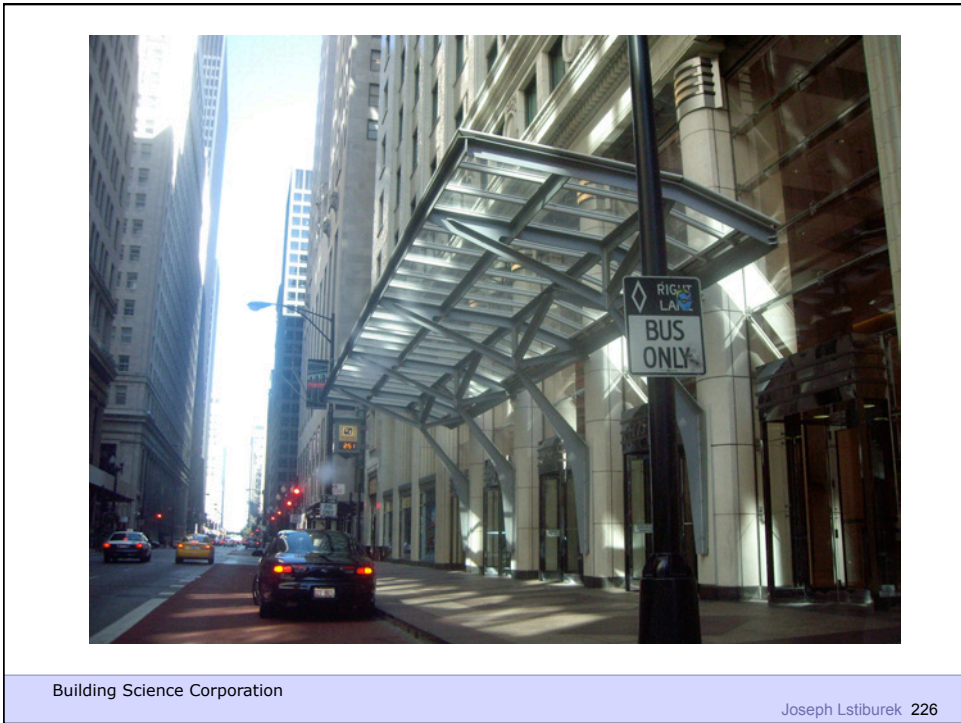
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