

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

# Building Science

Adventures In Building Science

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## What is a Building?

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## A Building is an Environmental Separator

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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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Zeroth Law –  $A=B$  and  $B=C$  therefore  $A=C$   
First Law - Conservation of Energy  
Second Law - Entropy  
Third Law – Absolute Zero

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2<sup>nd</sup> 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

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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

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

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

Thermal Gradient – Thermal Diffusion  
Concentration Gradient – Molecular Diffusion

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

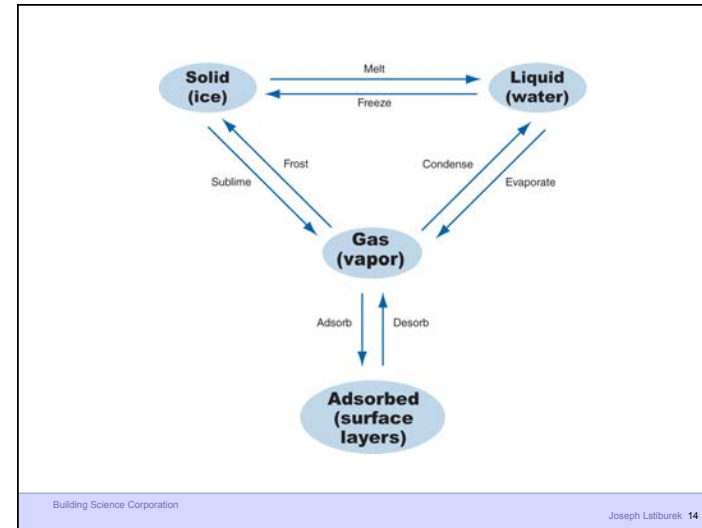
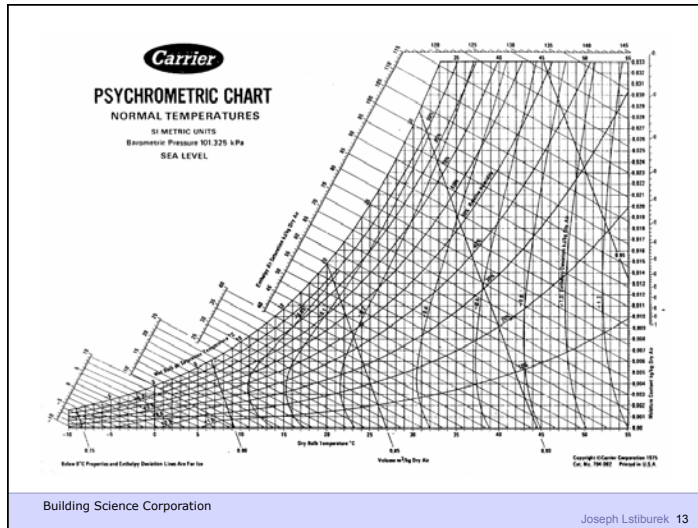
Thermal Gradient – Thermal Diffusion  
Concentration Gradient – Molecular Diffusion

Vapor Diffusion

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Thermodynamic Potential

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**Moisture Transport in Porous Media**

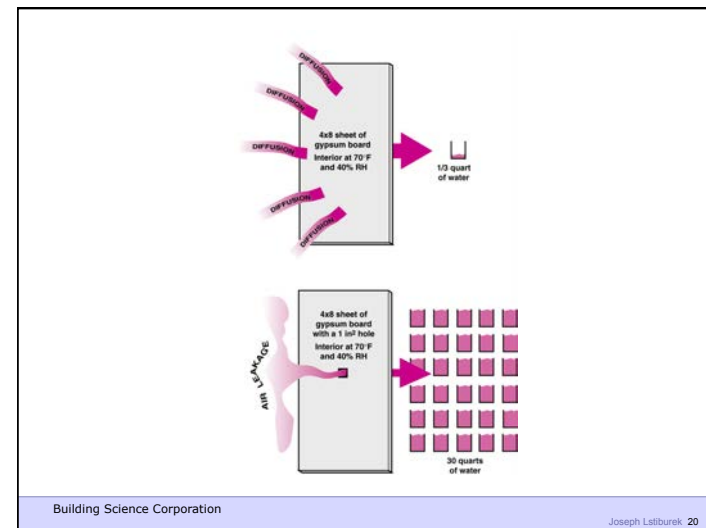
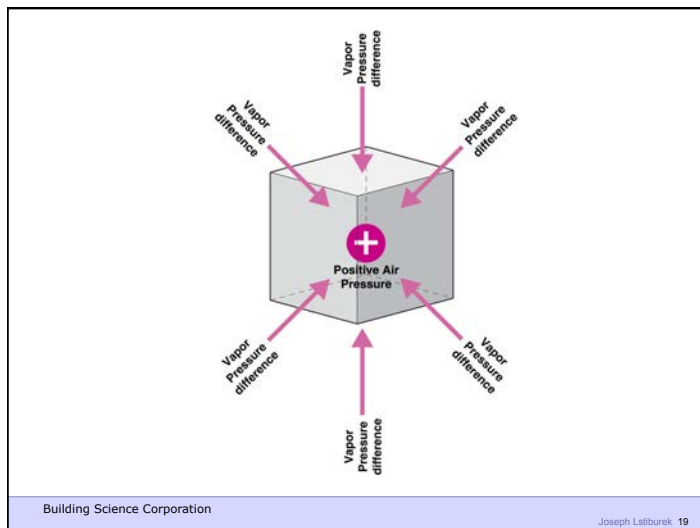
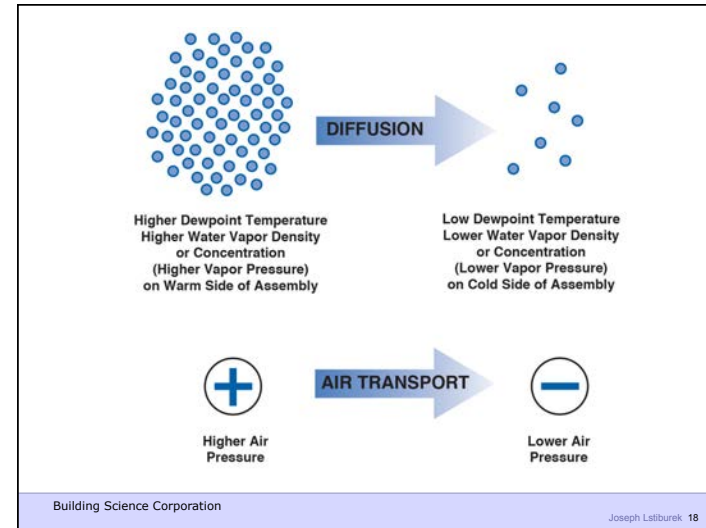
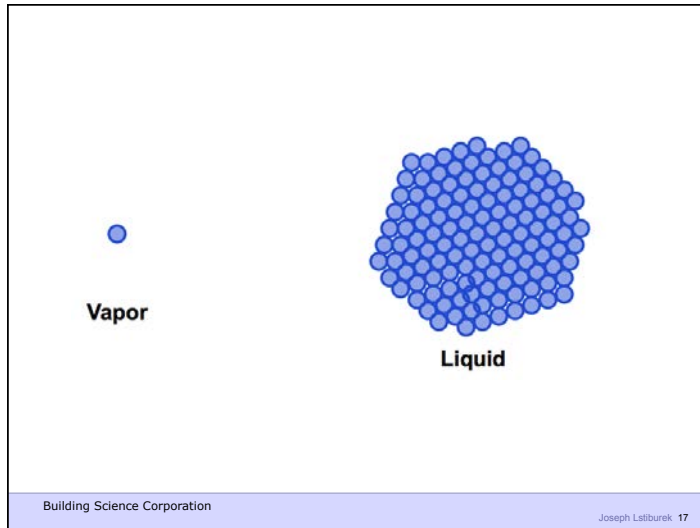
Phase	Transport Process	Driving Potential
<b>Vapor</b>	Diffusion	Vapor Concentration
<b>Adsorbate</b>	Surface Diffusion	Concentration
<b>Liquid</b>	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration

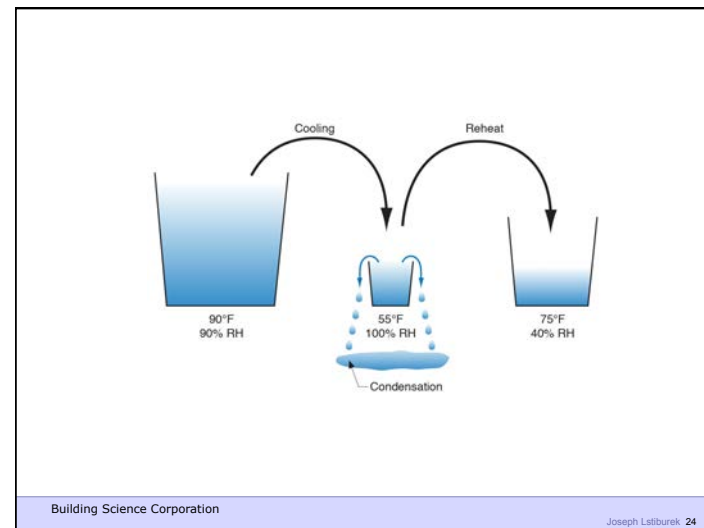
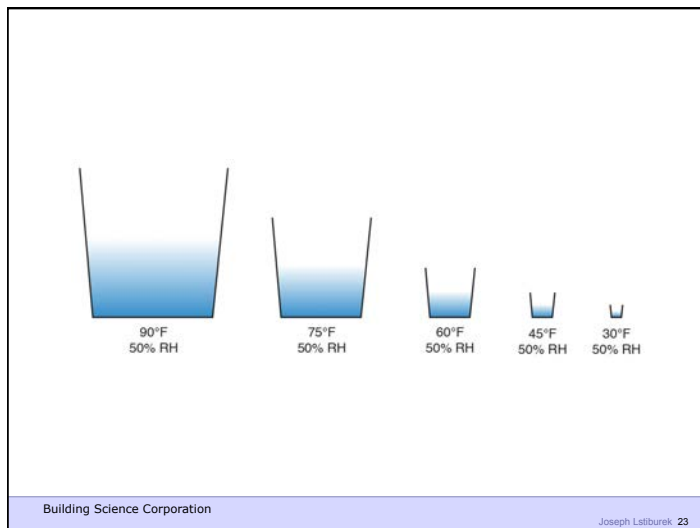
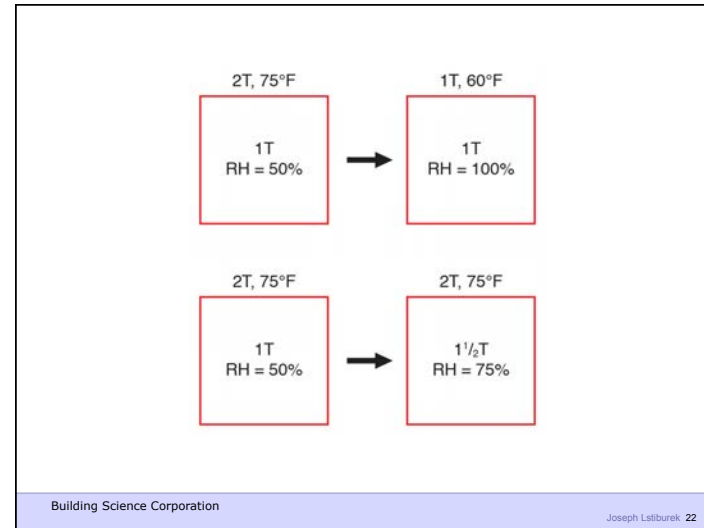
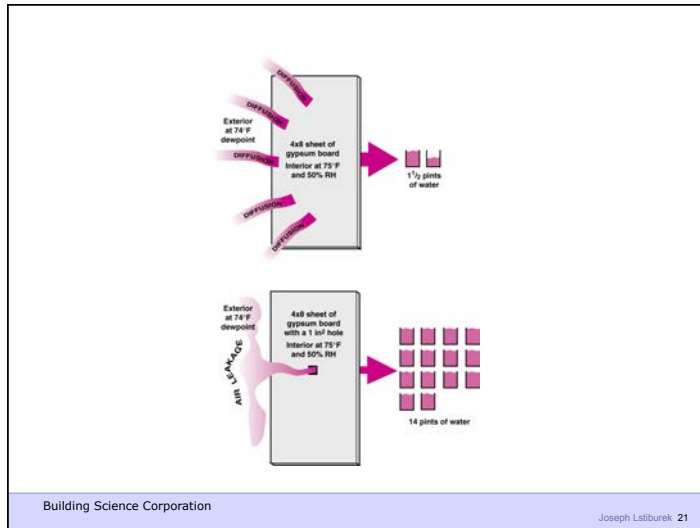
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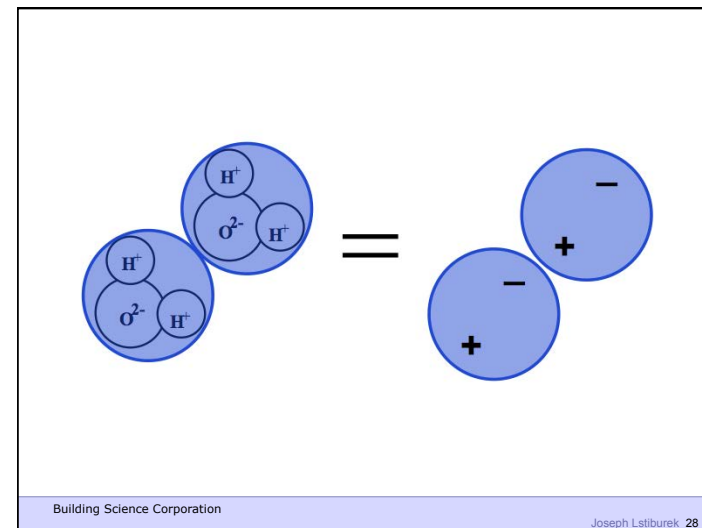
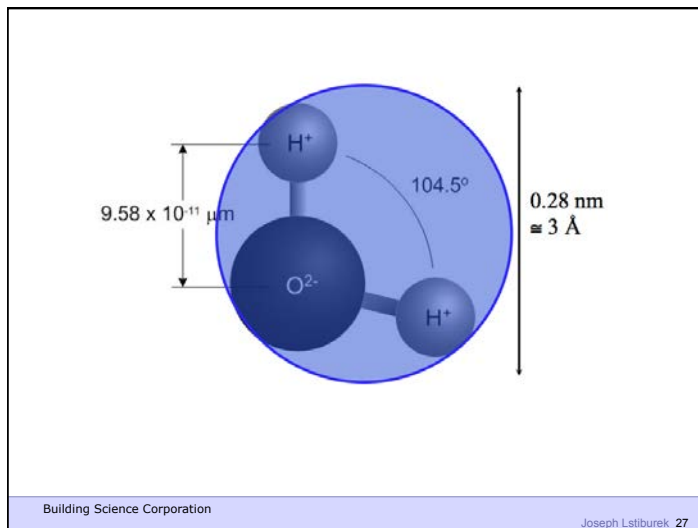
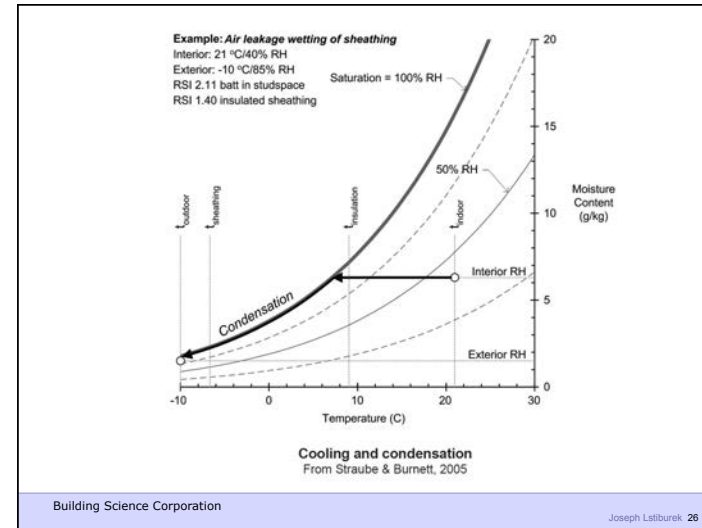
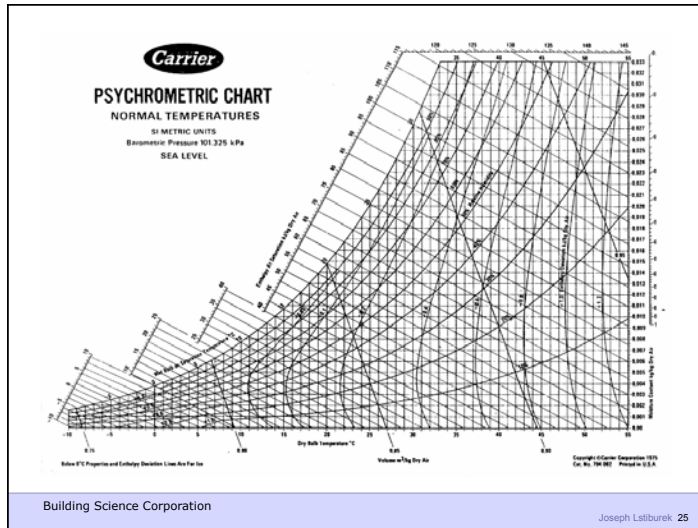
**Moisture Transport in Assemblies**

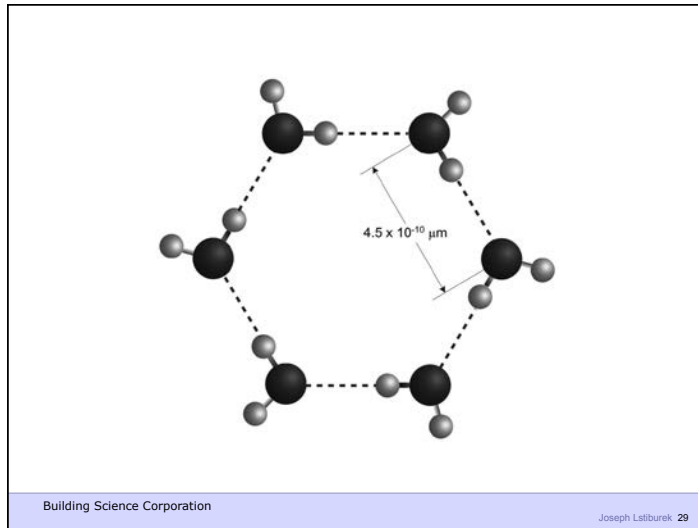
Phase	Transport Process	Driving Potential
<b>Vapor</b>	Diffusion	Vapor Concentration
	Convective Flow	Air Pressure
<b>Adsorbate</b>	Surface Diffusion	Concentration
<b>Liquid</b>	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration
	Gravitational Flow	Height
	Surface Tension	Surface Energy
	Momentum	Kinetic Energy
	Convective Flow	Air Pressure

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Damage Functions

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Damage Functions  
Water  
Heat  
Ultra Violet Radiation

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Damage Functions  
Water  
Heat  
Ultra Violet Radiation  
Oxidization (Ozone)  
Fatigue (Creep)

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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

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HAM

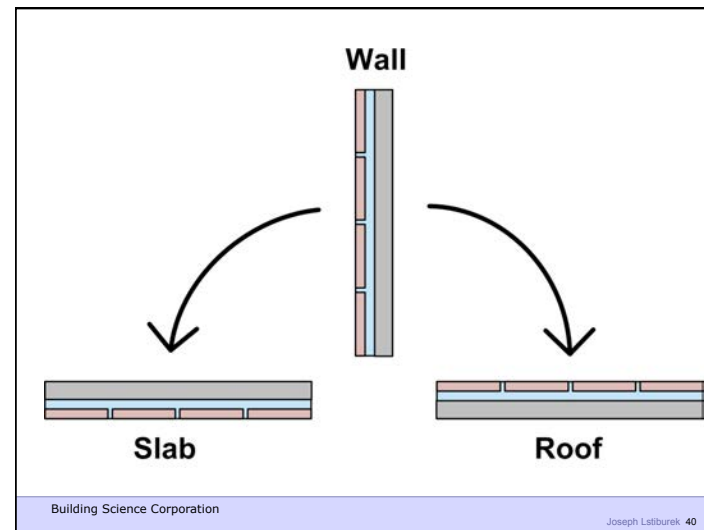
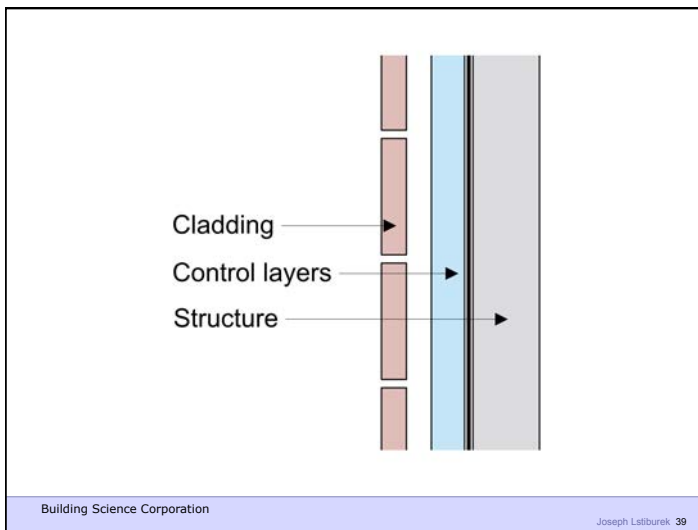
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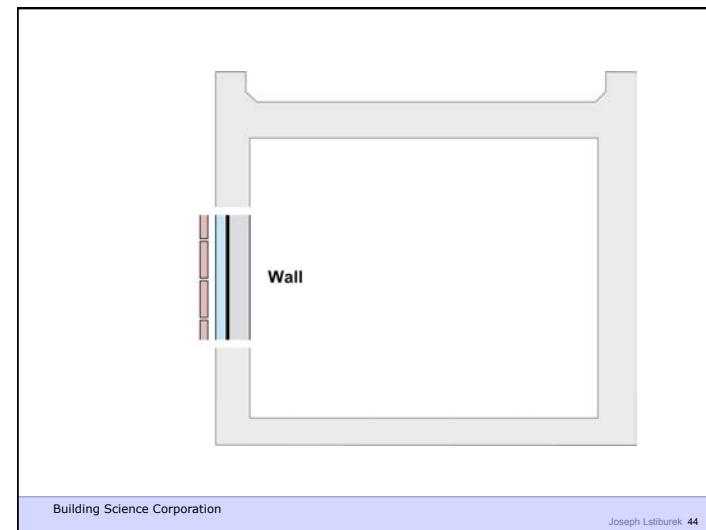
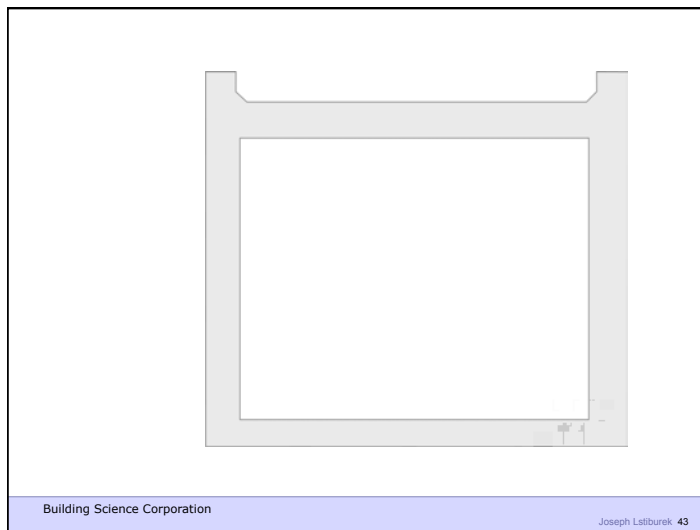
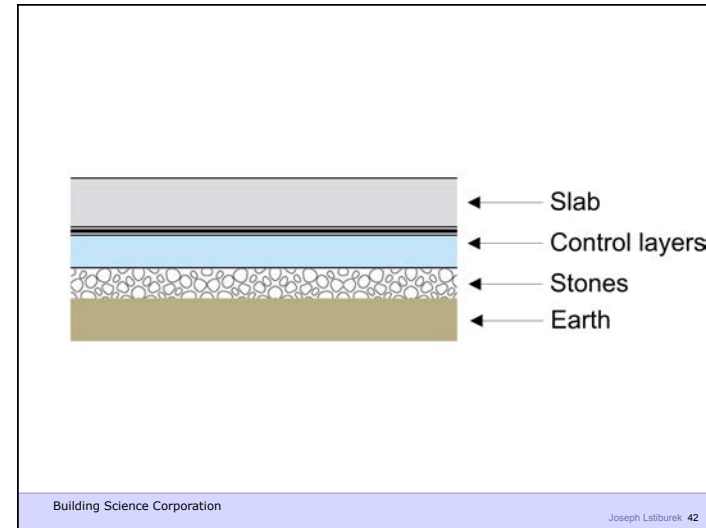
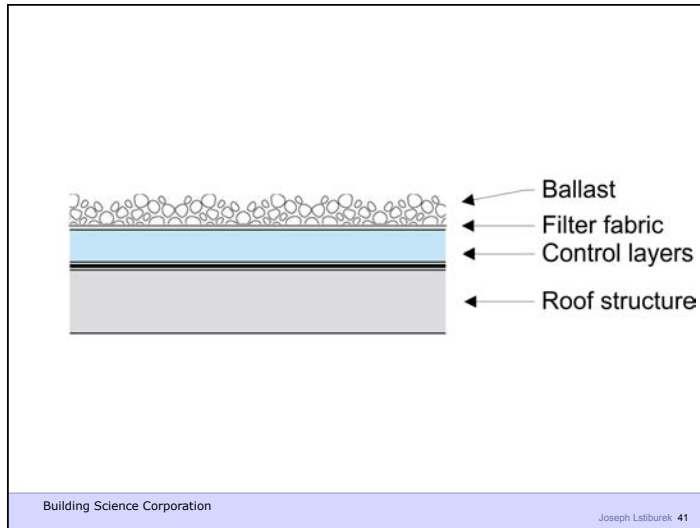
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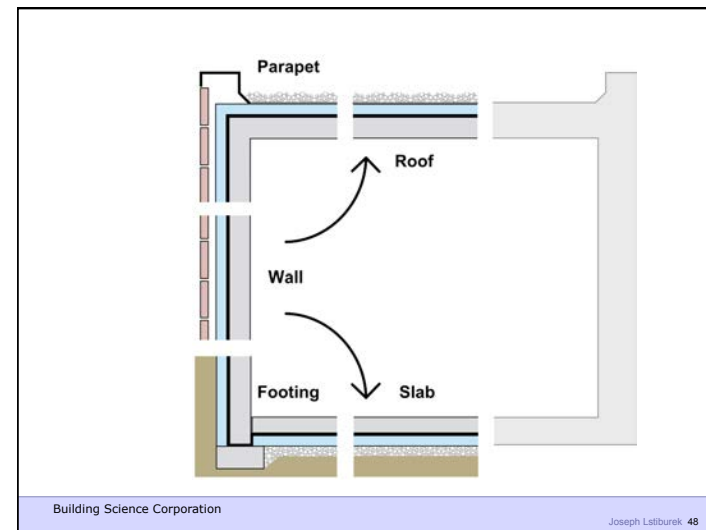
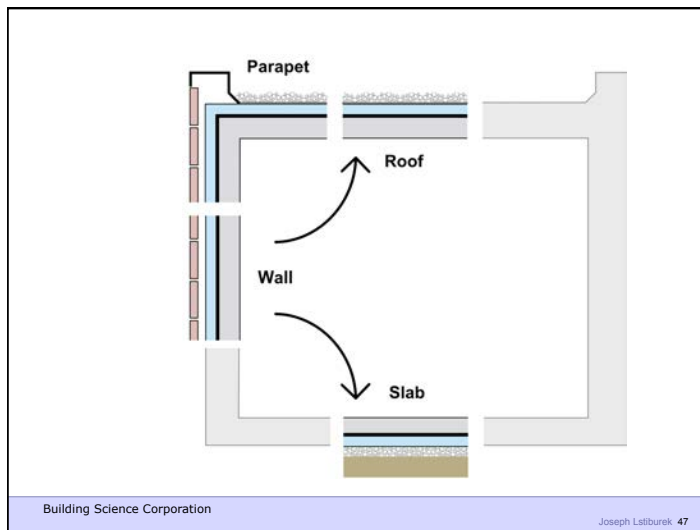
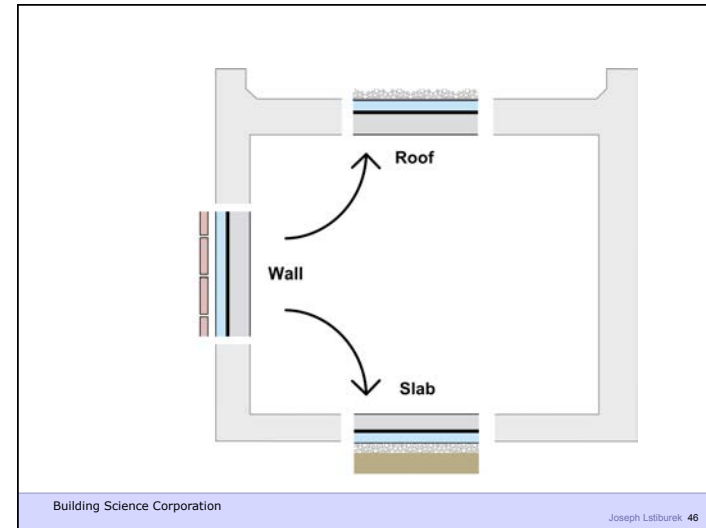
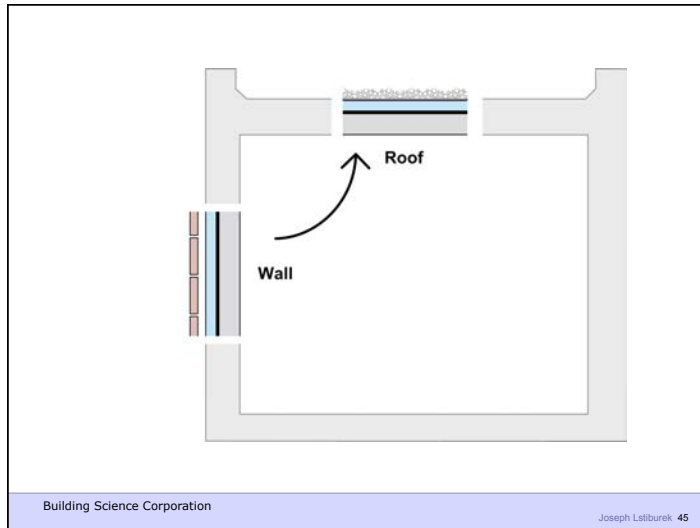
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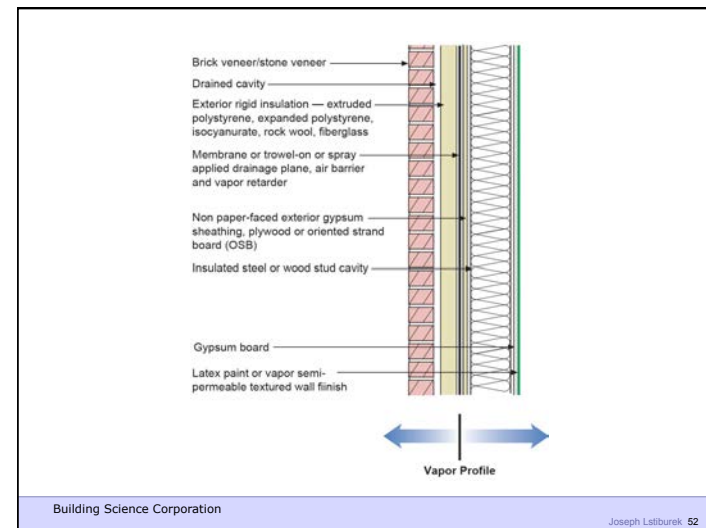
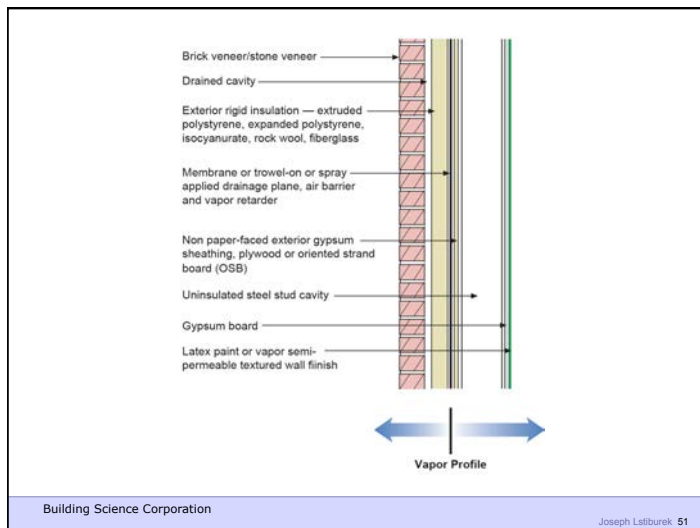
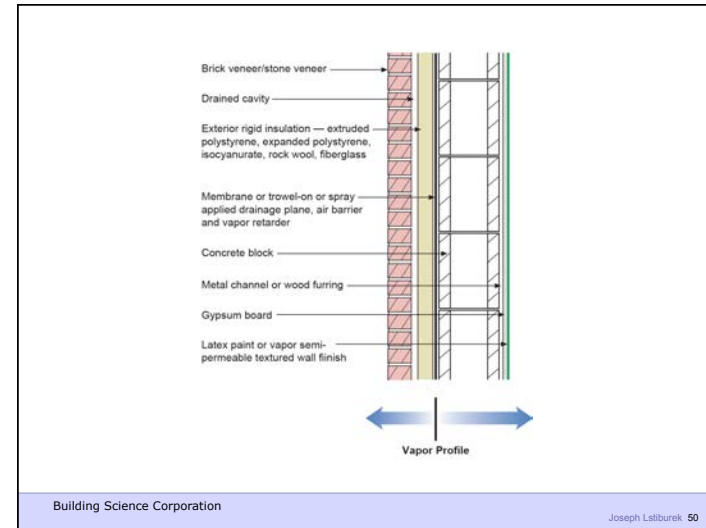
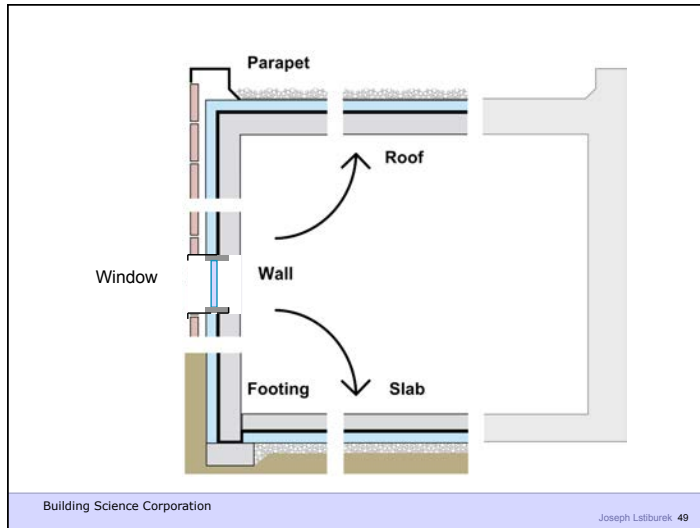
Water Control Layer  
Air Control Layer  
Vapor Control Layer  
Thermal Control Layer

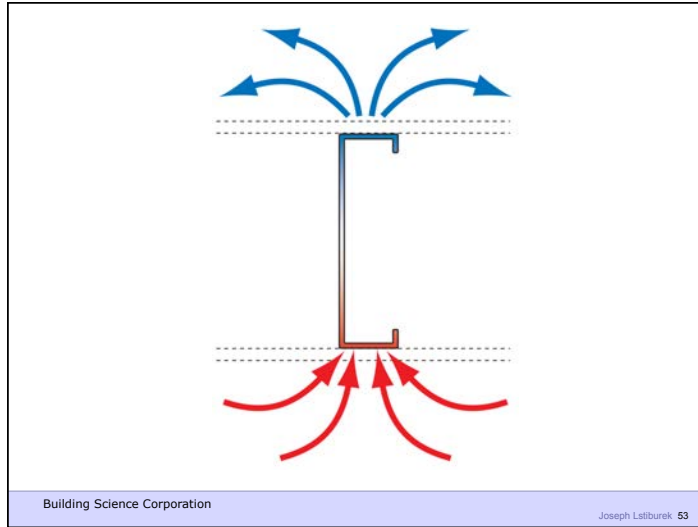
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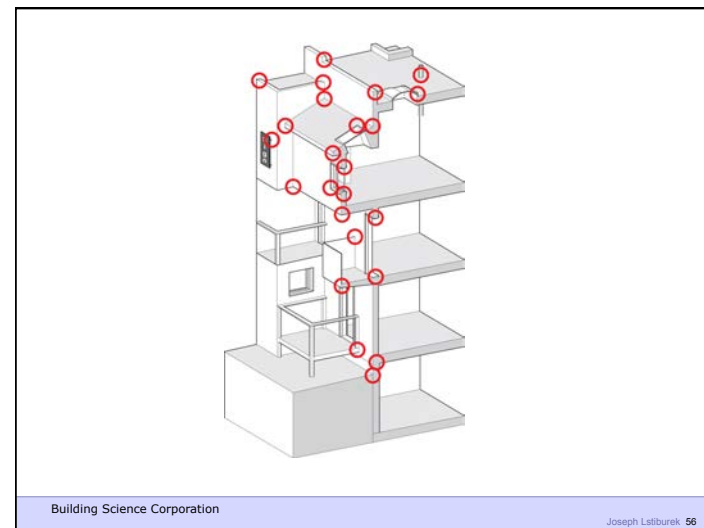


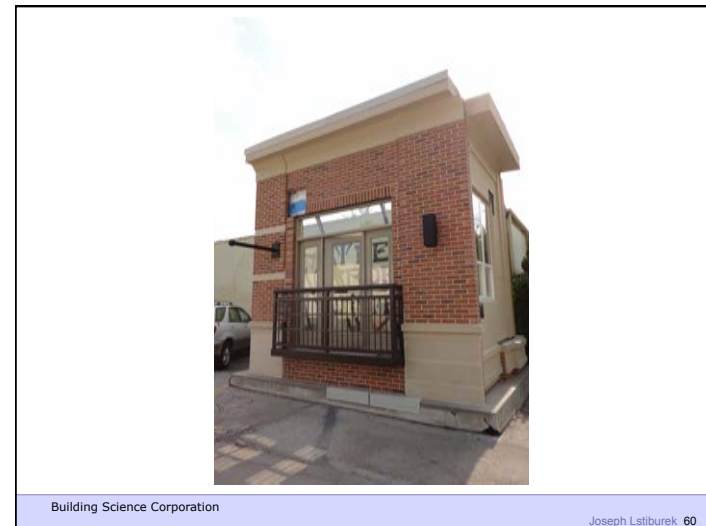


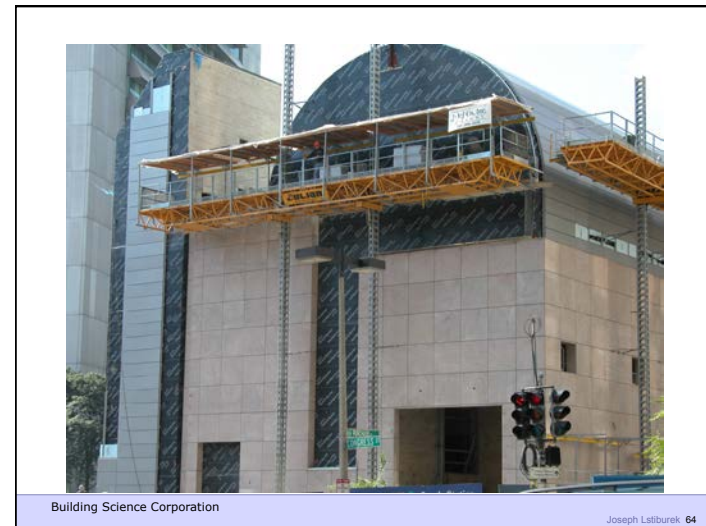
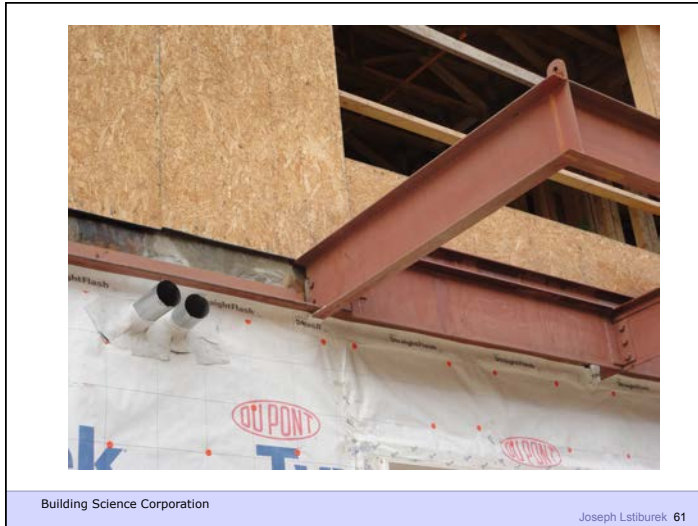
### Commercial Enclosure: Simple Layers

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

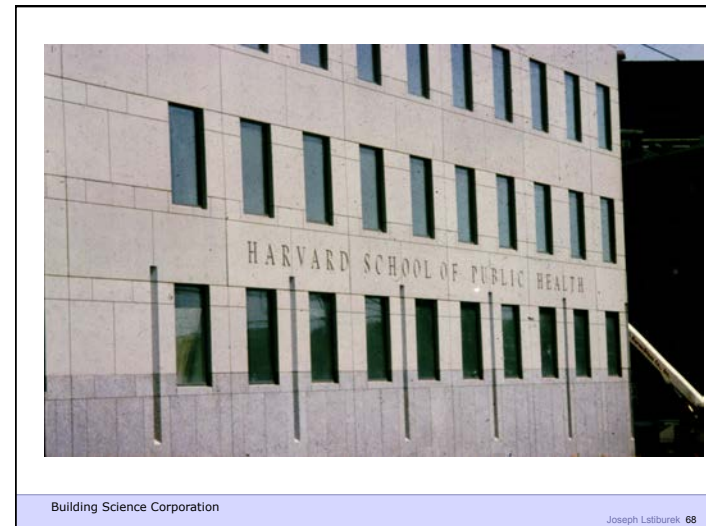
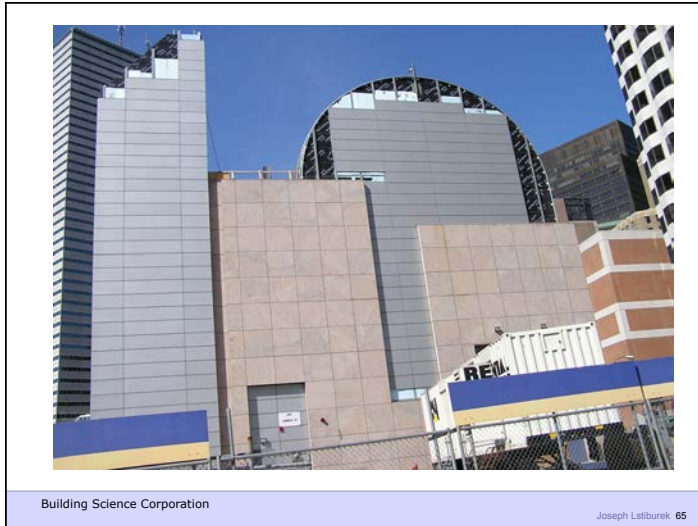
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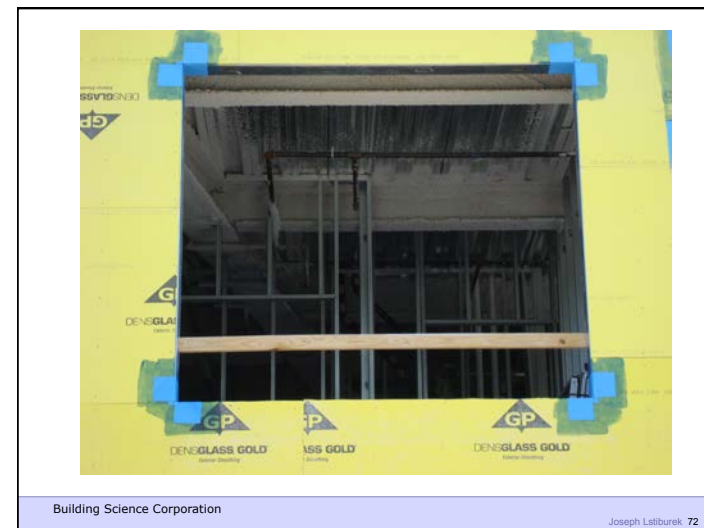
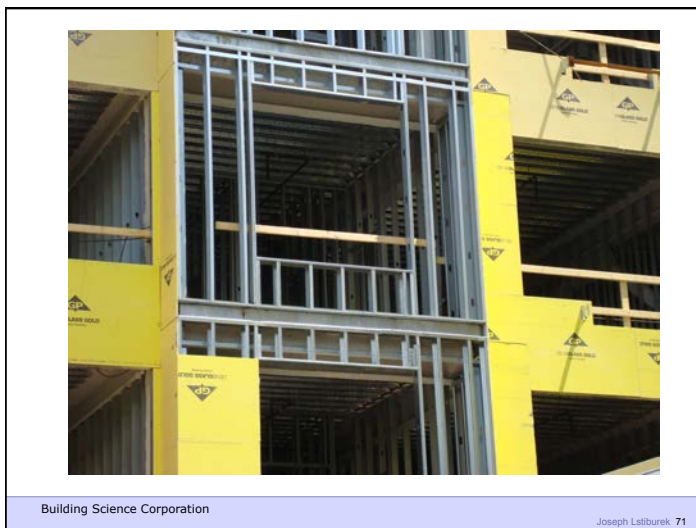


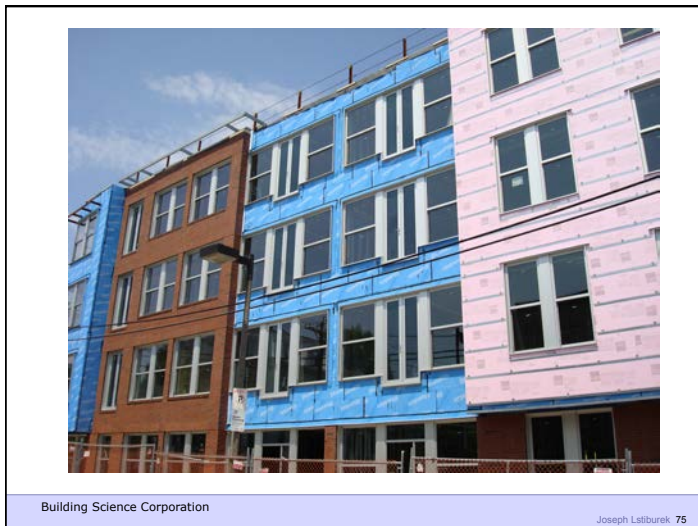
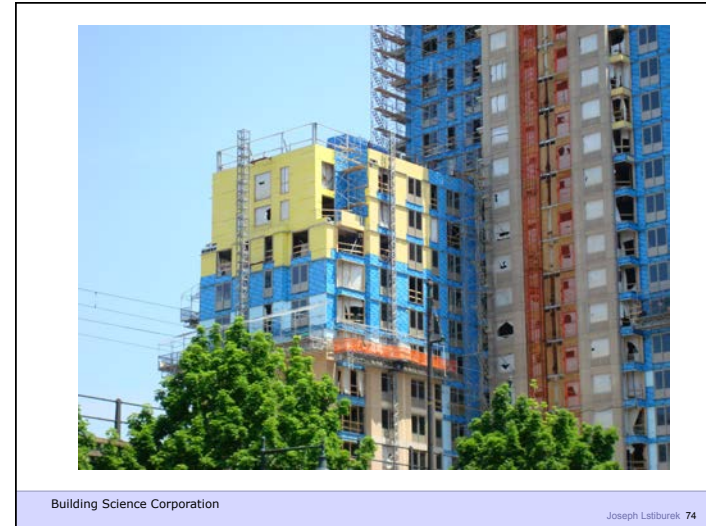




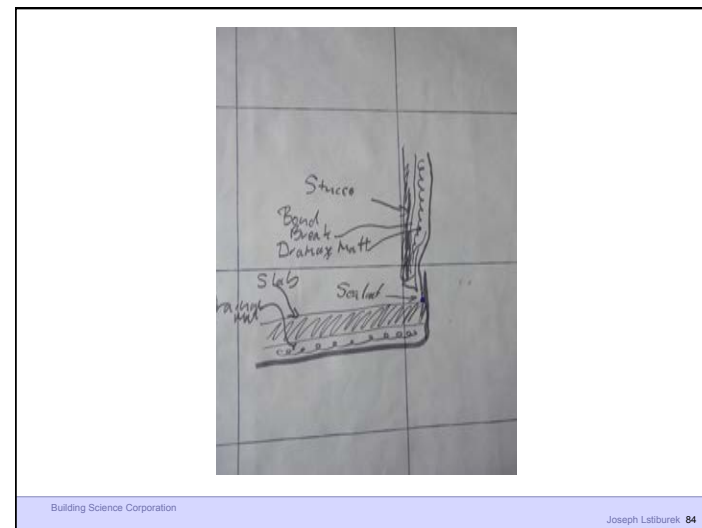


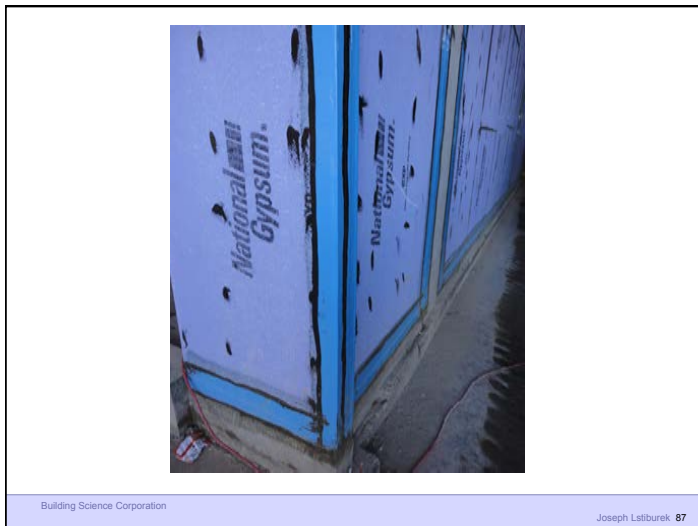




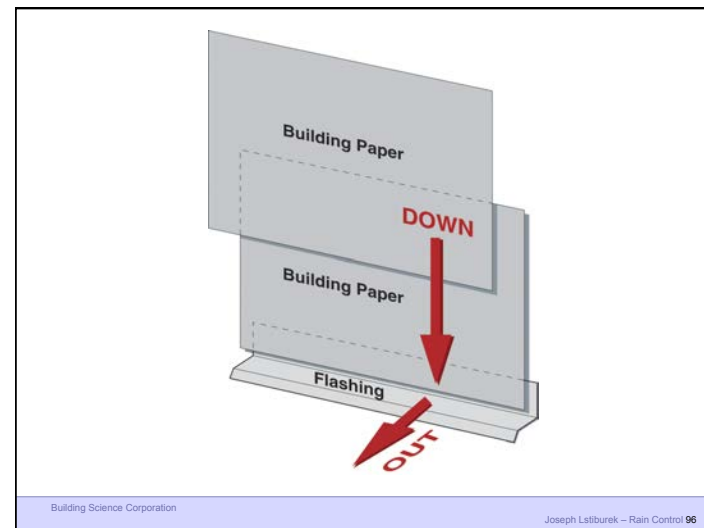
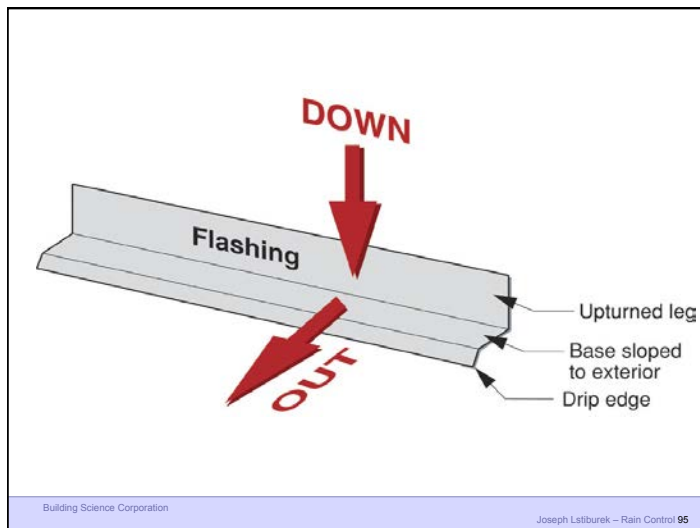
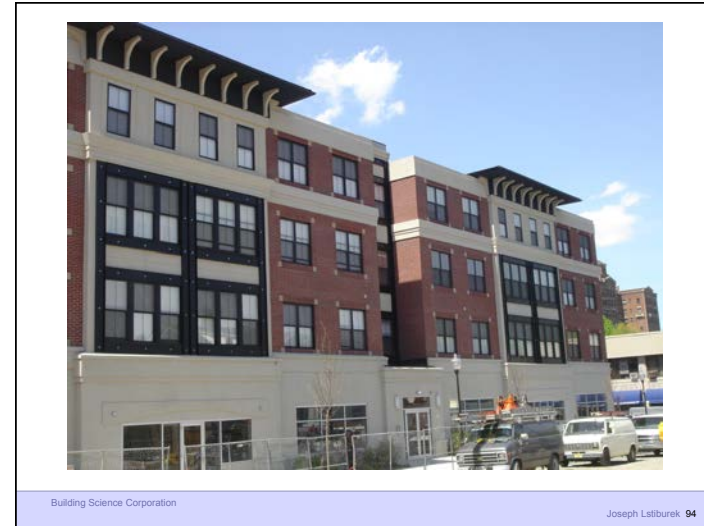
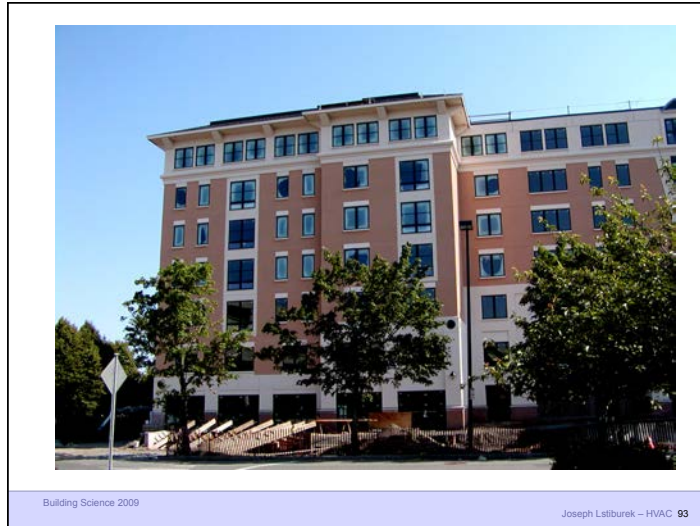




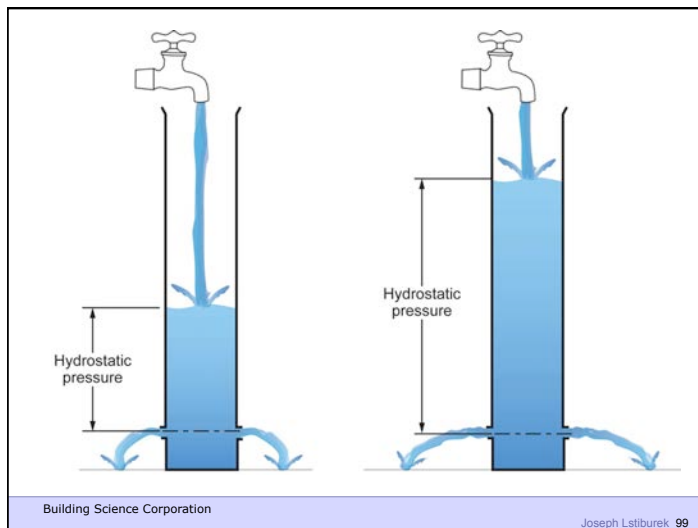


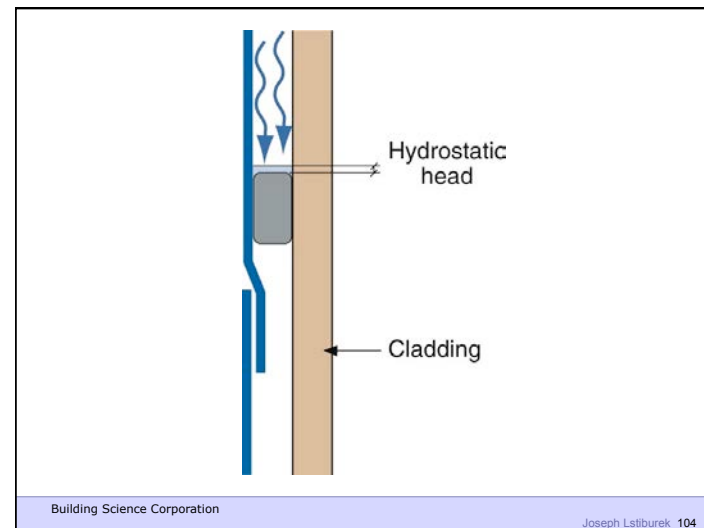
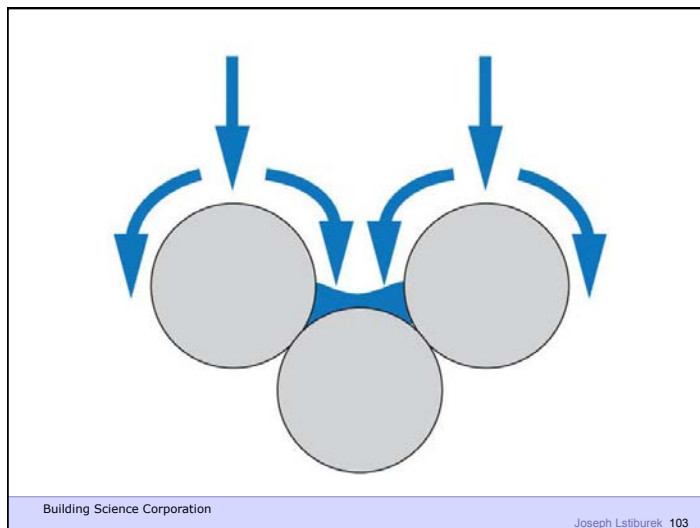
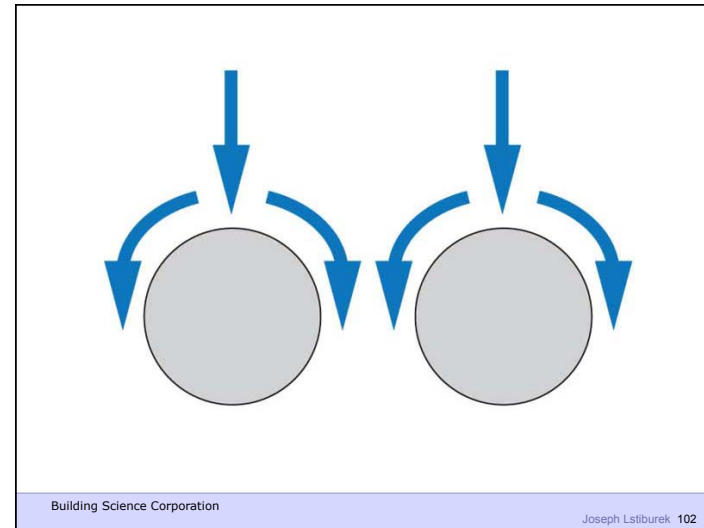
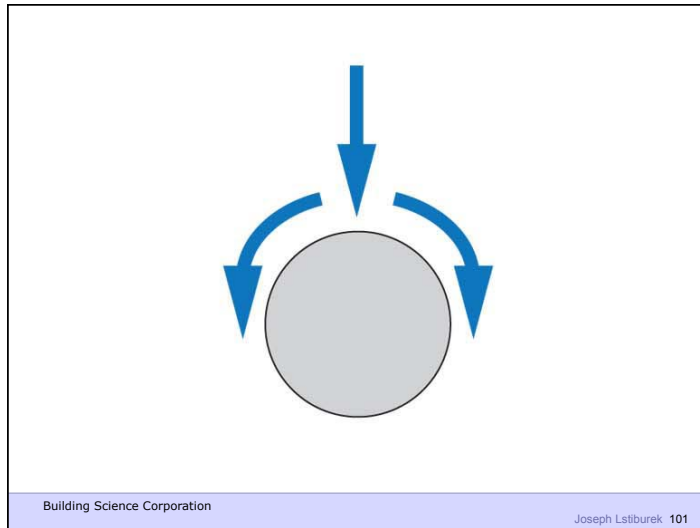


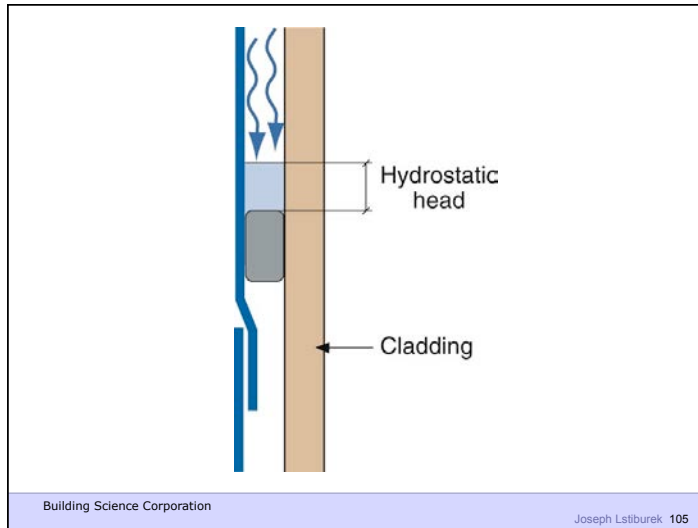






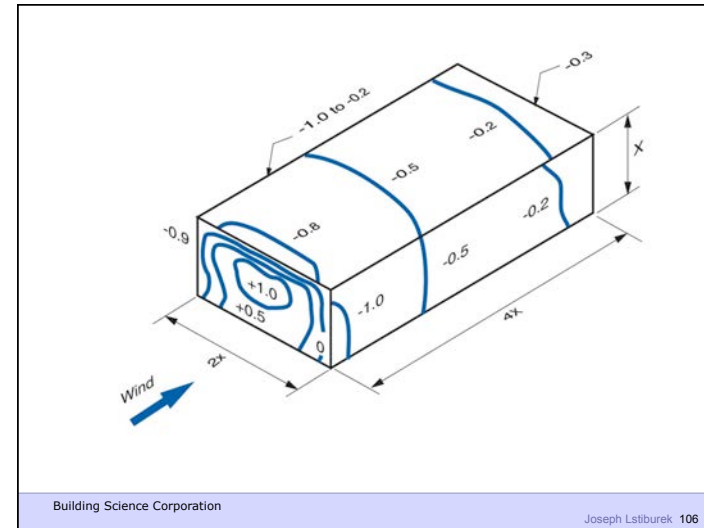






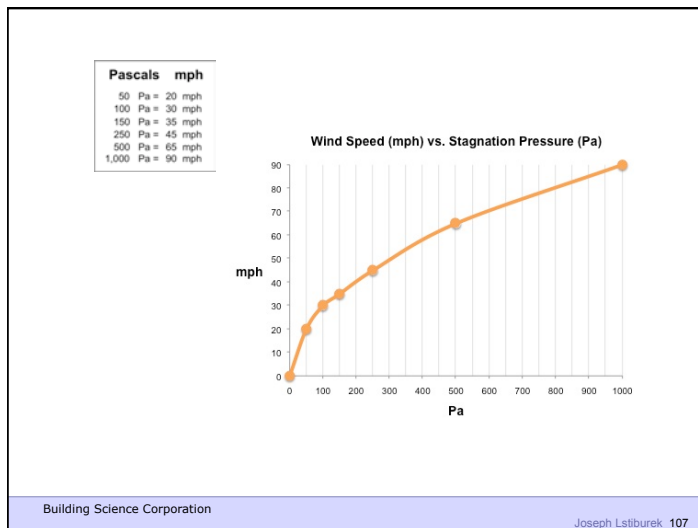
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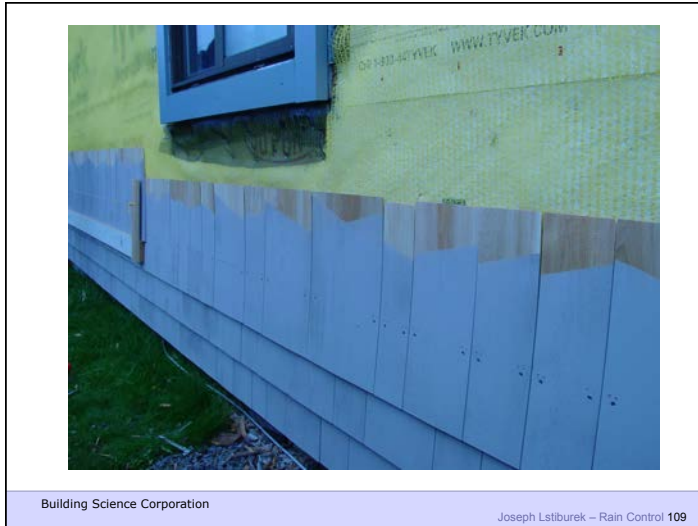
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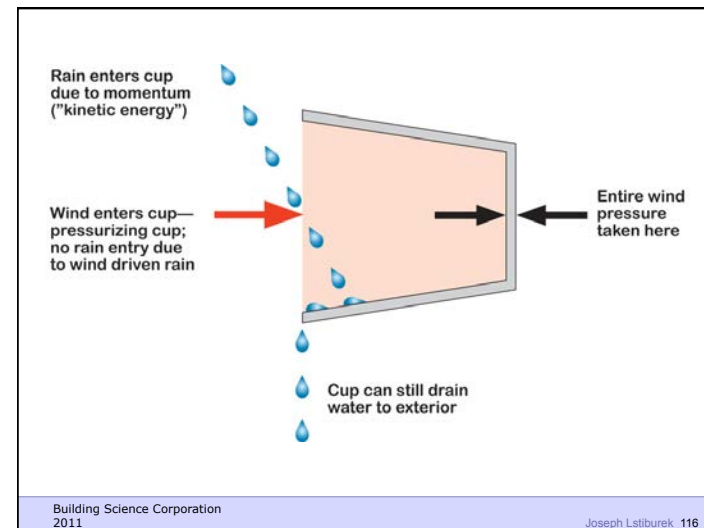
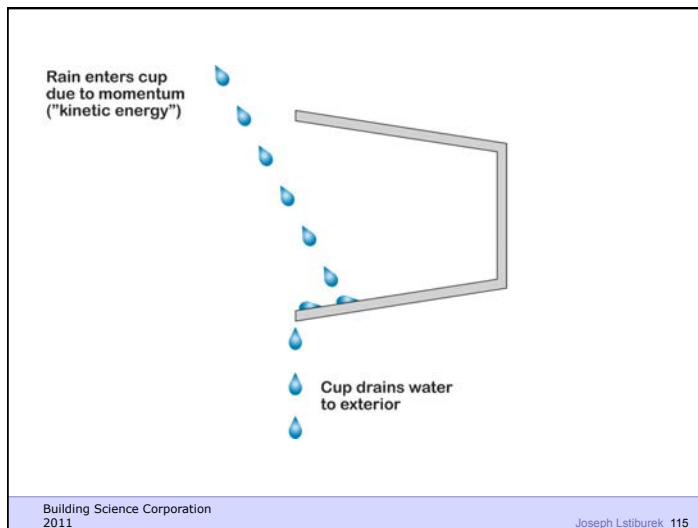
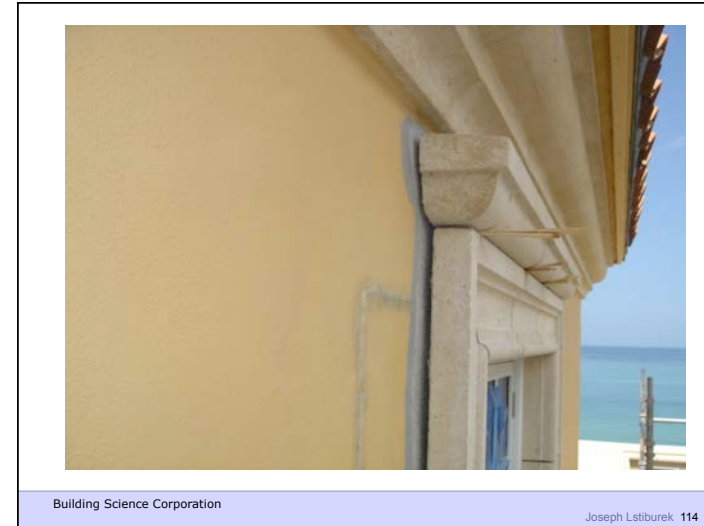
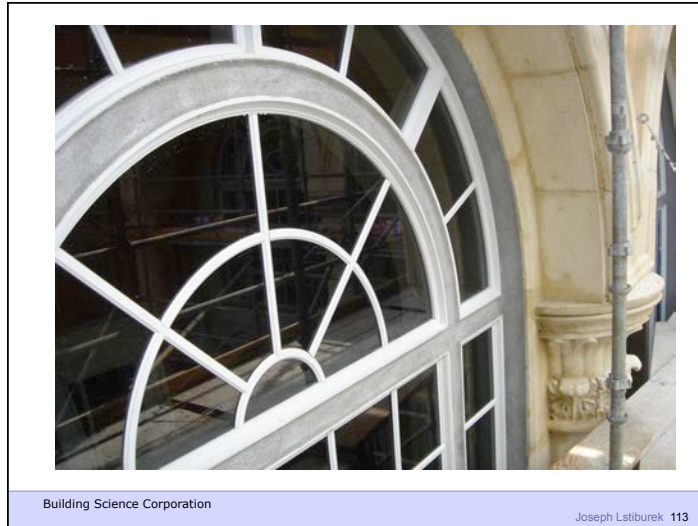
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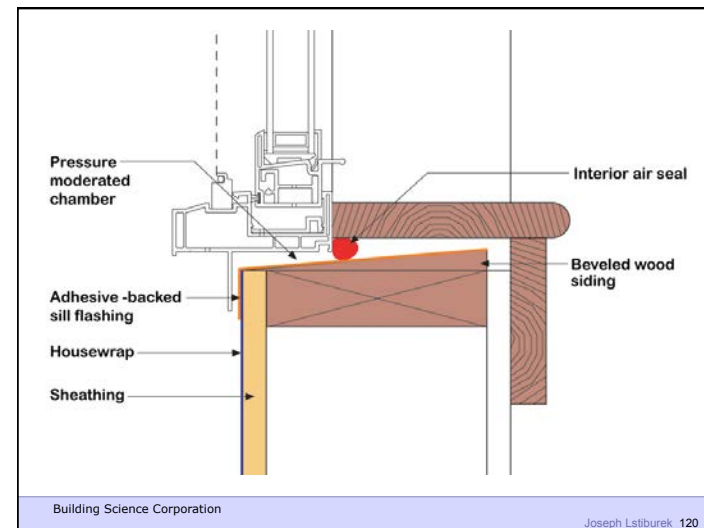
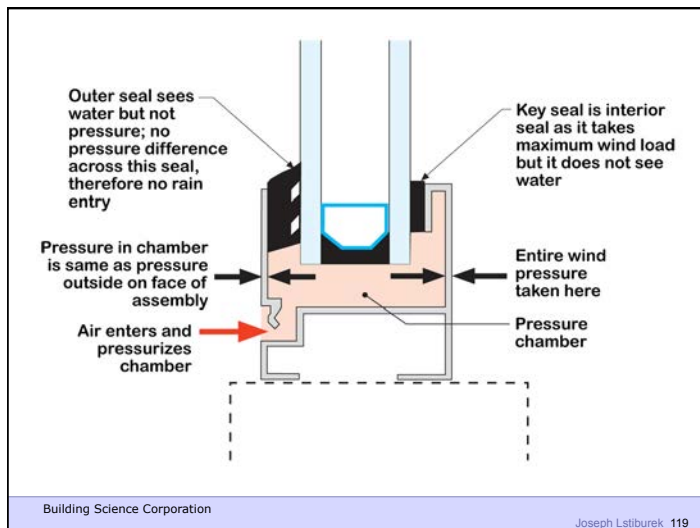
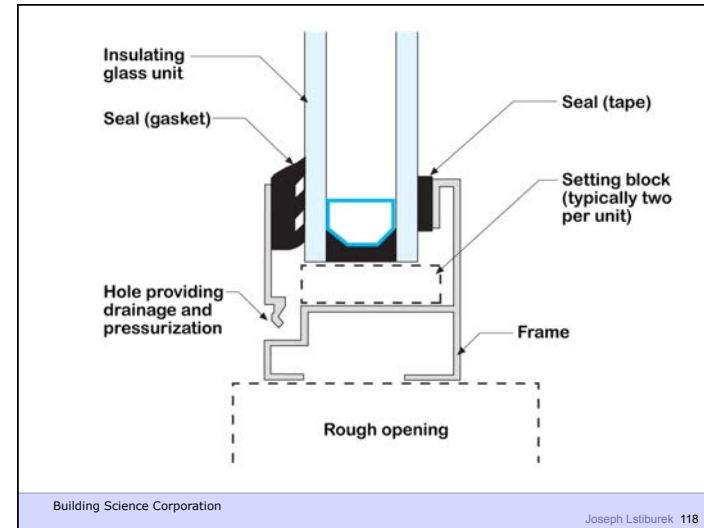
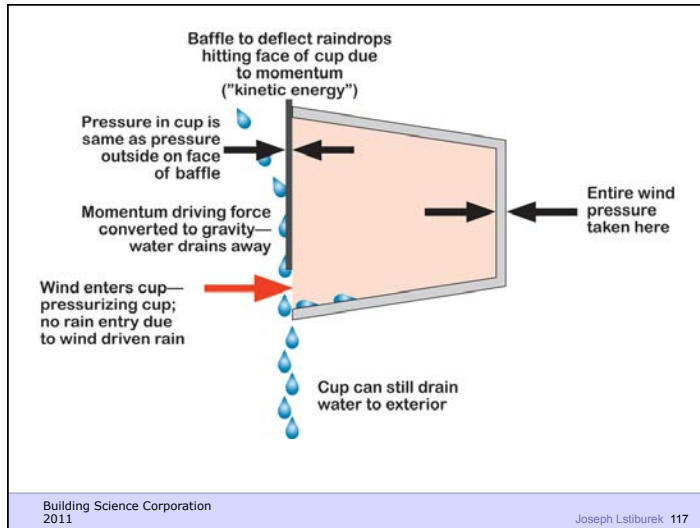


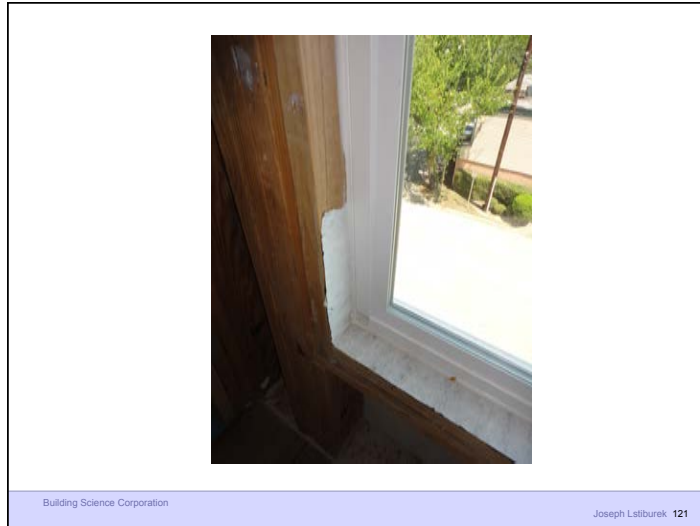
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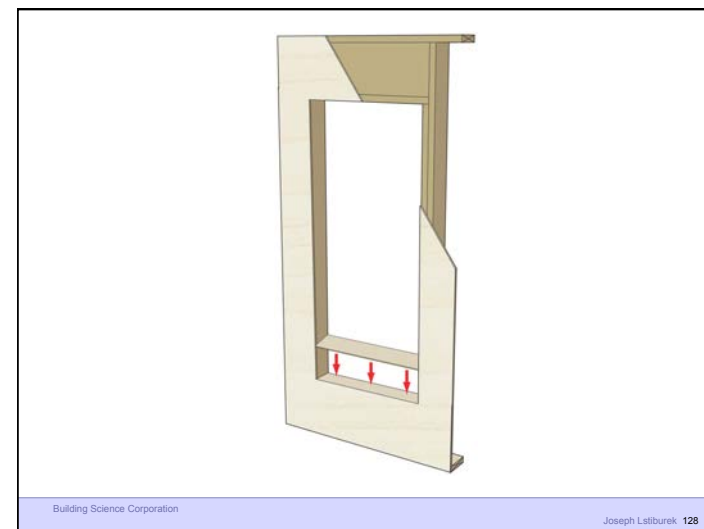
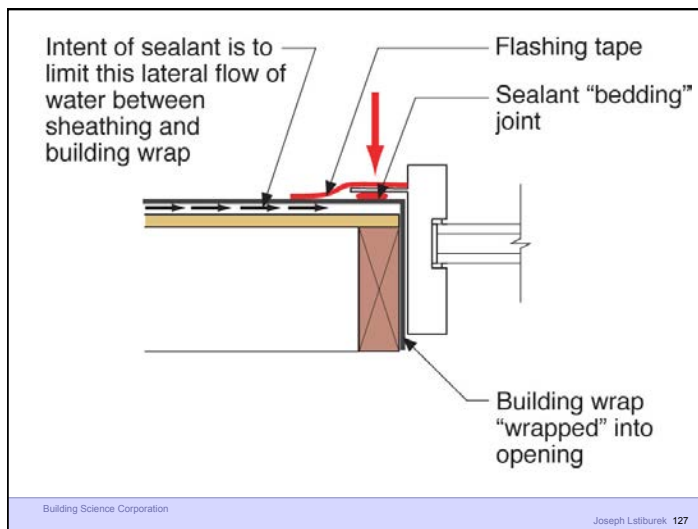
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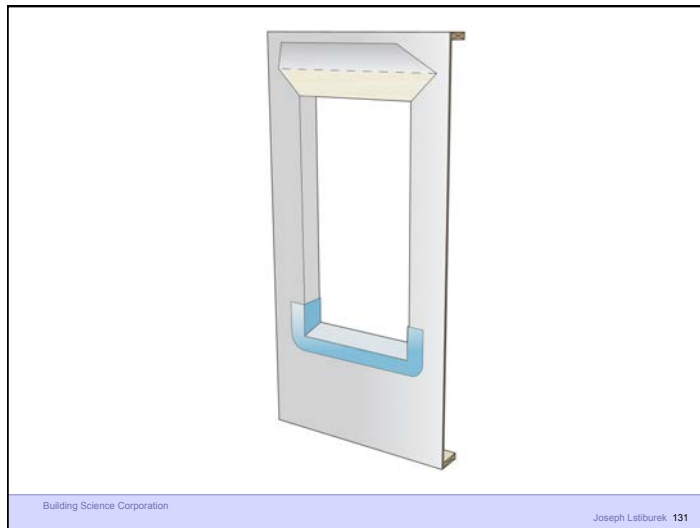
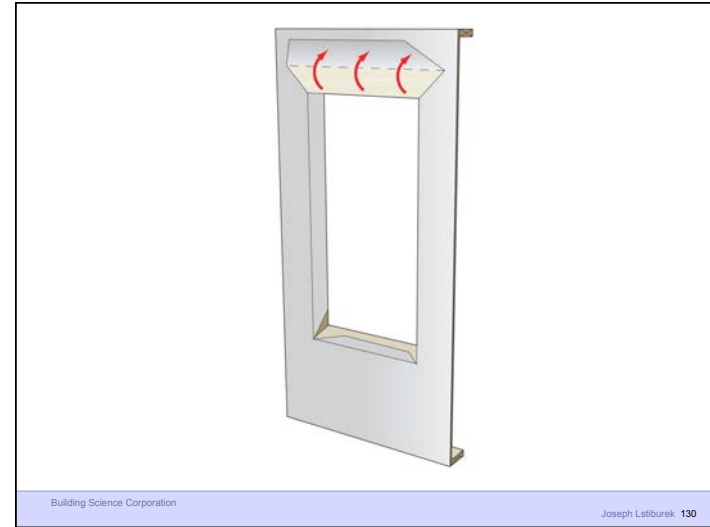
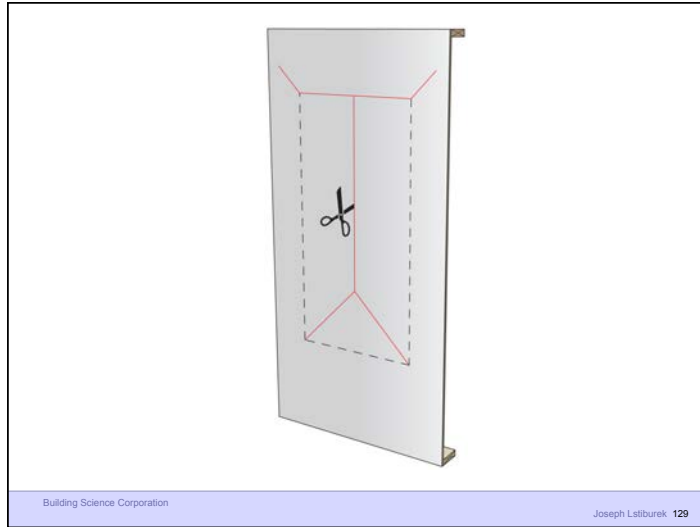


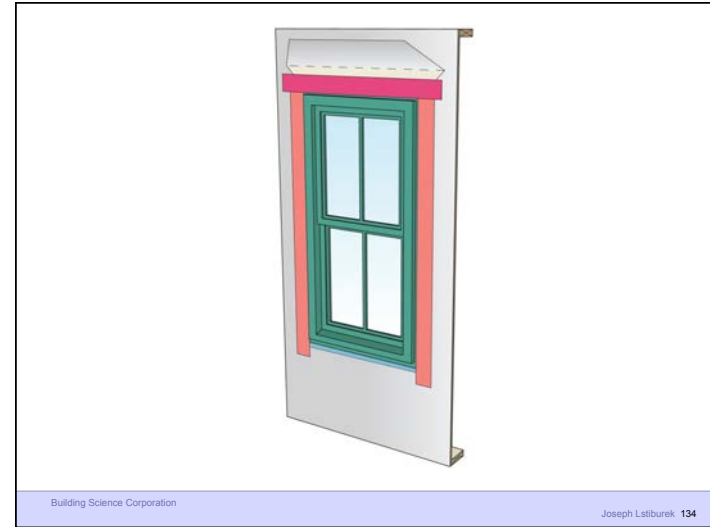
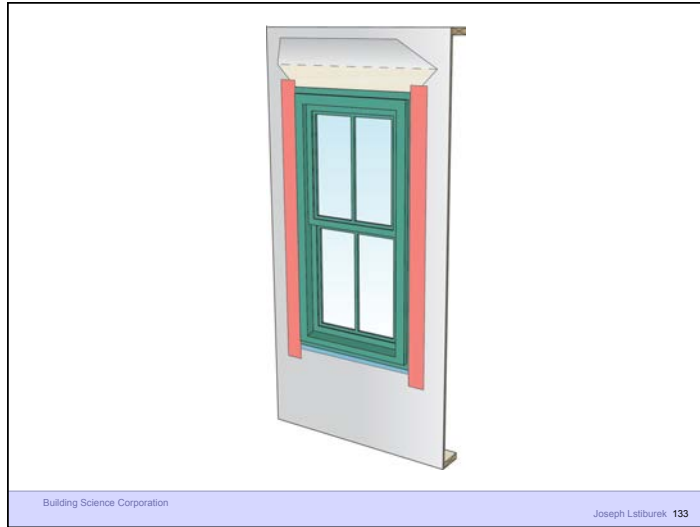


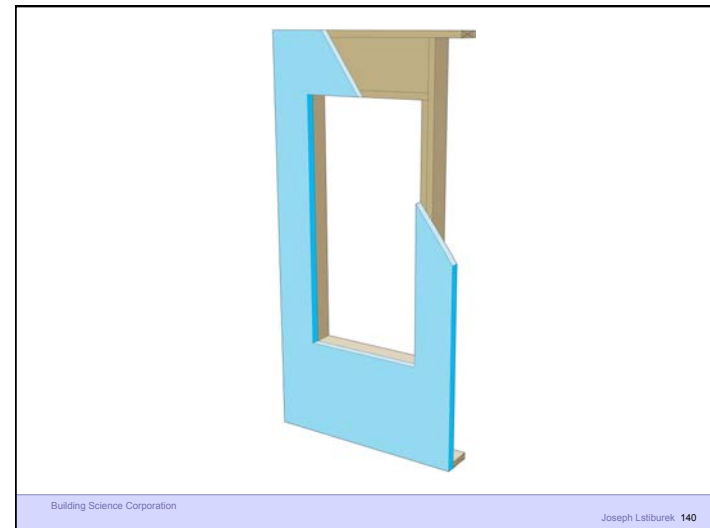
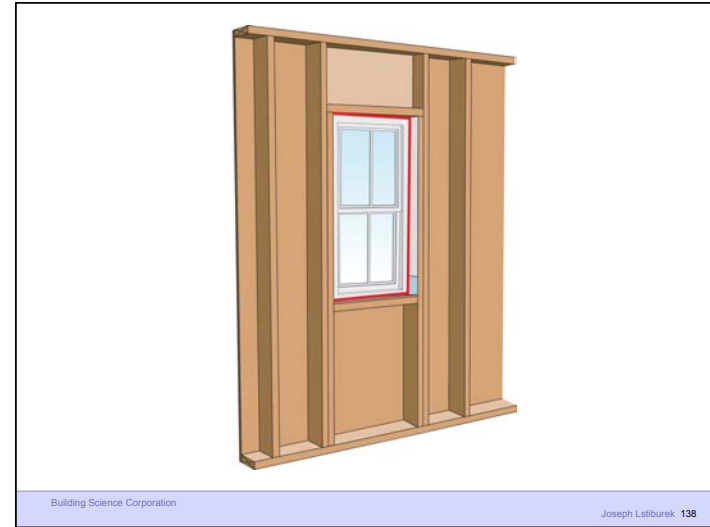
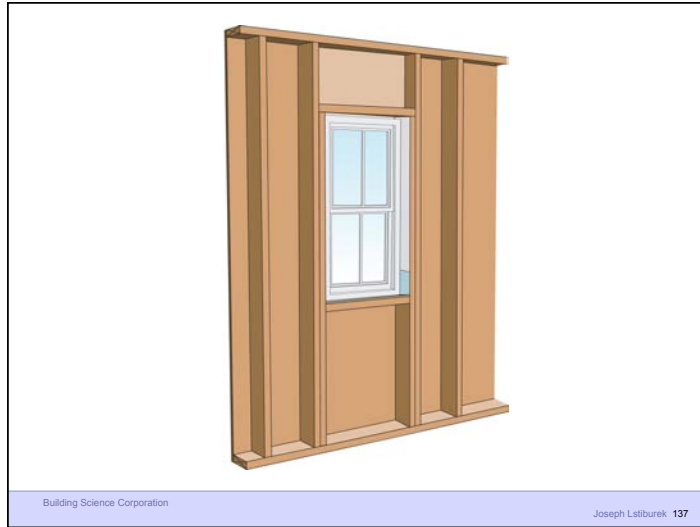


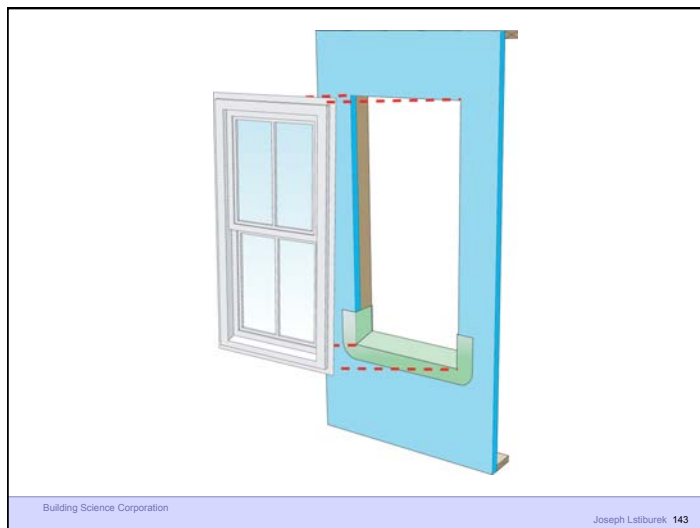
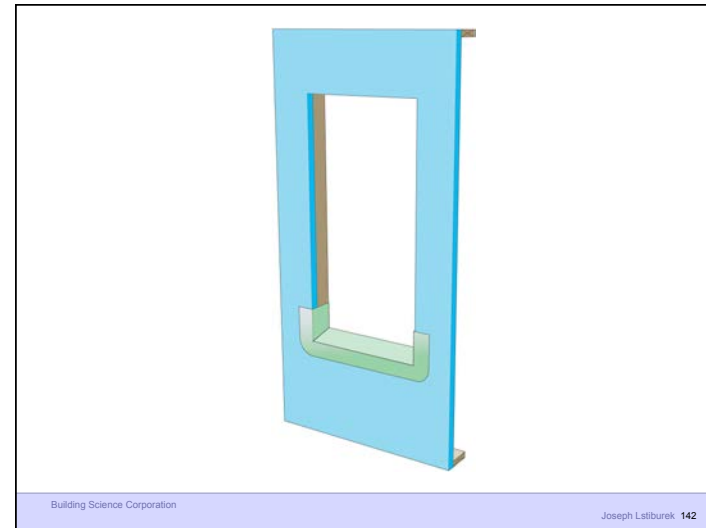
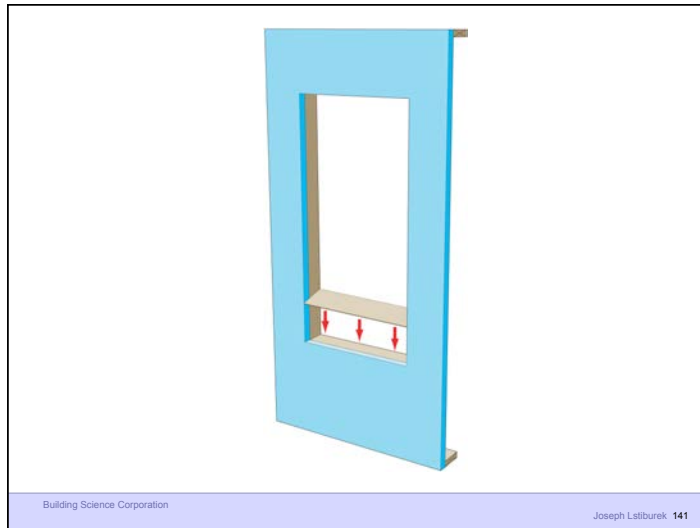


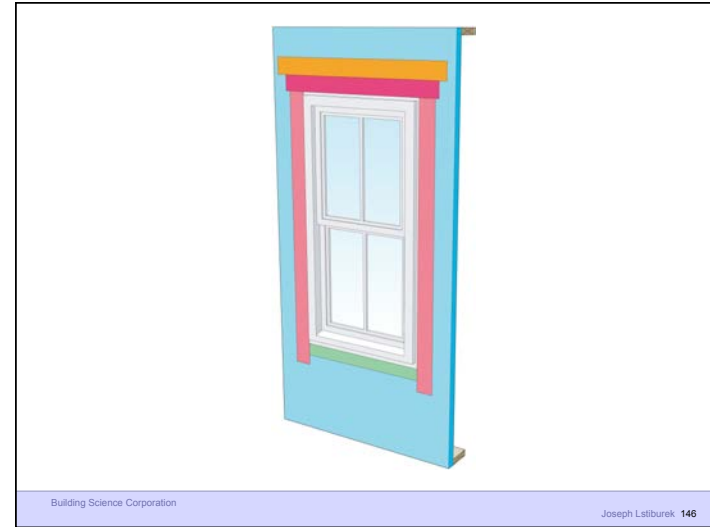
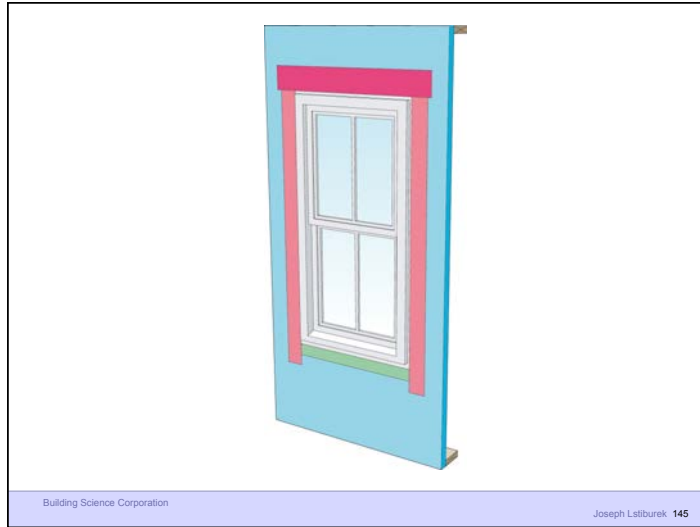


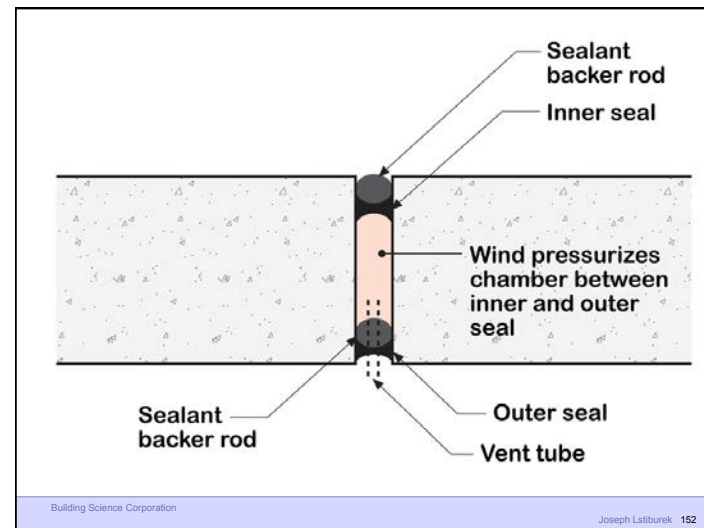


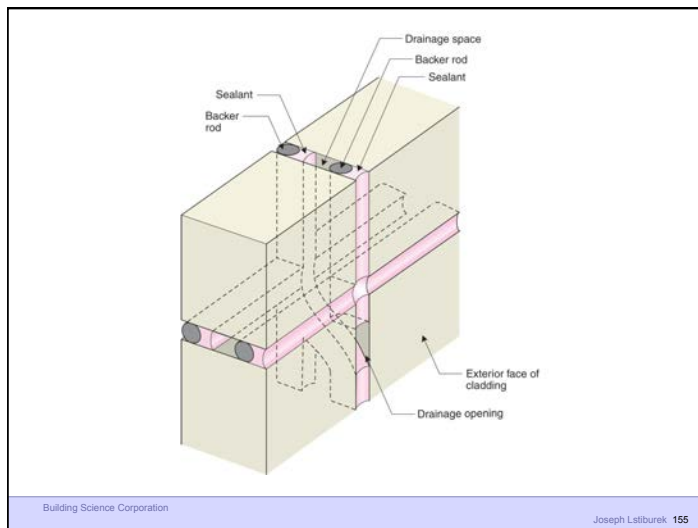
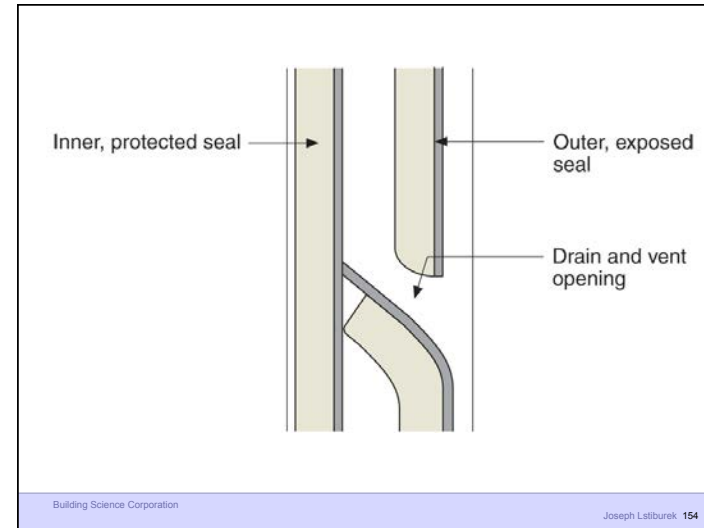
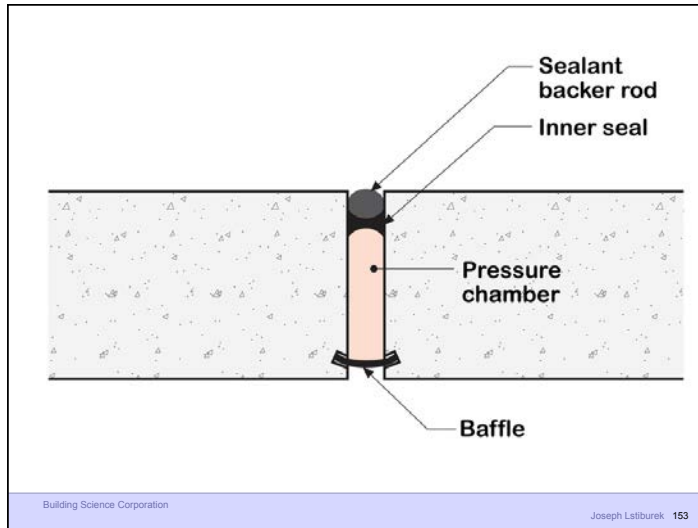


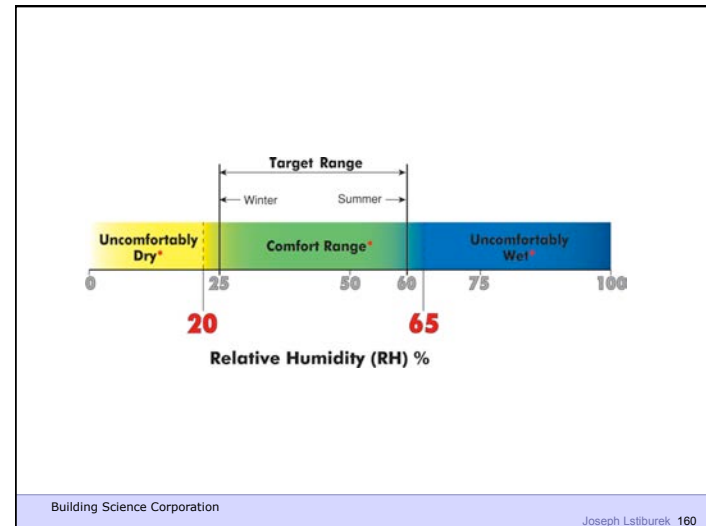
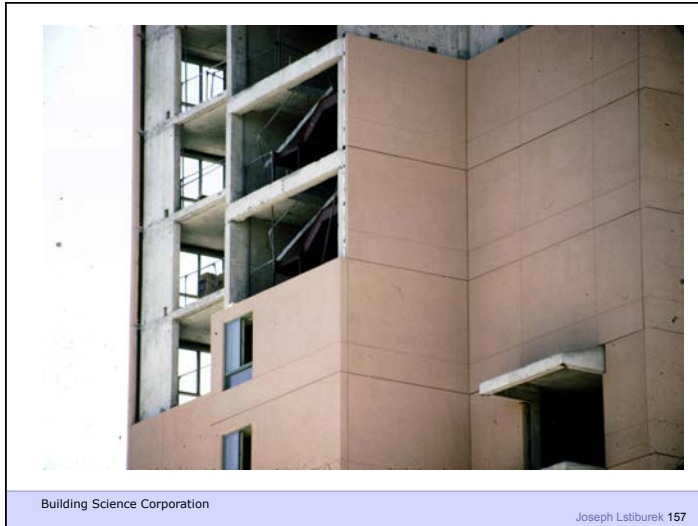




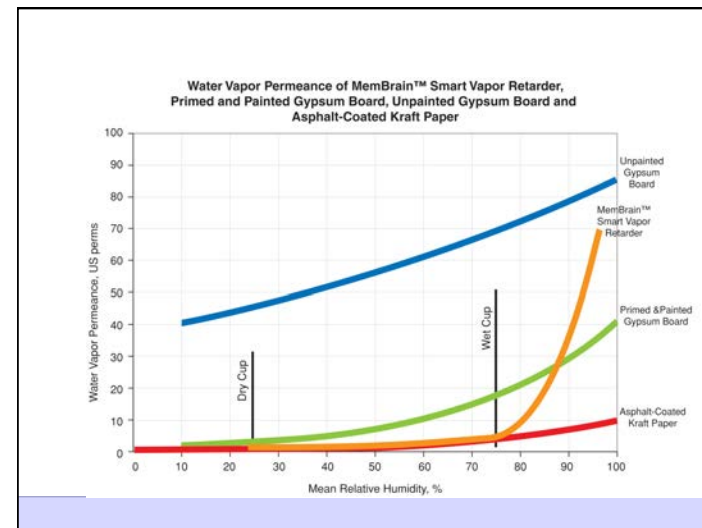
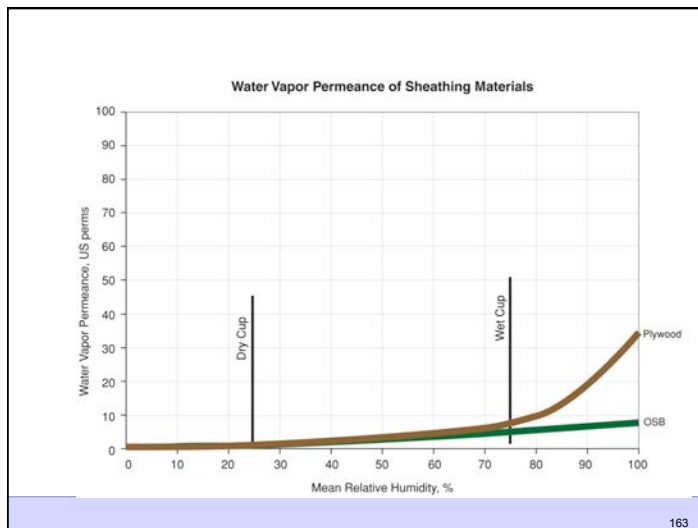
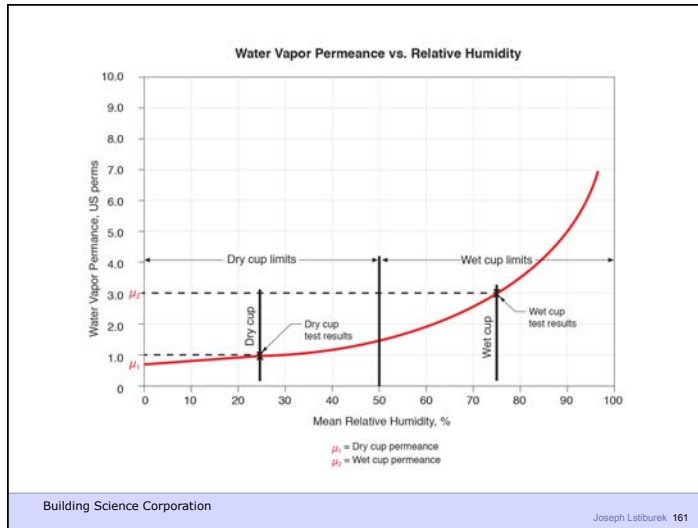


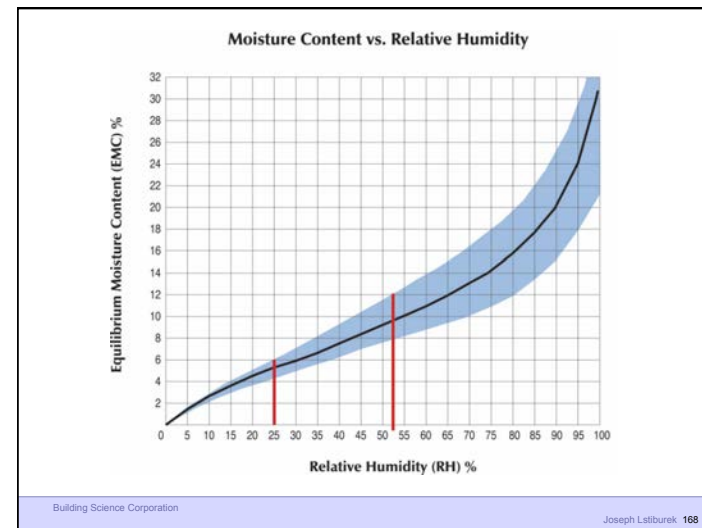
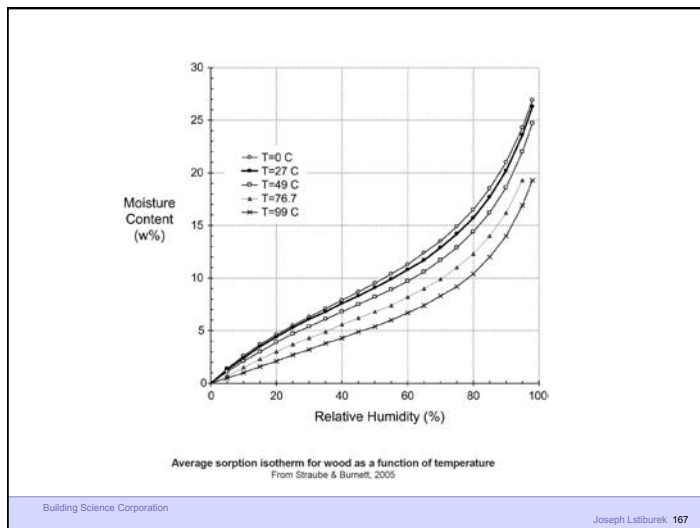
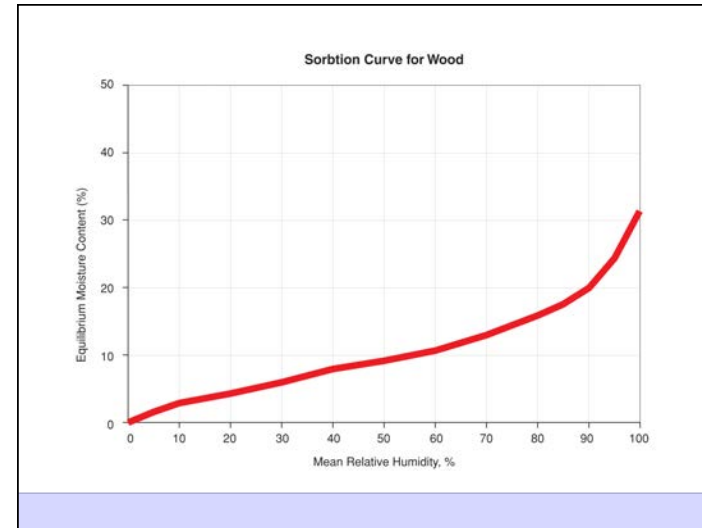
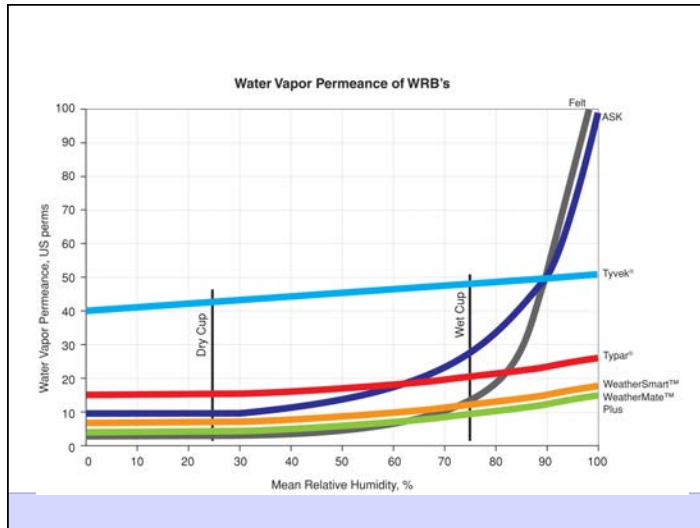


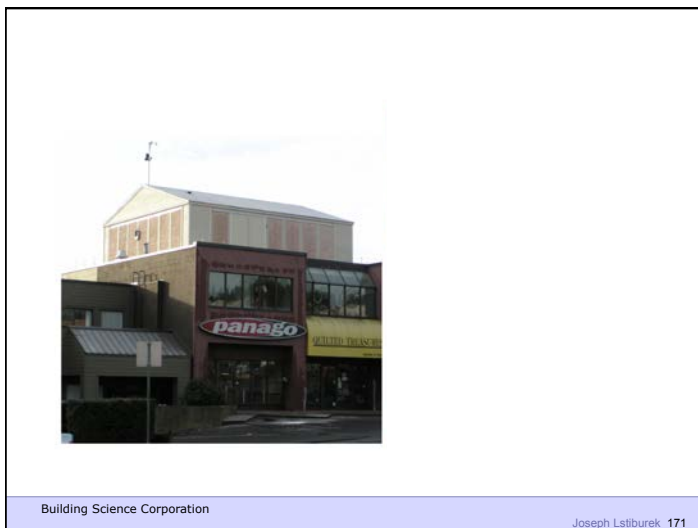
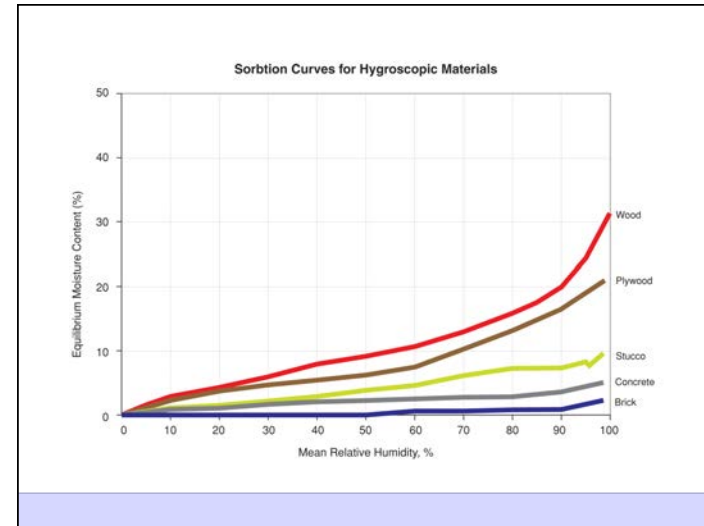






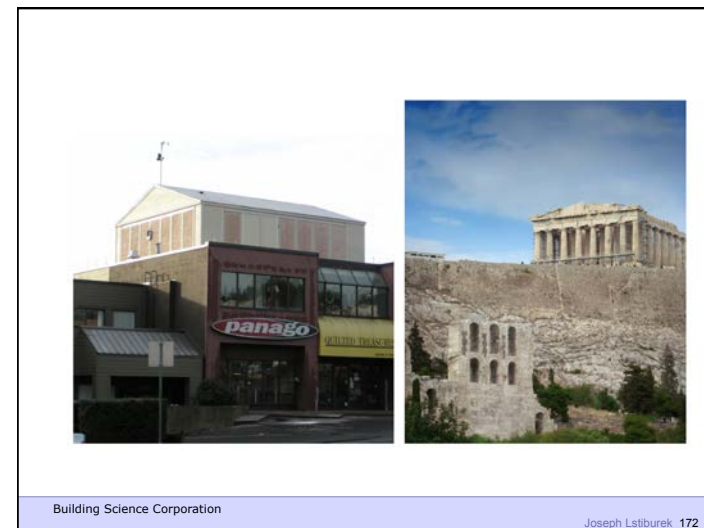






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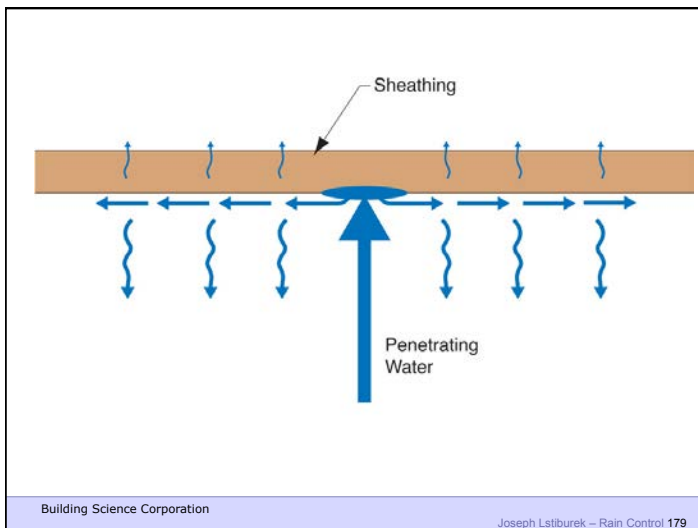
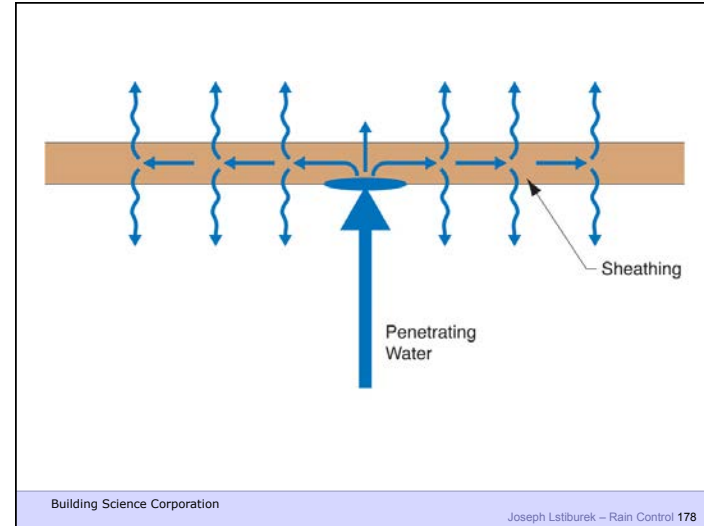
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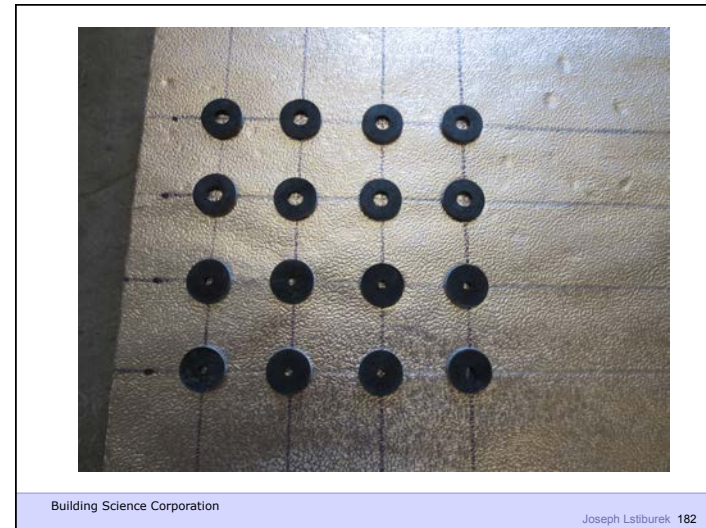
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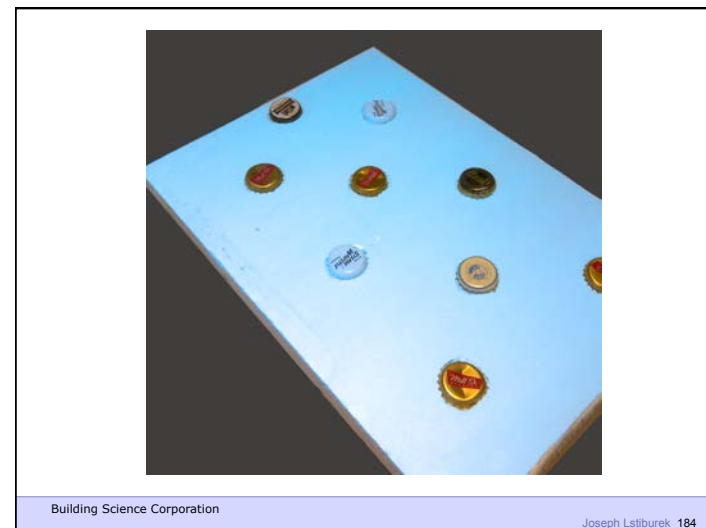
Rain Screen

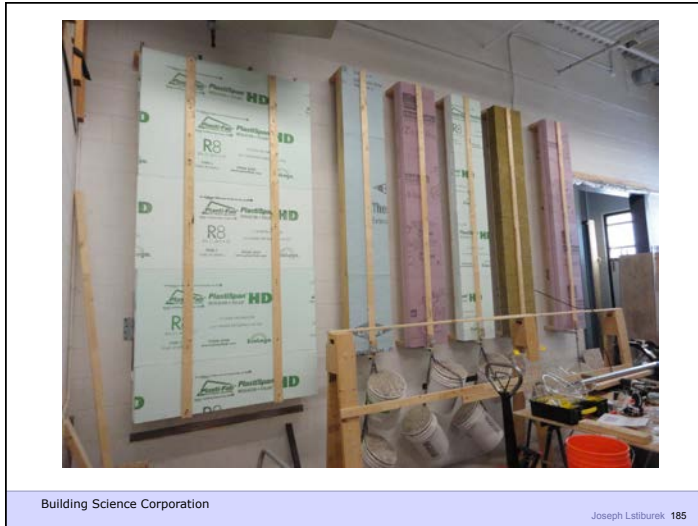
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Beer Screen?

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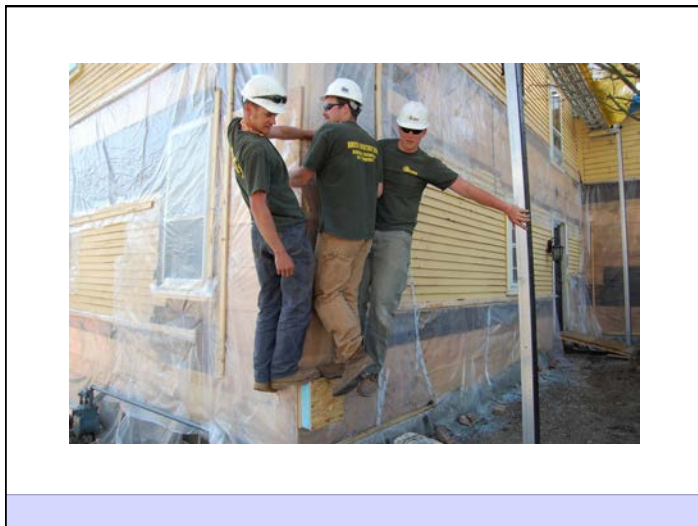
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### Rockwool

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

Average Deflection of Framing (inches)	Vertical Load (psf) - Red Curve	Vertical Load (psf) - Blue Curve	Vertical Load (psf) - Green Curve
0.00	0	0	0
0.02	~1000	~500	~200
0.04	~1500	~800	~300
0.06	~1800	~1000	~350
0.08	~1900	~1100	~380
0.10	~1950	~1150	~400