

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

# Building Science

Adventures In Building Science

[www.buildingscience.com](http://www.buildingscience.com)

## What is a Building?

## A Building is an Environmental Separator

Building Science Corporation

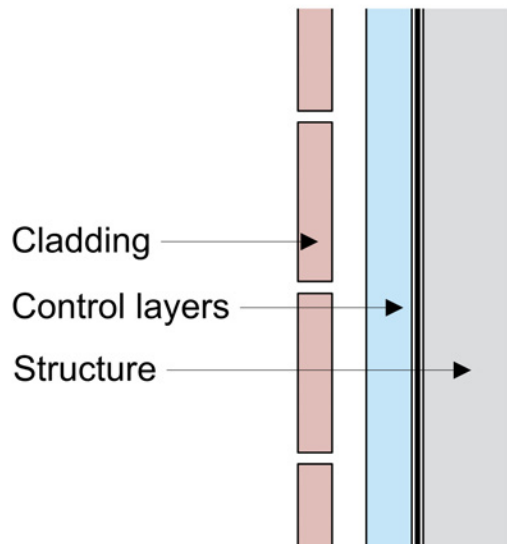
Joseph Lstiburek 3

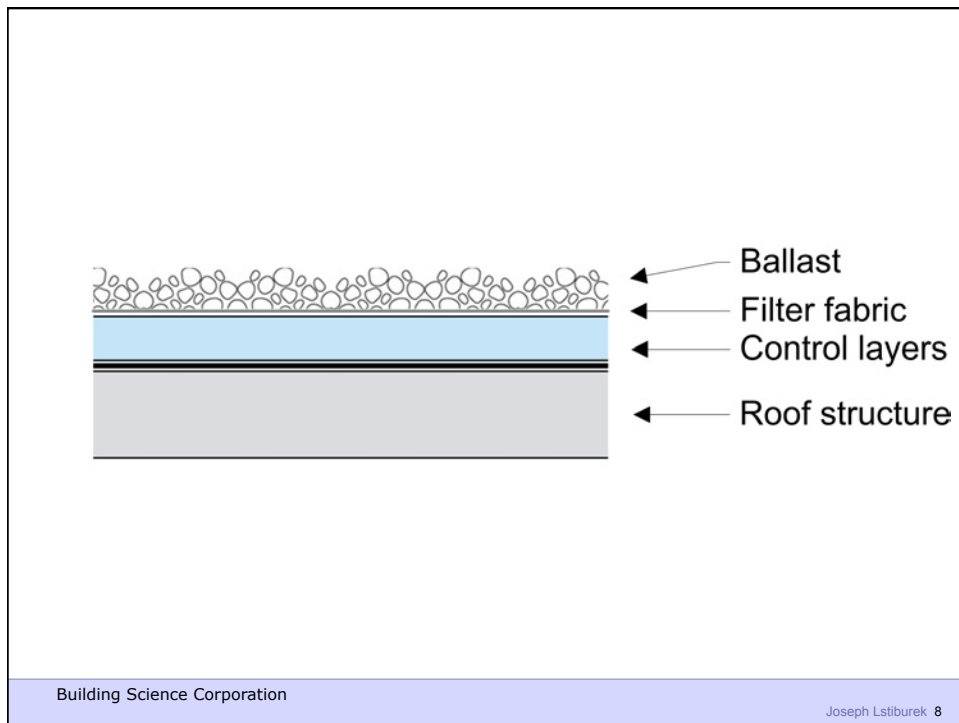
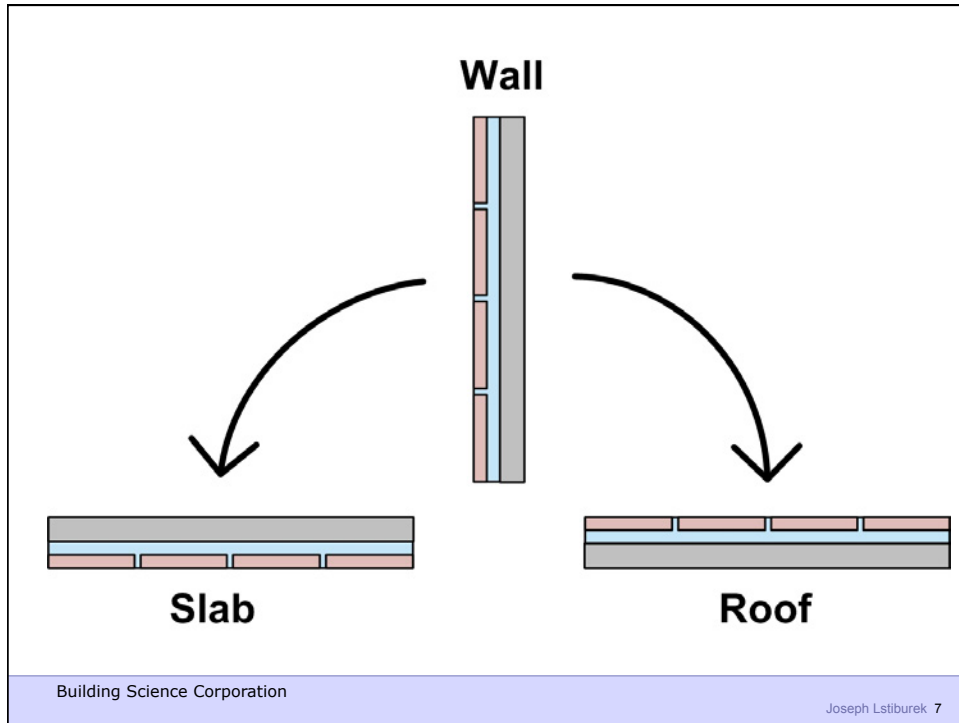
- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and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

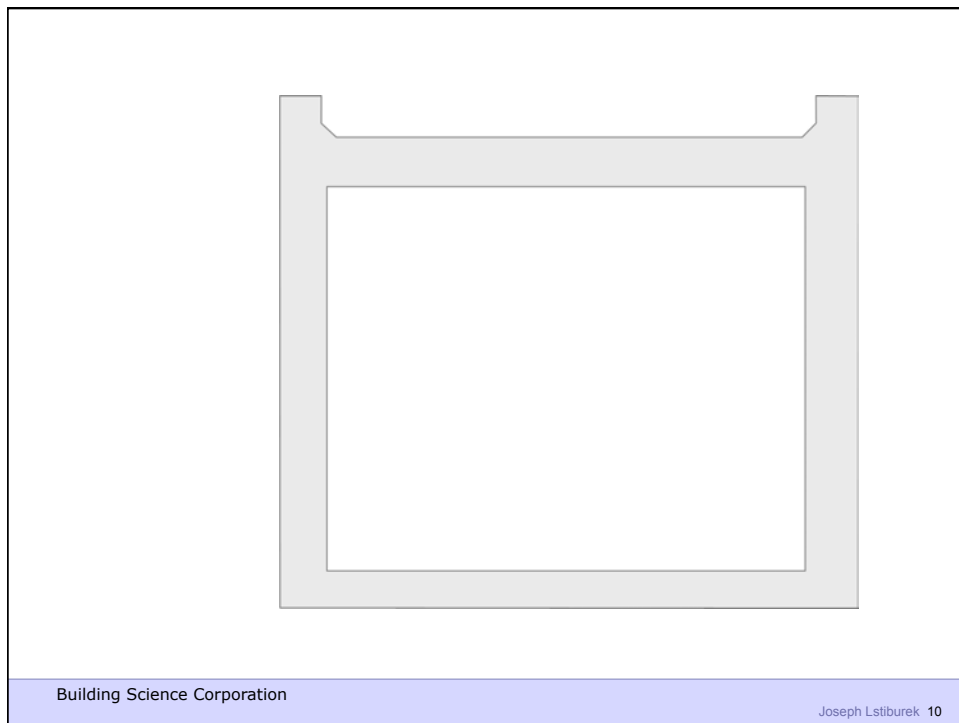
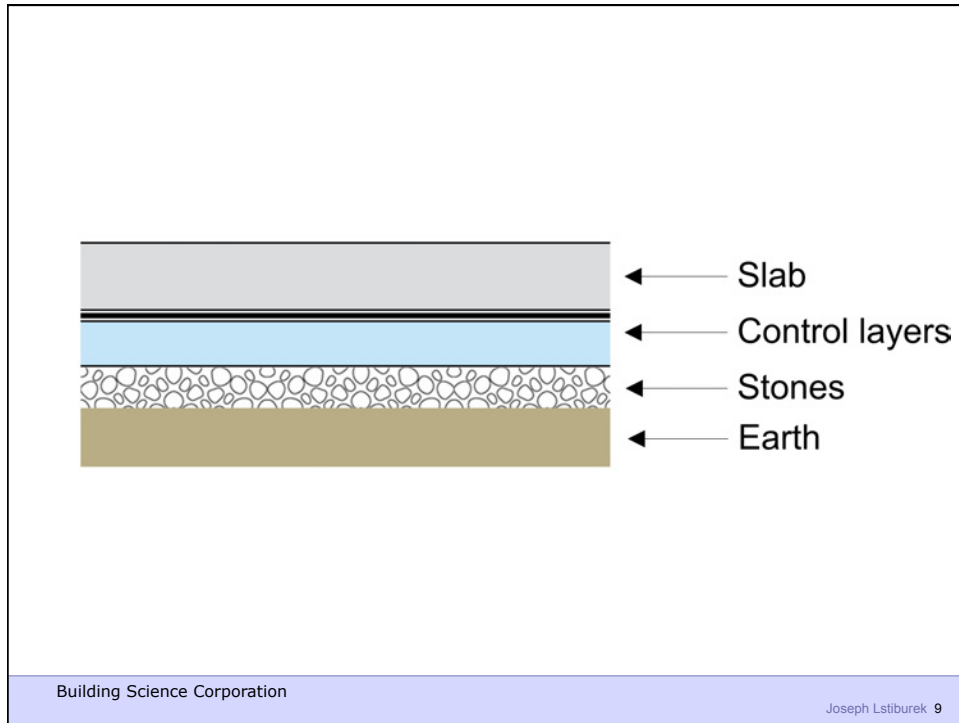
Building Science Corporation

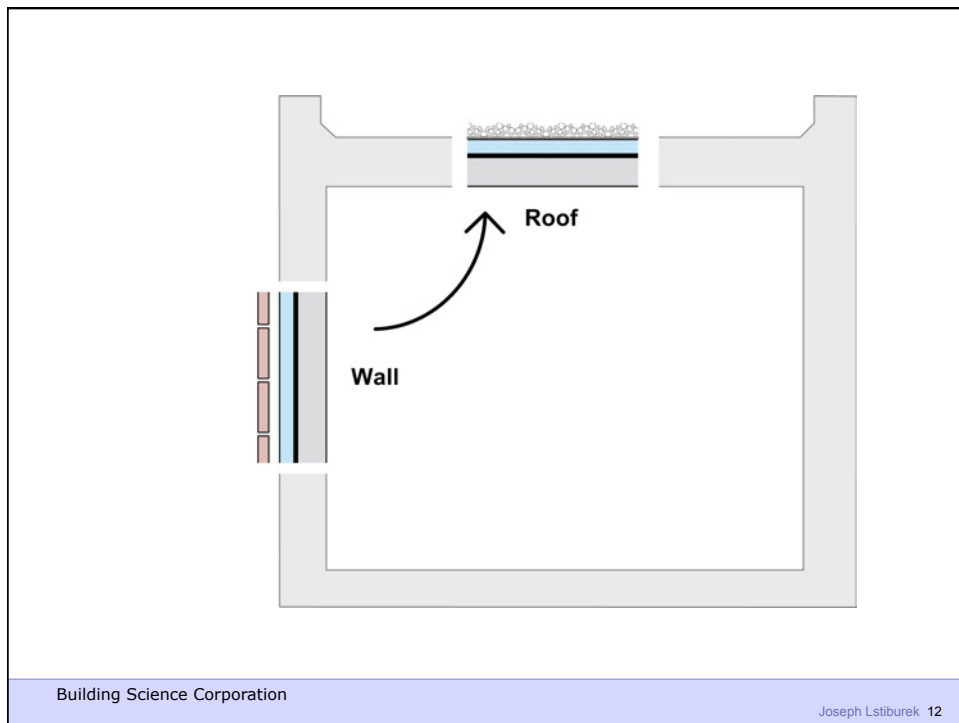
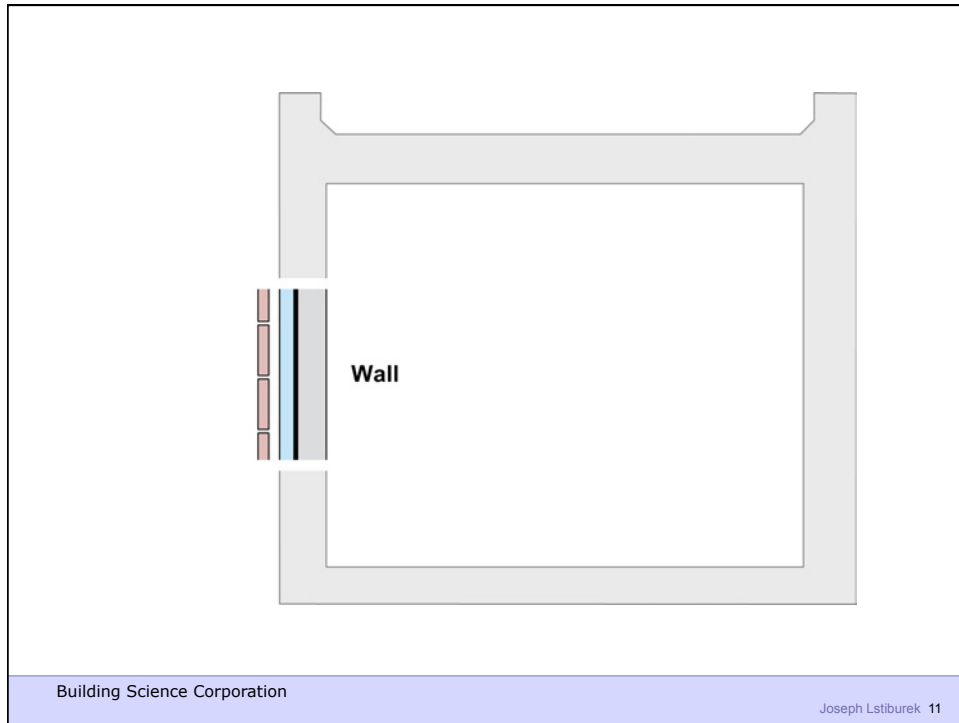
Joseph Lstiburek 4

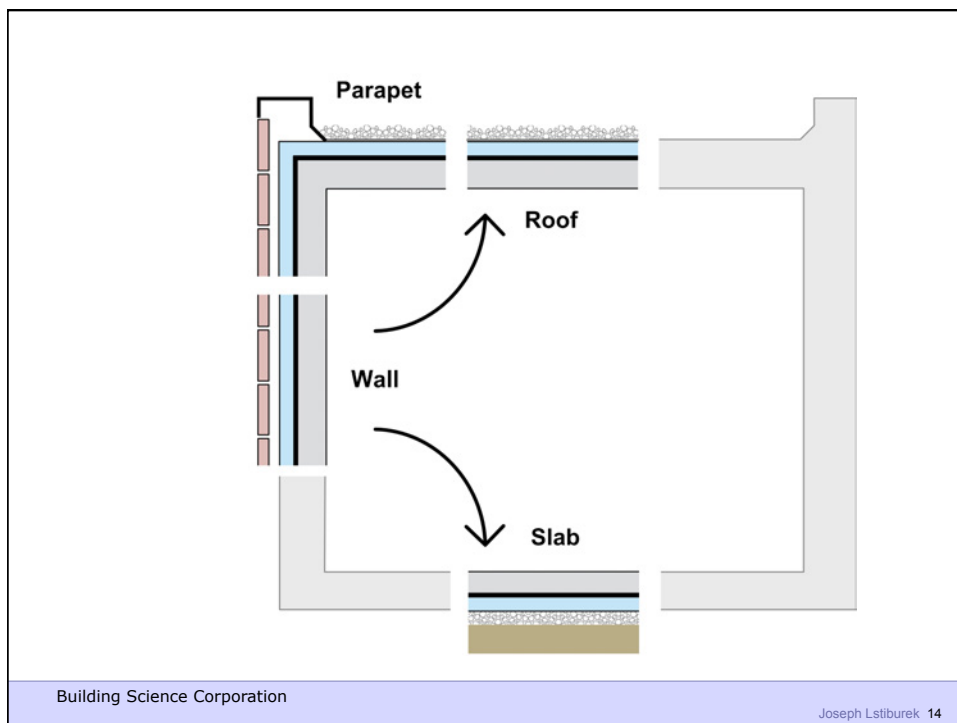
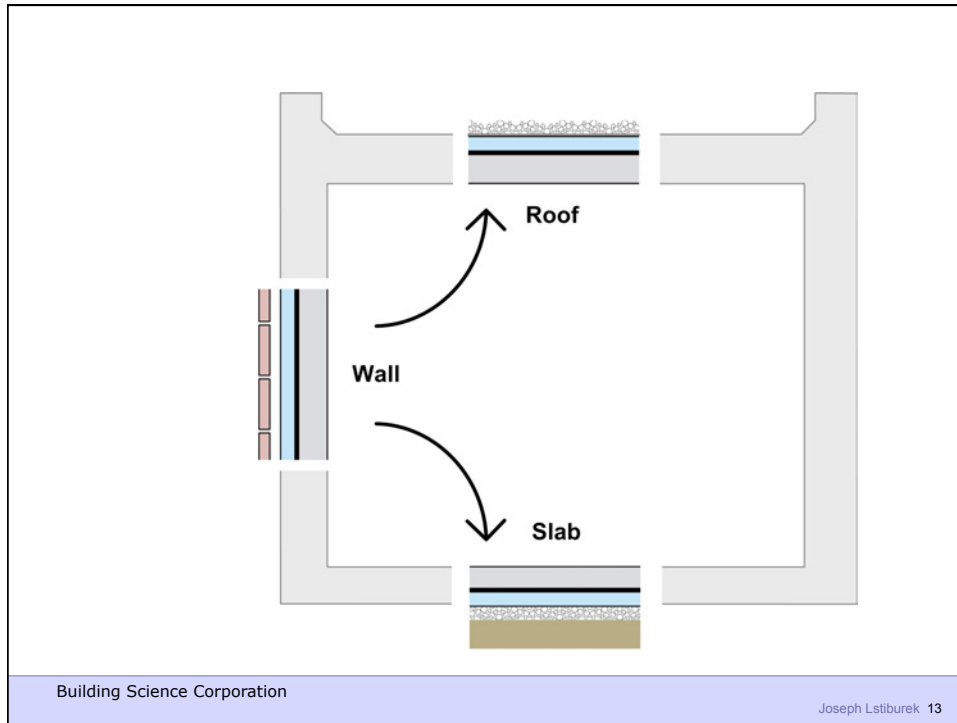
Water Control Layer  
Air Control Layer  
Vapor Control Layer  
Thermal Control Layer

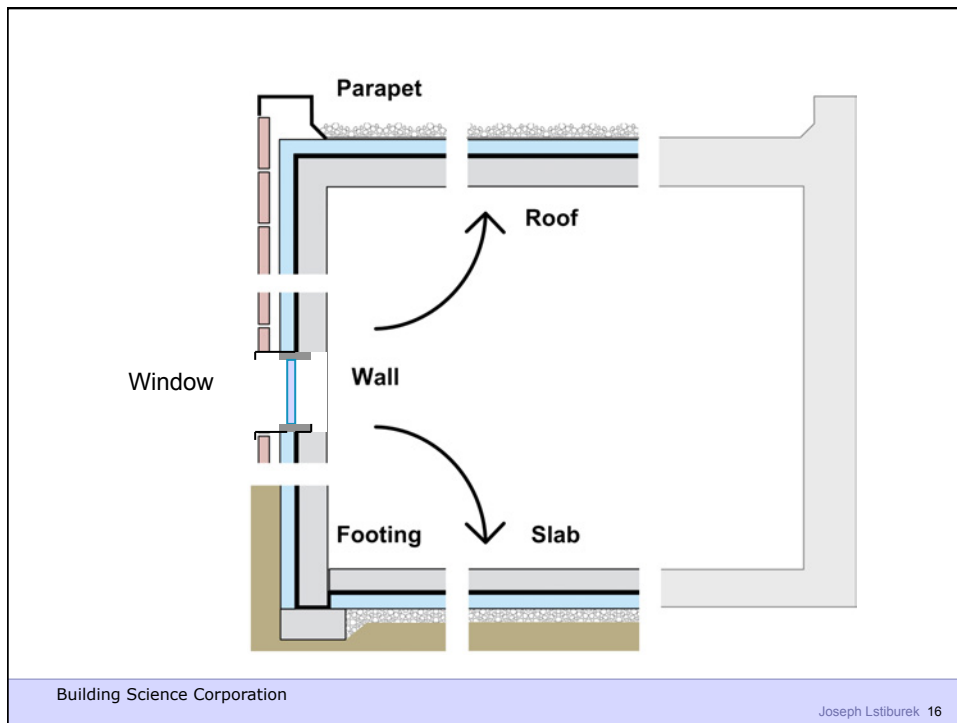
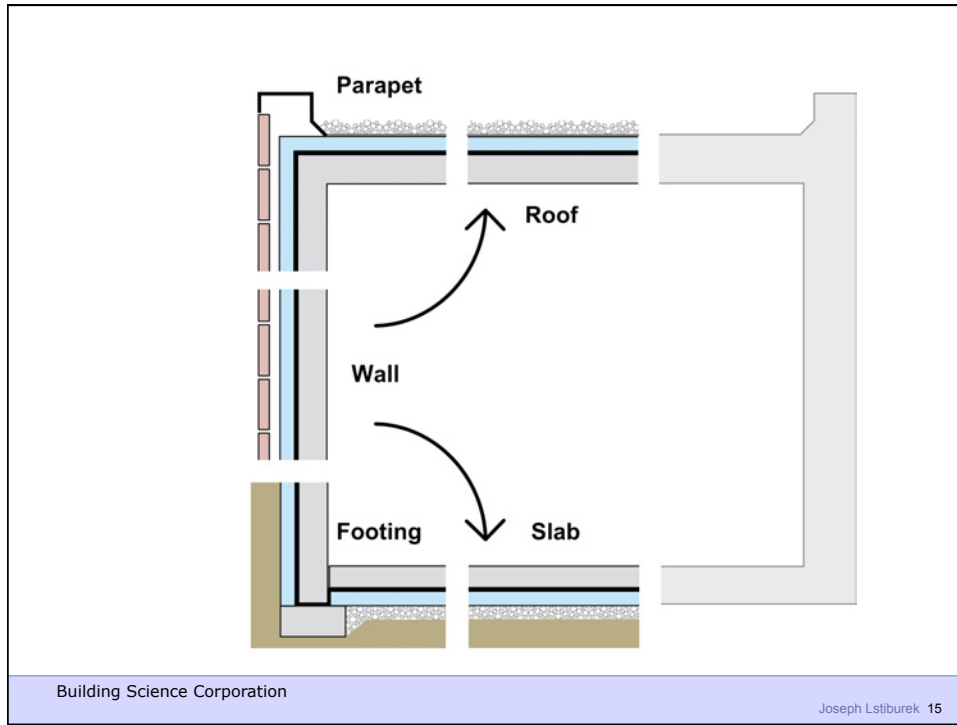




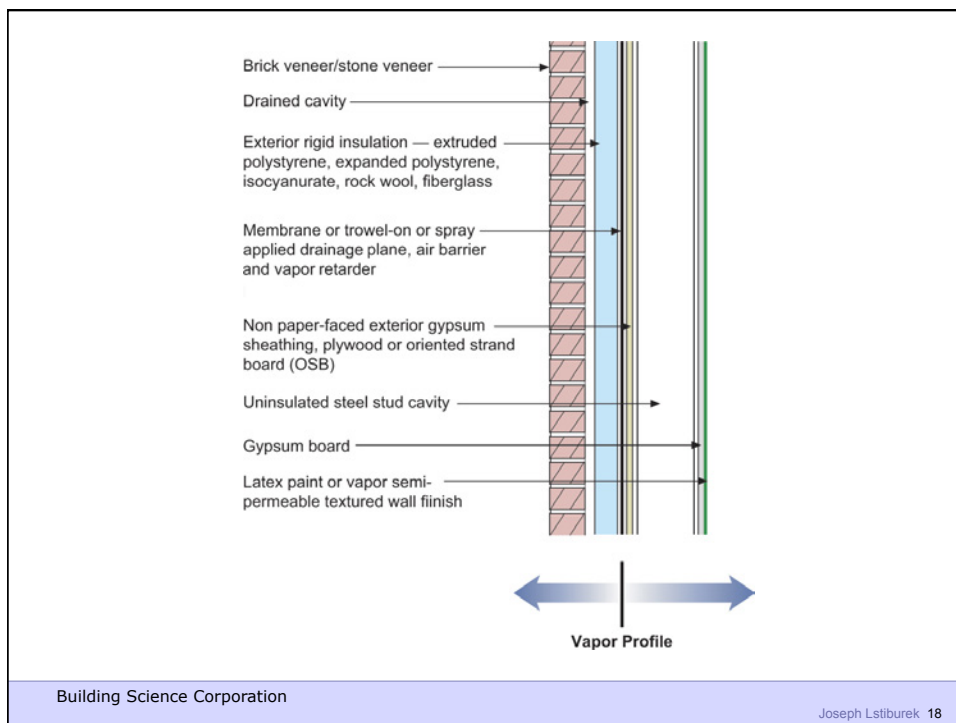
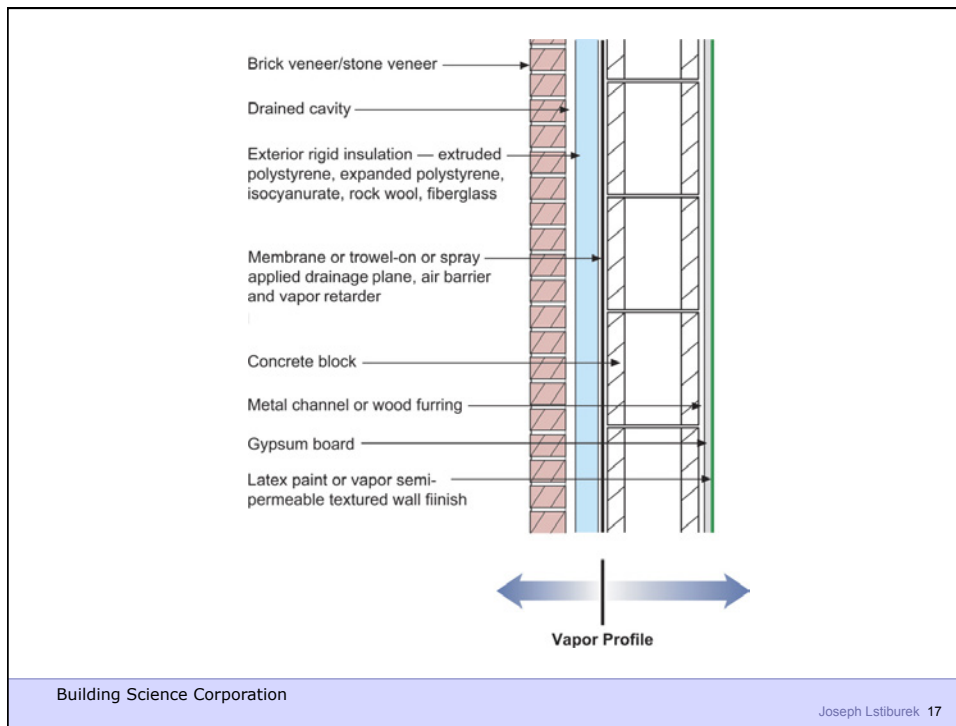


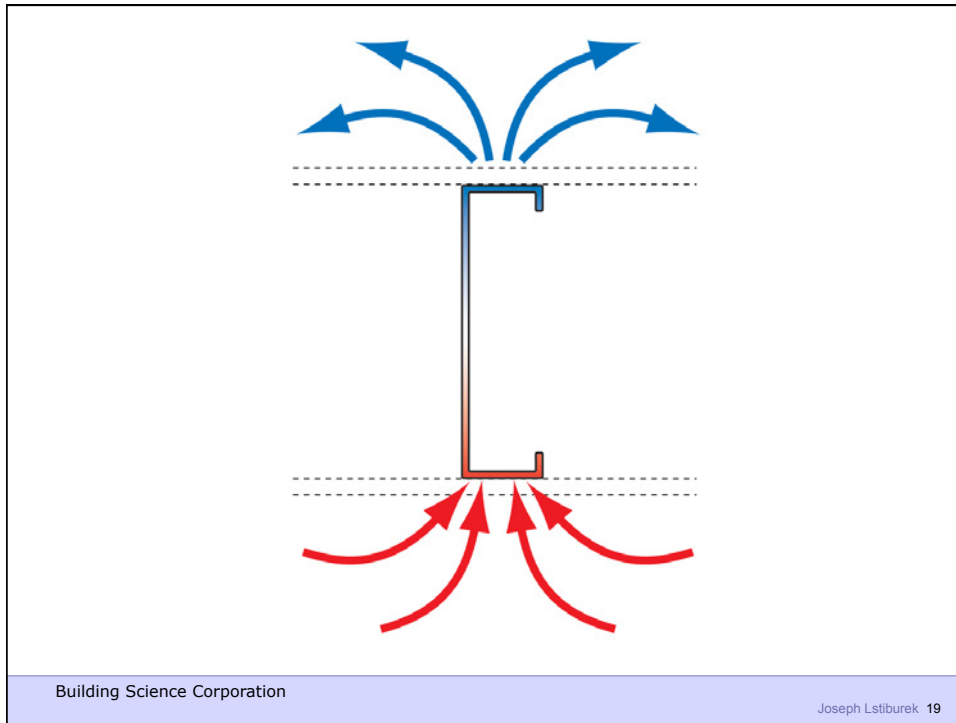


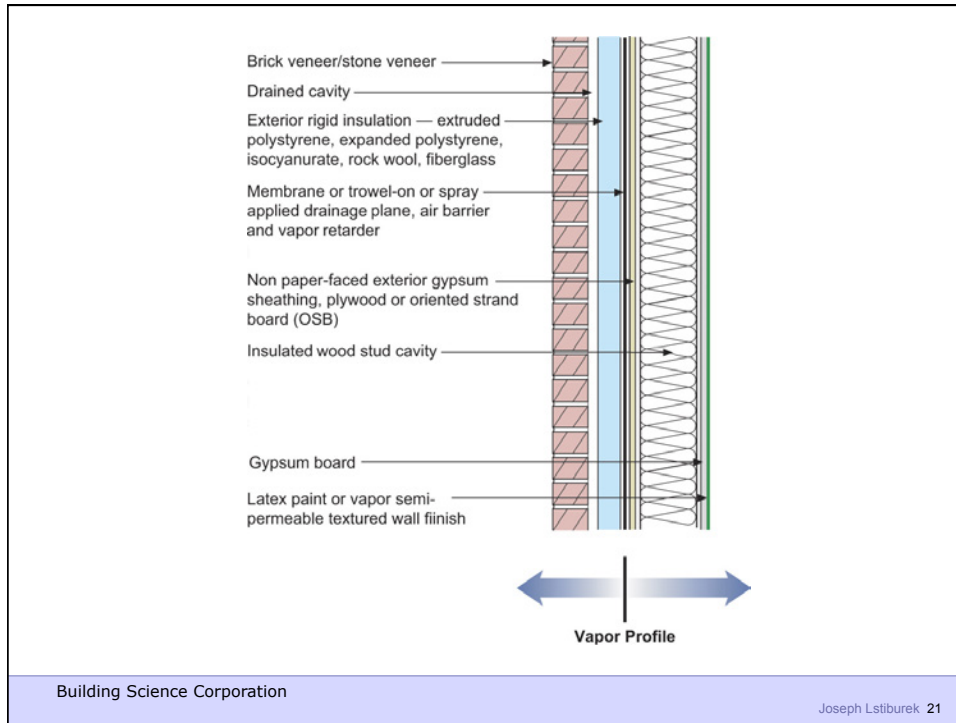




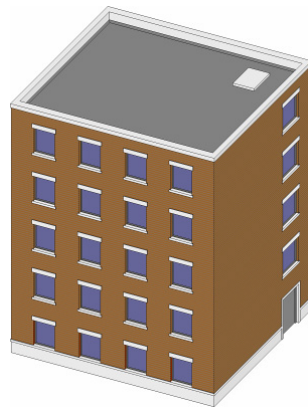




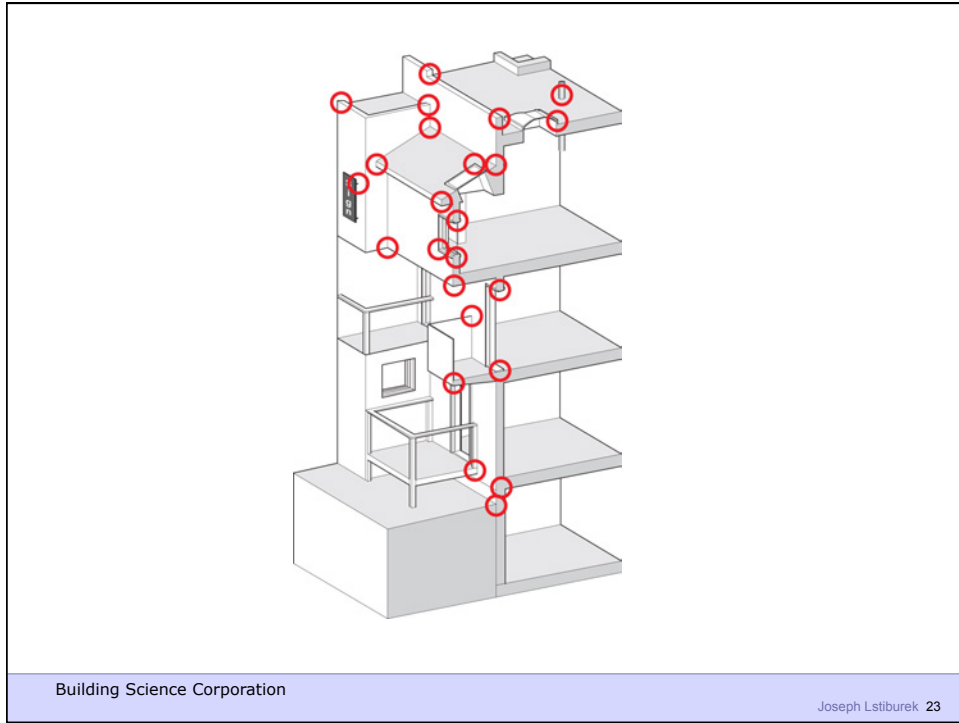




## Commercial Enclosure: Simple Layers



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





Building Science Corporation

Joseph Lstiburek 25

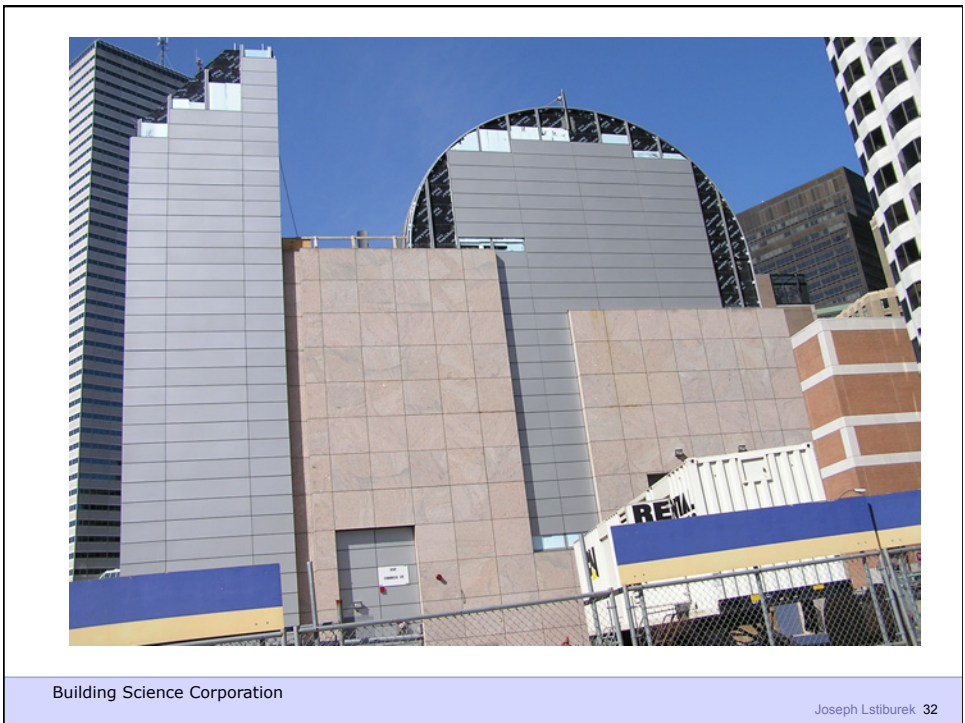
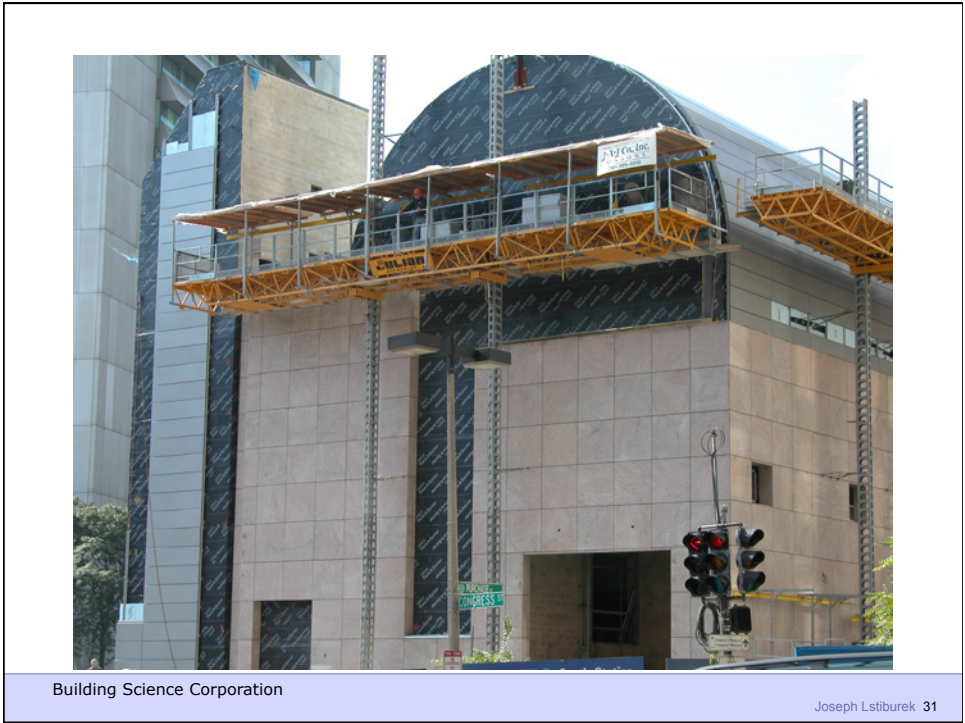


Building Science Corporation

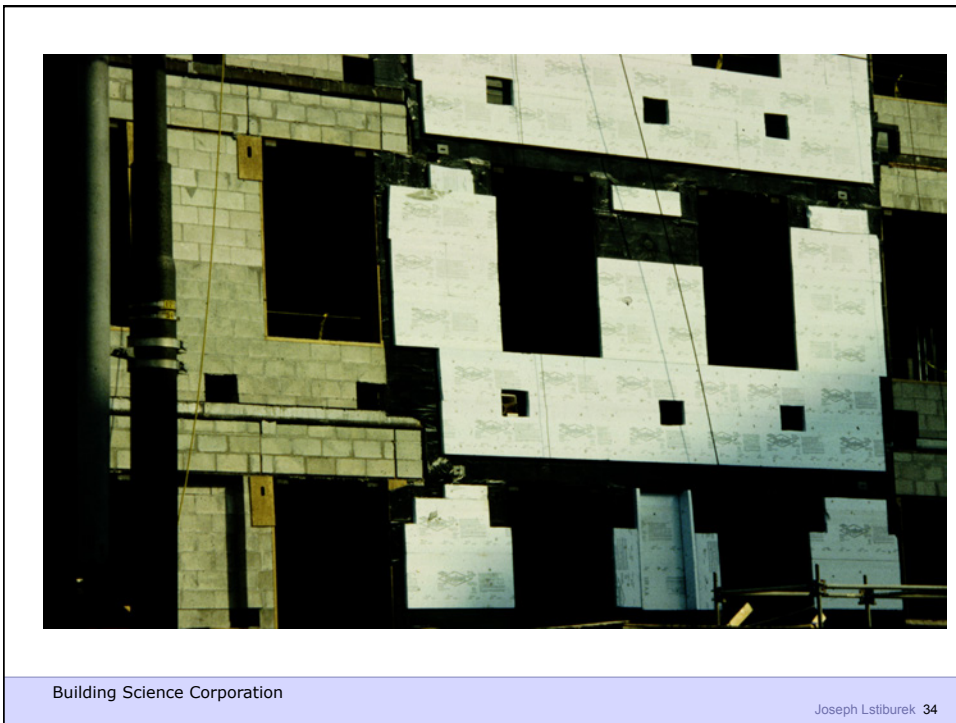
Joseph Lstiburek 26













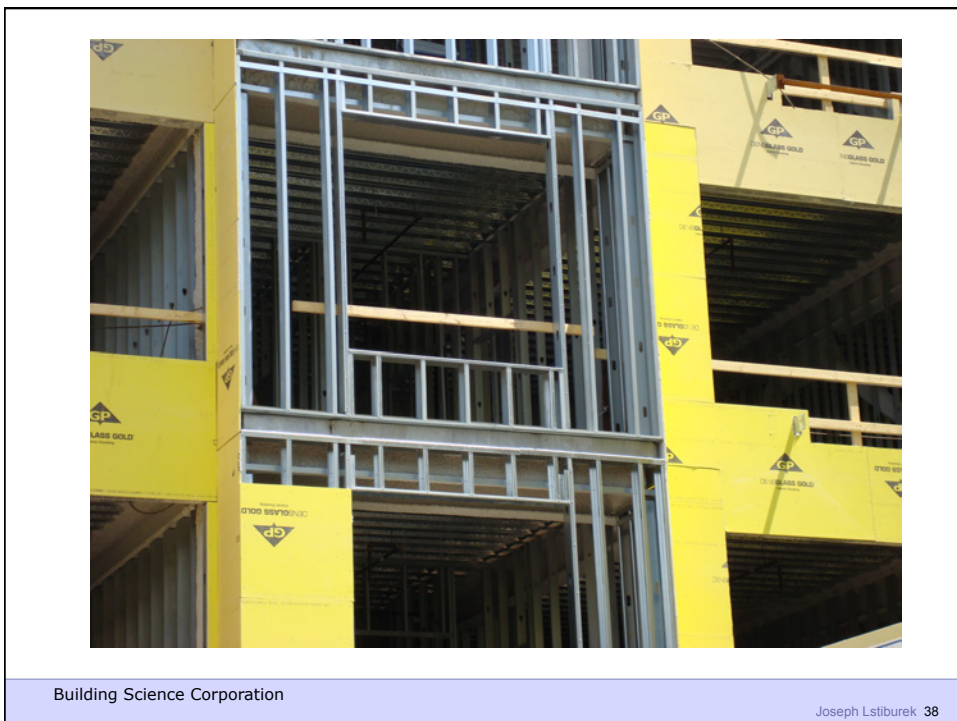
Building Science Corporation

Joseph Lstiburek 35

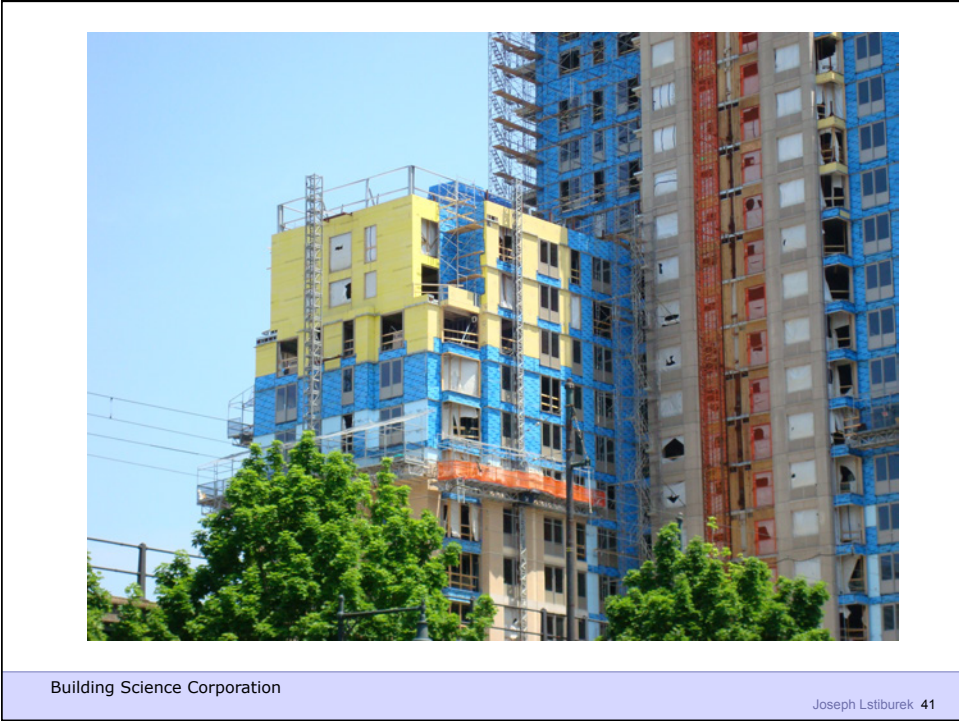


Building Science Corporation

Joseph Lstiburek 36











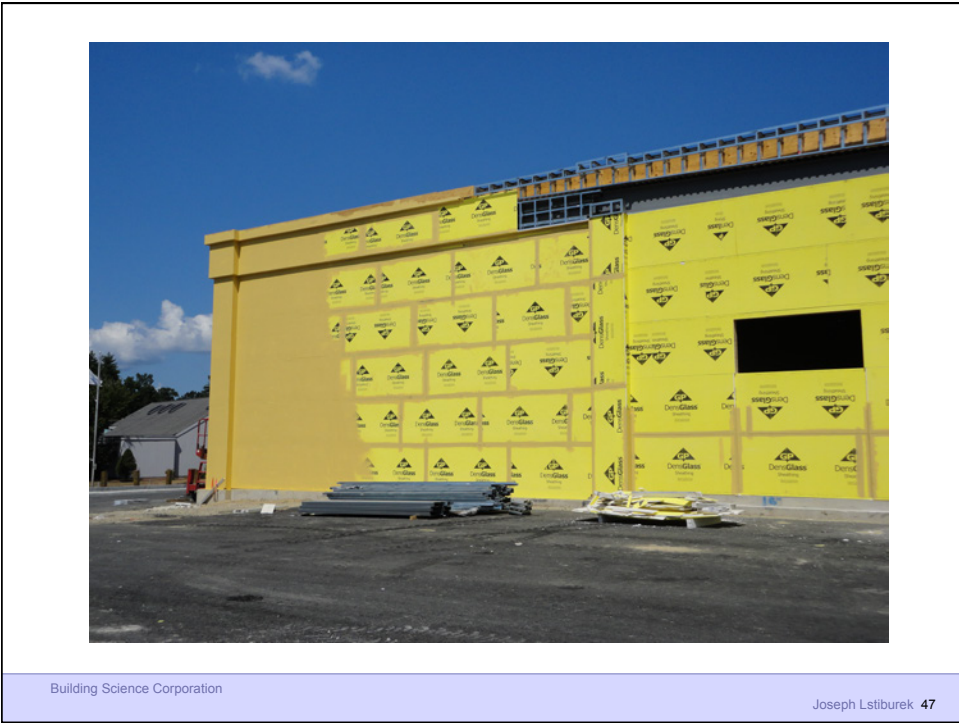
Building Science Corporation

Joseph Lstiburek 45



Building Science Corporation

Joseph Lstiburek 46







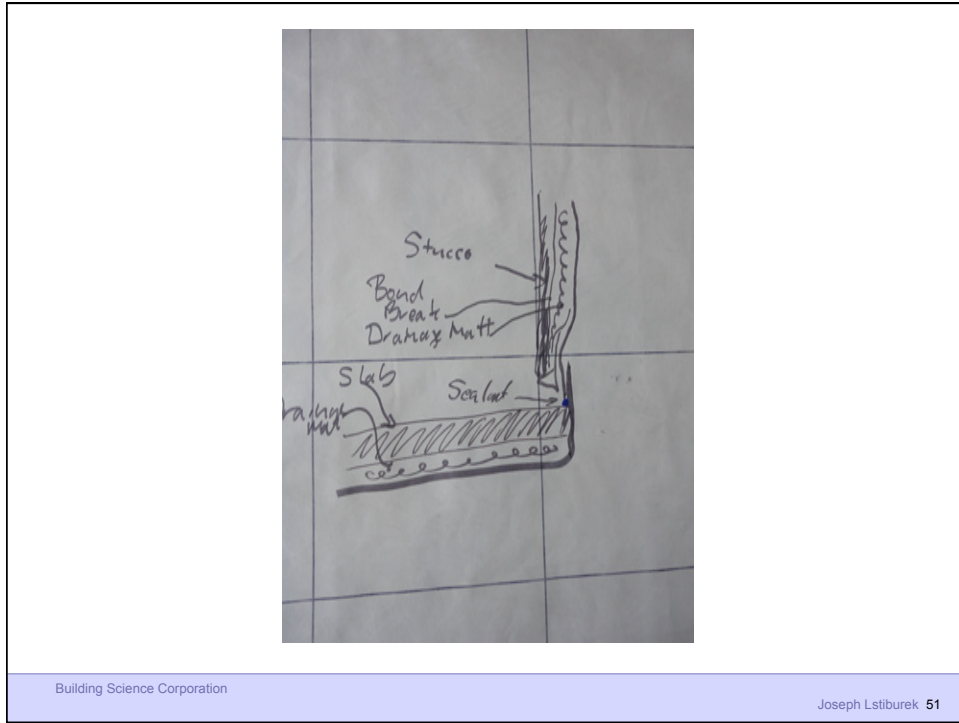
Building Science Corporation

Joseph Lstiburek 49



Building Science Corporation

Joseph Lstiburek 50





Building Science Corporation

Joseph Lstiburek 53



Building Science Corporation

Joseph Lstiburek 54





Building Science 2009

Joseph Lstiburek – HVAC 57



Building Science Corporation

Joseph Lstiburek 58



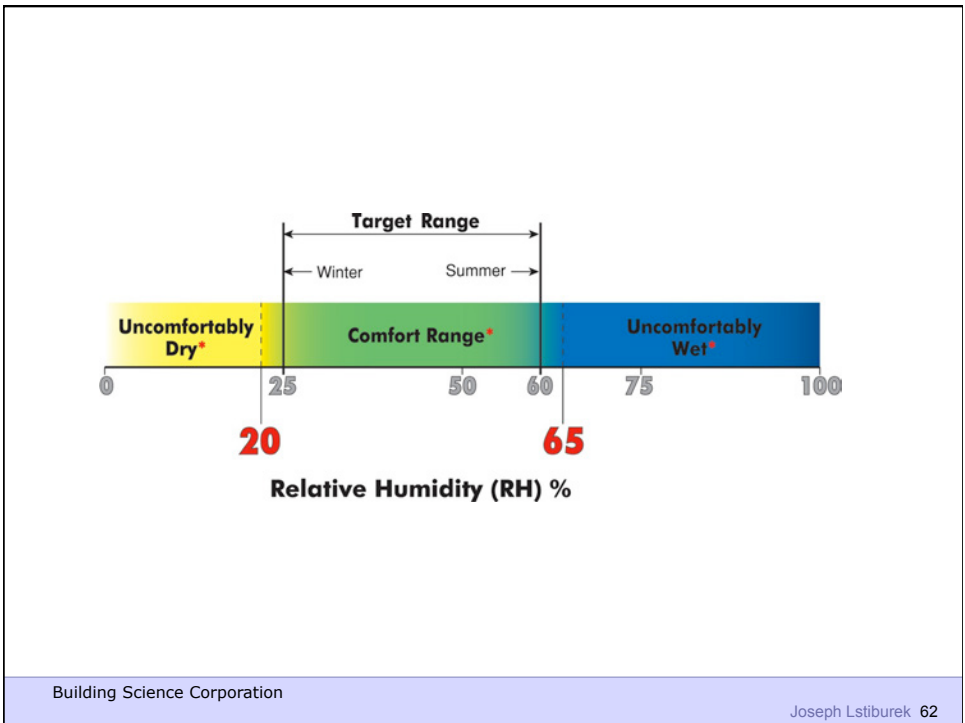
Building Science Corporation

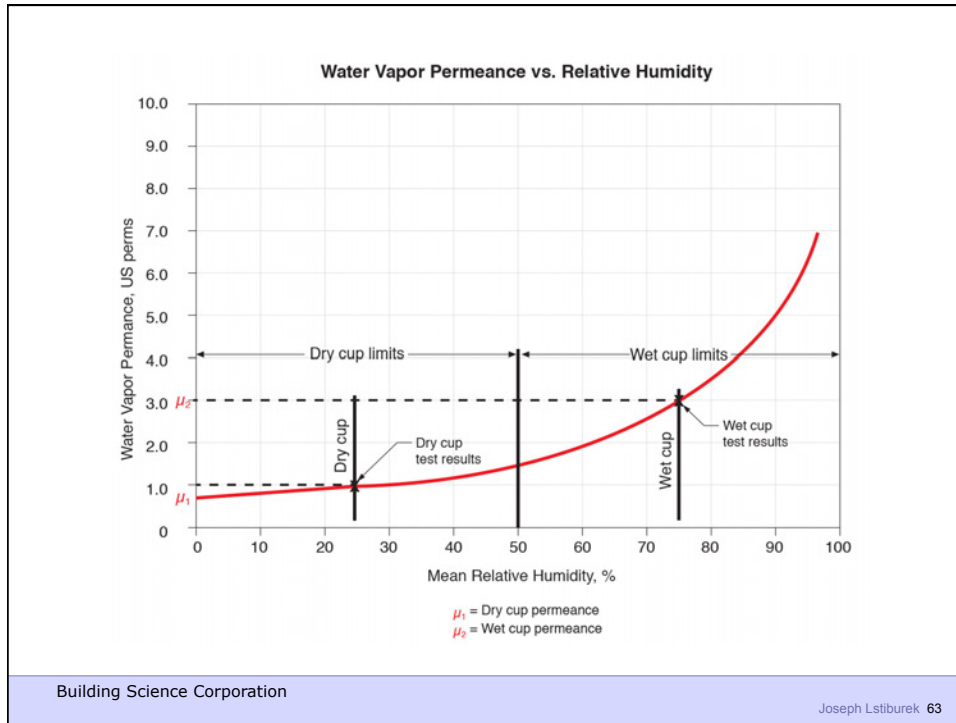
Joseph Lstiburek 59



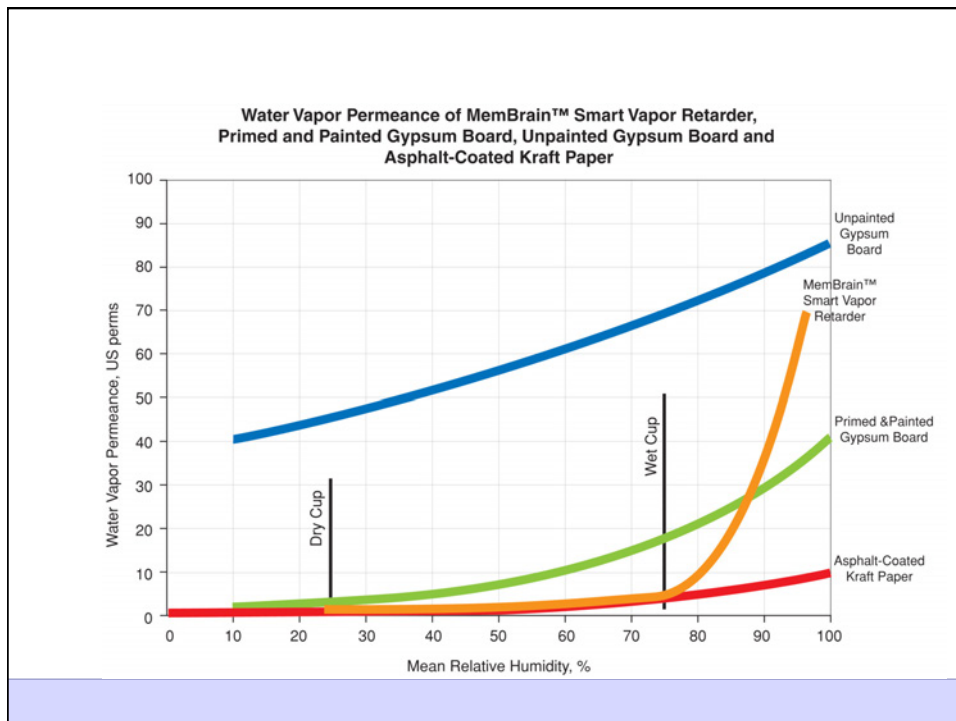
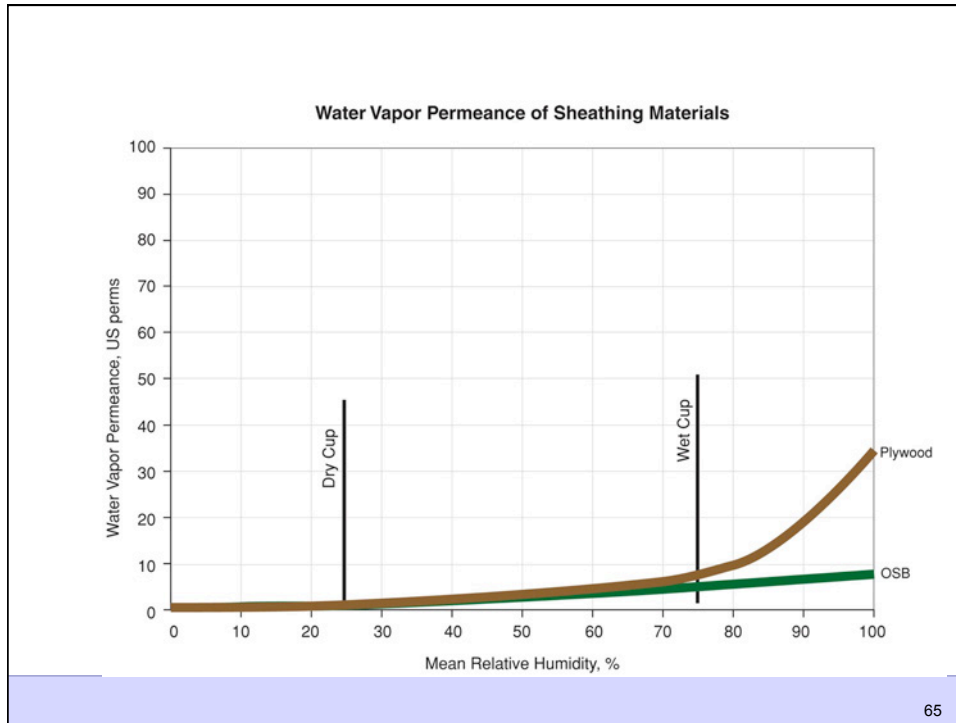
Building Science 2009

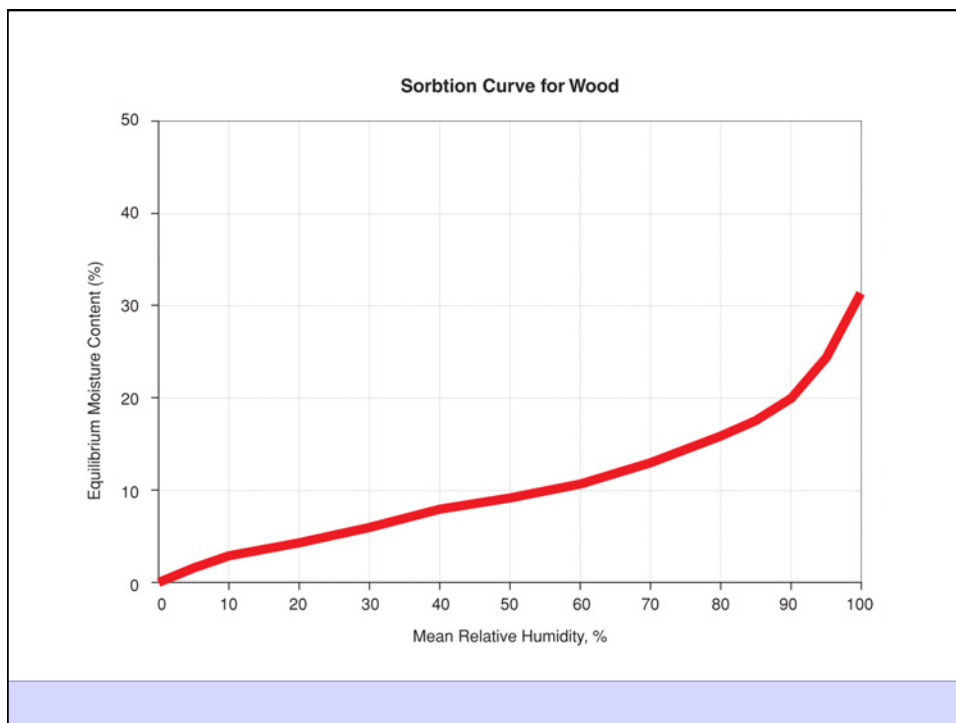
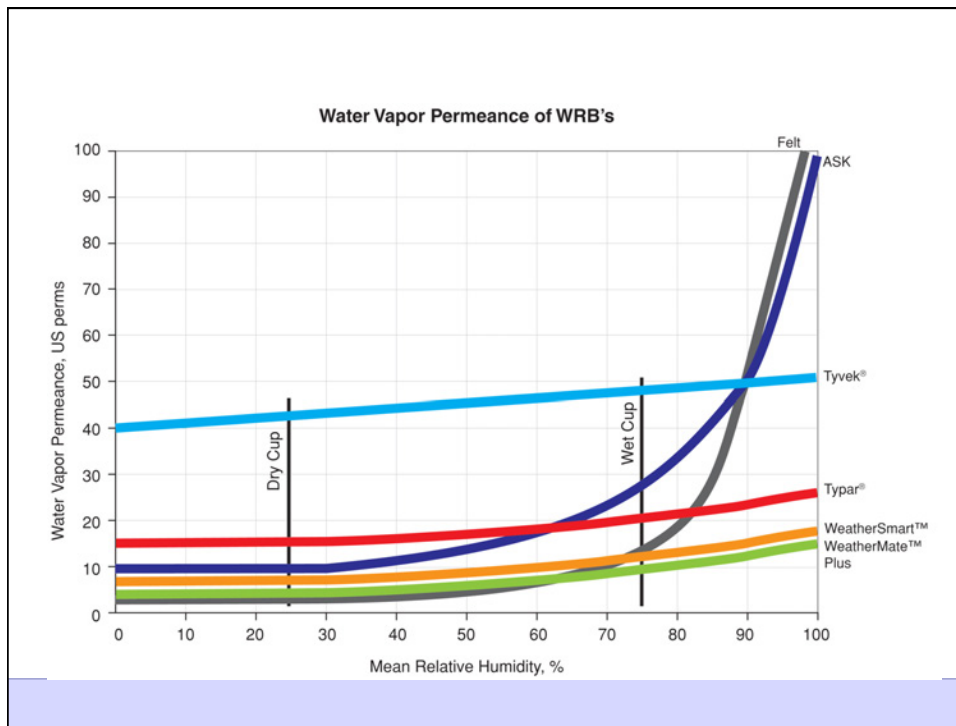
Joseph Lstiburek – HVAC 60

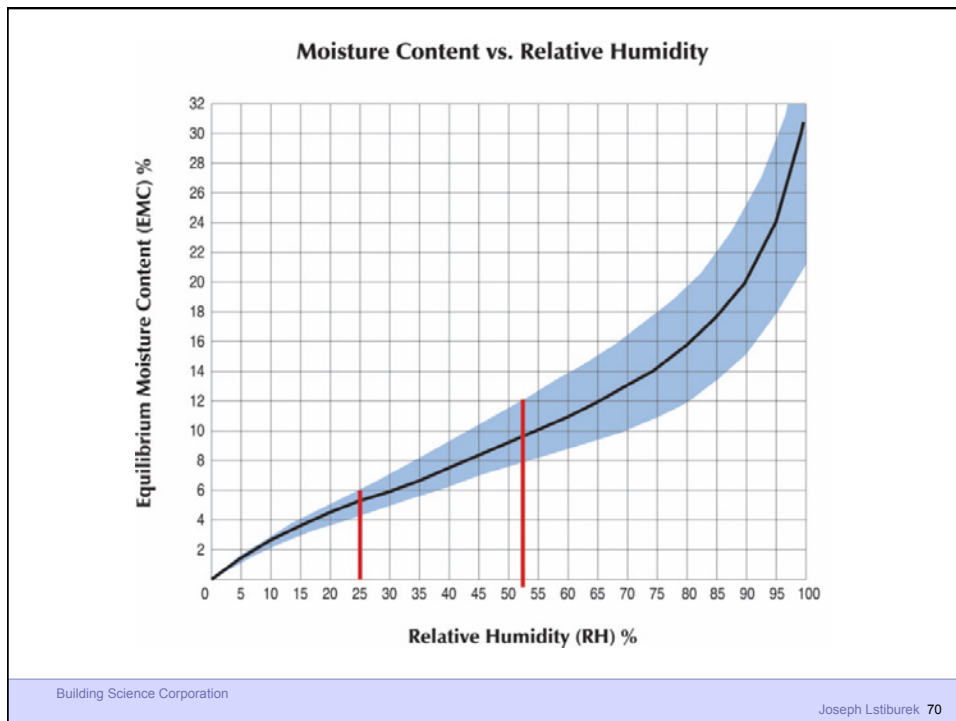
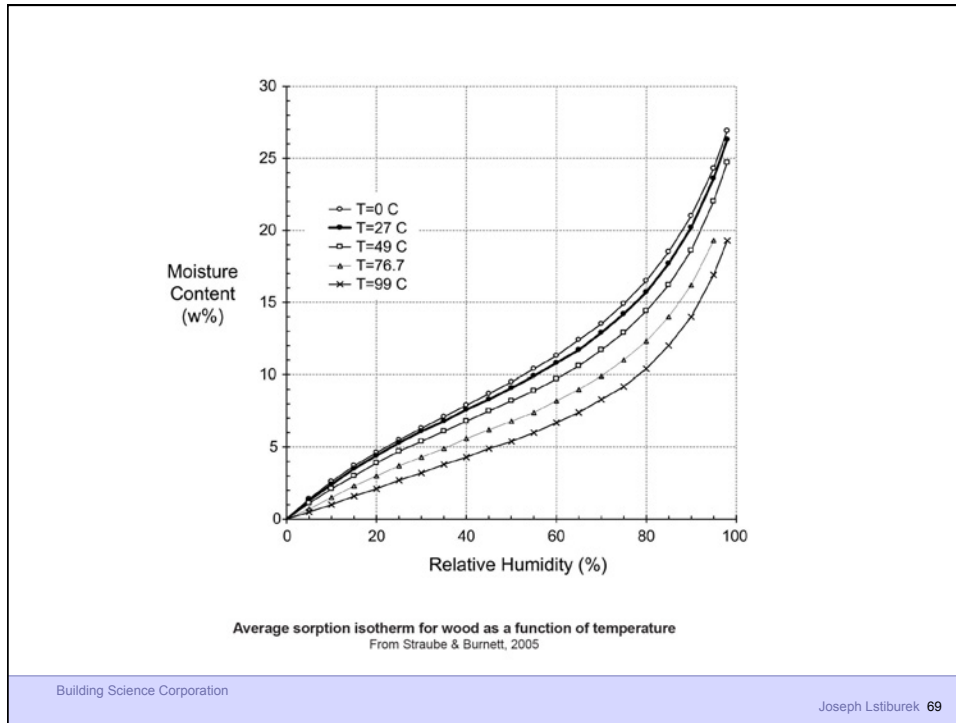


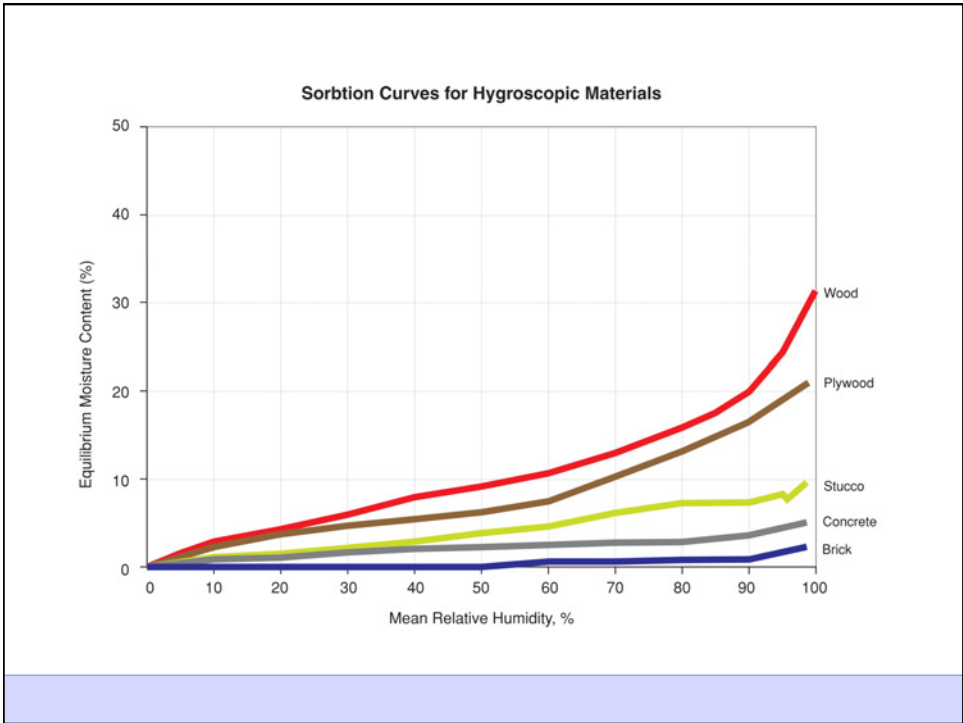














Building Science Corporation

Joseph Lstiburek 73



Building Science Corporation

Joseph Lstiburek 74



Building Science Corporation

Joseph Lstiburek 75



Building Science Corporation

Joseph Lstiburek 76



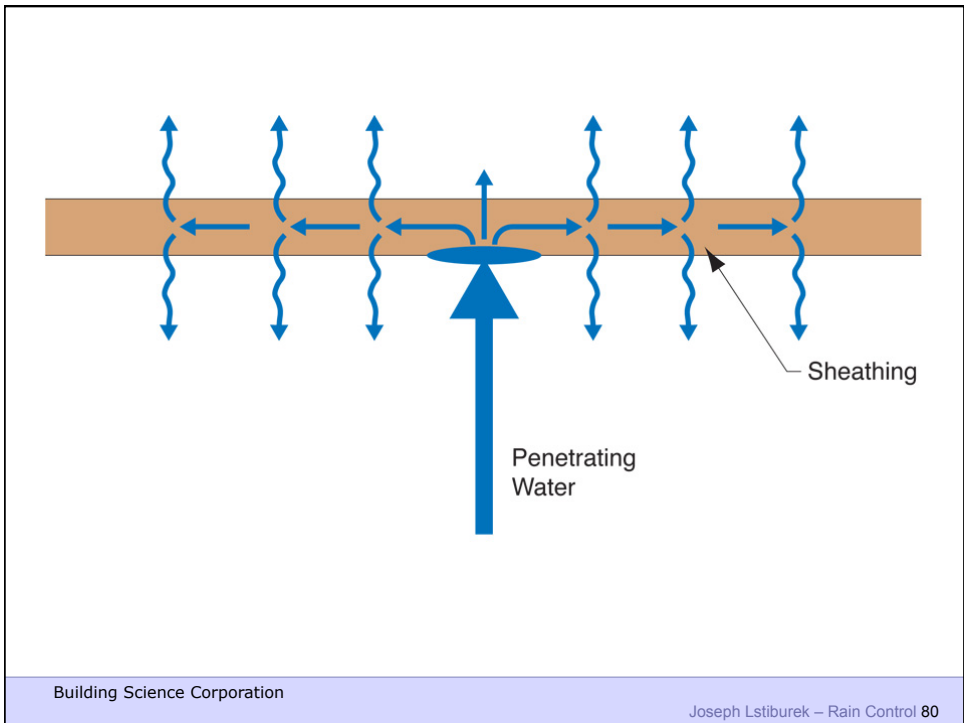
Building Science Corporation

Joseph Lstiburek 77

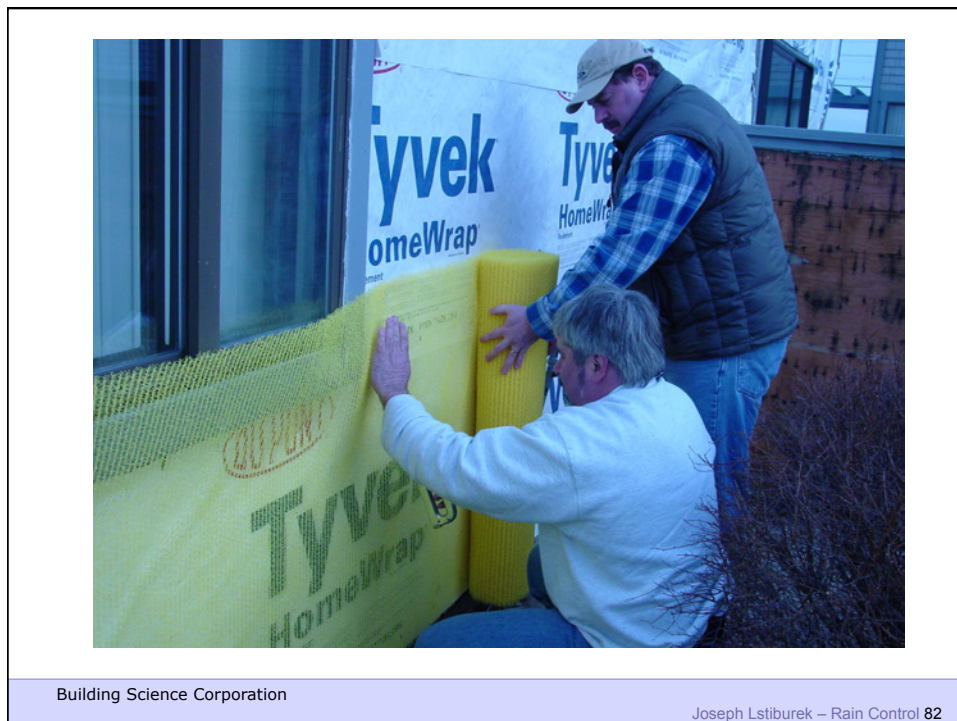
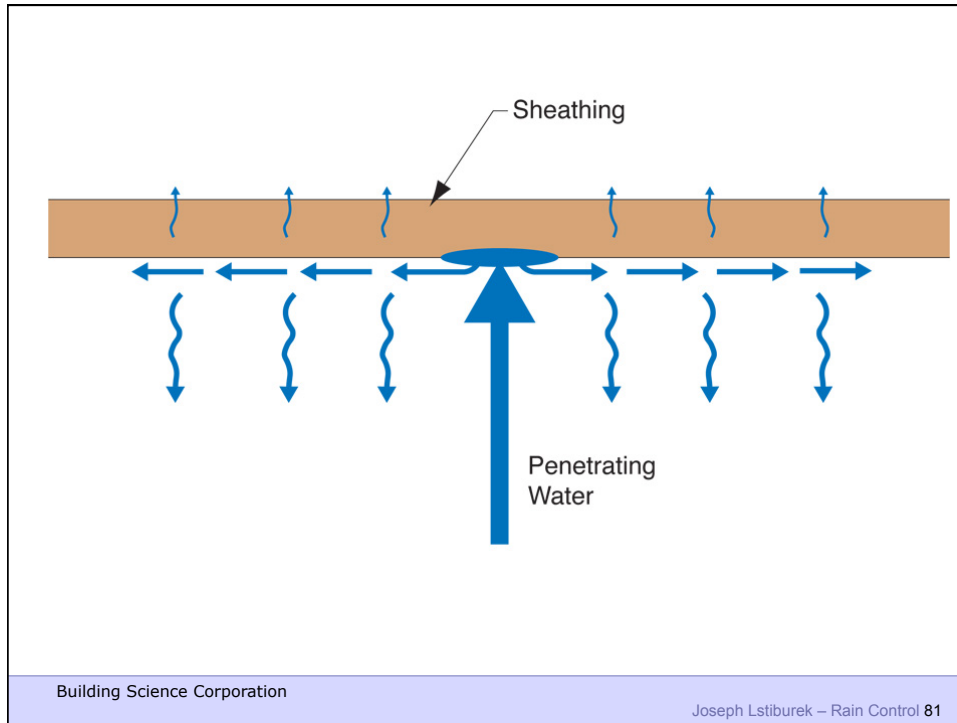


Building Science Corporation

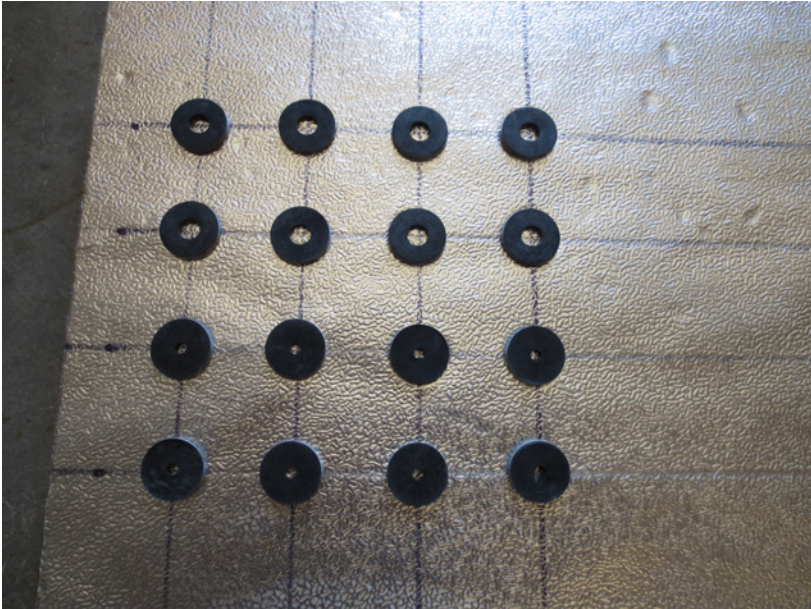
Joseph Lstiburek 78







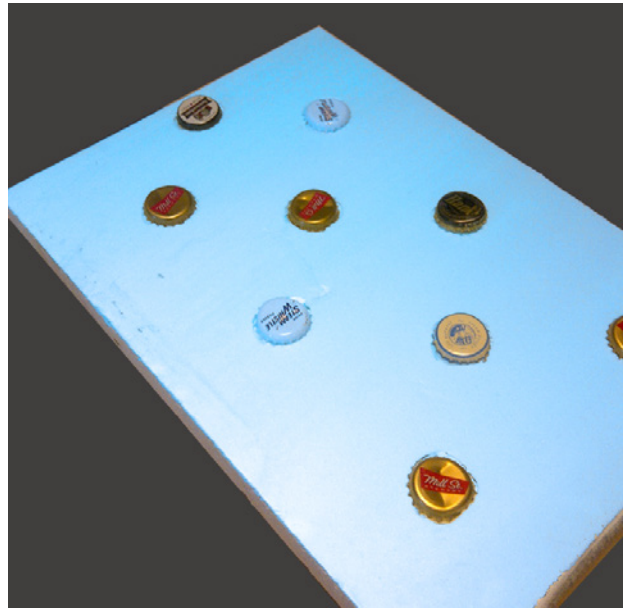
# Rain Screen



## Beer Screen?

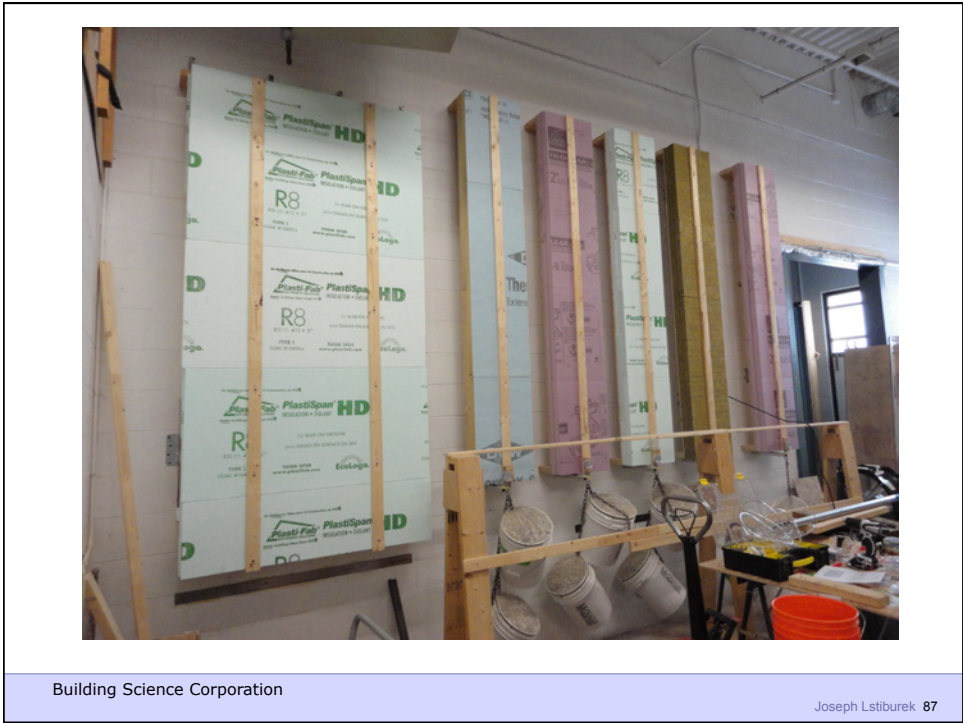
Building Science Corporation

Joseph Lstiburek 85



Building Science Corporation

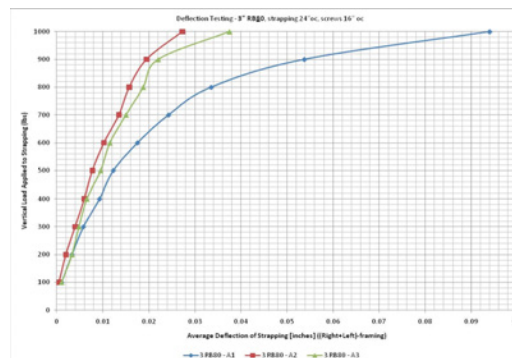
Joseph Lstiburek 86





## Rockwool

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



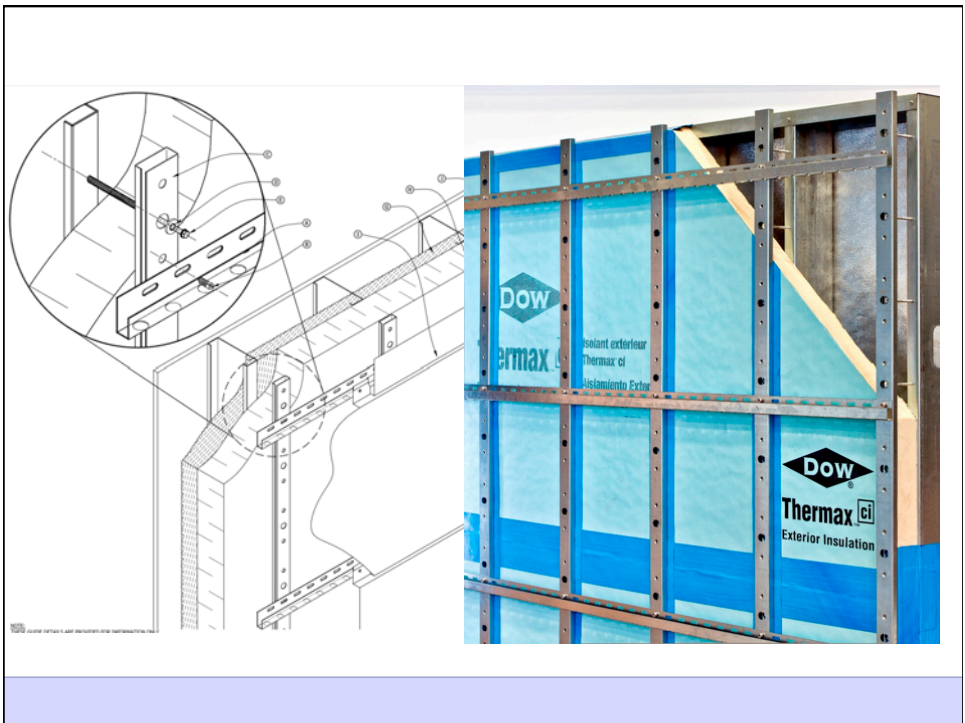
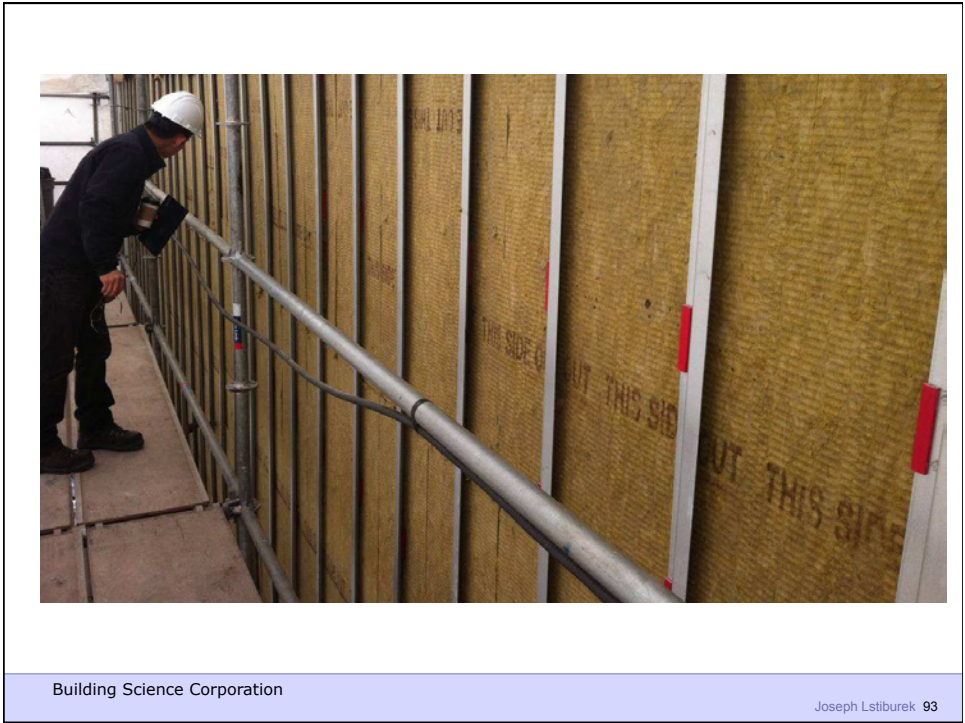


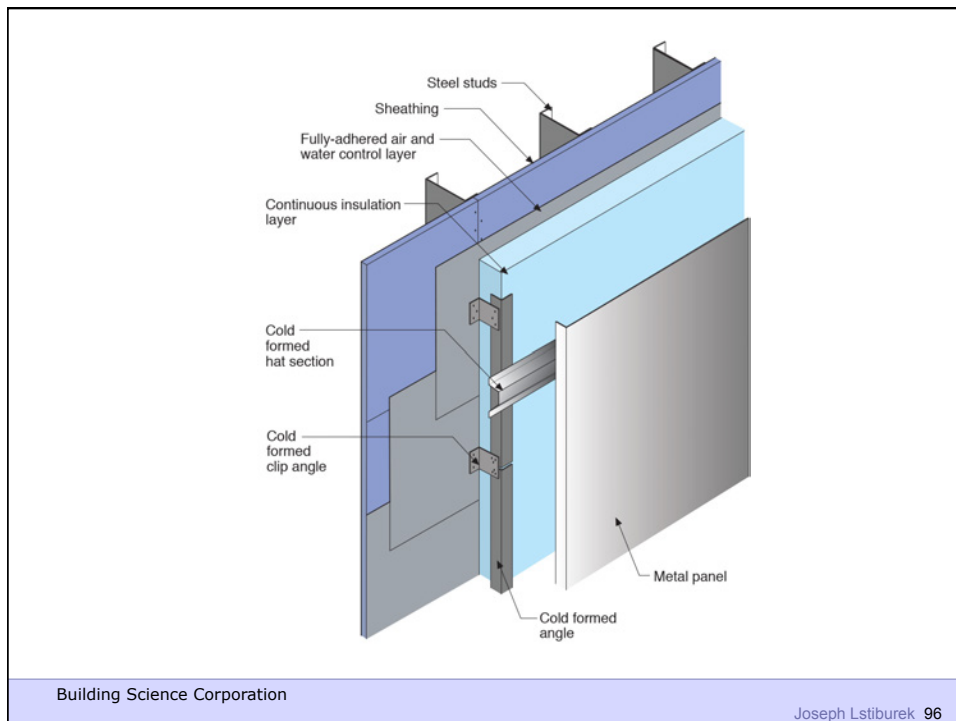
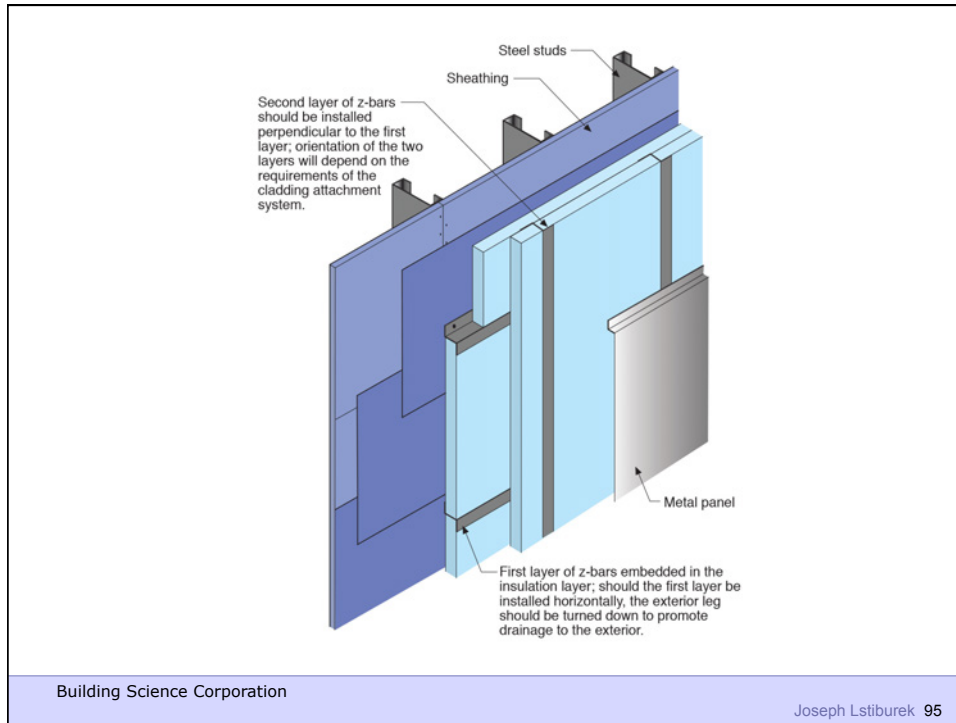
Building Science Corporation

Joseph Lstiburek 91



92







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

# Building Science

Adventures In Building Science

[www.buildingscience.com](http://www.buildingscience.com)

## Order of Magnitude

## Order of Magnitude

1 to 10

10 to 100

100 to 1000

1000 to 10000

First Order Effects, Second Order Effects....

## Laws of Thermodynamics

Zeroth Law – Equal Systems  
First Law - Conservation of Energy  
Second Law - Entropy  
Third Law – Absolute Zero

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

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

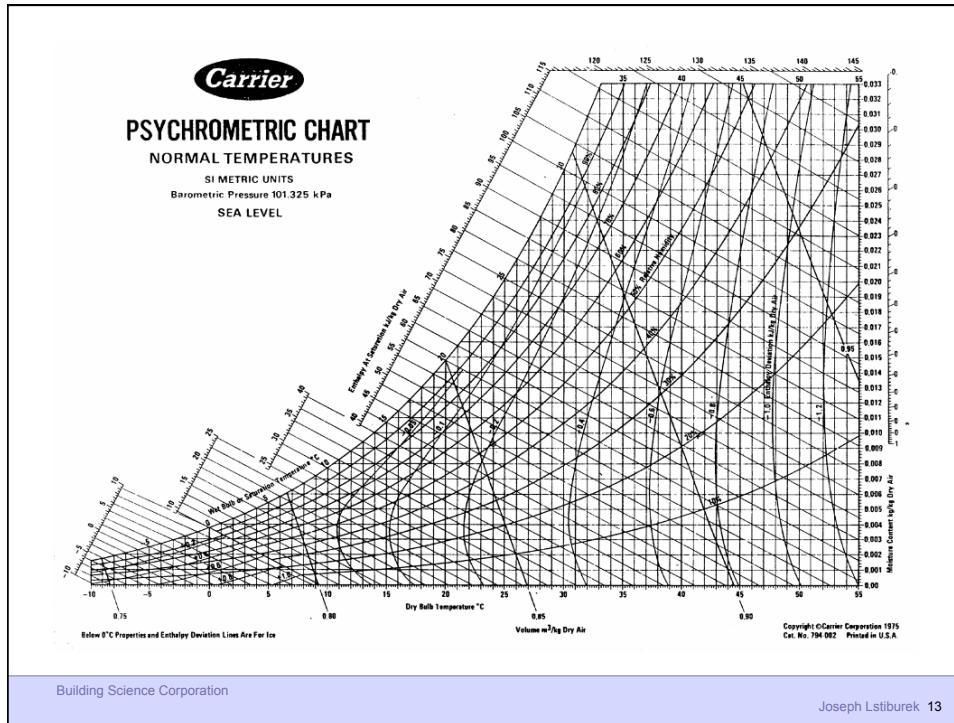
Thermal Gradient – Thermal Diffusion  
Concentration Gradient – Molecular Diffusion

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



Damage Functions

Building Science Corporation

Joseph Lstiburek 14

Damage Functions  
Water  
Heat  
Ultra Violet Radiation

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



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

Building Science Corporation

Joseph Lstiburek 17

## 80 Percent of all Construction Problems are Related to Water

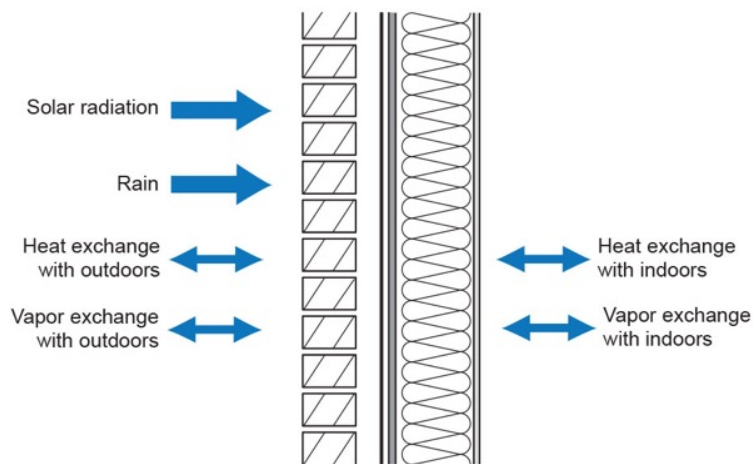
Building Science Corporation

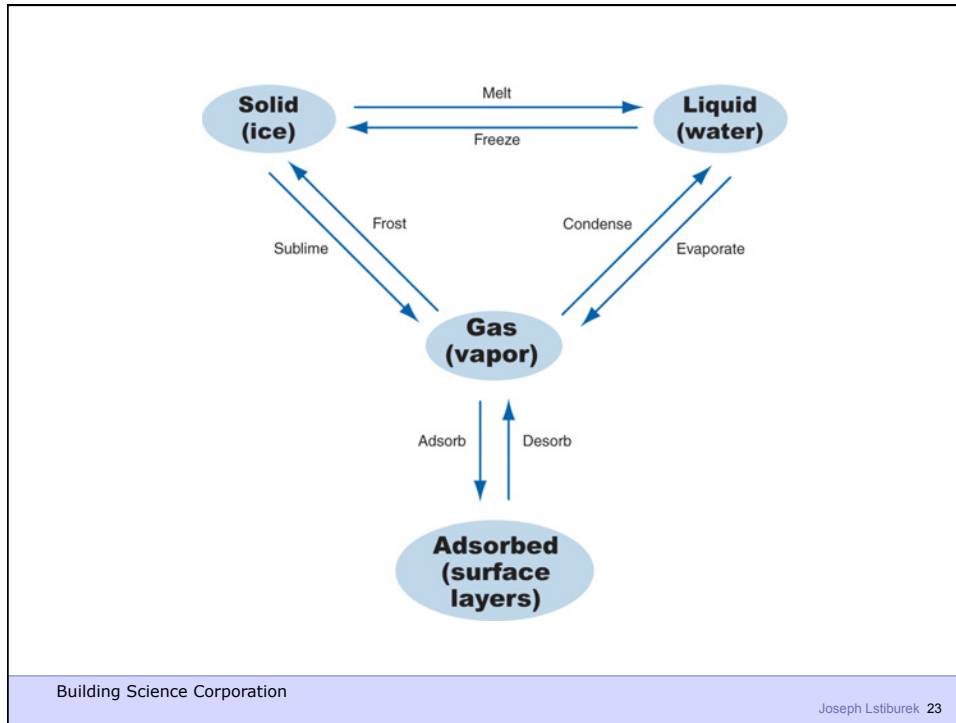
Joseph Lstiburek 18

Heat  
Air  
Moisture

HAM

# Hygrothermal Analysis





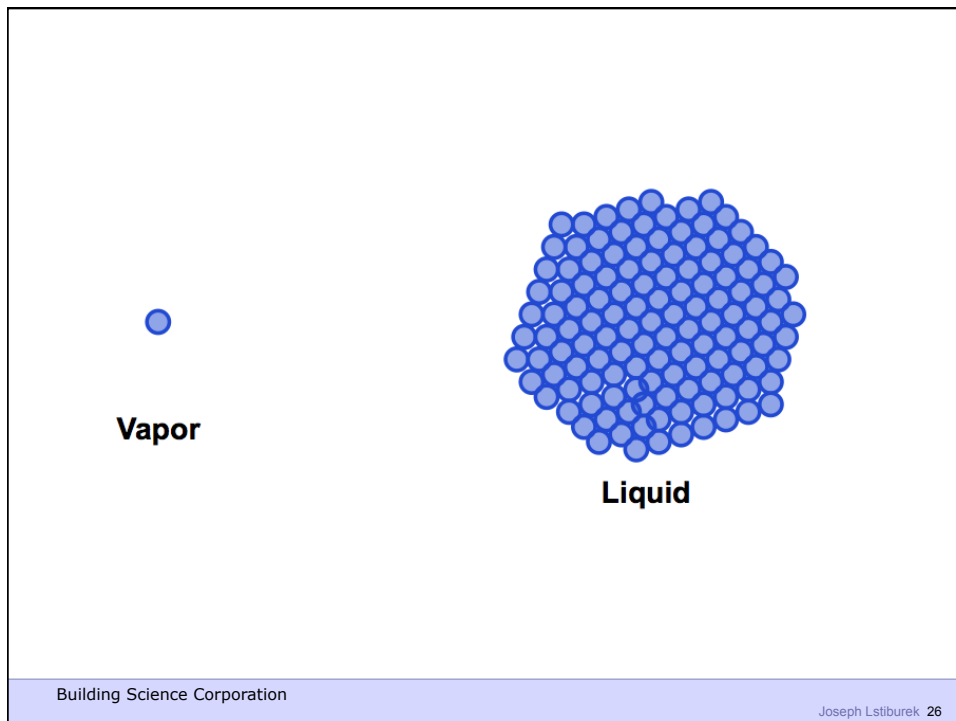
**Moisture Transport in Porous Media**

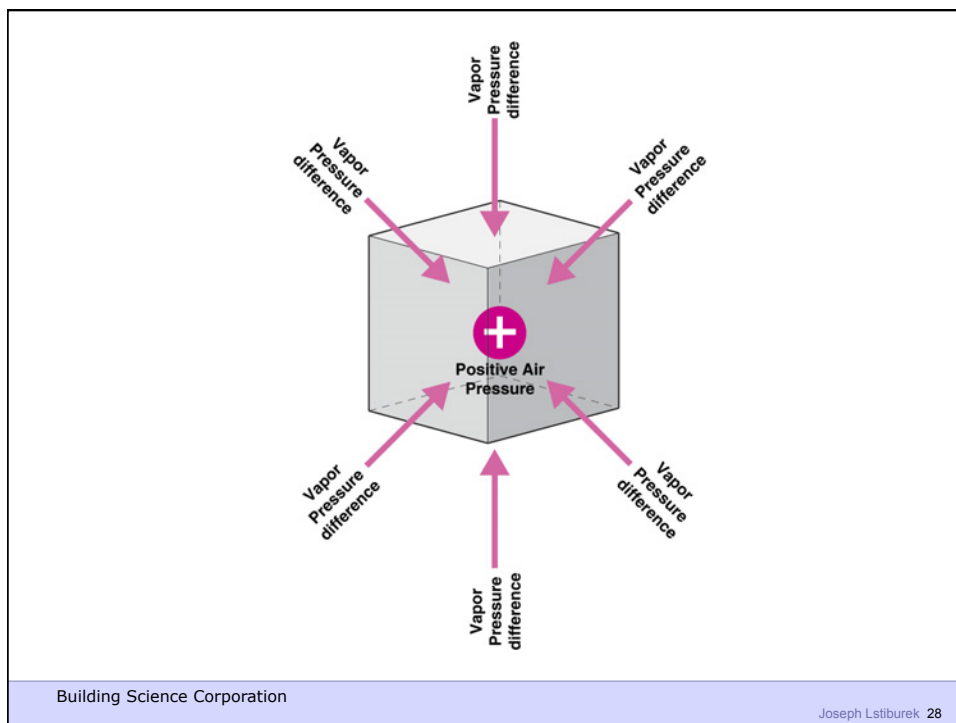
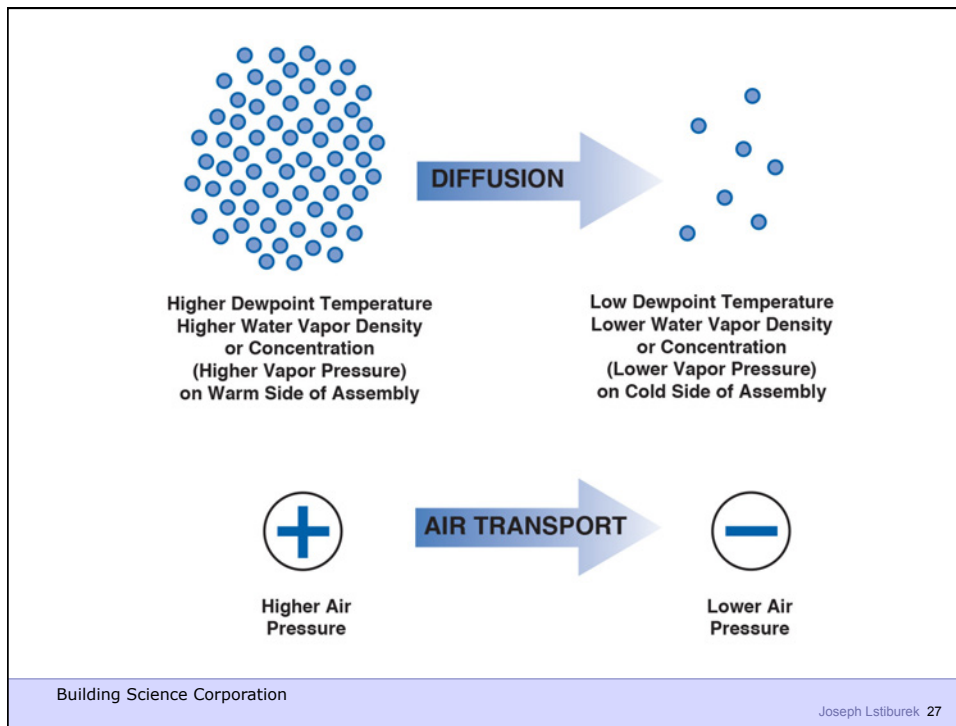
Phase	Transport Process	Driving Potential
Vapor	Diffusion	Vapor Concentration
Adsorbate	Surface Diffusion	Concentration
Liquid	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration

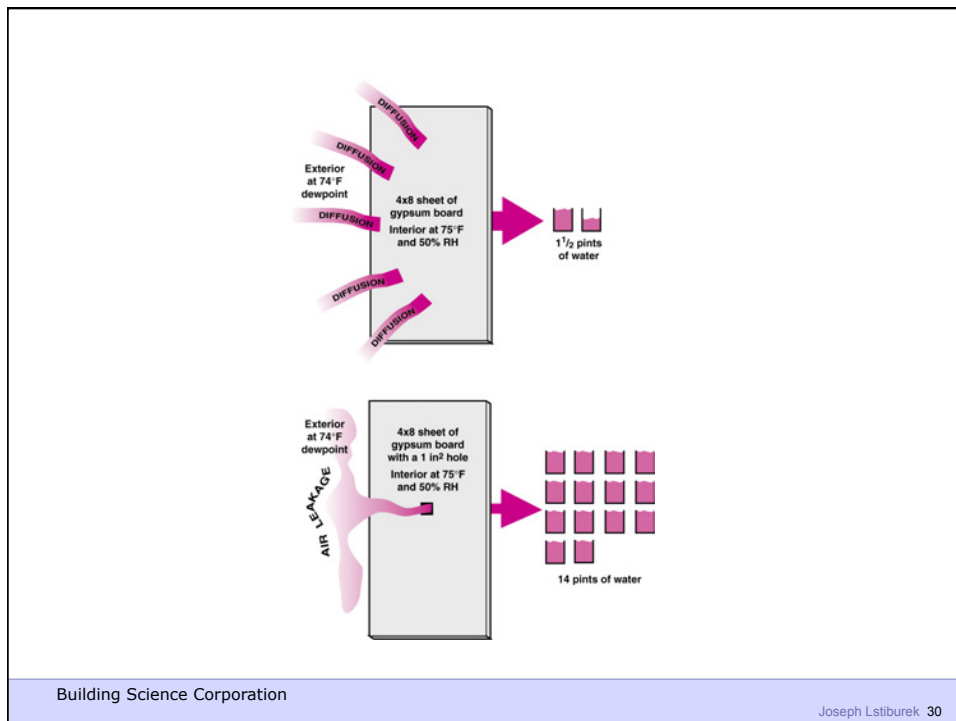
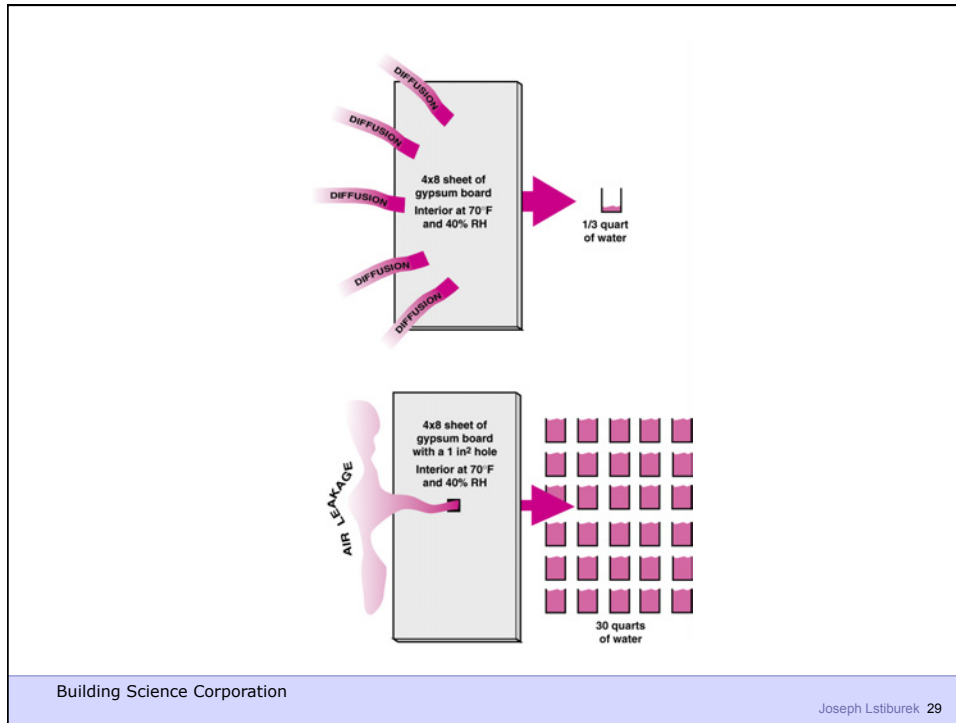
Building Science Corporation Joseph Lstiburek 24

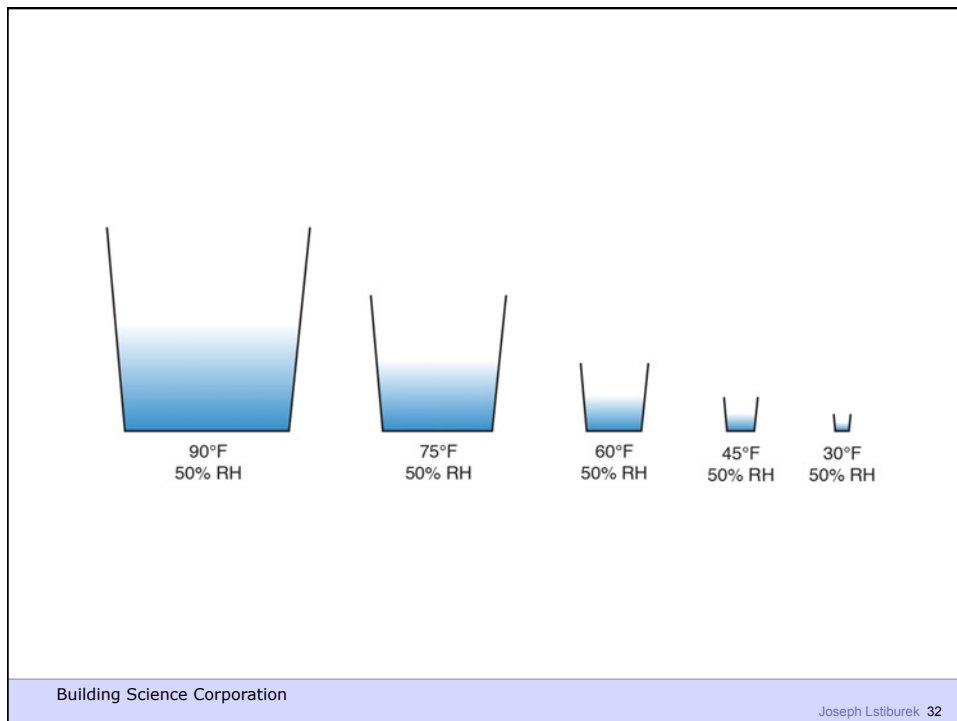
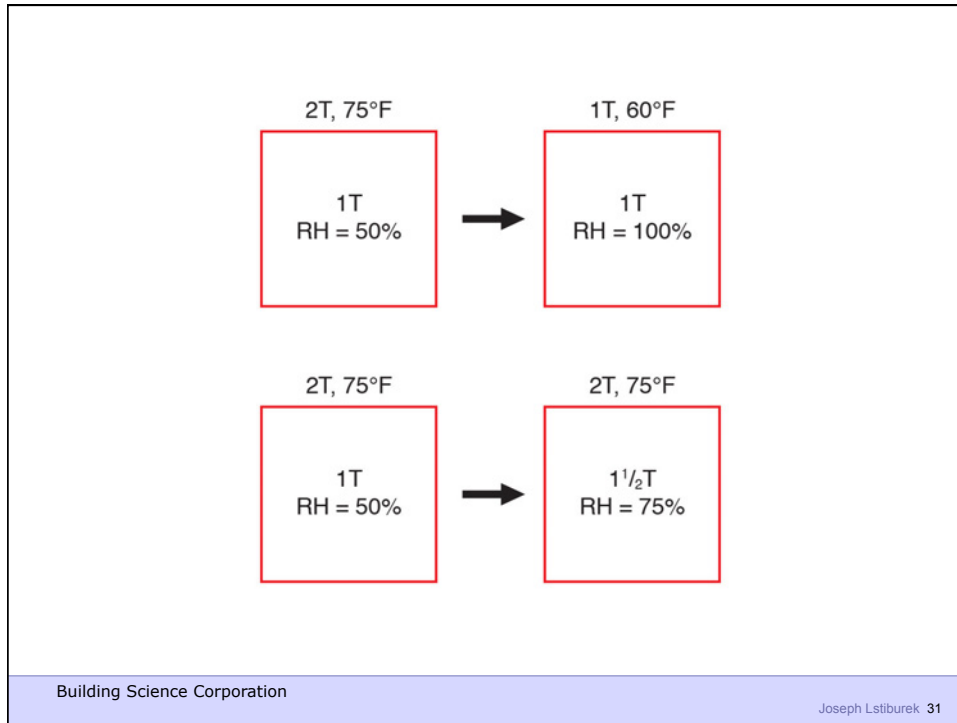
Moisture Transport in Assemblies		
Phase	Transport Process	Driving Potential
<b>Vapor</b>	Diffusion	Vapor Concentration
	Convective Flow	Air Pressure
<b>Adsorbate</b>	Surface Diffusion	Concentration
<b>Liquid</b>	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration
	Gravitational Flow	Height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

Building Science Corporation Joseph Lstiburek 25

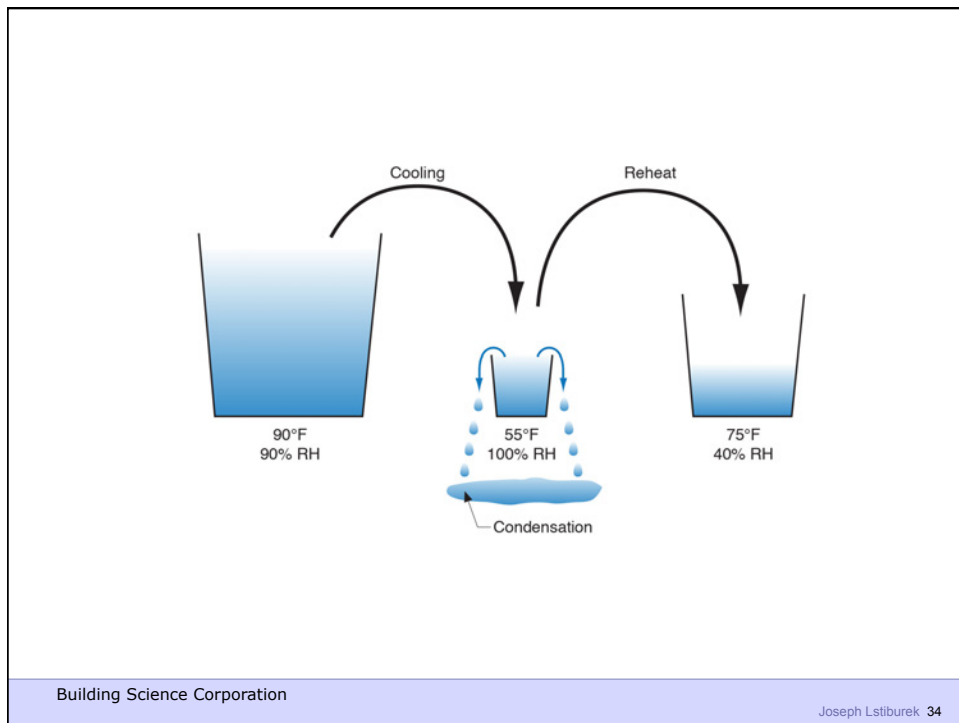
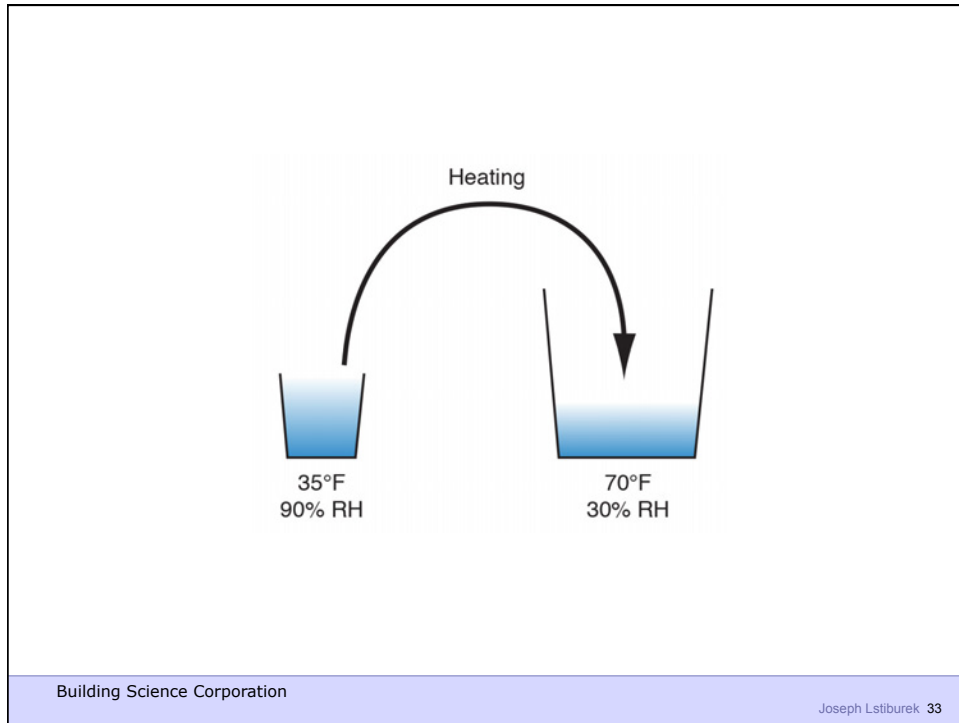


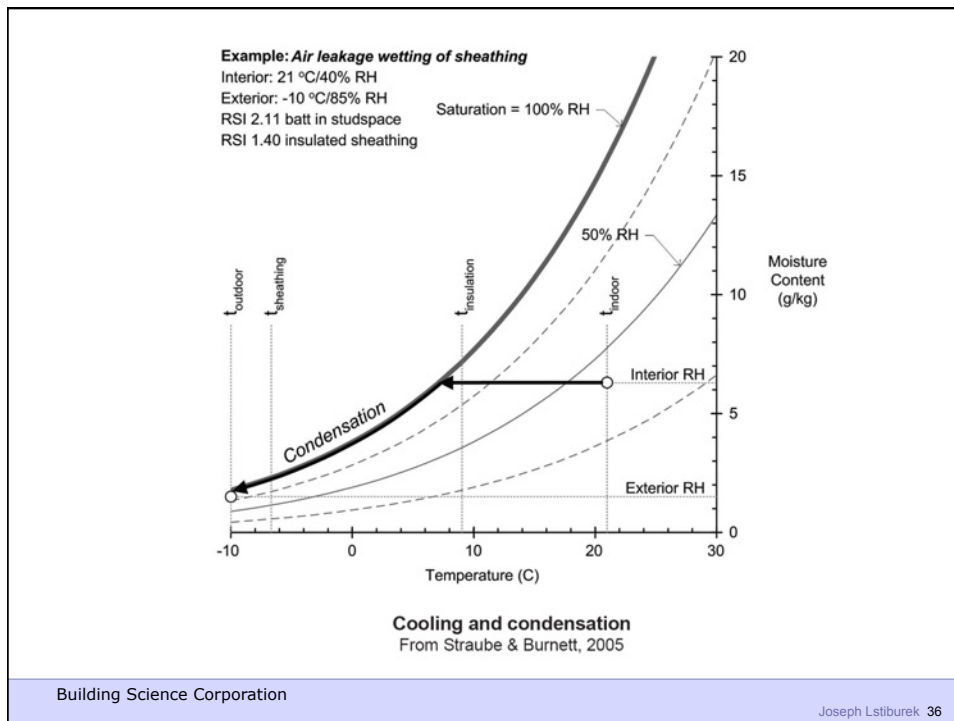
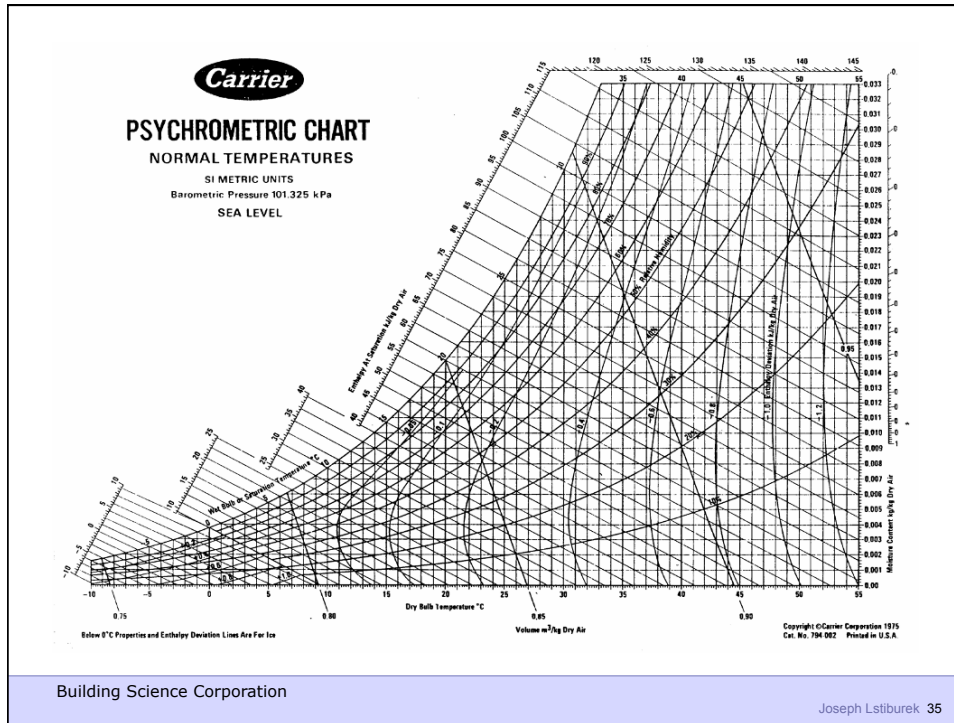


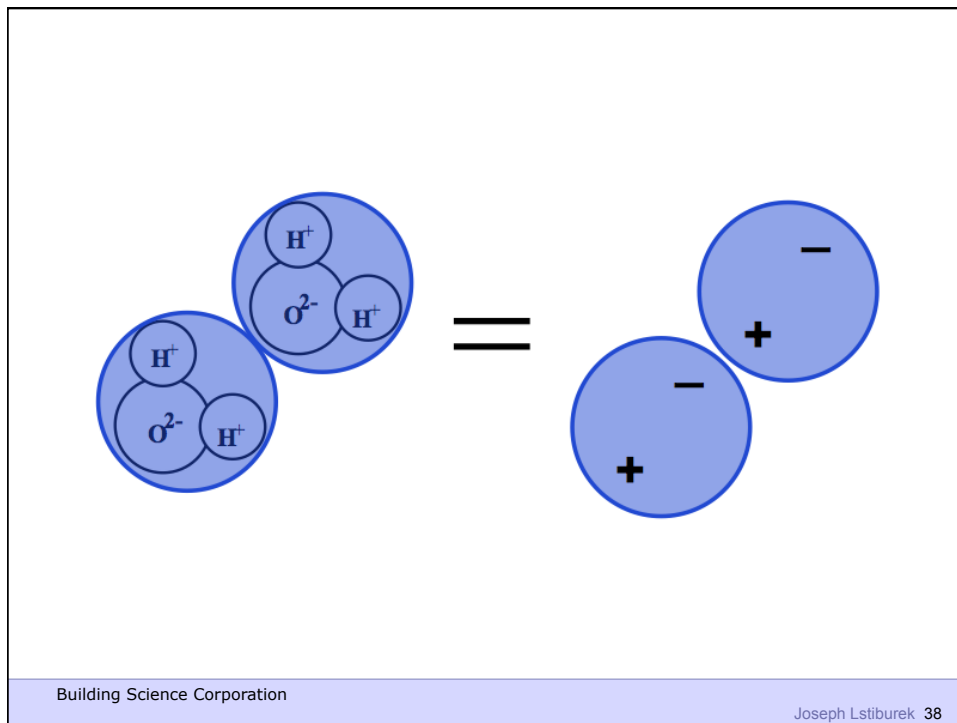
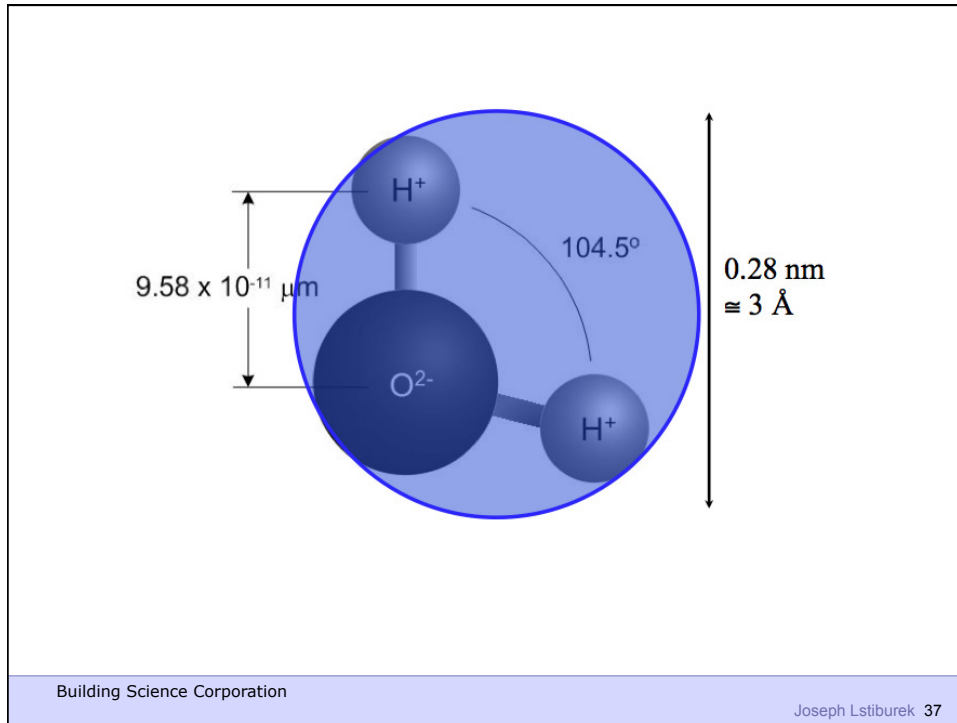


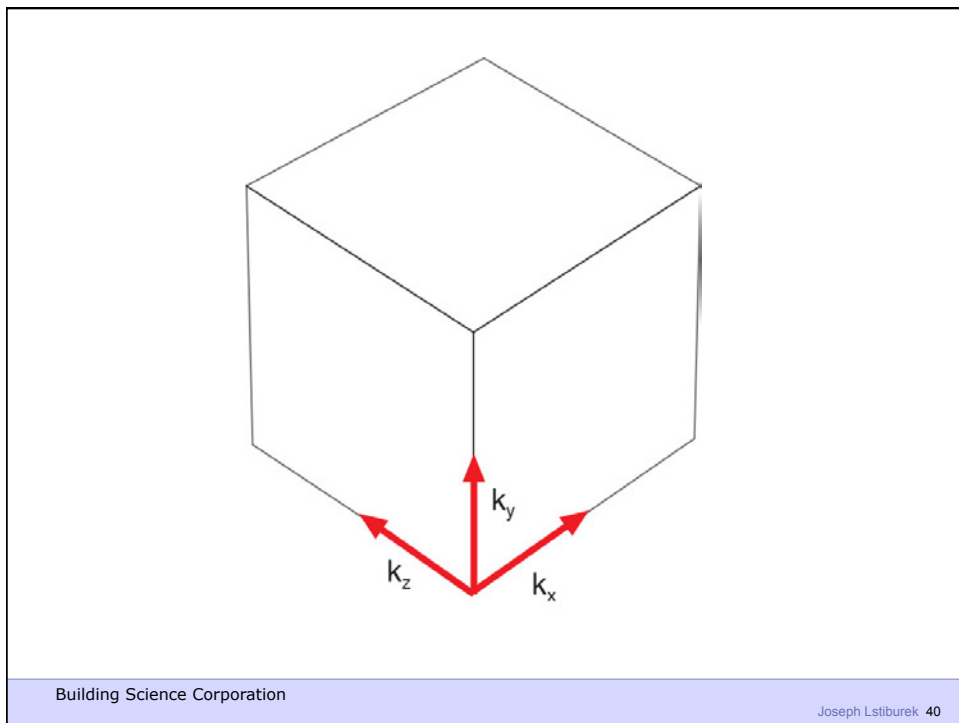
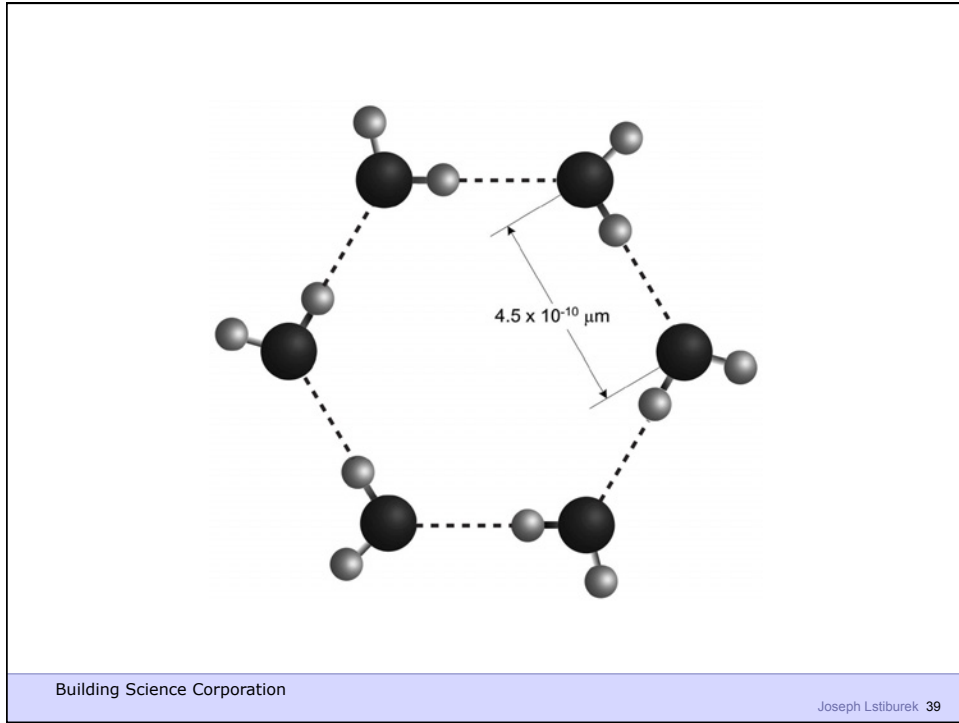


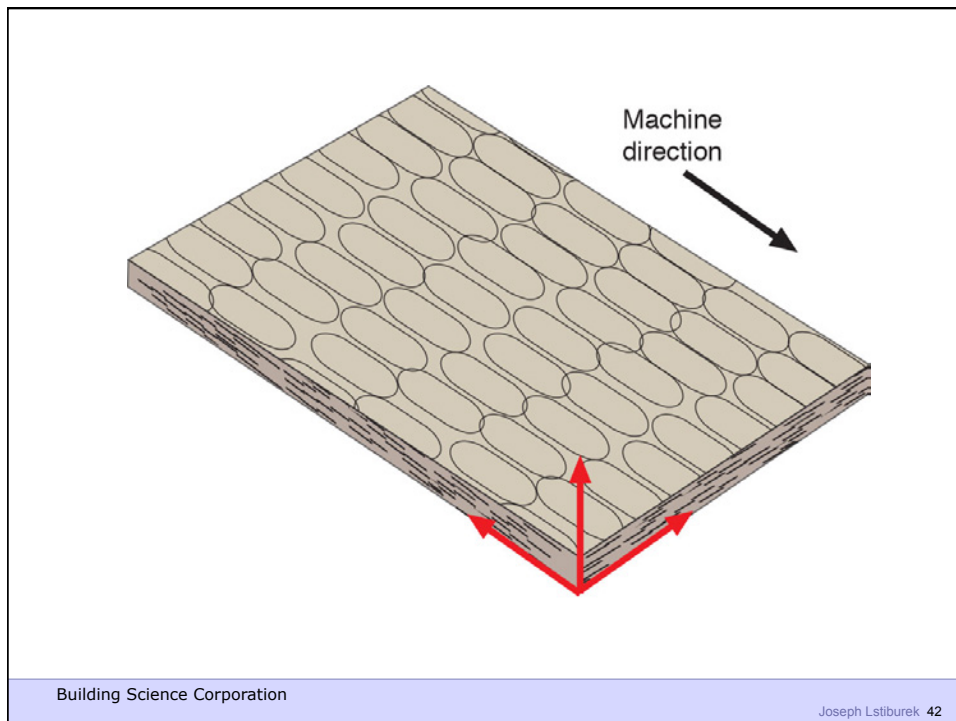
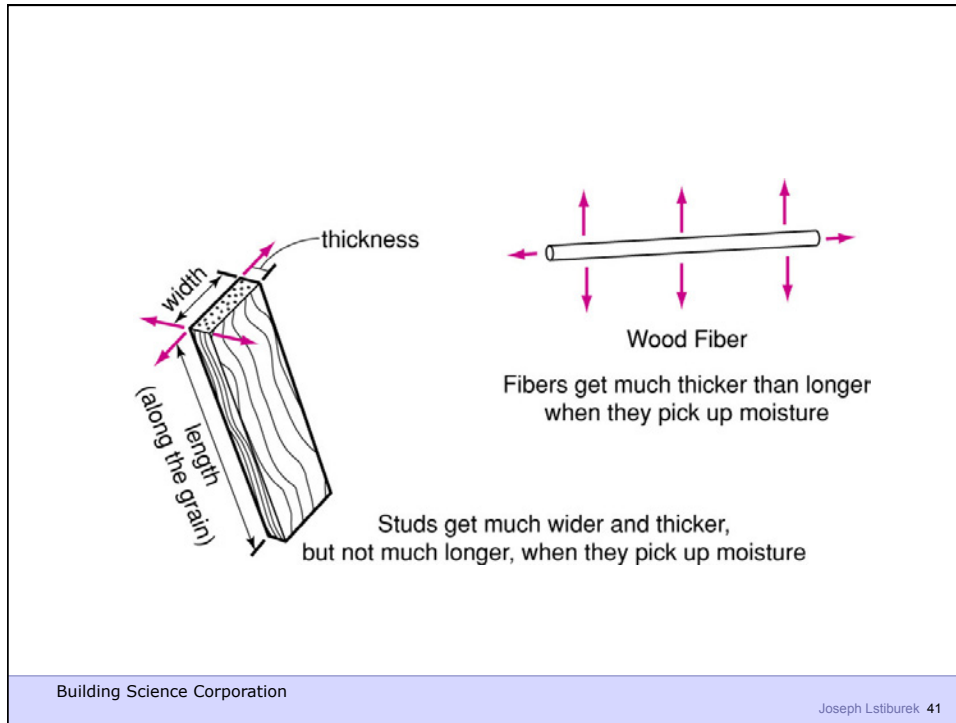














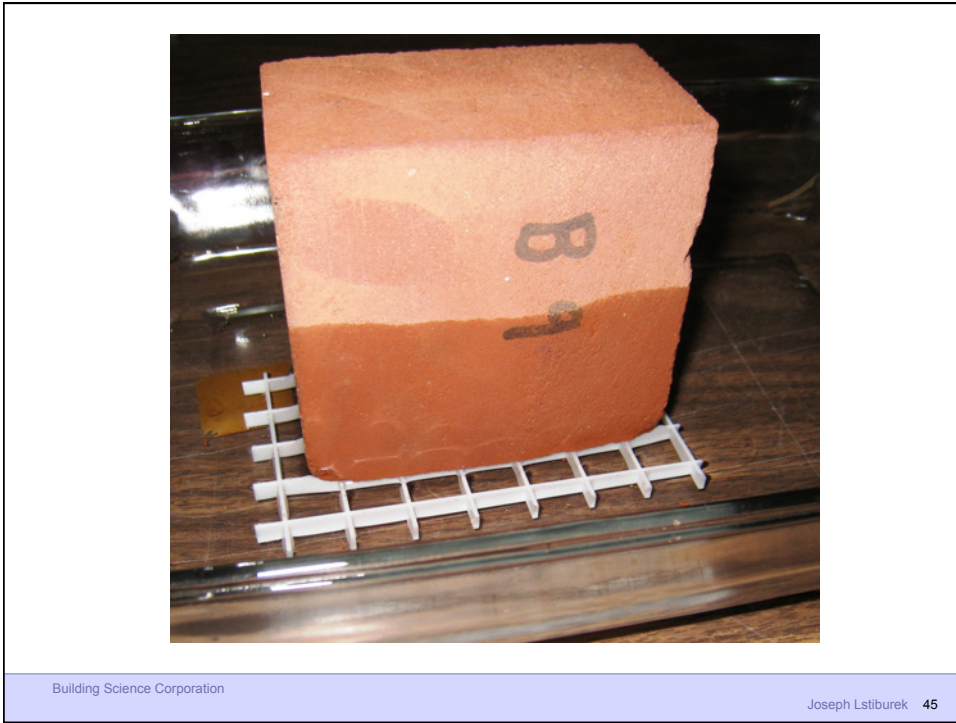
Building Science Corporation

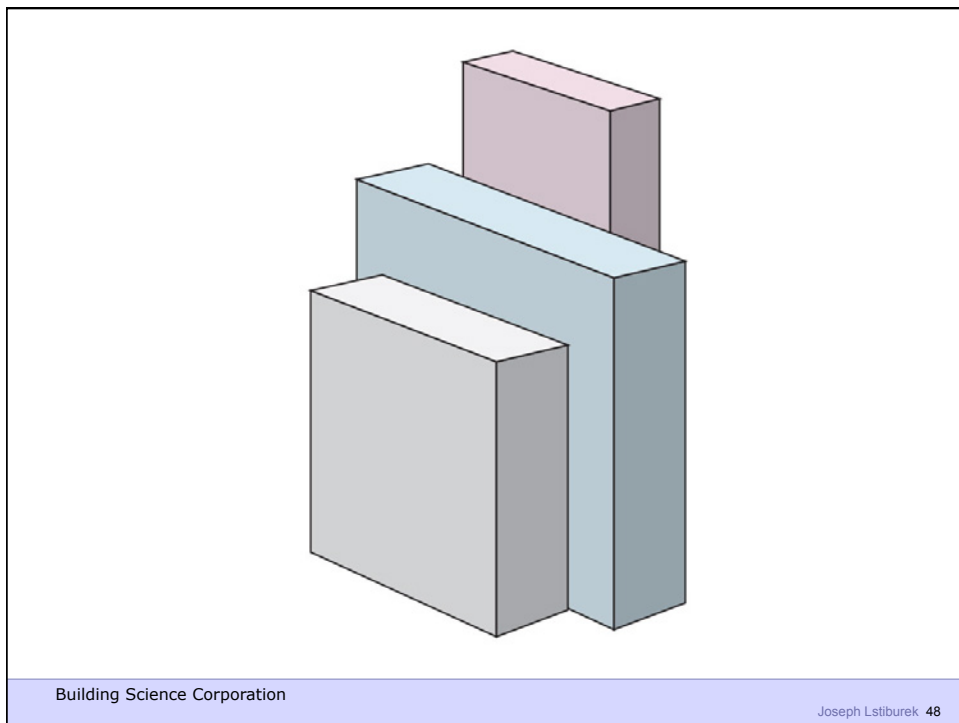
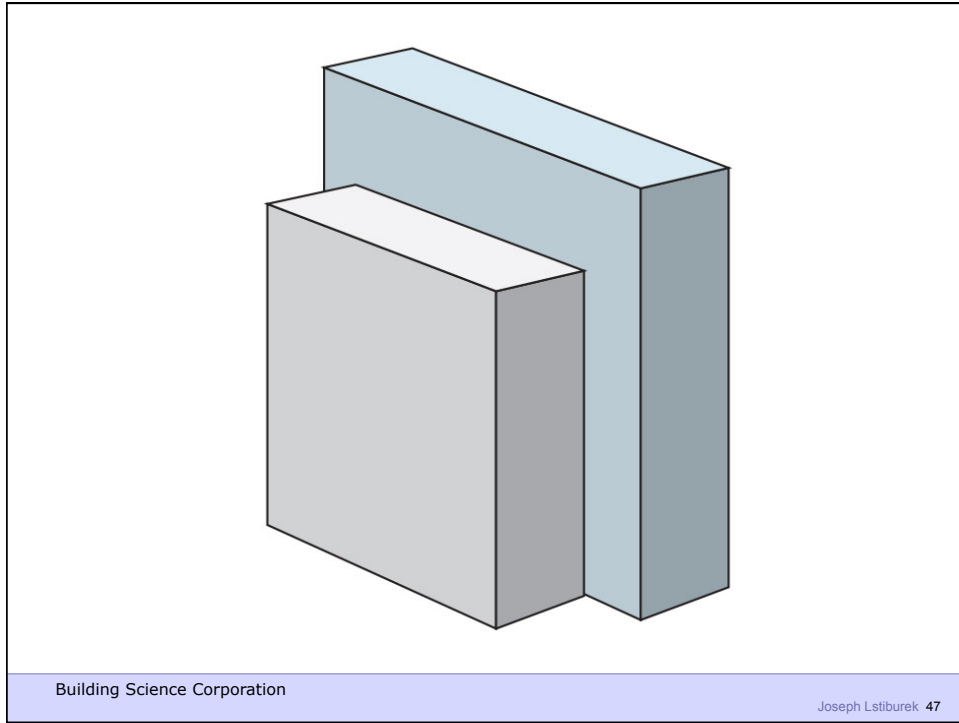
Joseph Lstiburek 43



Building Science Corporation

Joseph Lstiburek 44



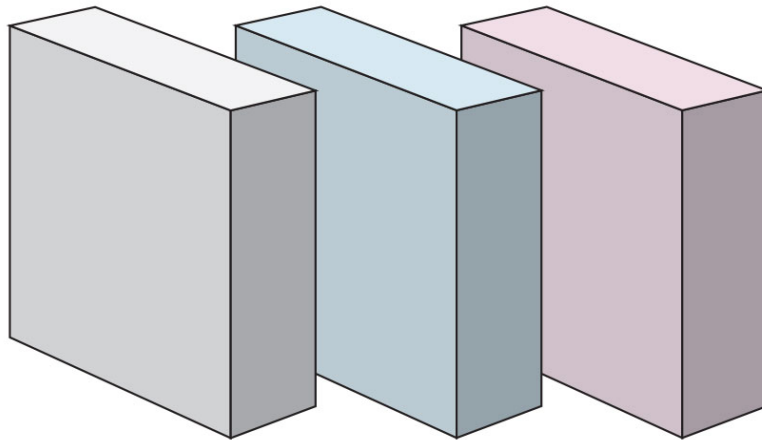




## Rain and Airflow Missing

Building Science Corporation

Joseph Lstiburek 49



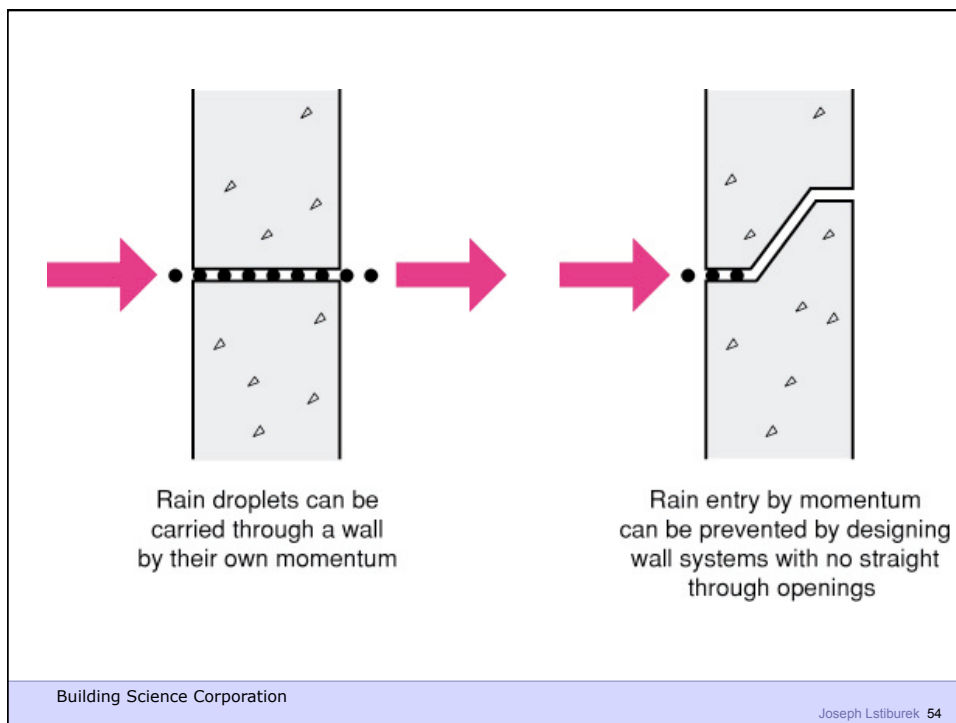
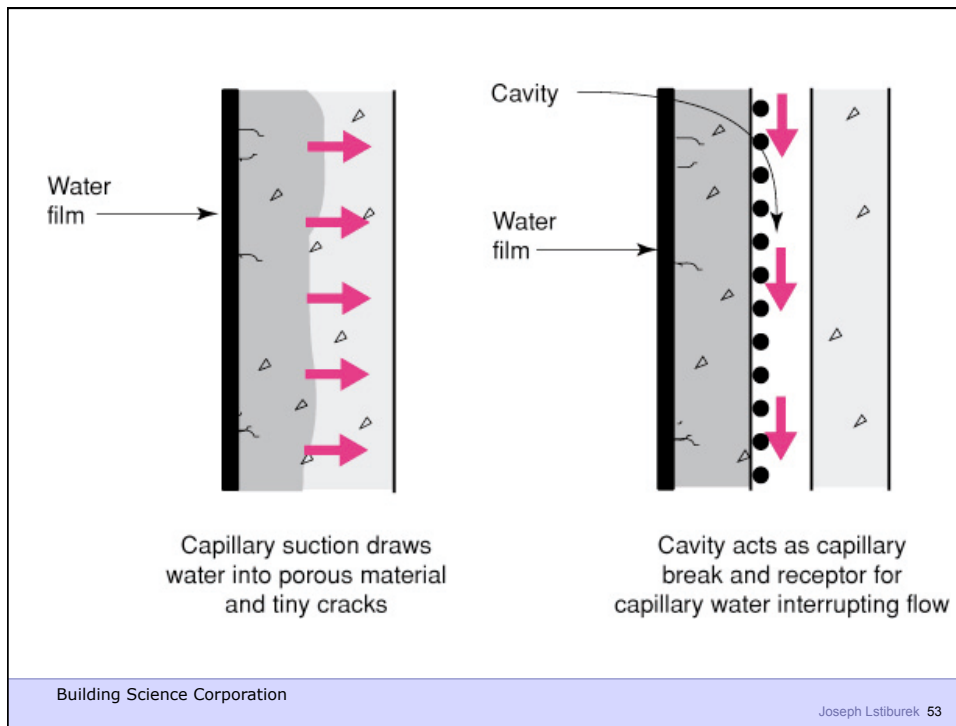
Building Science Corporation

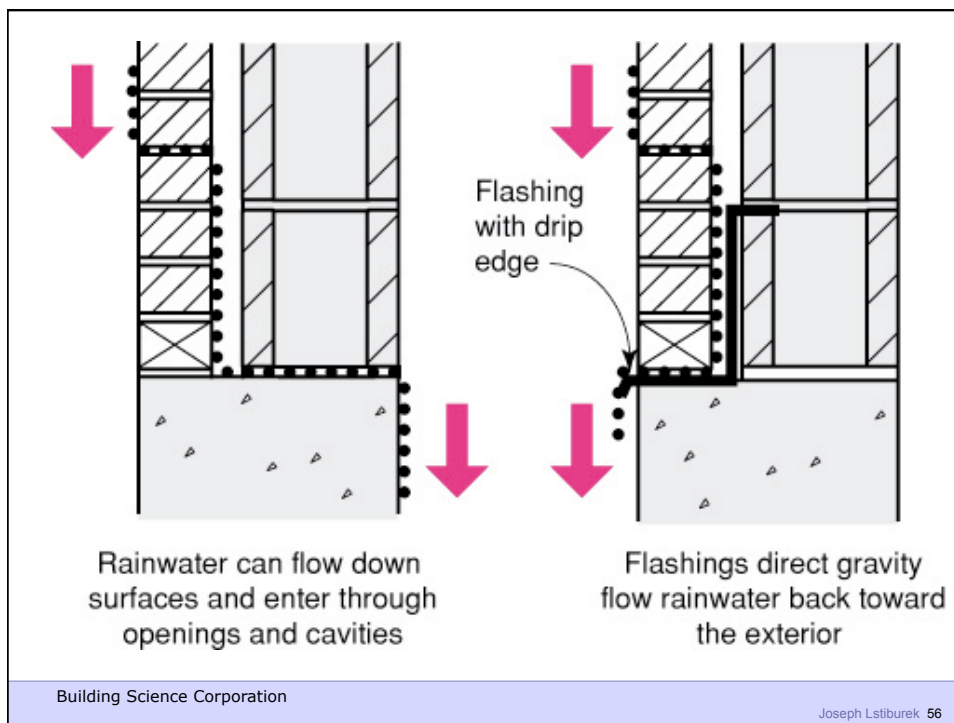
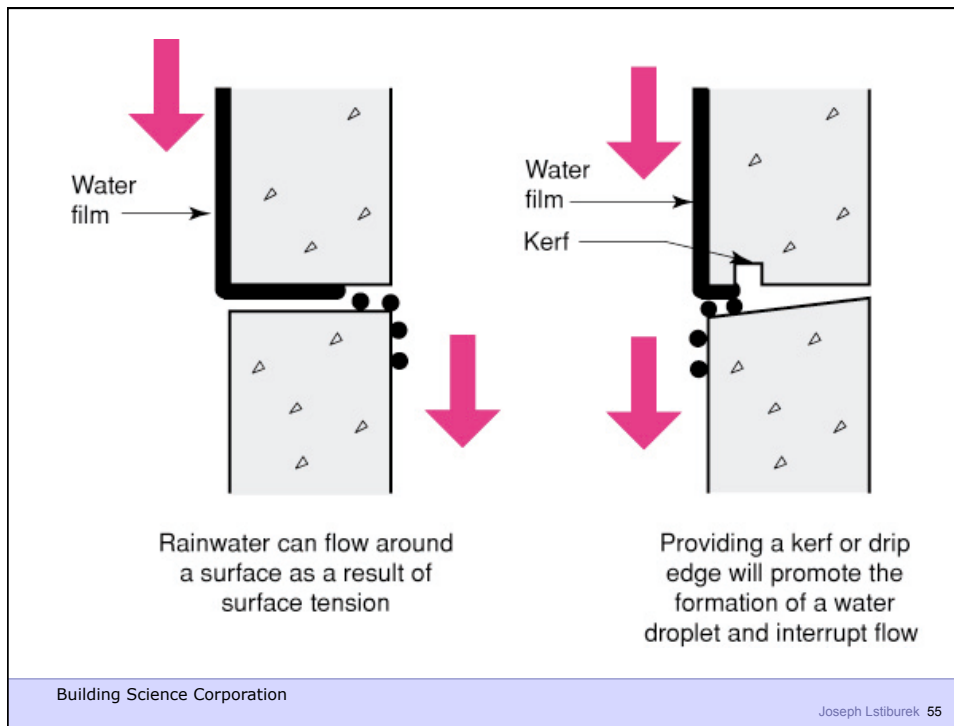
Joseph Lstiburek 50

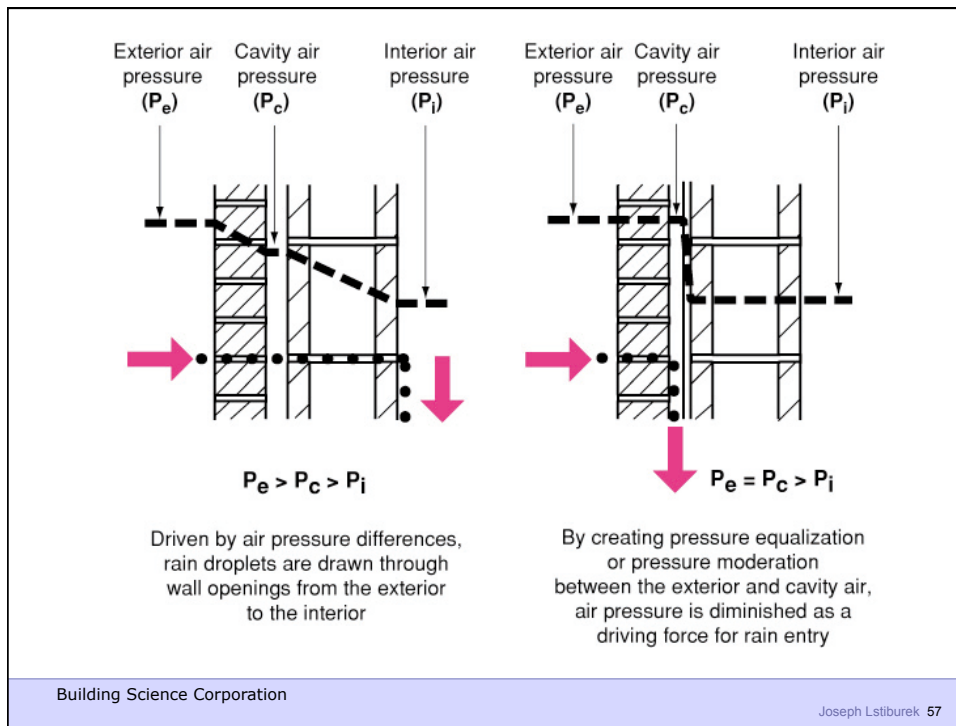
## Recall That Rain and Airflow Are Missing

### 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



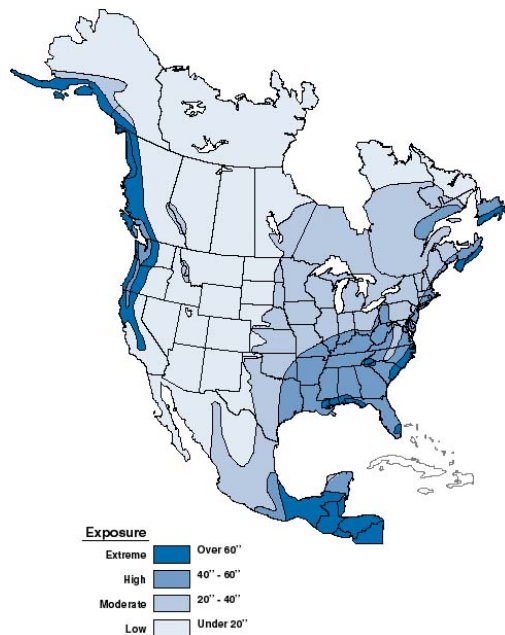


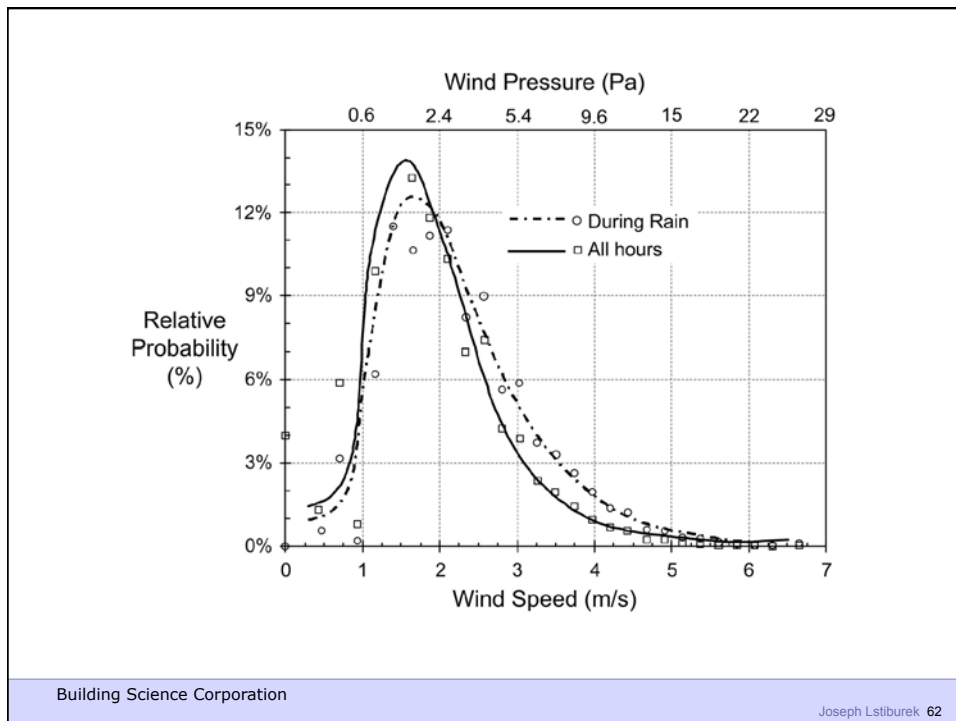
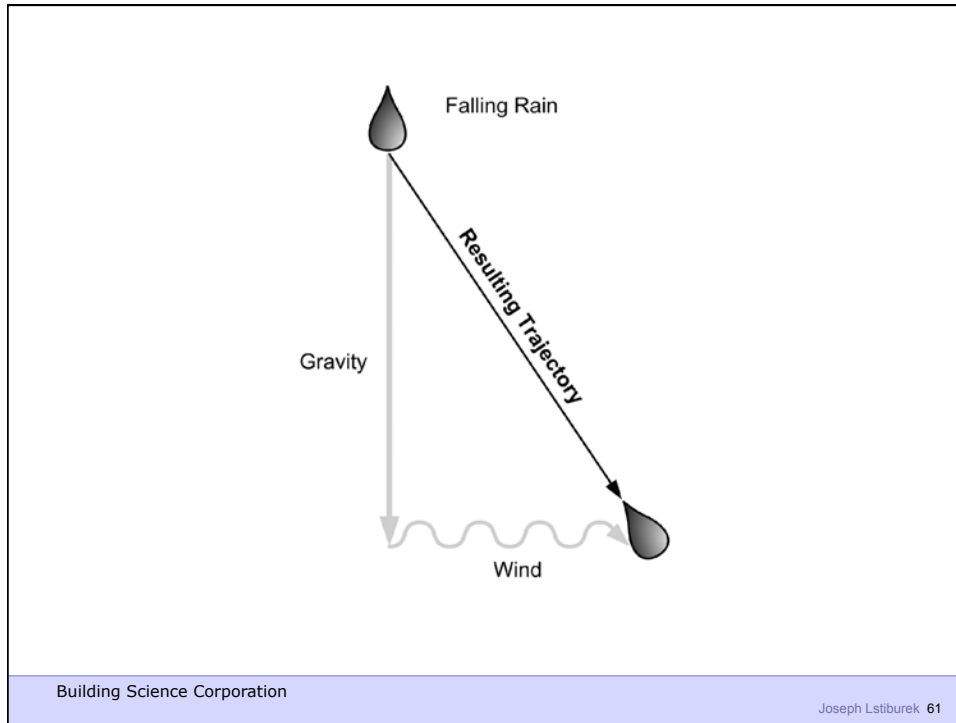


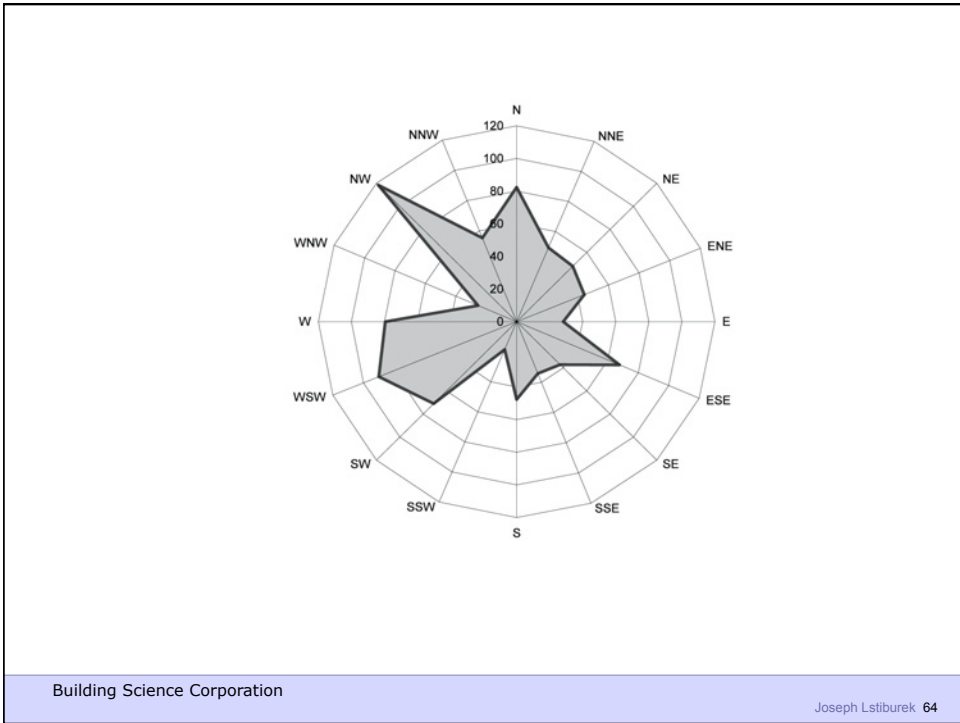
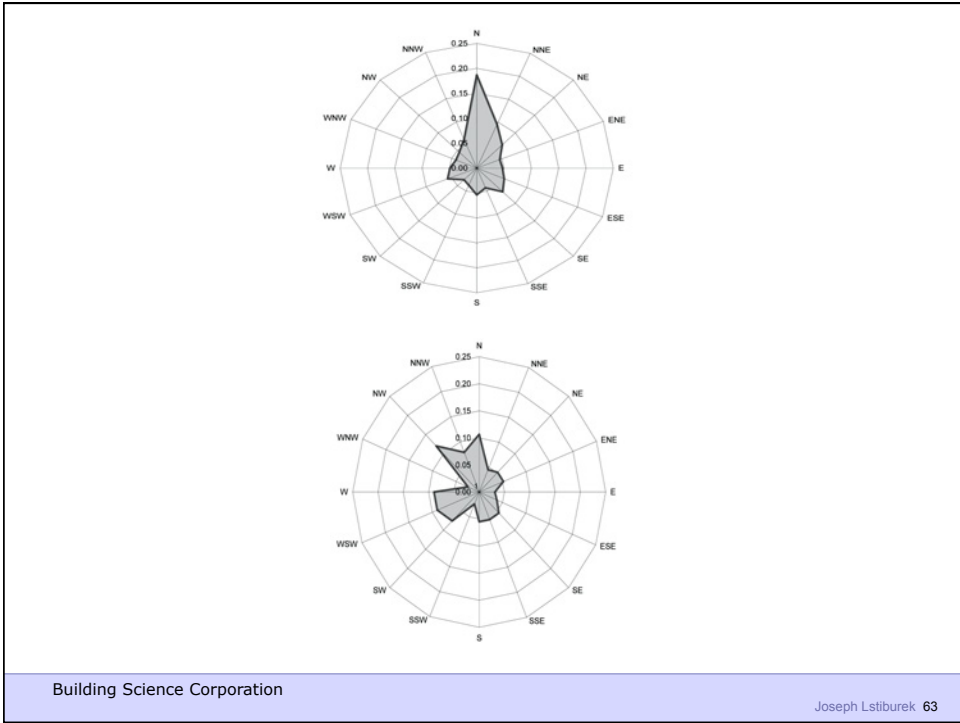
All We Have To Figure Out Is How Much Hits The Wall

# All We Have To Figure Out Is How Much Hits The Wall

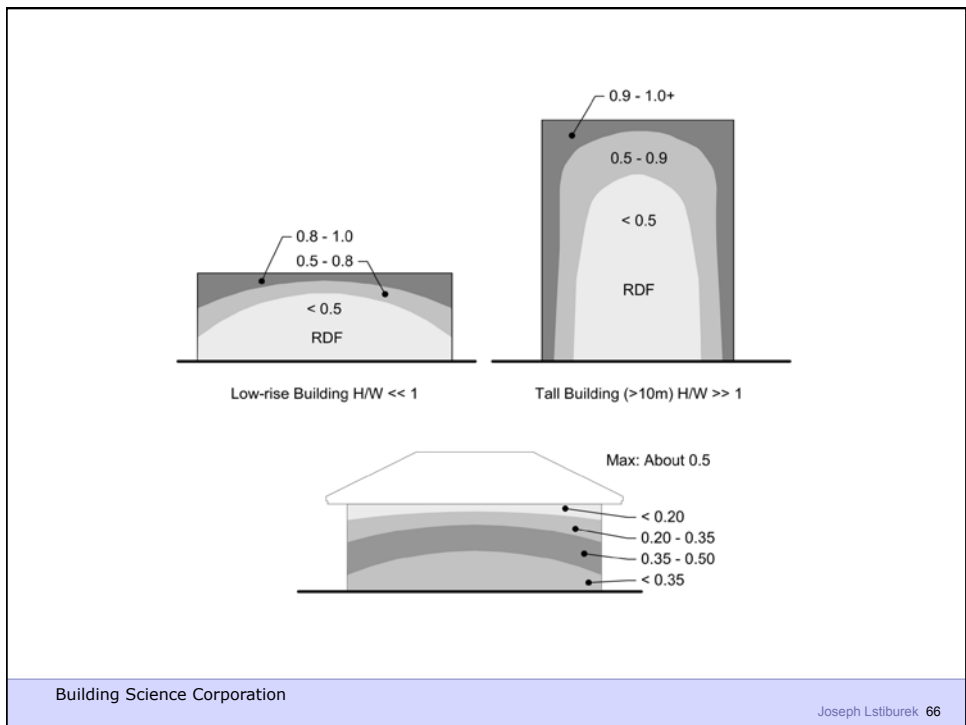
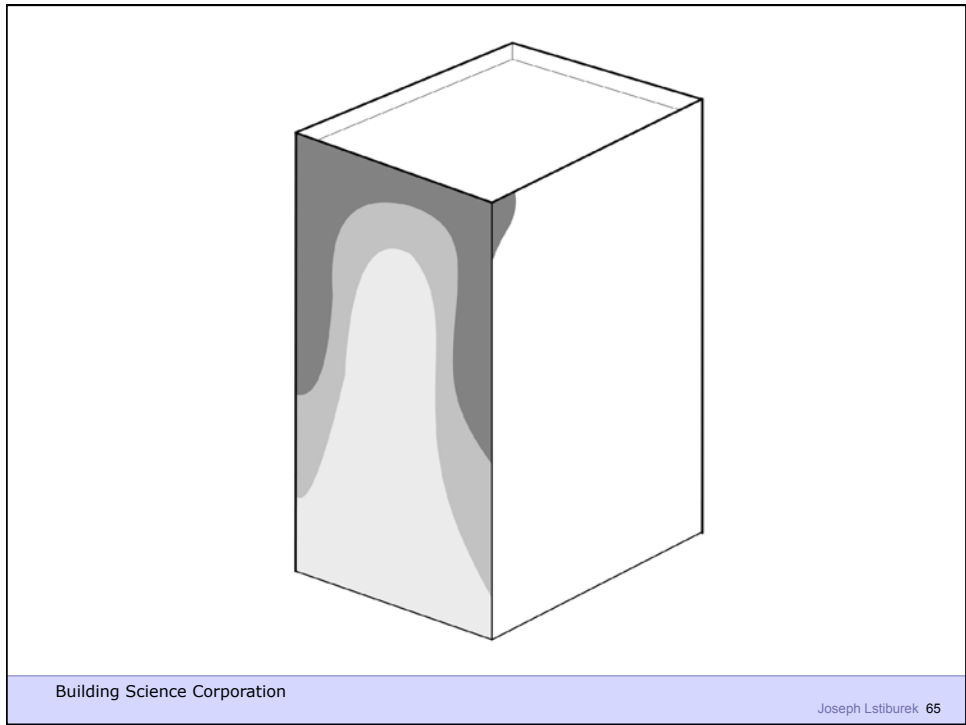
## We Need Straube and Kuenzel











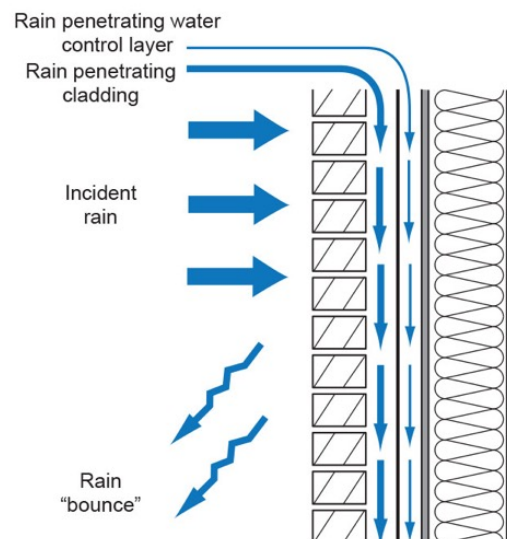
We use Straube/Kuenzel to determine how much rain water impinges on the wall.

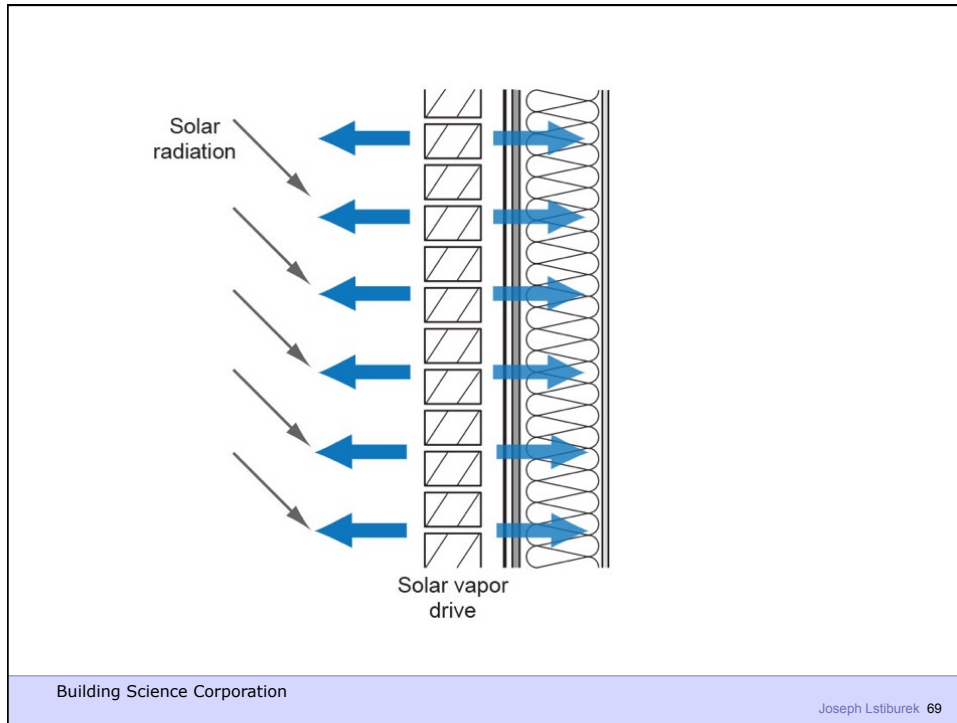
We assume 30% bounces off  
70% stays on the wall.

The 70% that stays on the wall is addressed by liquid conductivity (capillary flow) and vapor diffusion.

We assume 1% of the 70% penetrates to the back side of the cladding.

We further assume that 1% of the 1% gets past the water control layer into the sheathing.

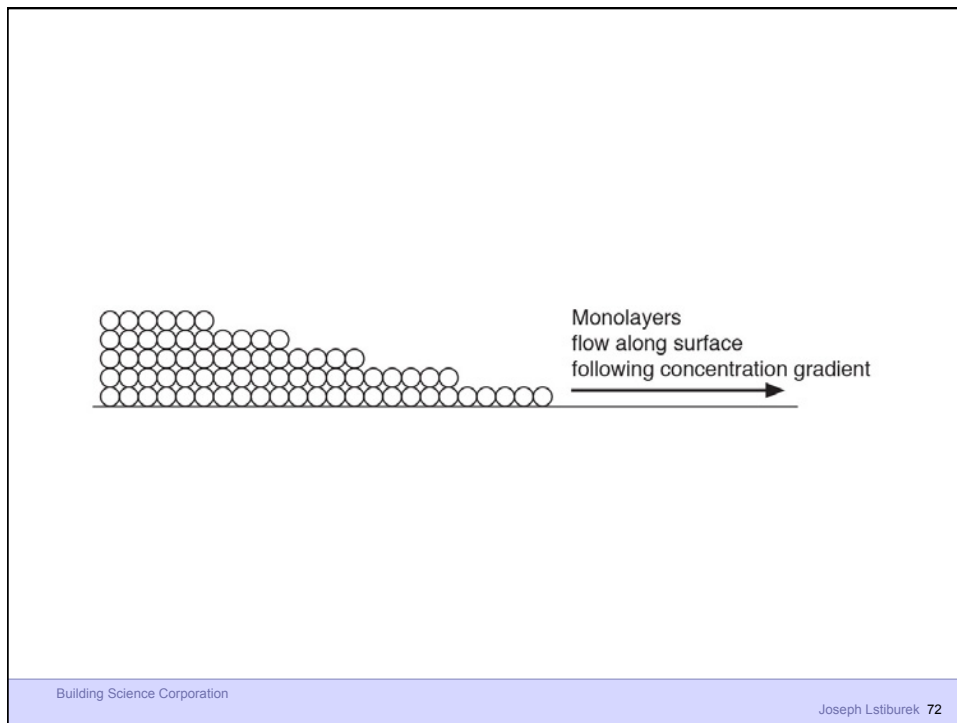
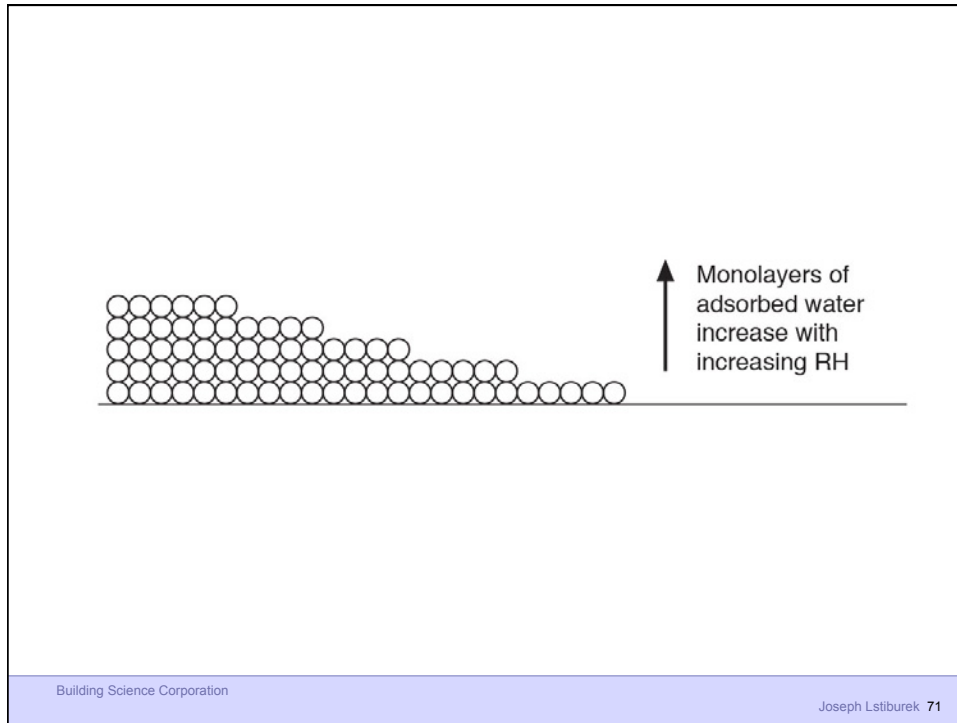




Adsorbed Water

Building Science Corporation

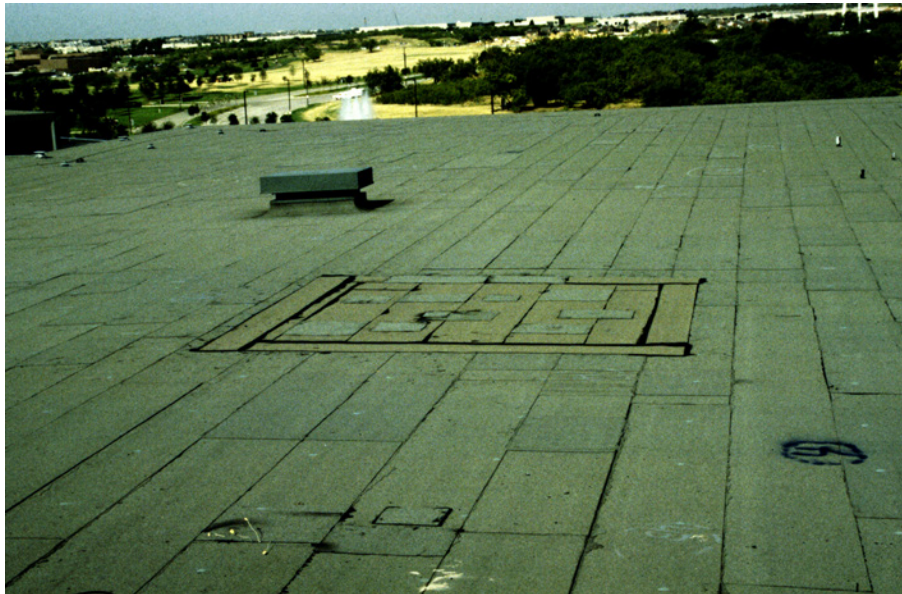
Joseph Lstiburek 70





Building Science Corporation

Joseph Lstiburek 73



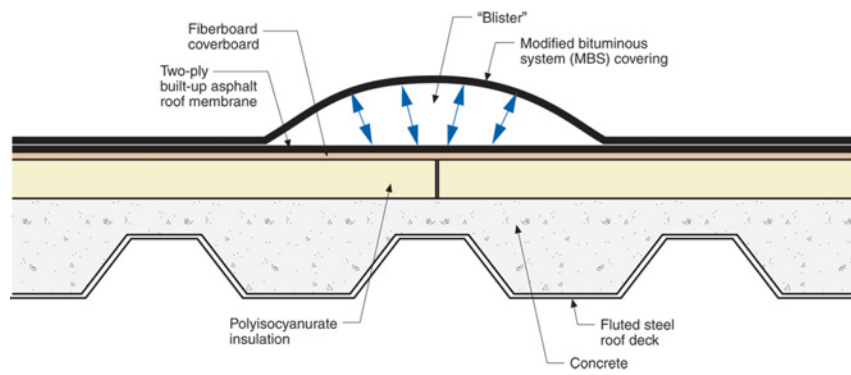
Building Science Corporation

Joseph Lstiburek 74



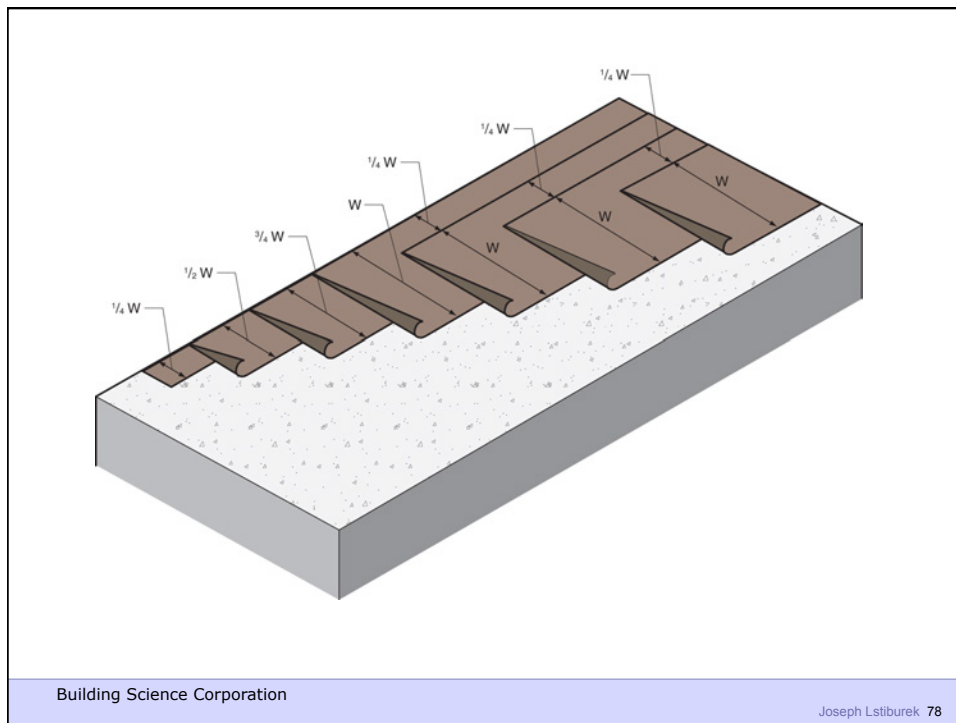
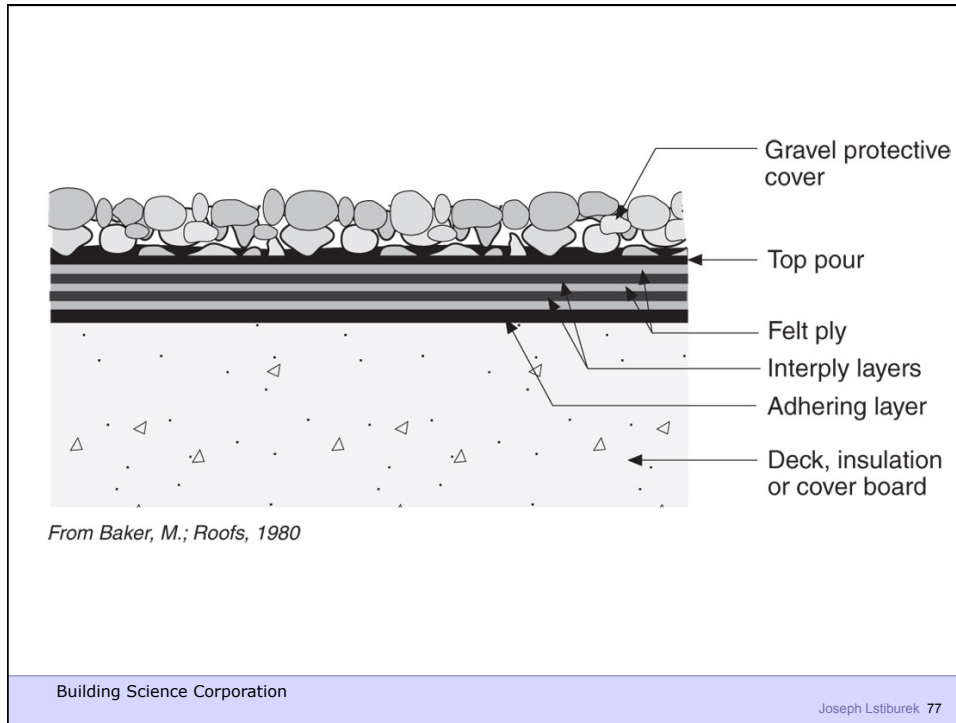
Building Science Corporation

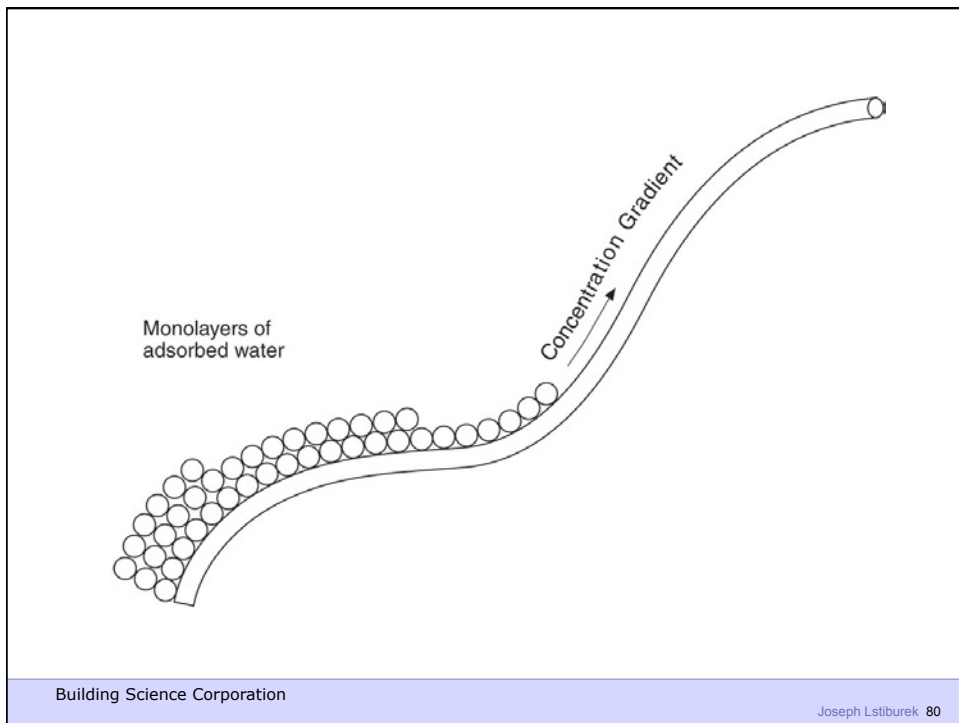
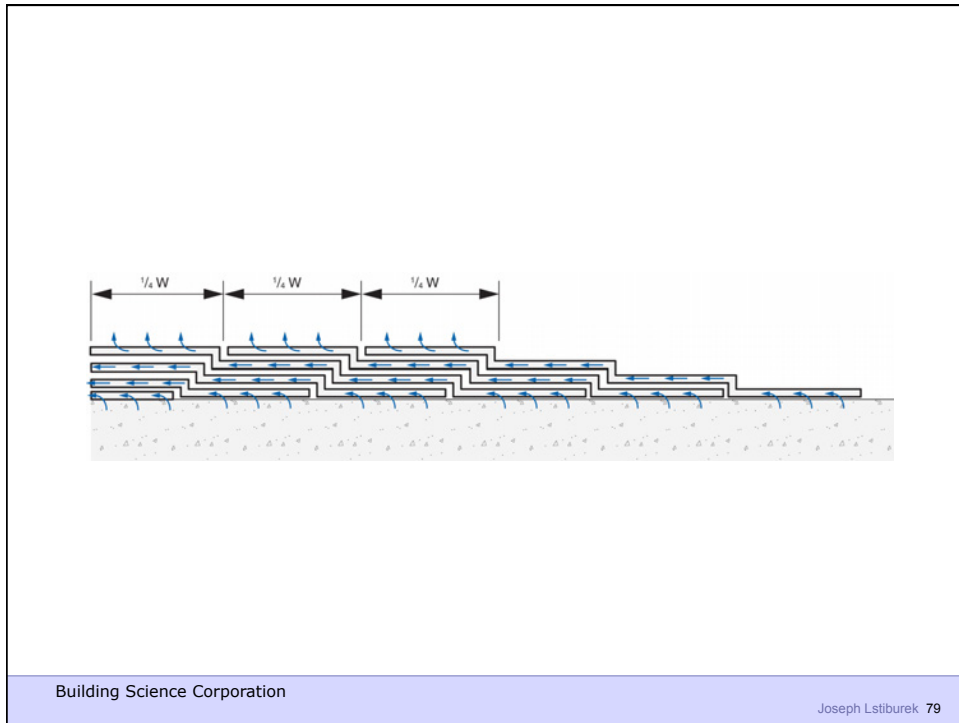
Joseph Lstiburek 75



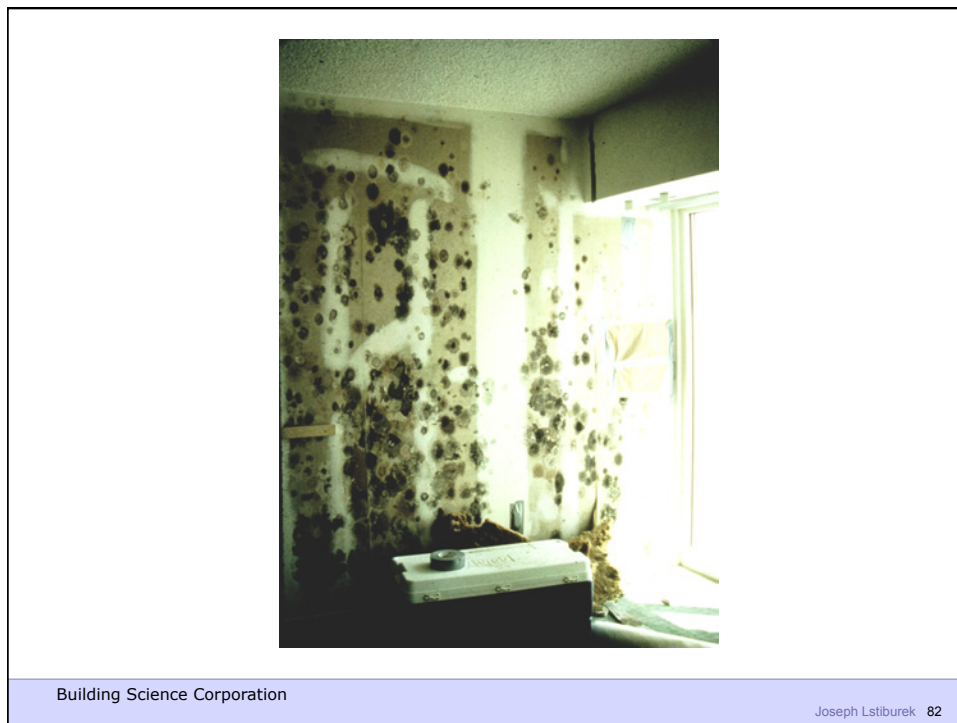
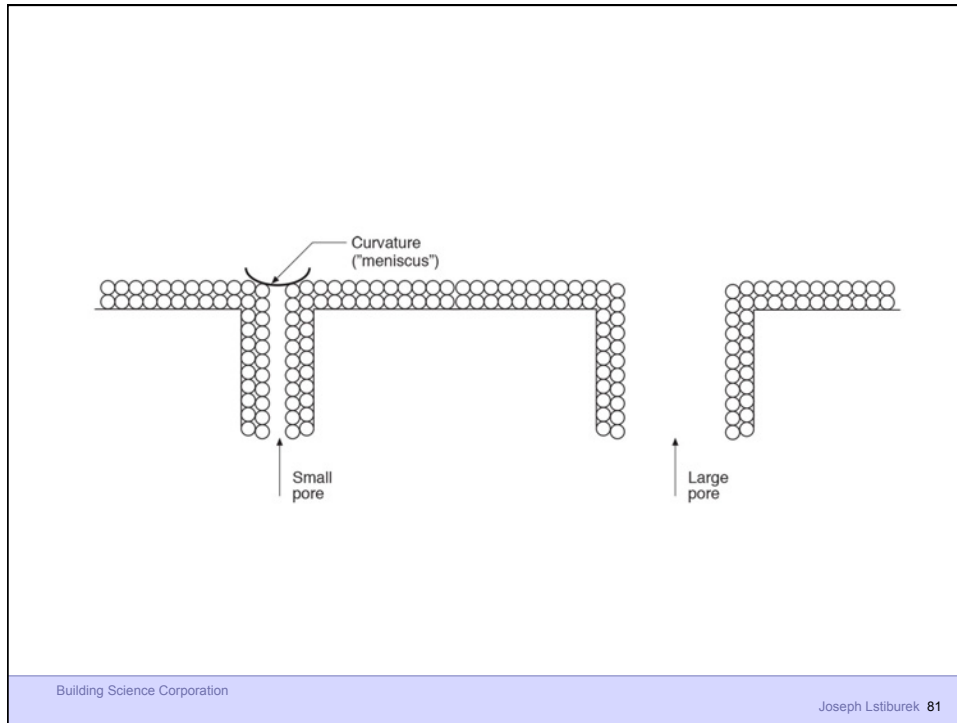
Building Science Corporation


Joseph Lstiburek 76







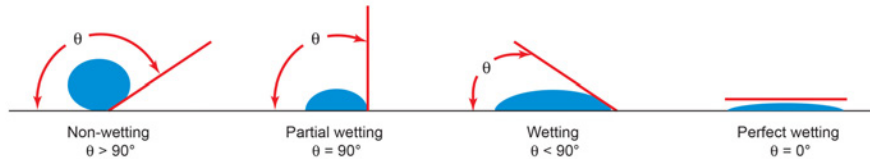




- "non-wettable" surface
- water repellent surface
- hydrophobic surface
- water more attracted to itself than to surface
- surface energy of water greater than surface energy of surface
- water "beads up"
- "greasy" surface
- high contact angle " $\theta$ "

- "wettable" surface
- non-water repellent surface
- hygroscopic surface
- water more attracted to surface than itself
- surface energy of surface greater than surface energy of water
- water "spreads out"
- "non-greasy" surface
- low contact angle " $\theta$ "

Building Science Corporation Joseph Lstiburek 83



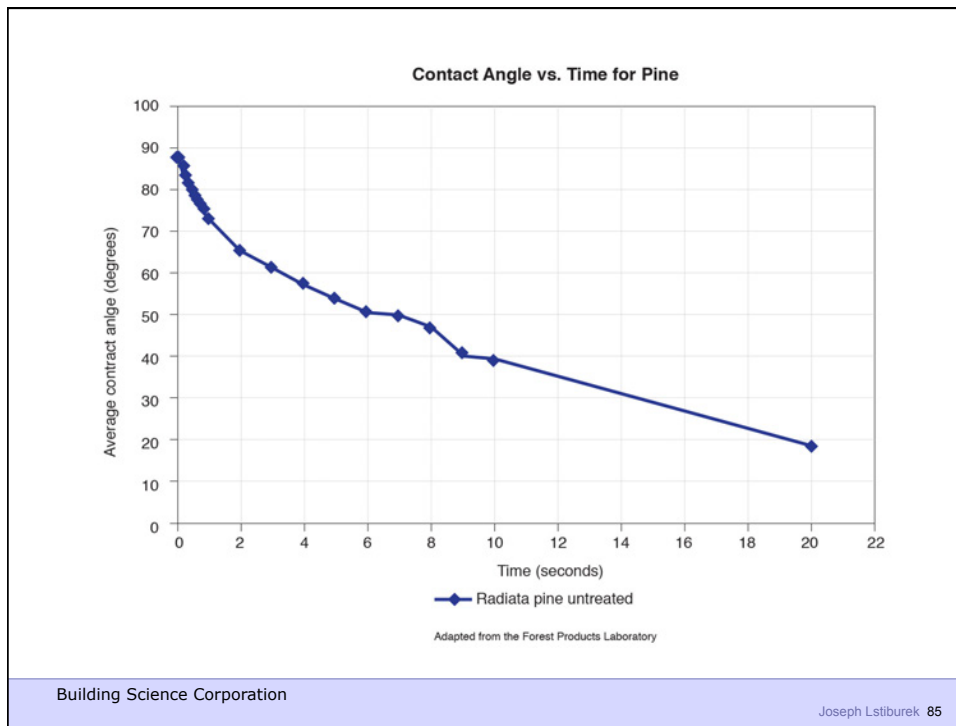
Non-wetting  
 $\theta > 90^\circ$

Partial wetting  
 $\theta = 90^\circ$

Wetting  
 $\theta < 90^\circ$

Perfect wetting  
 $\theta = 0^\circ$

Building Science Corporation Joseph Lstiburek 84





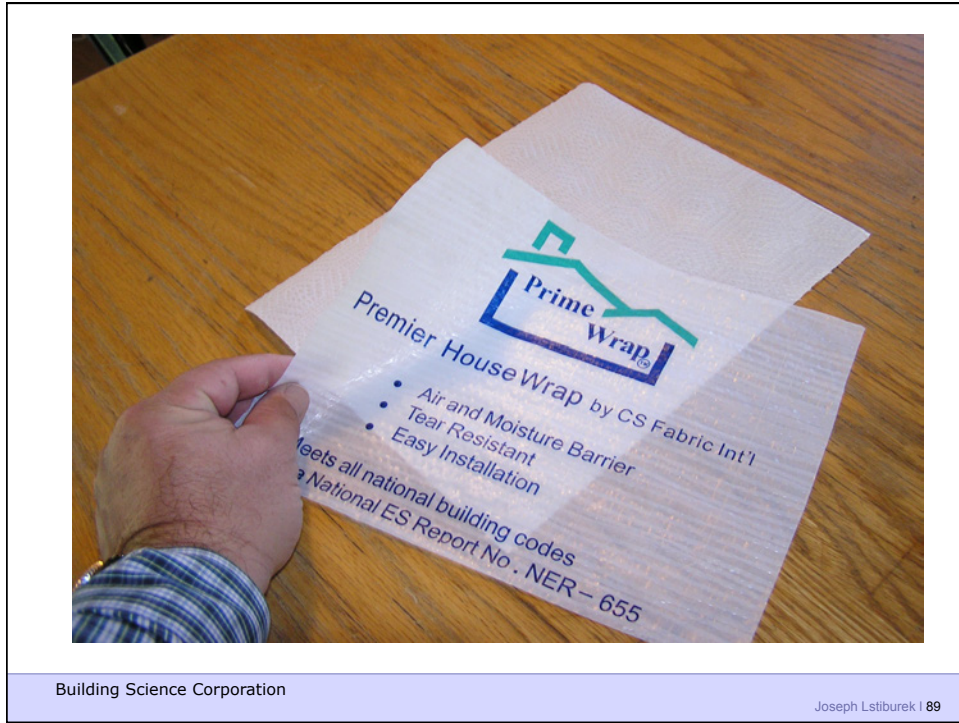
Building Science Corporation

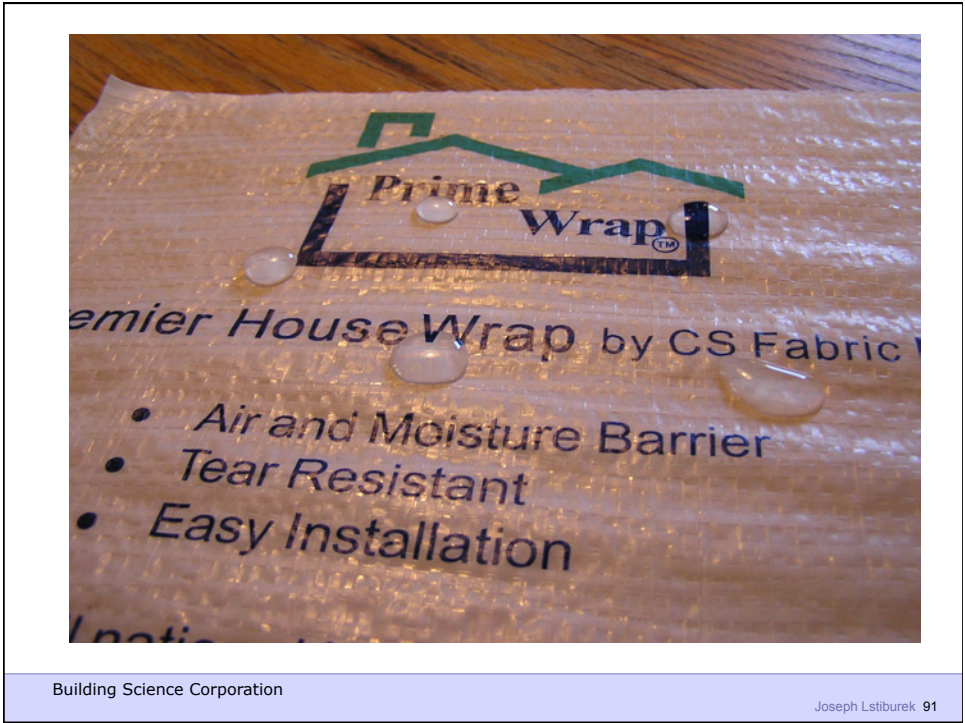
Joseph Lstiburek 87



Building Science Corporation

Joseph Lstiburek 88







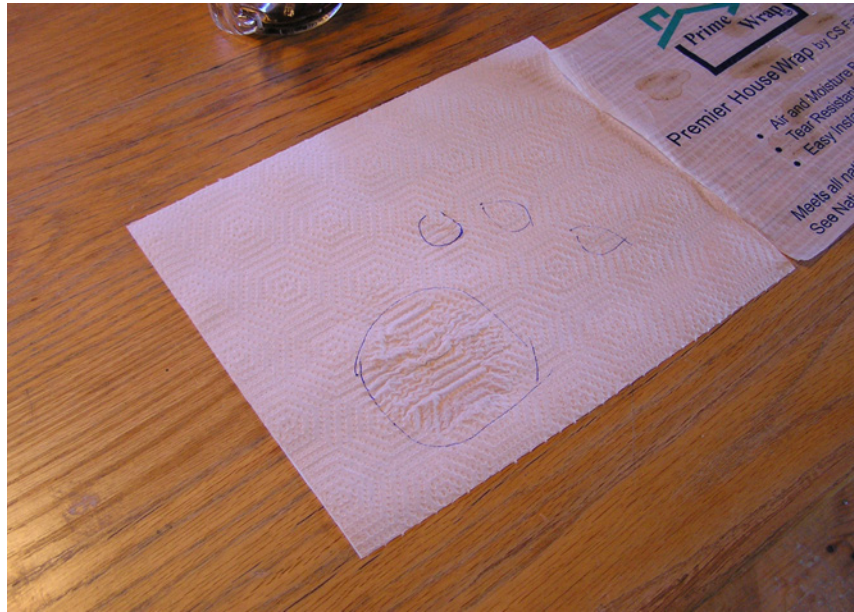
Building Science Corporation

Joseph Lstiburek 93



Building Science Corporation

Joseph Lstiburek 94



Building Science Corporation

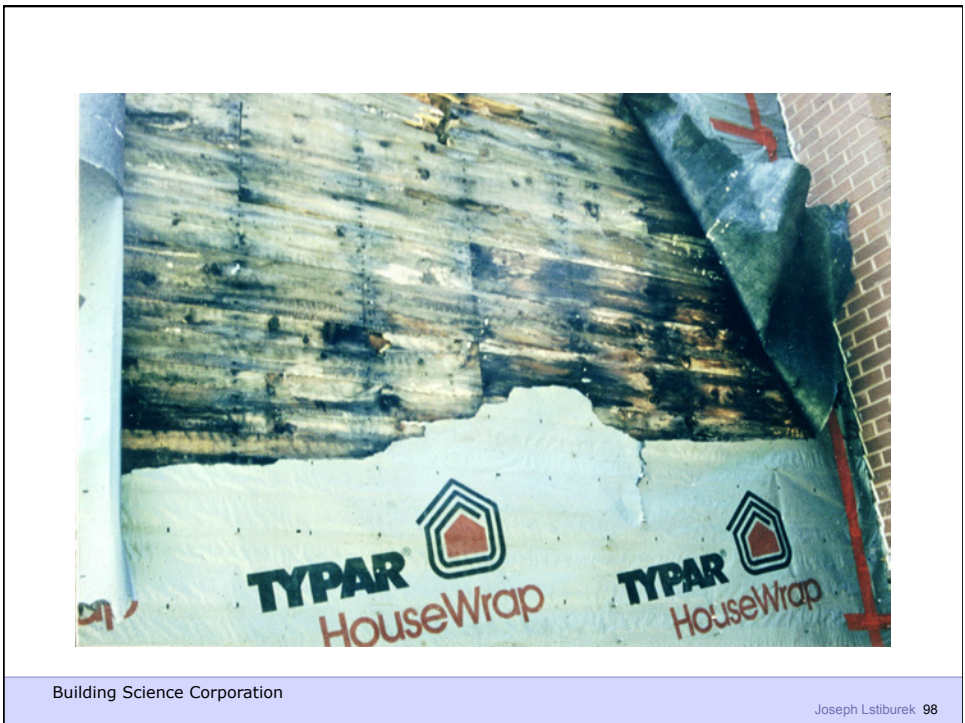
Joseph Lstiburek 95



Building Science 2008

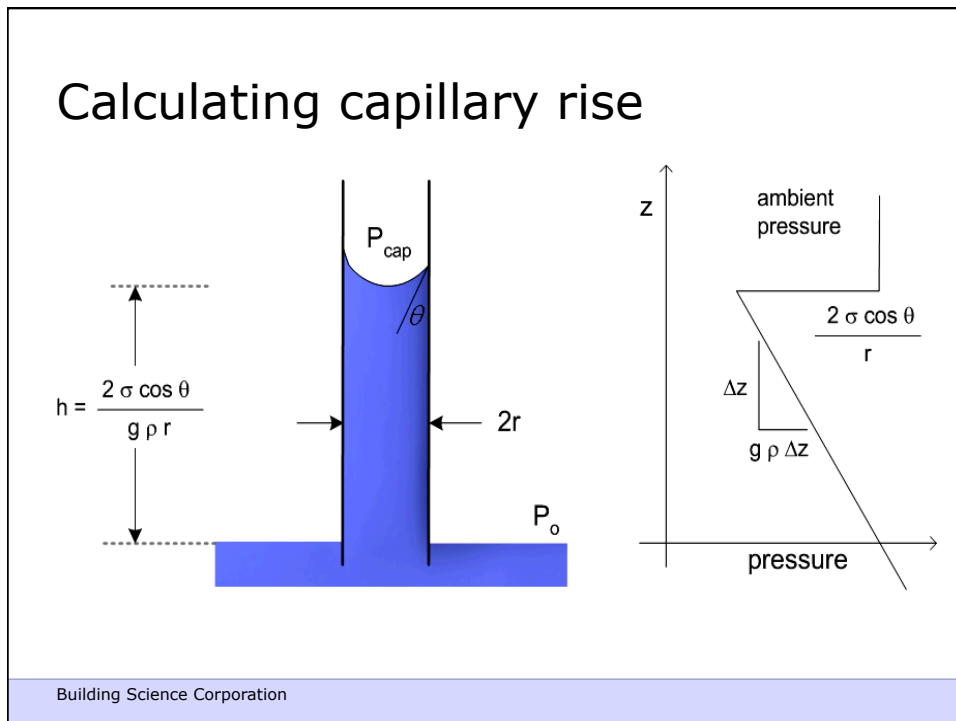
Joseph Lstiburek – Rain Control 96



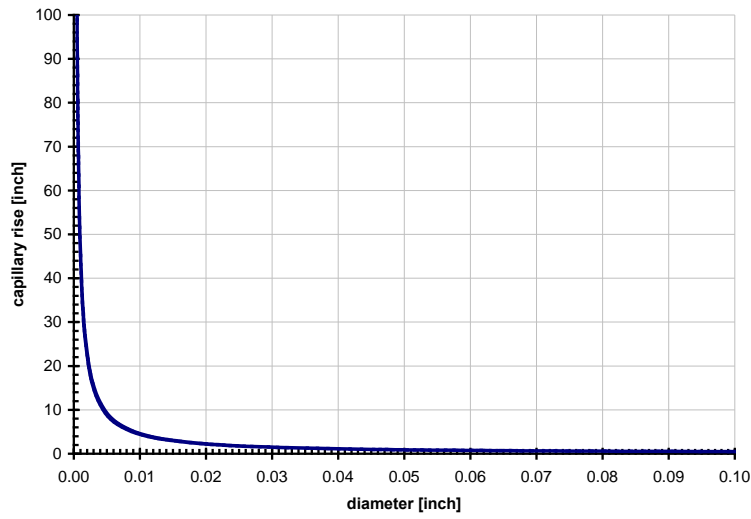


	Surface Energy
Water (20 C)	73 dynes/cm
Water (100 C)	59 dynes/cm
Epoxy	46 dynes/cm
Polyethylene	31 dynes/cm
Soapy water	30 dynes/cm
Paraffin wax	25 dynes/cm
Silicone	24 dynes/cm
Teflon	18 dynes/cm

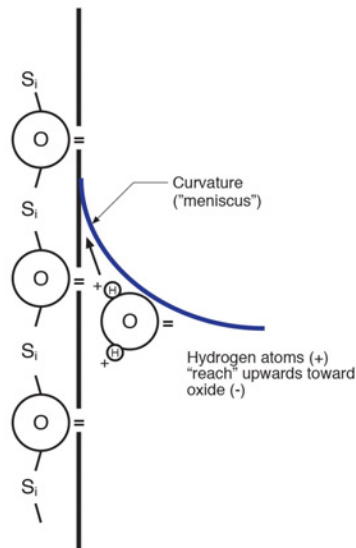
Building Science Corporation Joseph Lstiburek 99



## Capillary rise versus diameter

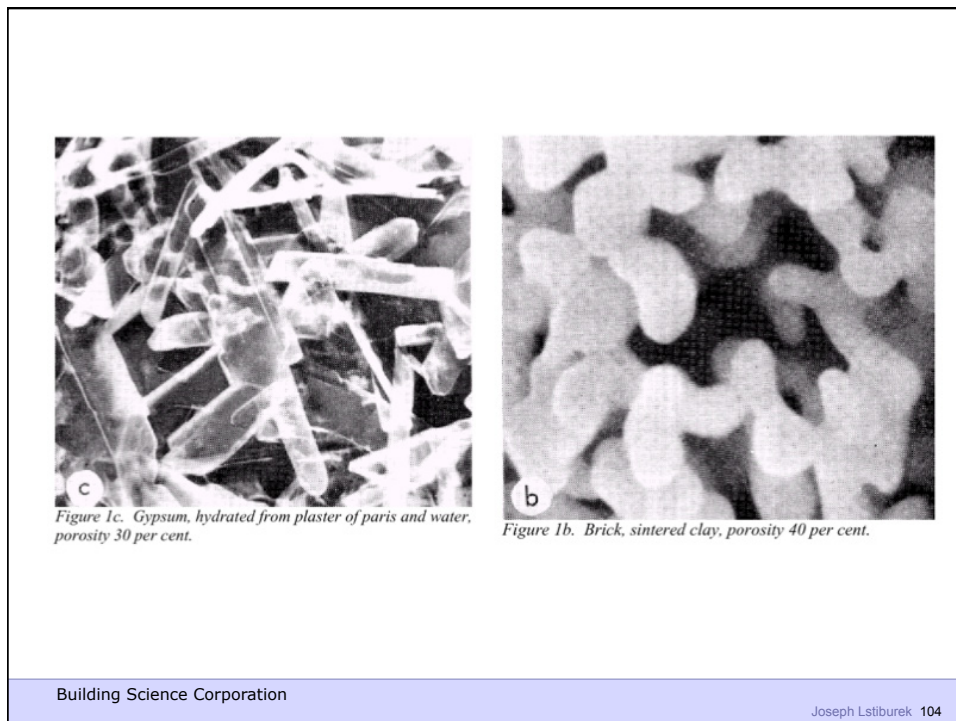
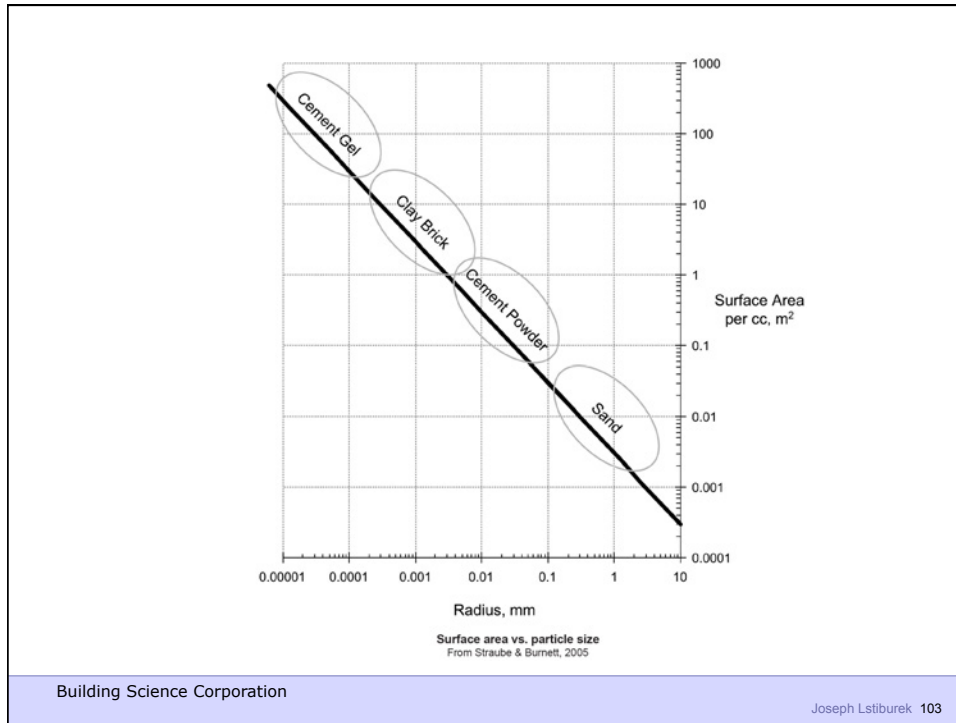


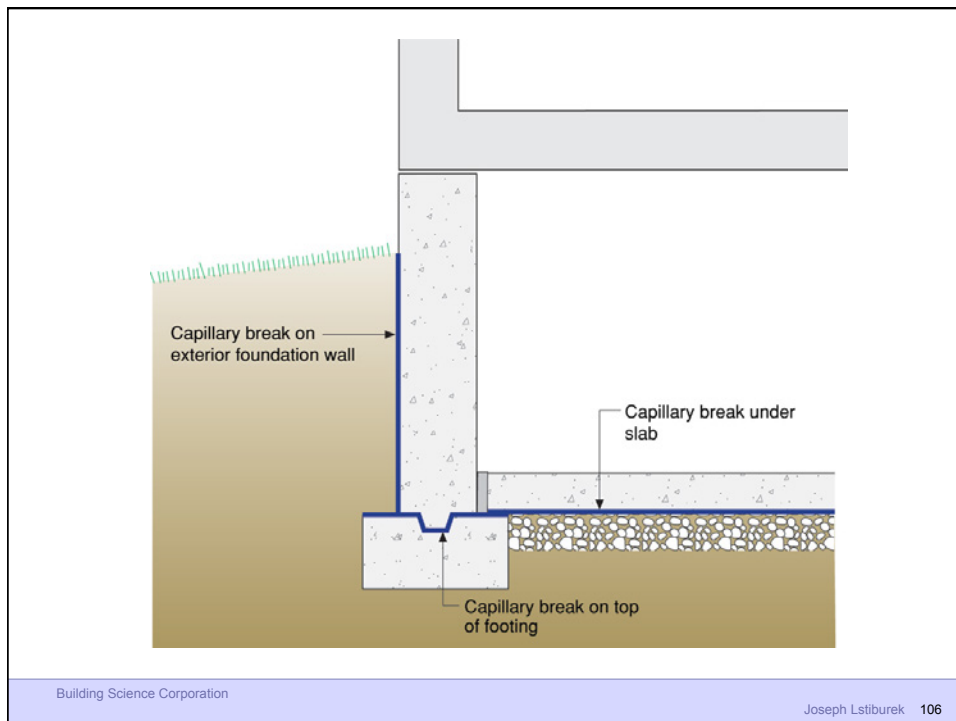
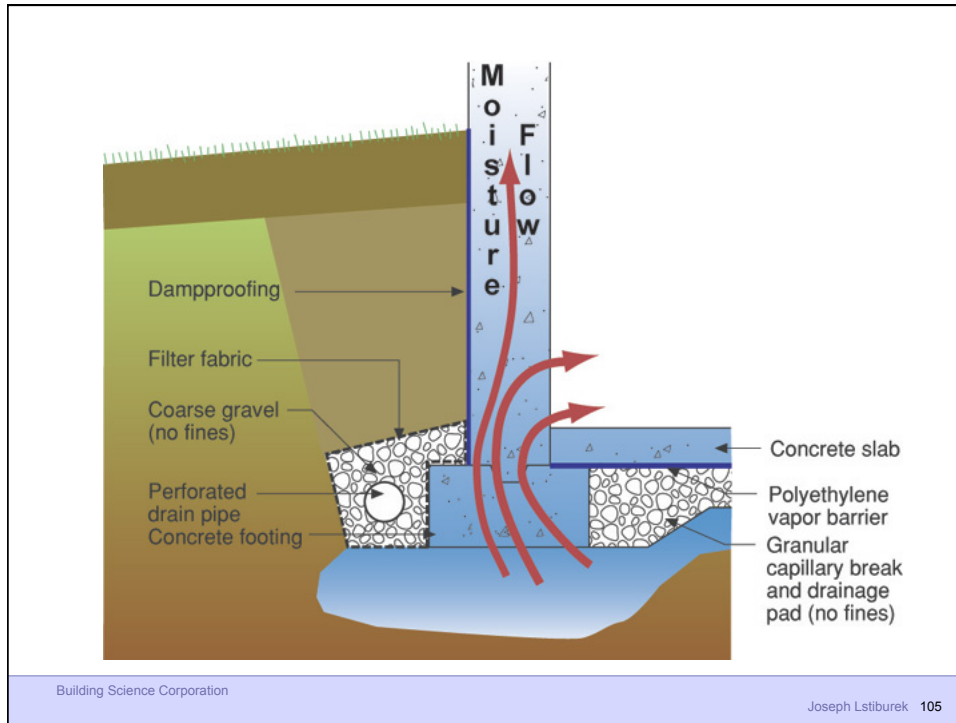
Building Science Corporation

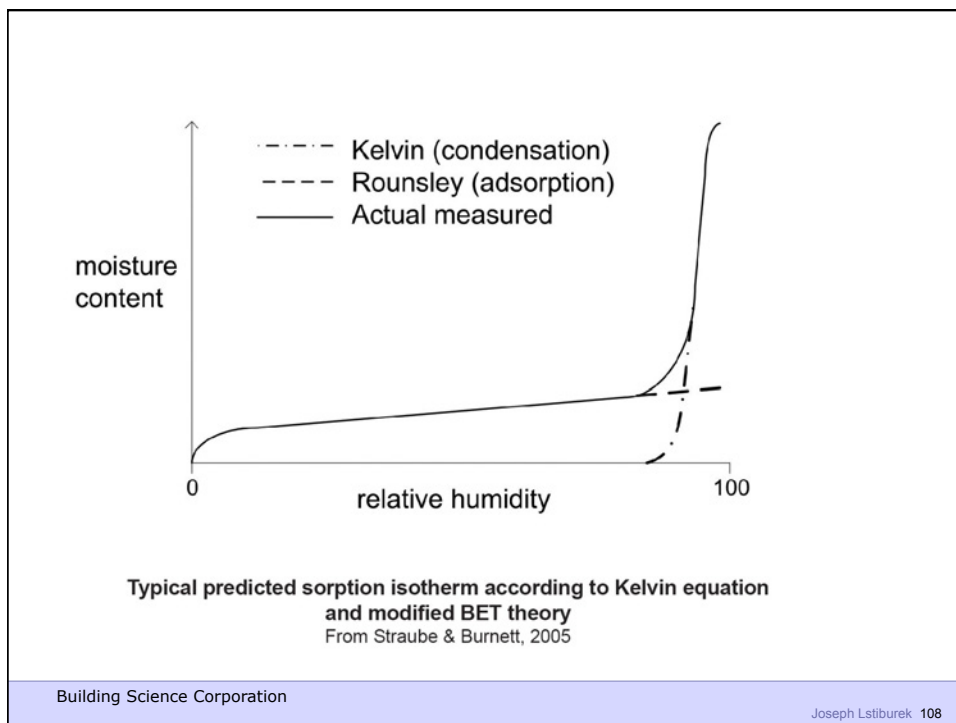
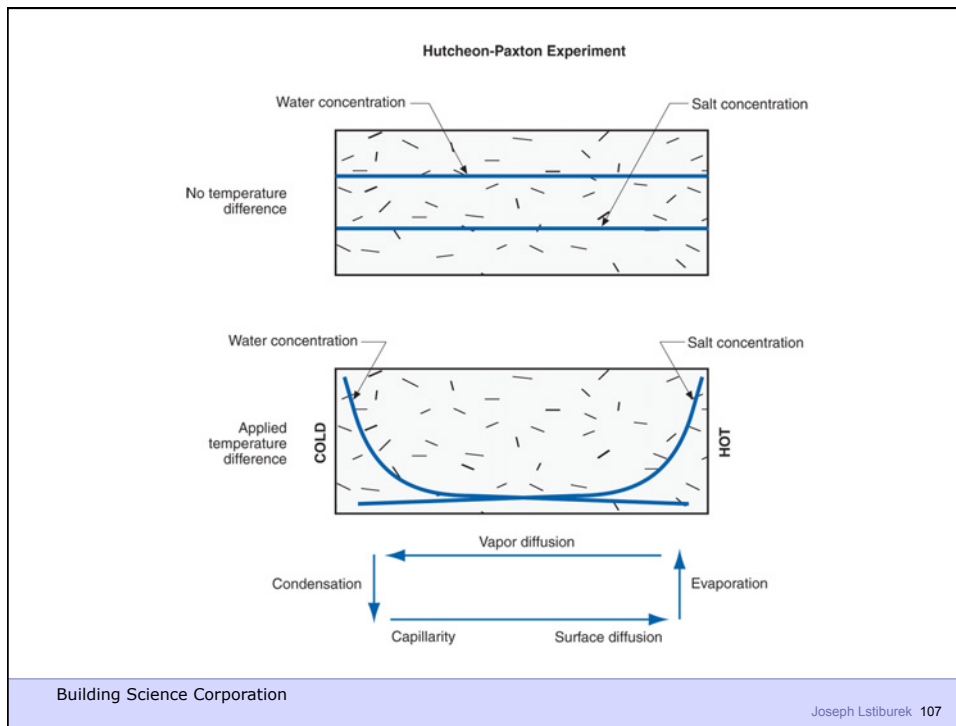


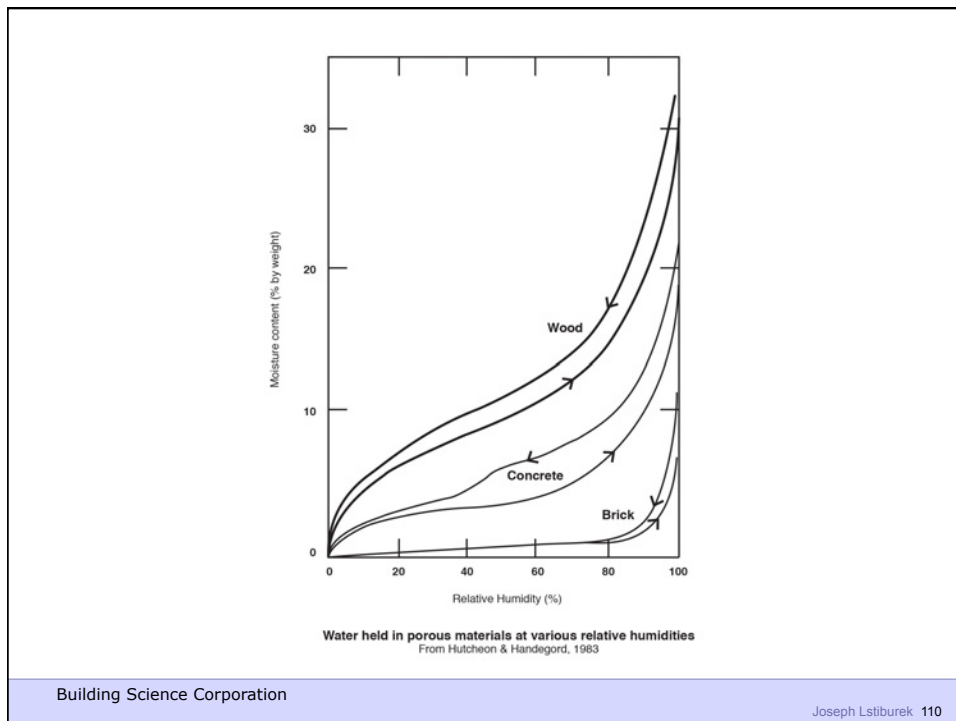
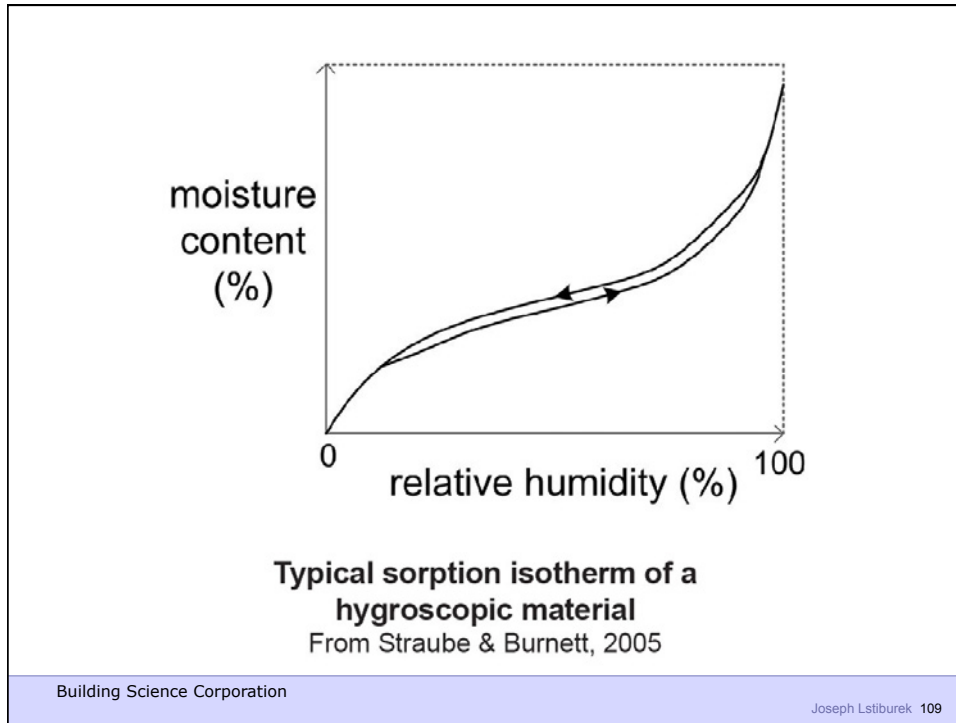
Building Science Corporation

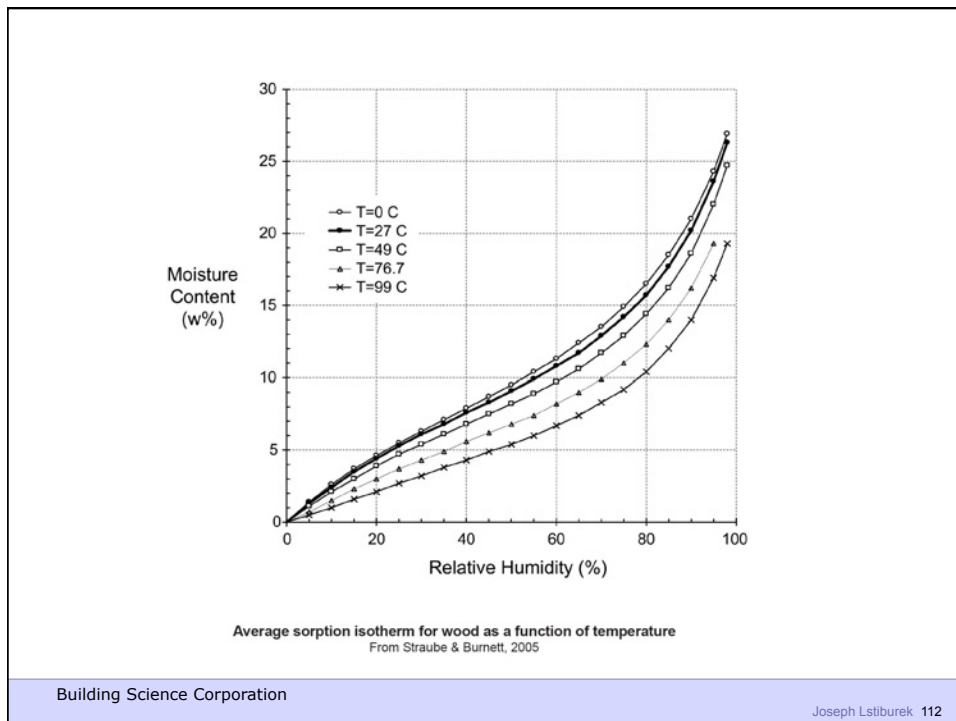
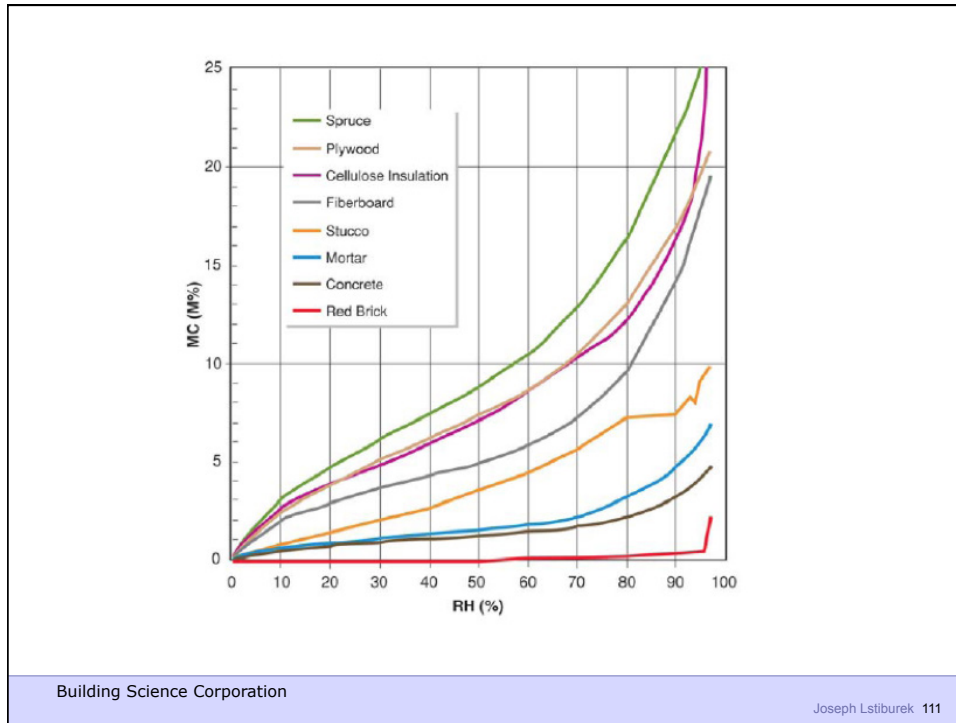
Joseph Lstiburek 102



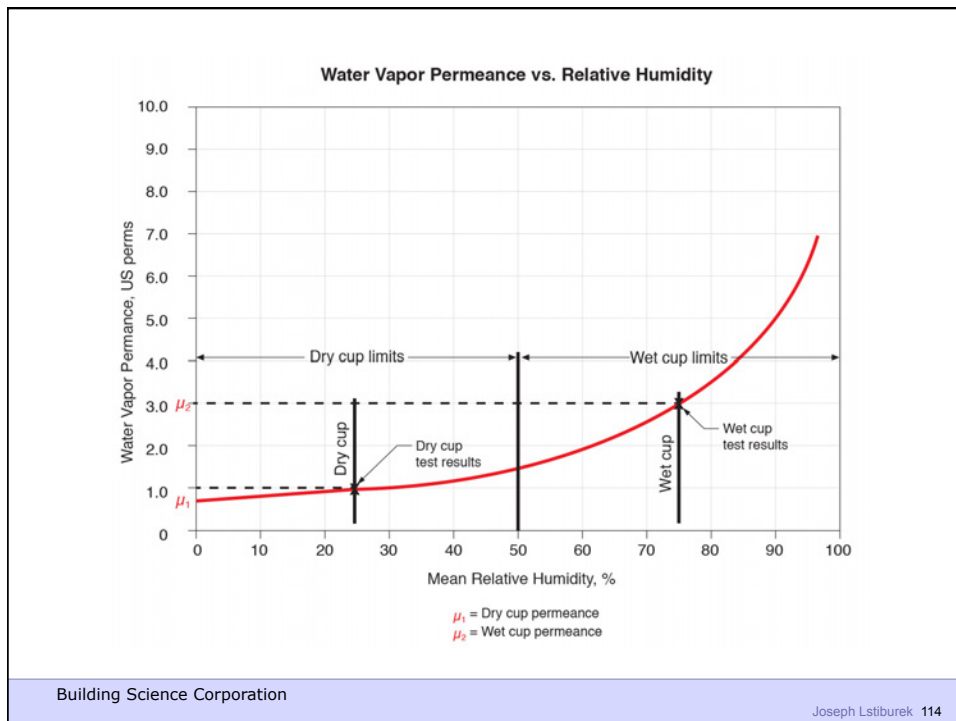
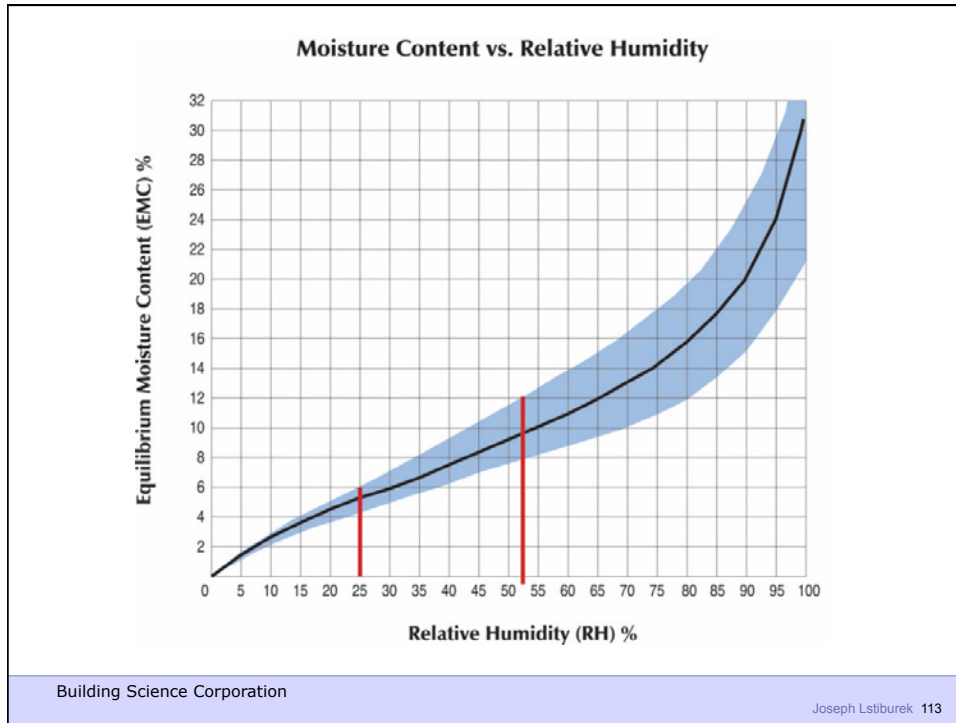


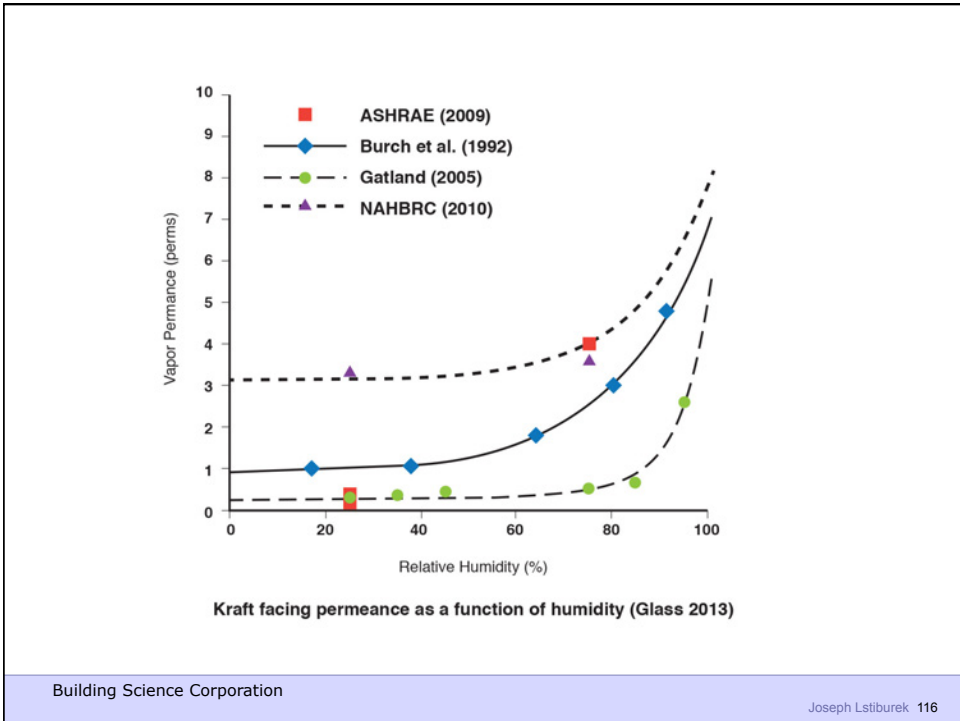


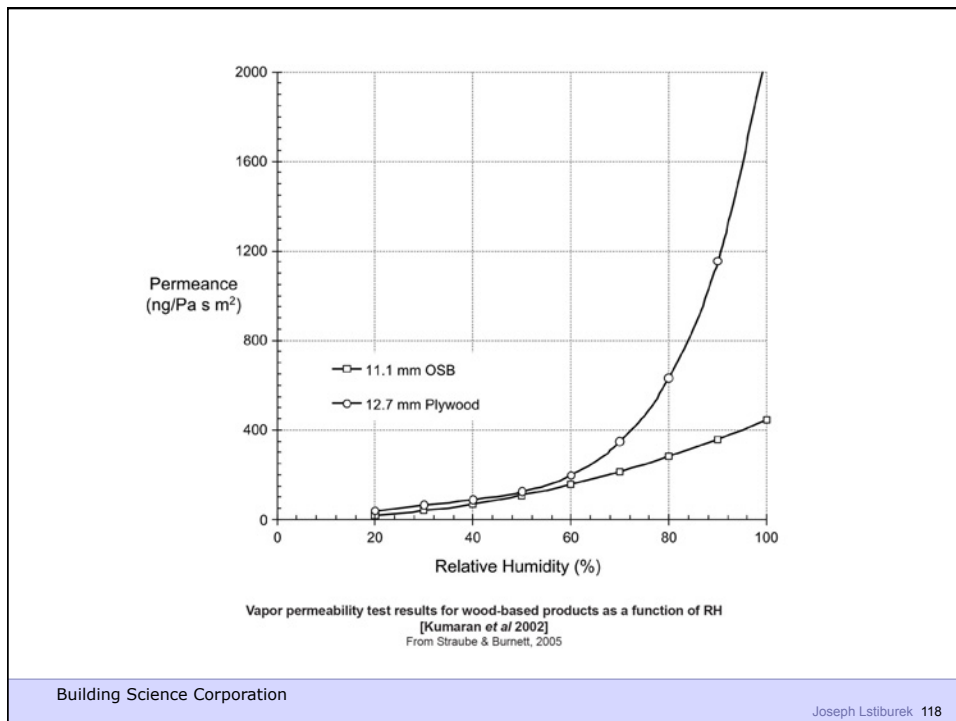
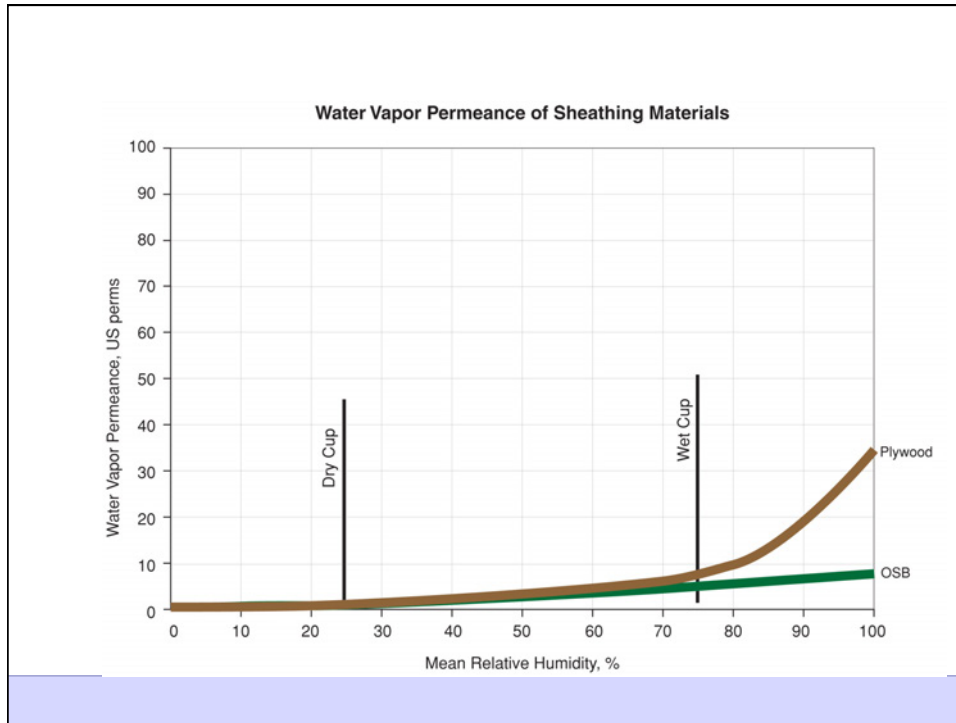


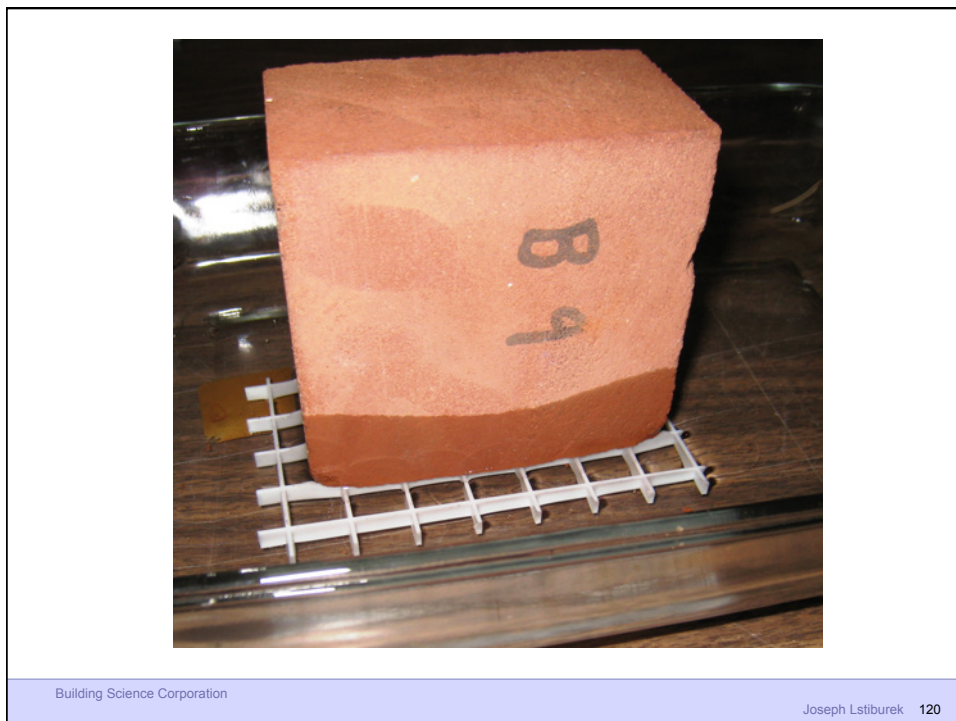


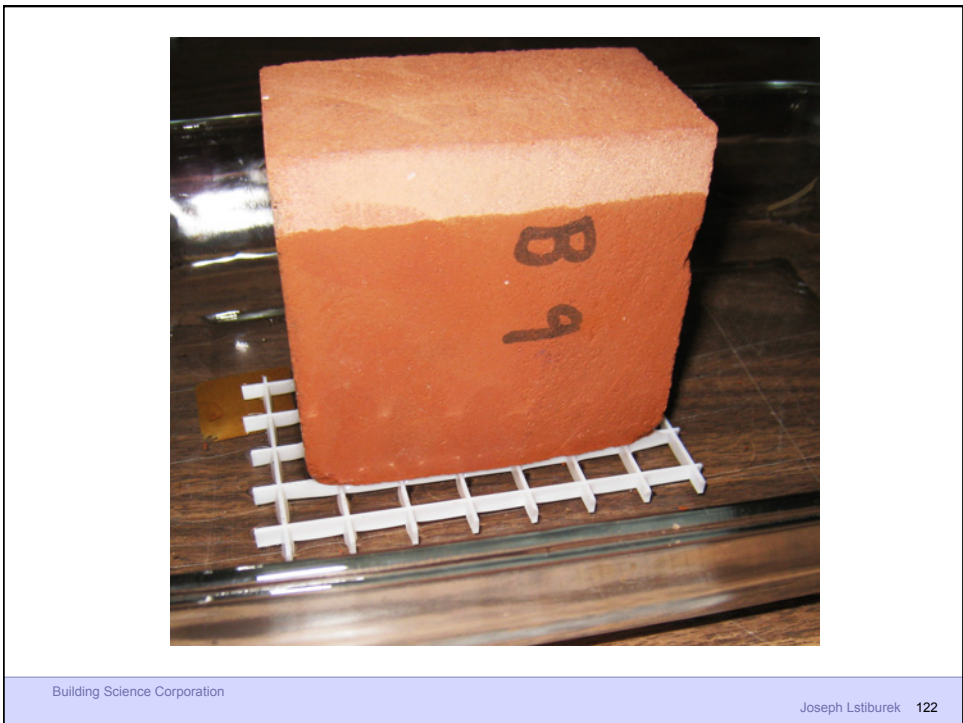
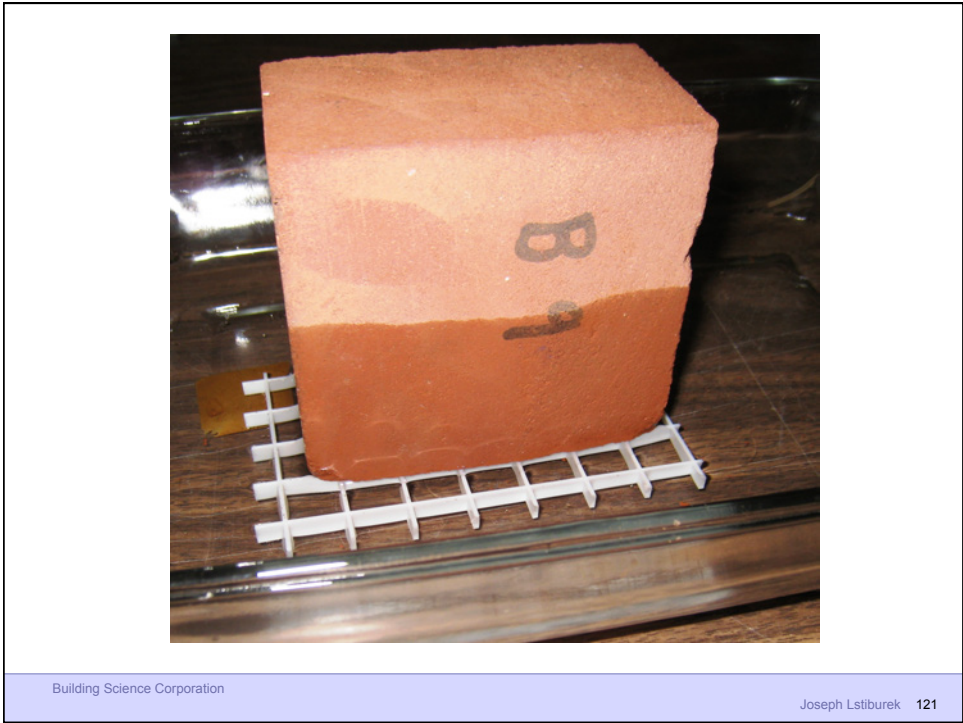


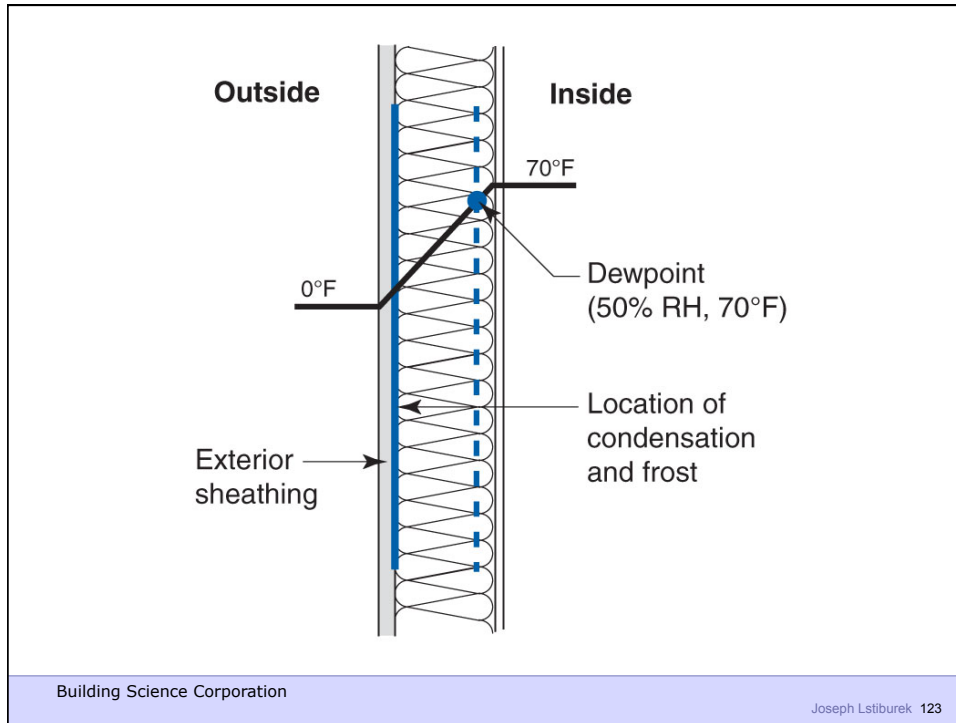


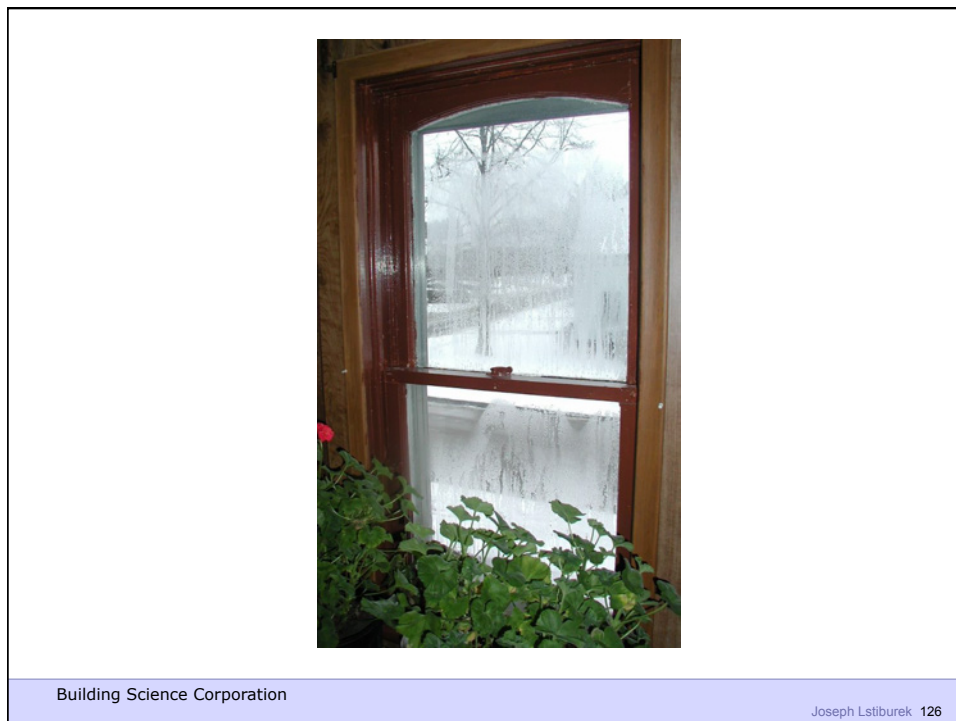
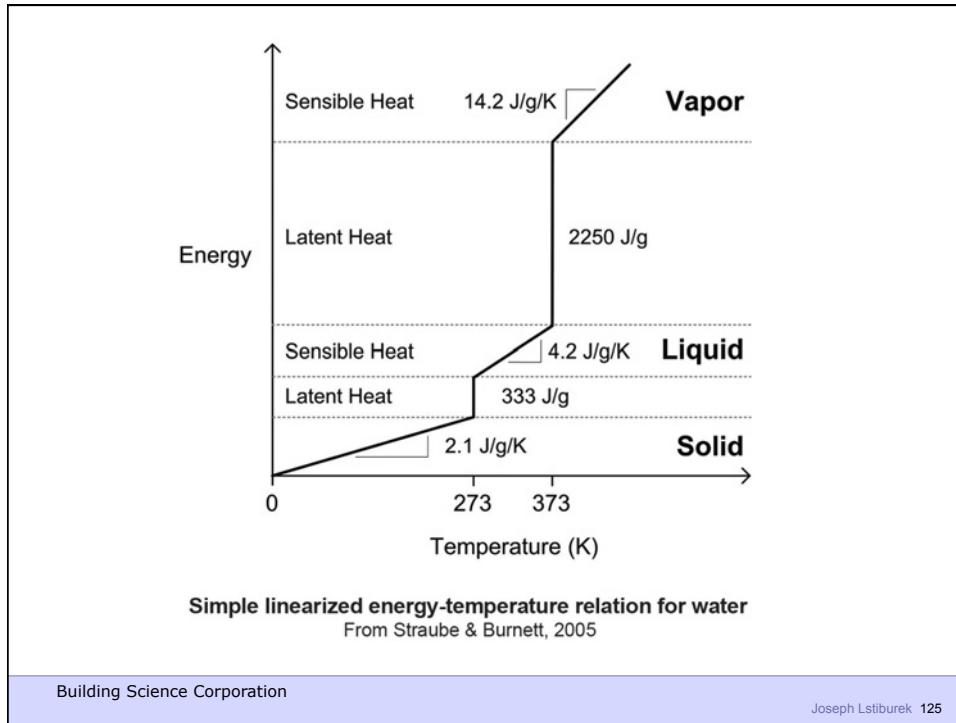


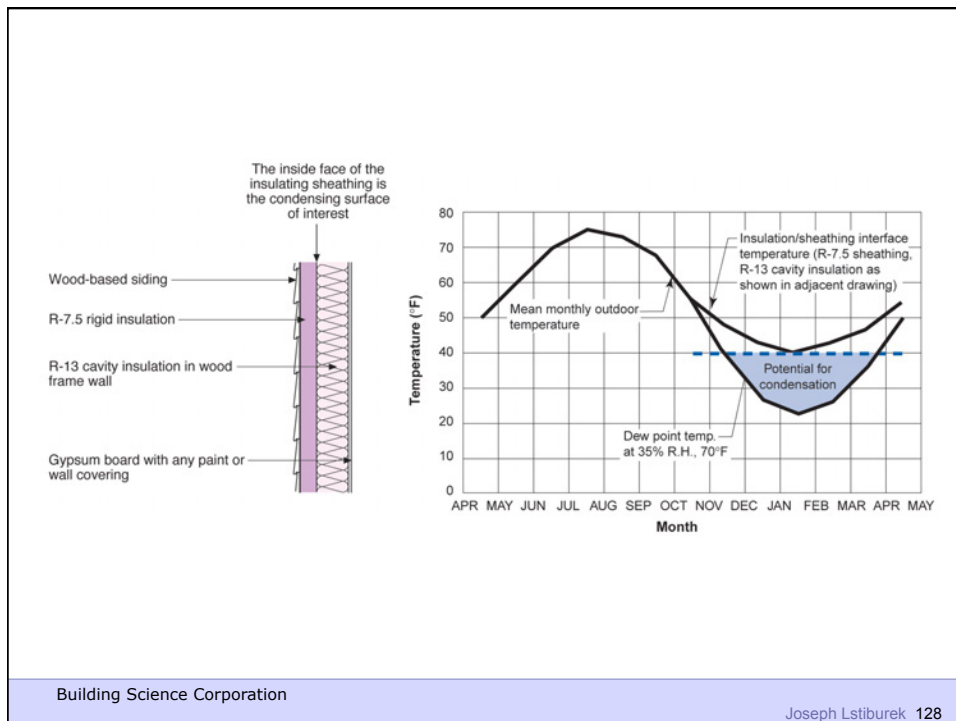
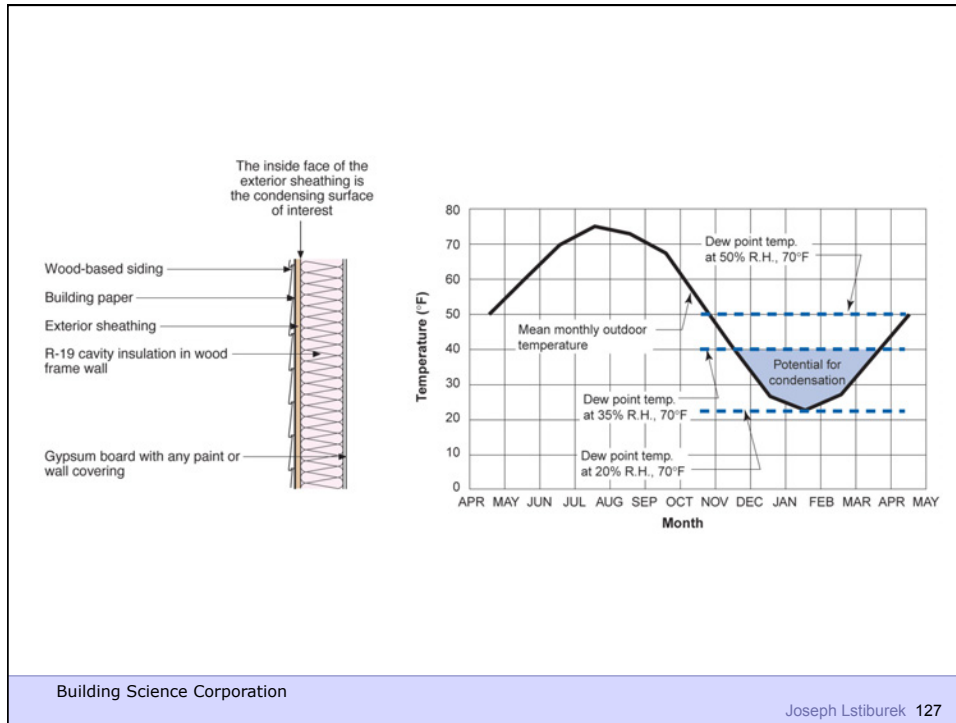




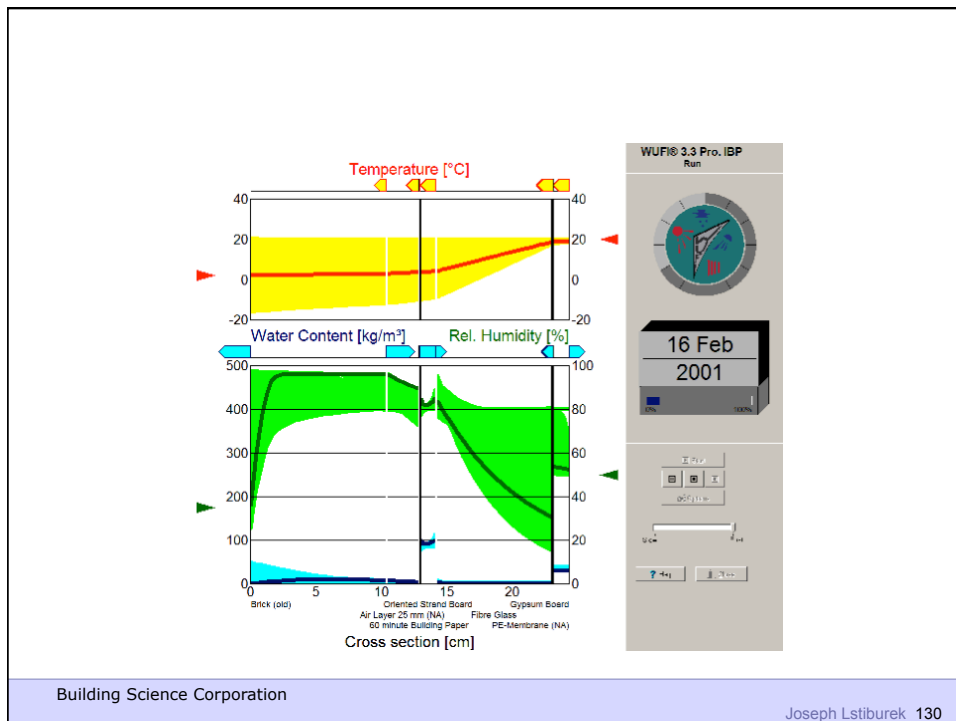
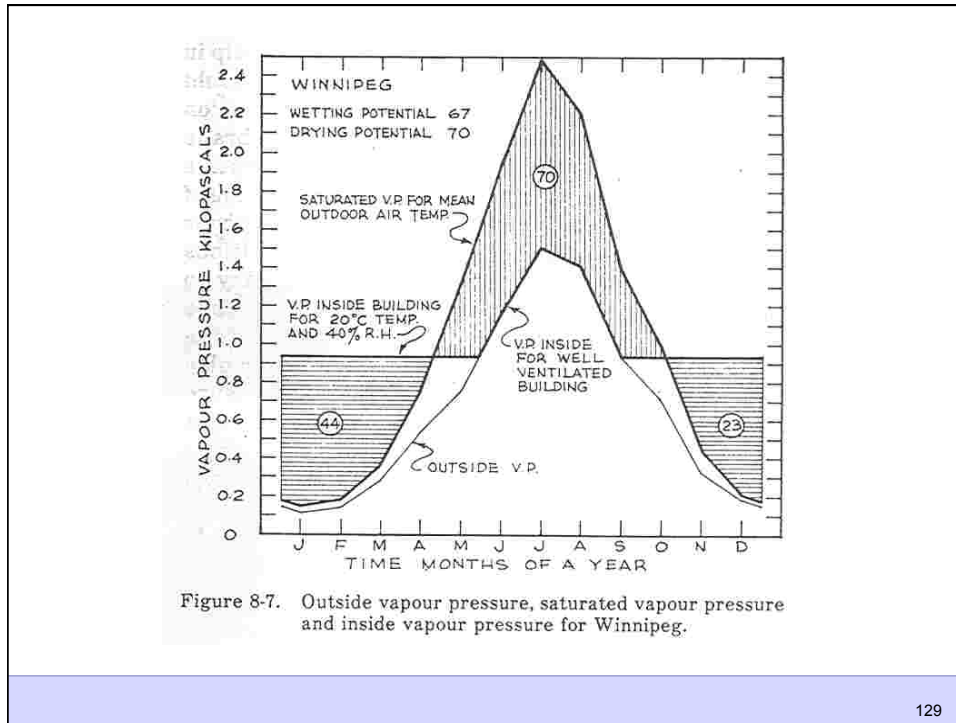


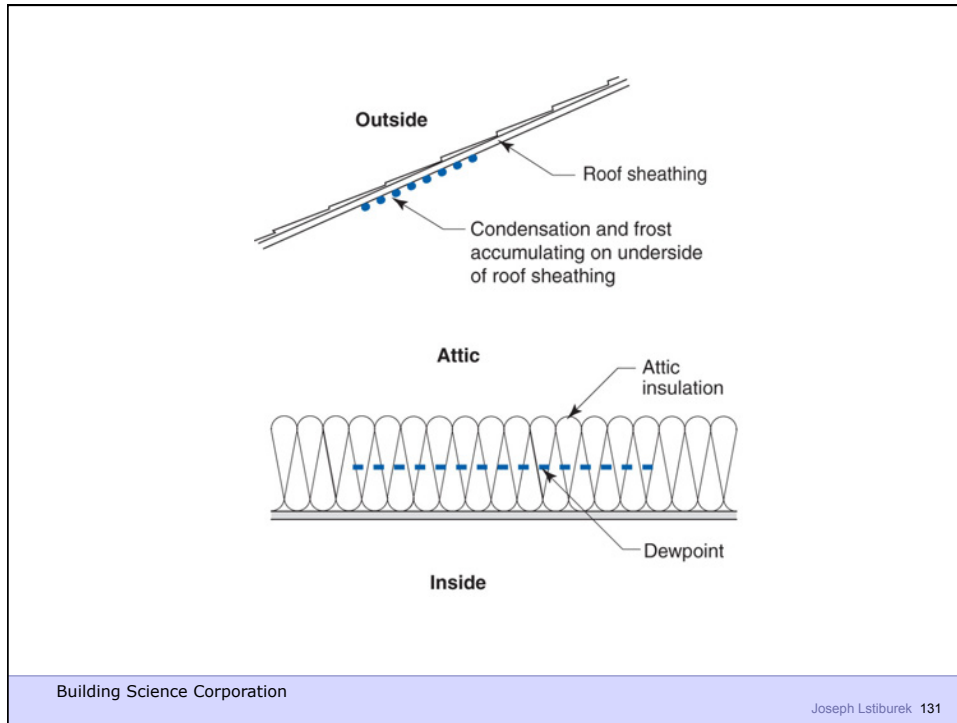


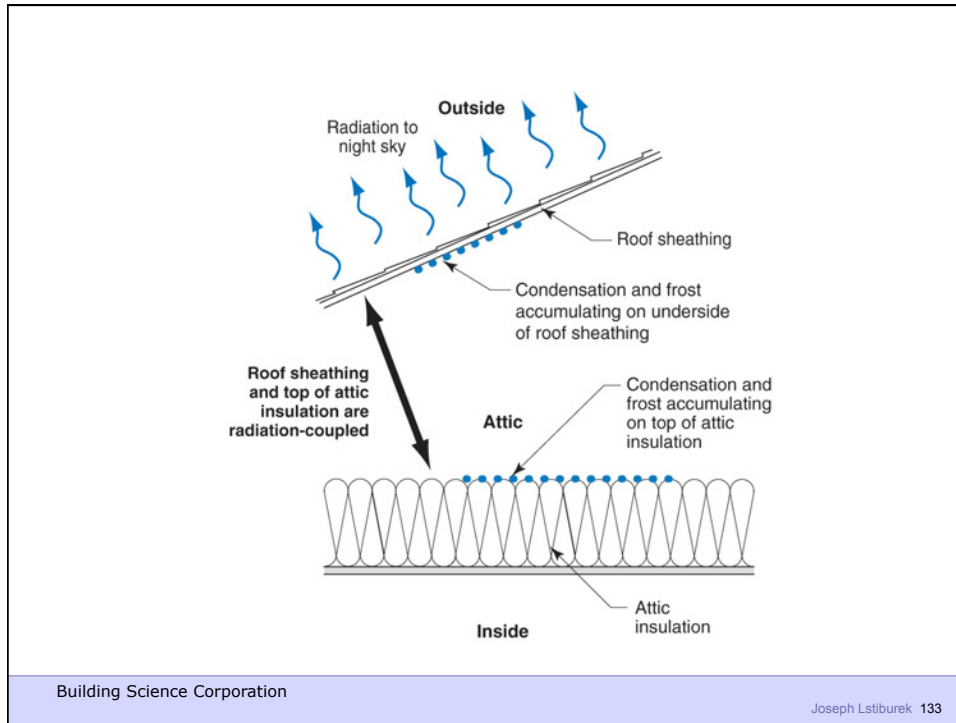


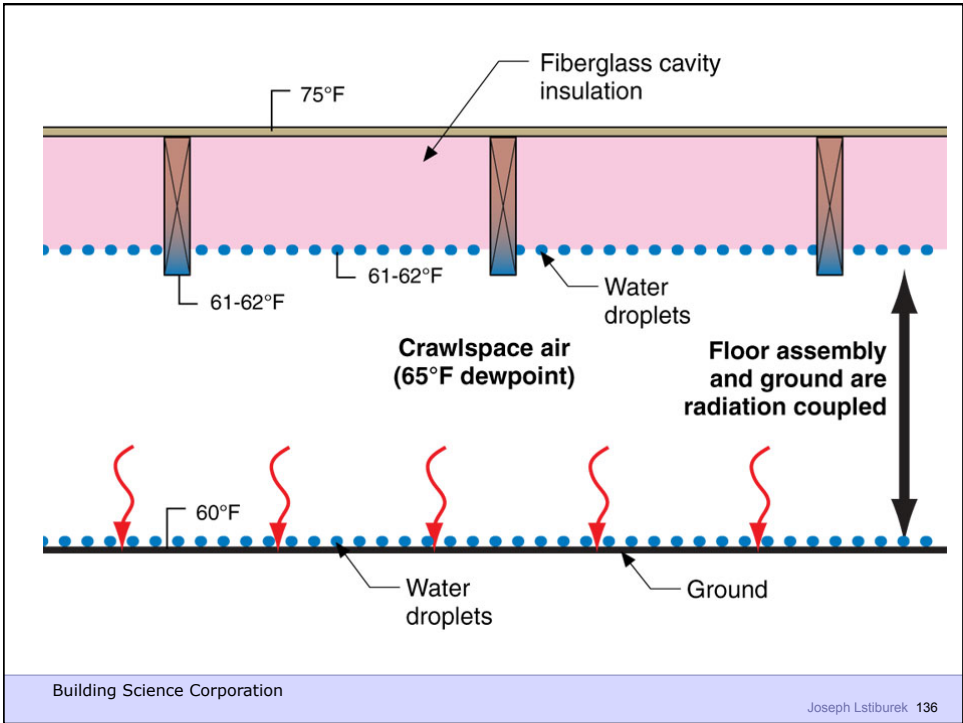


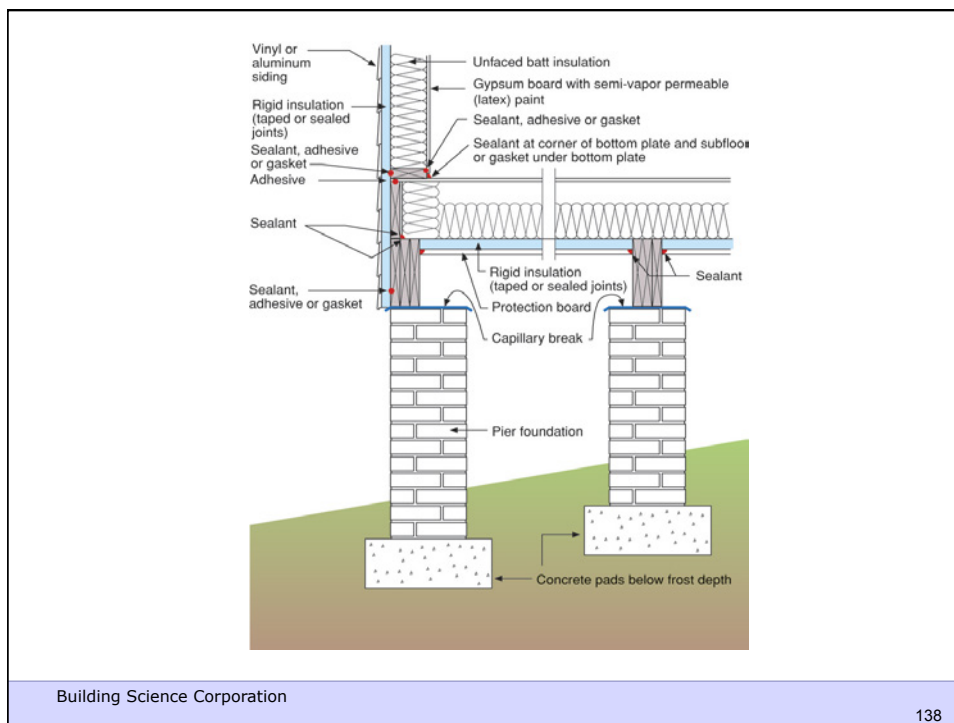
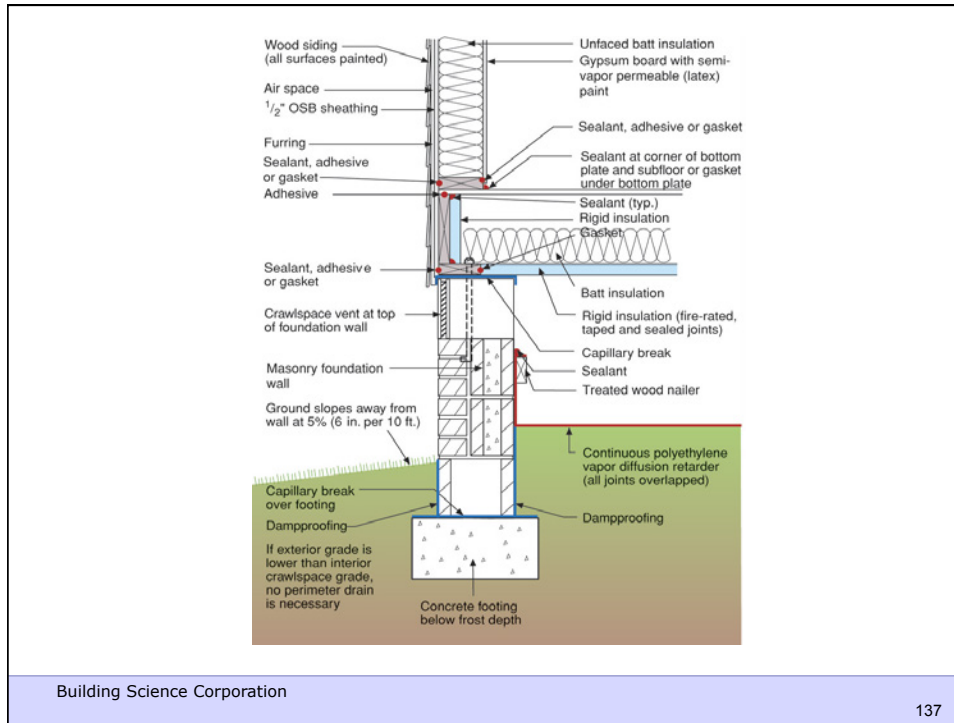


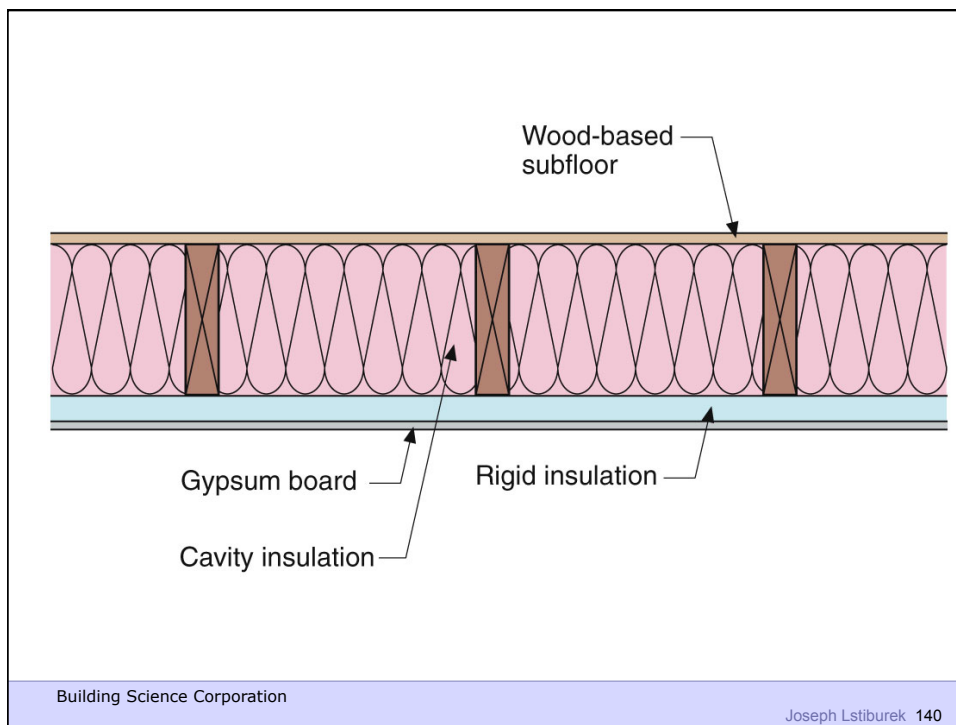
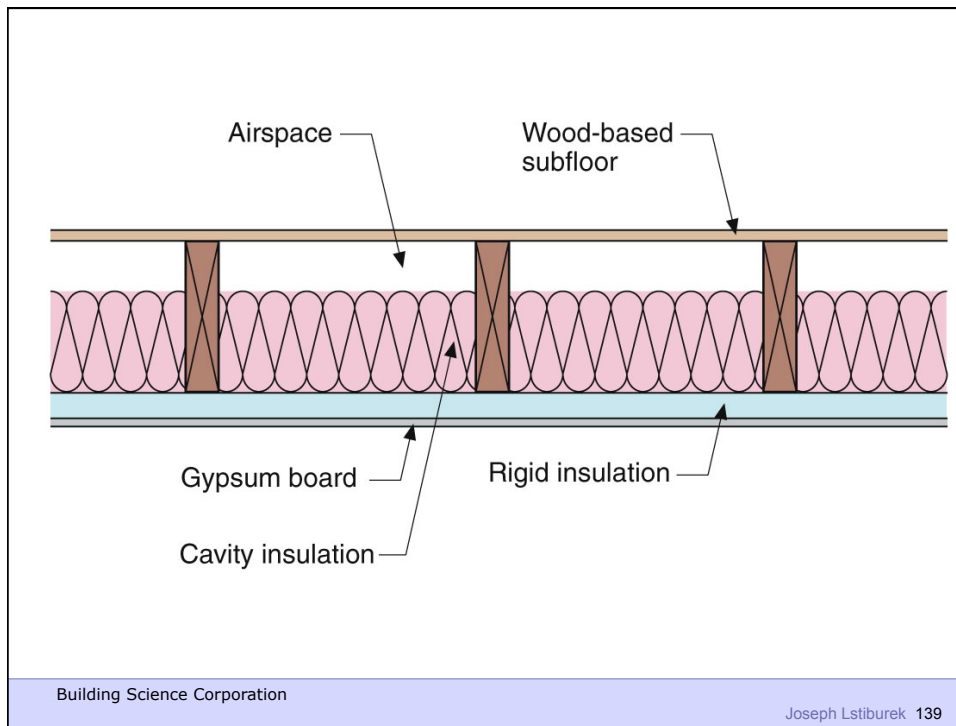


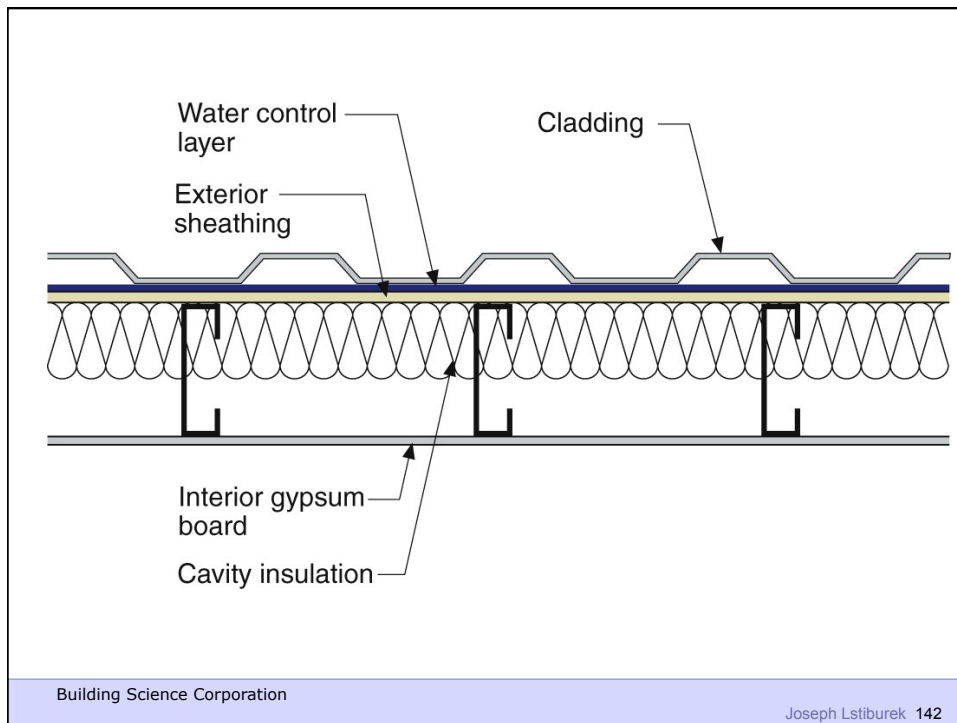
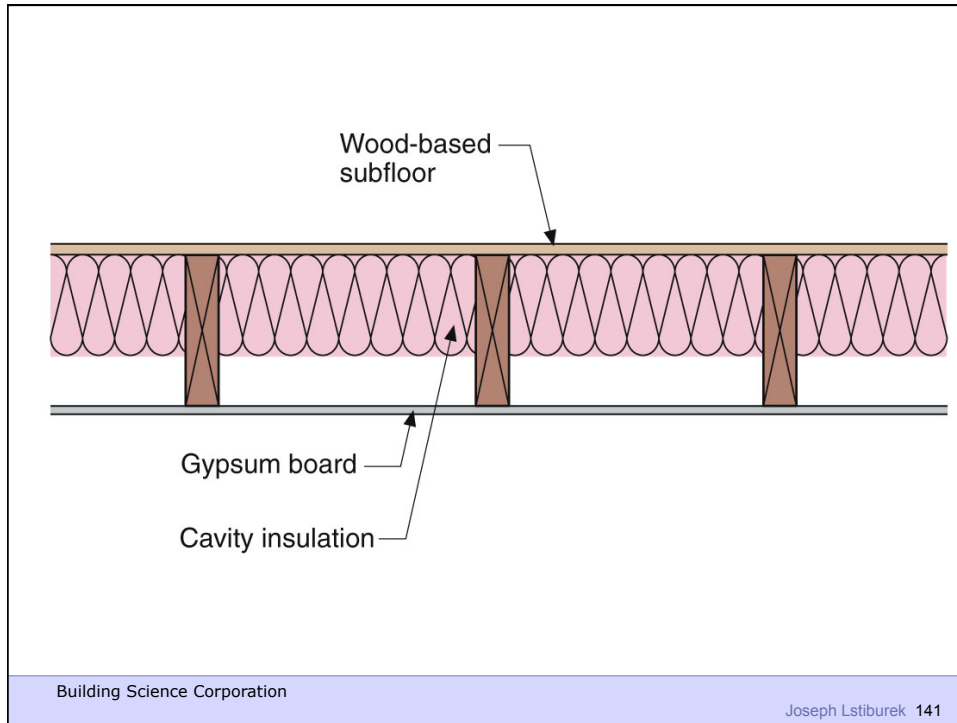


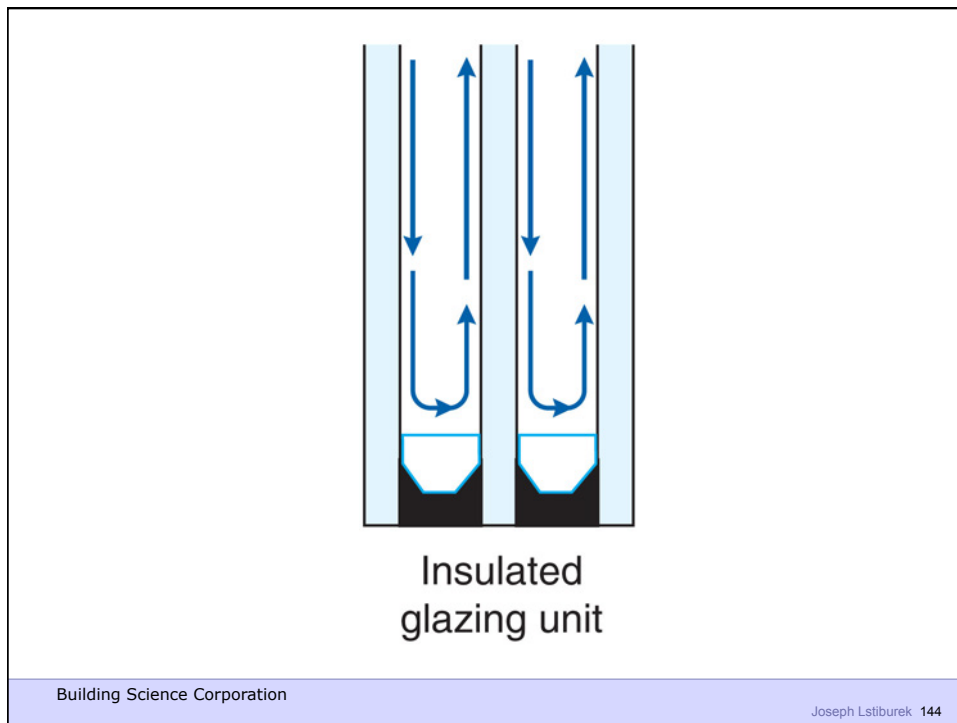
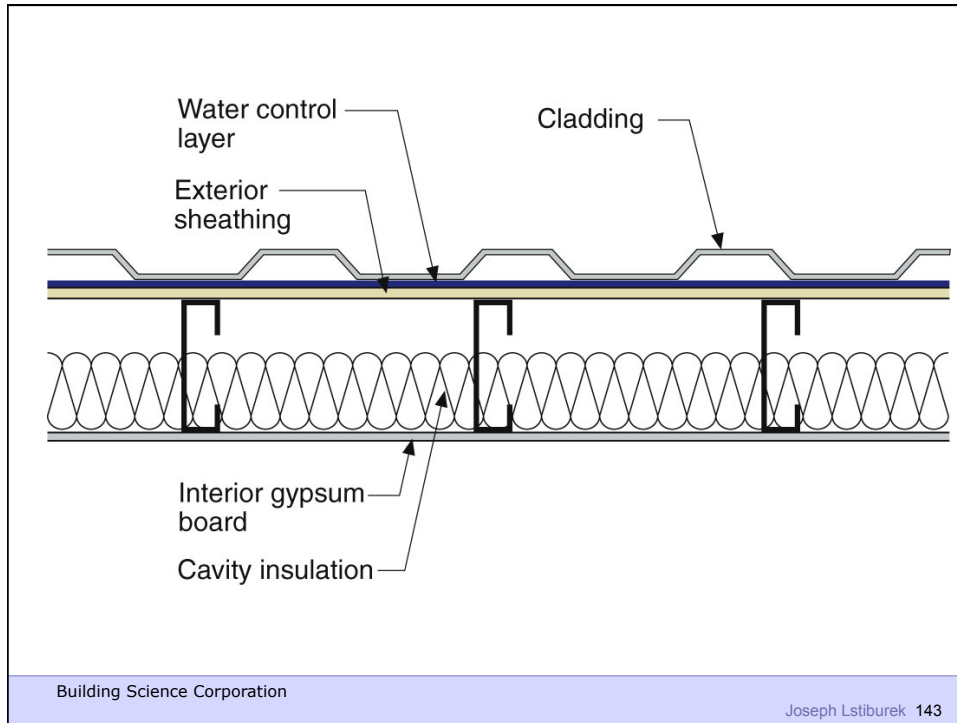




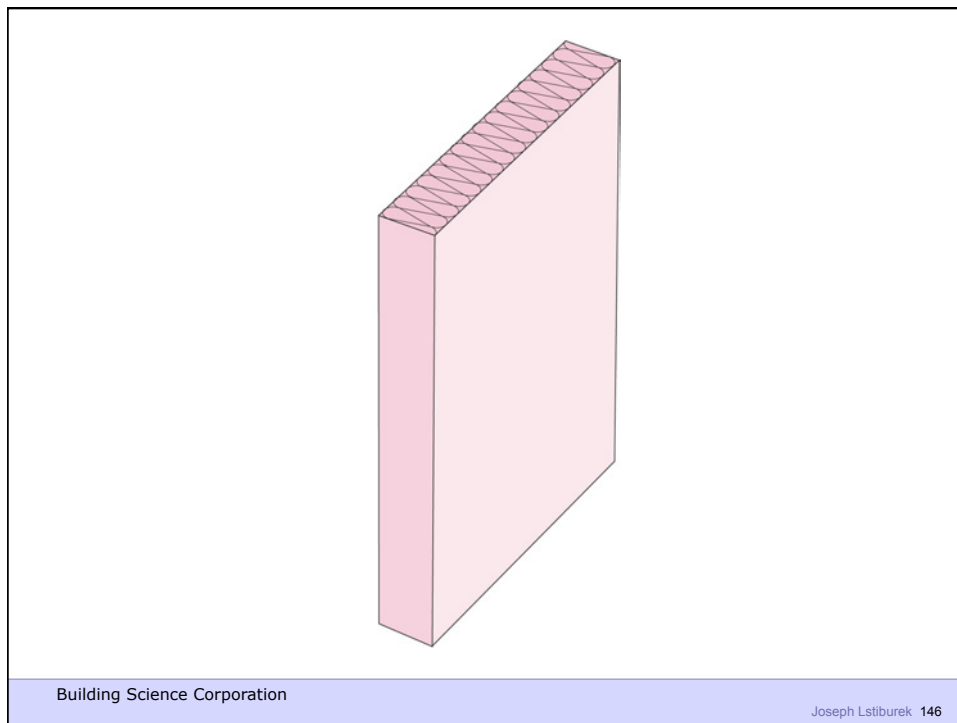
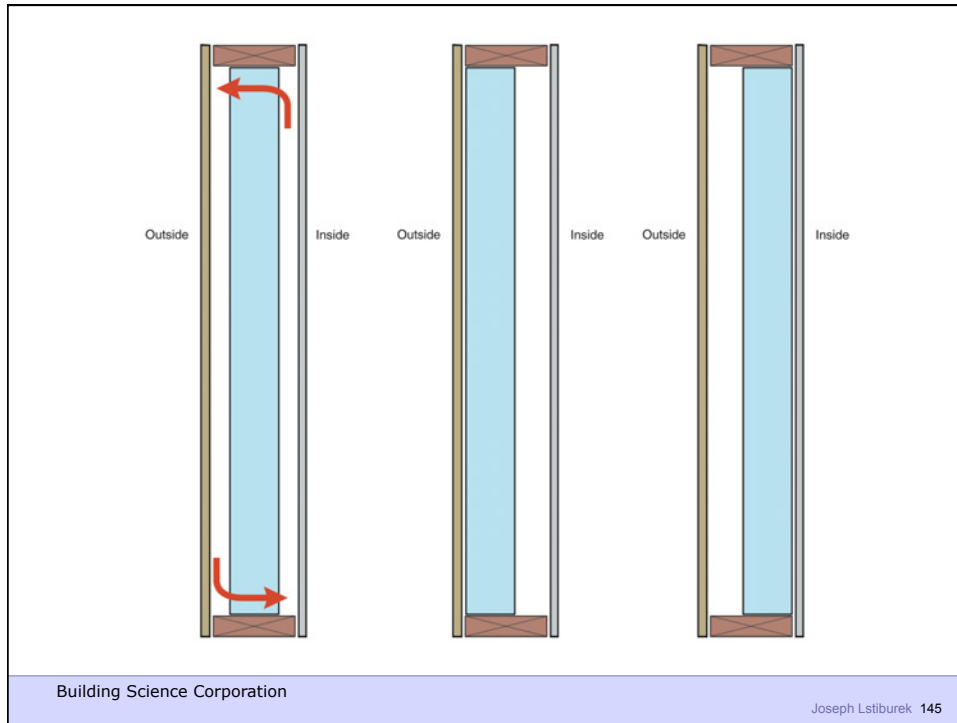


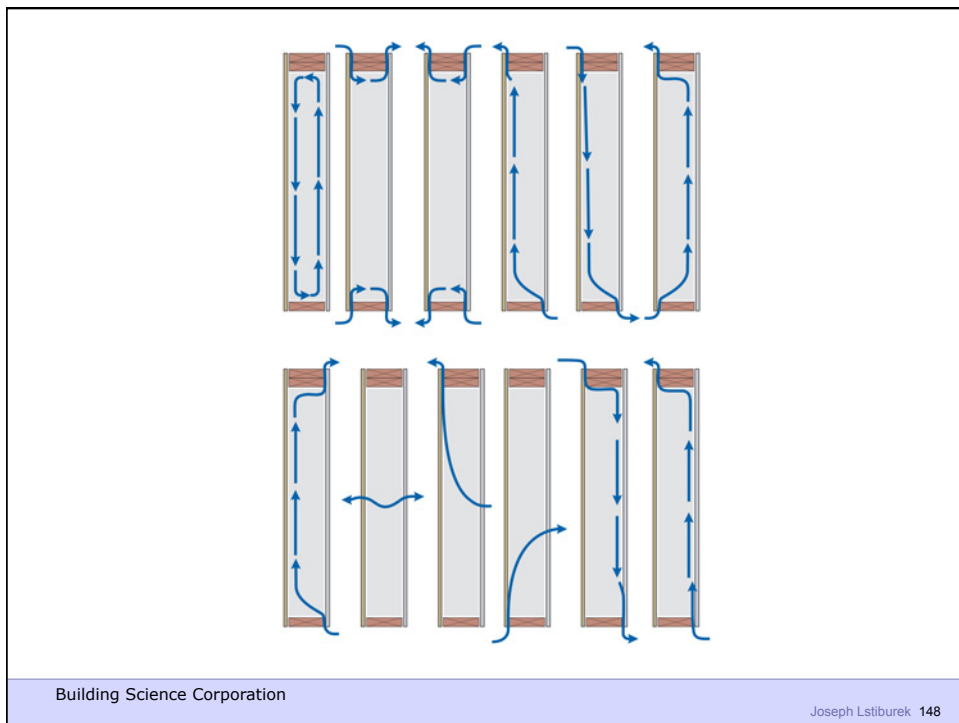
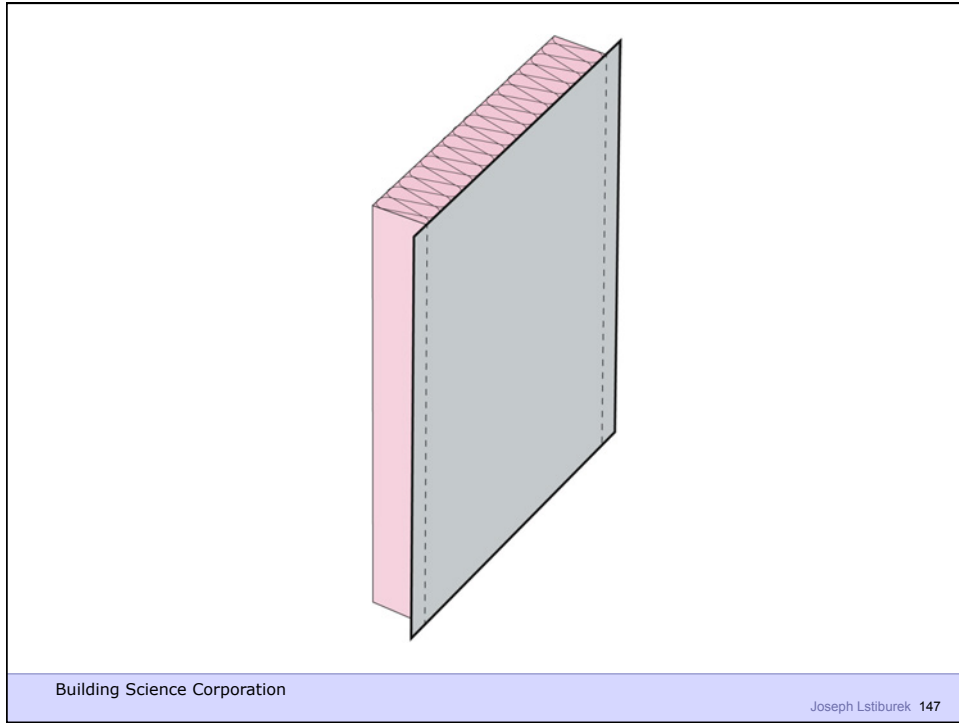


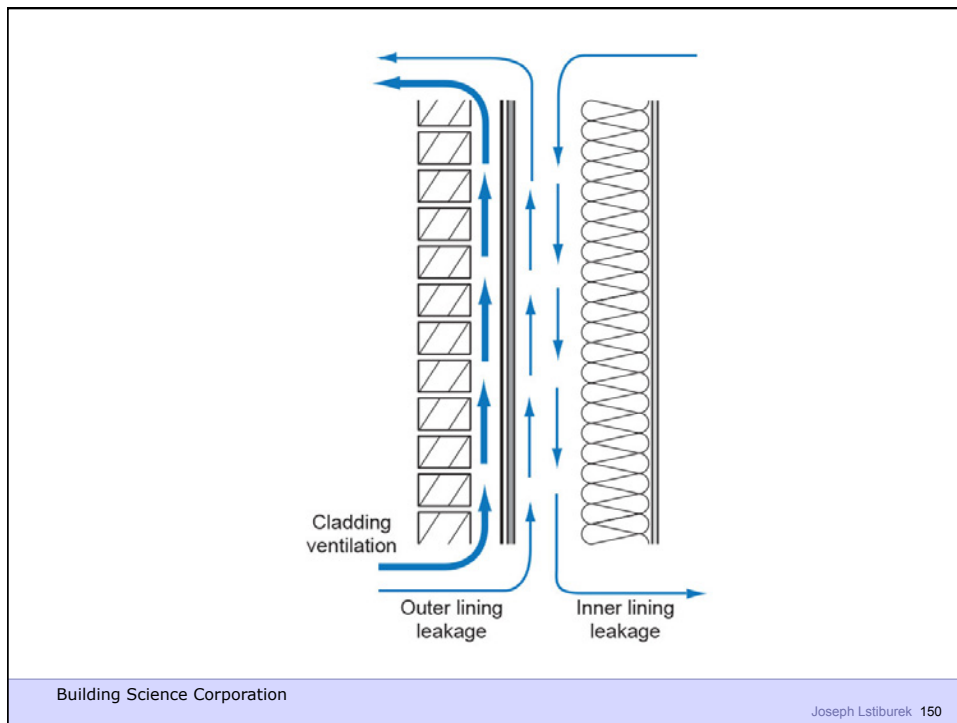
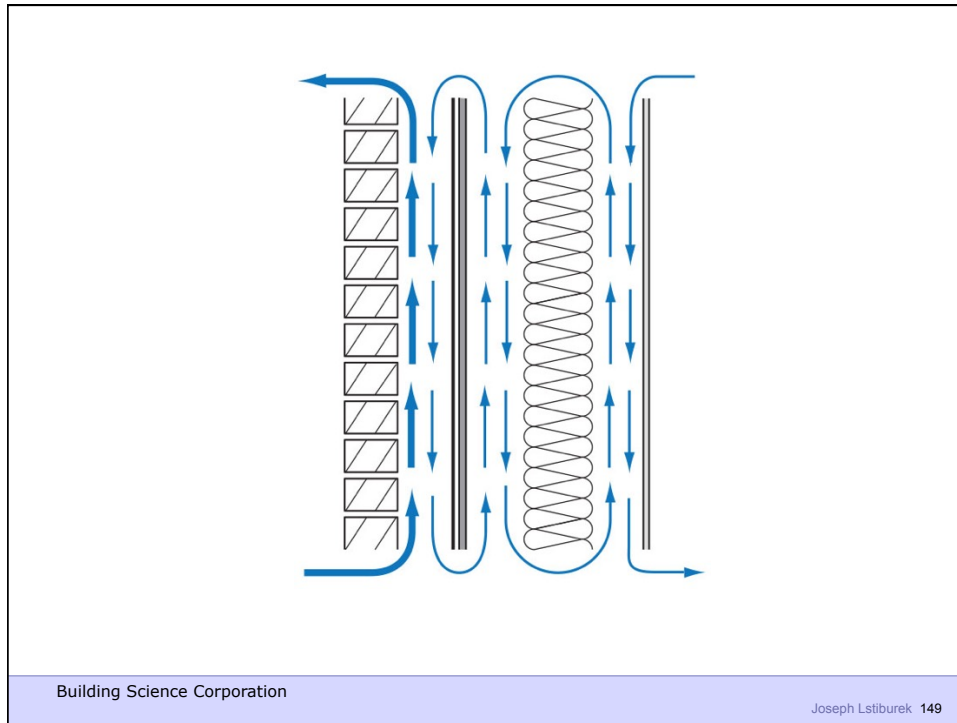


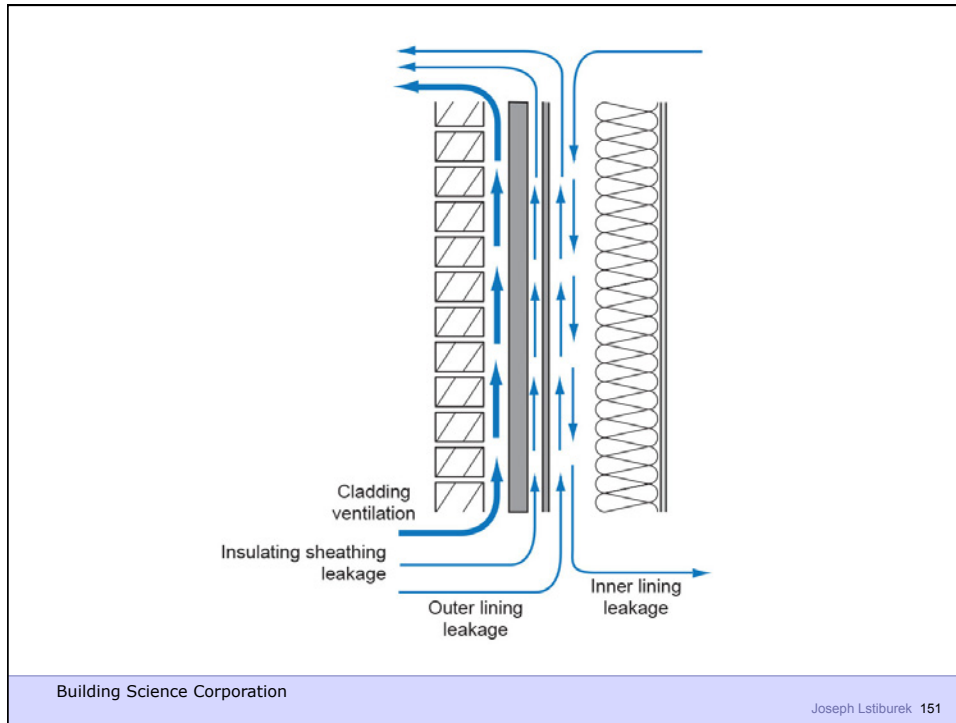










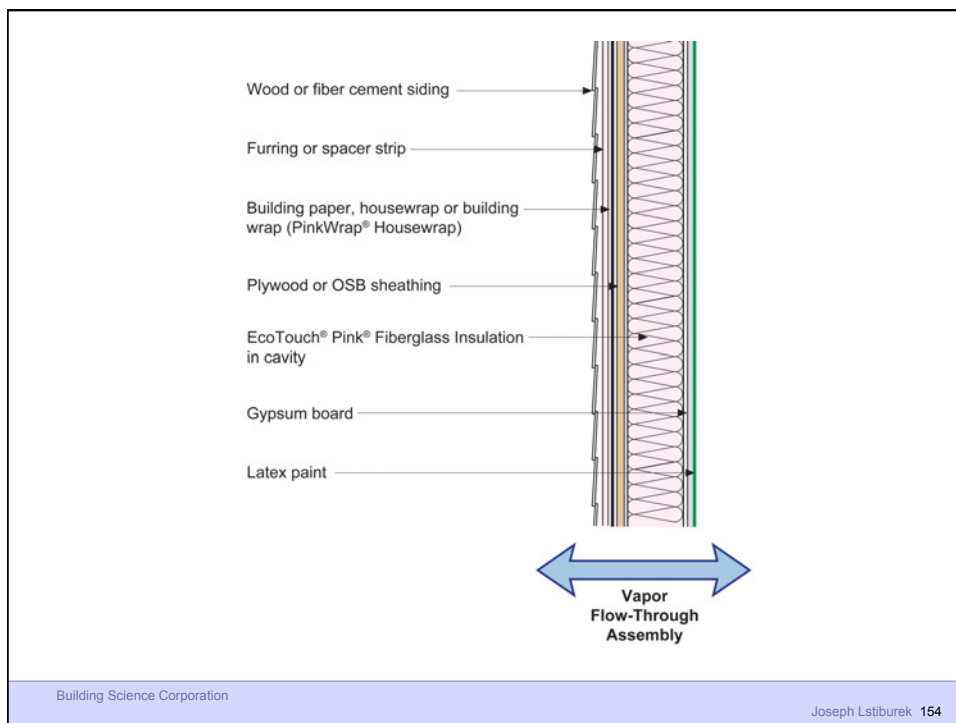
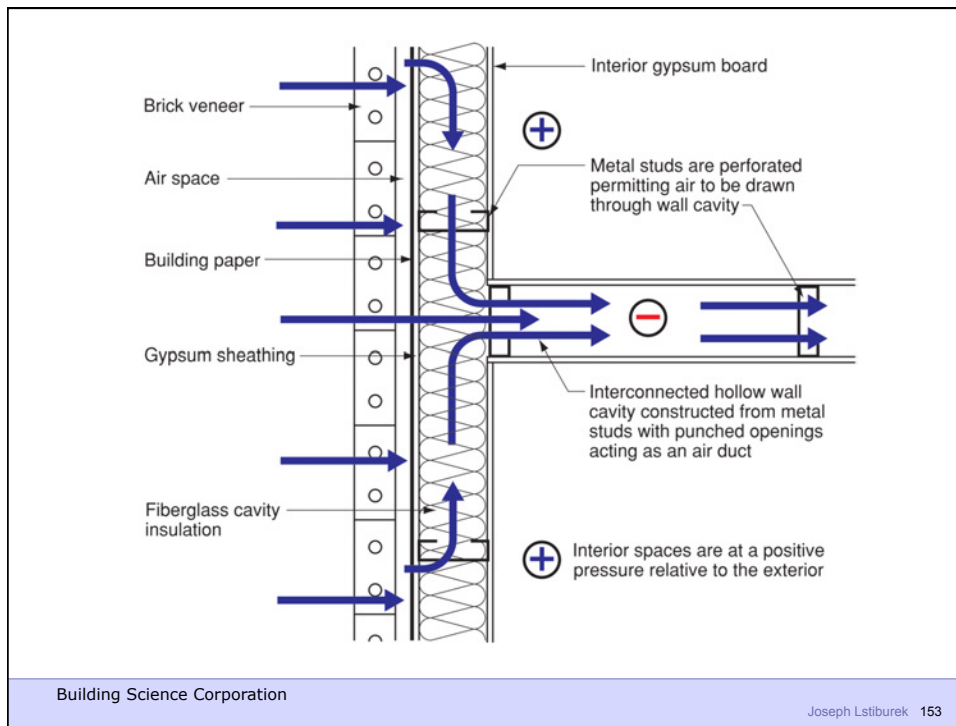


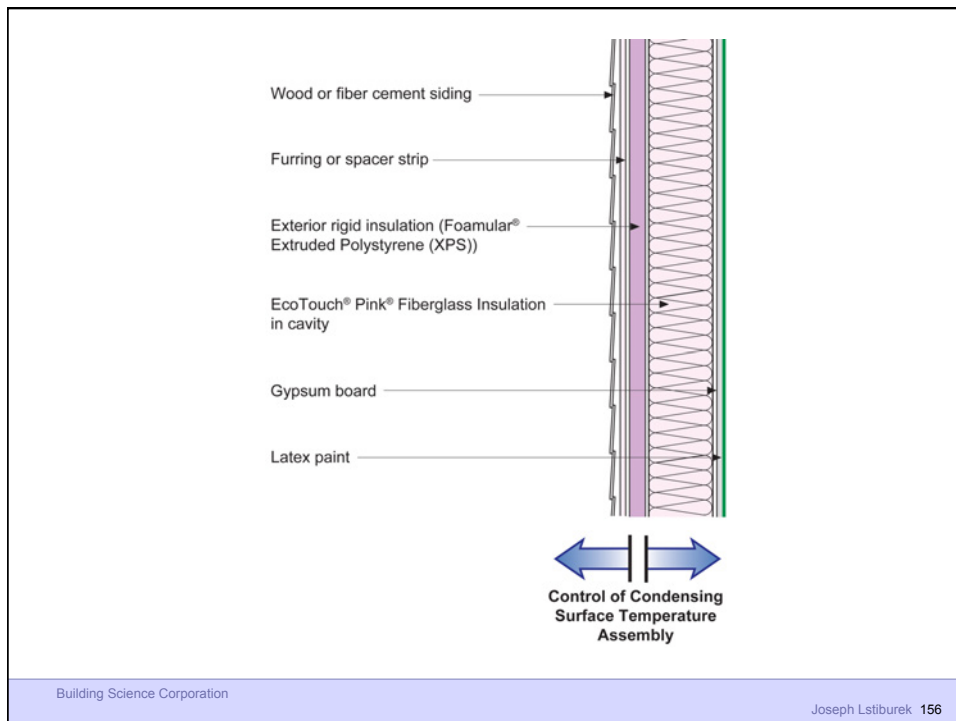
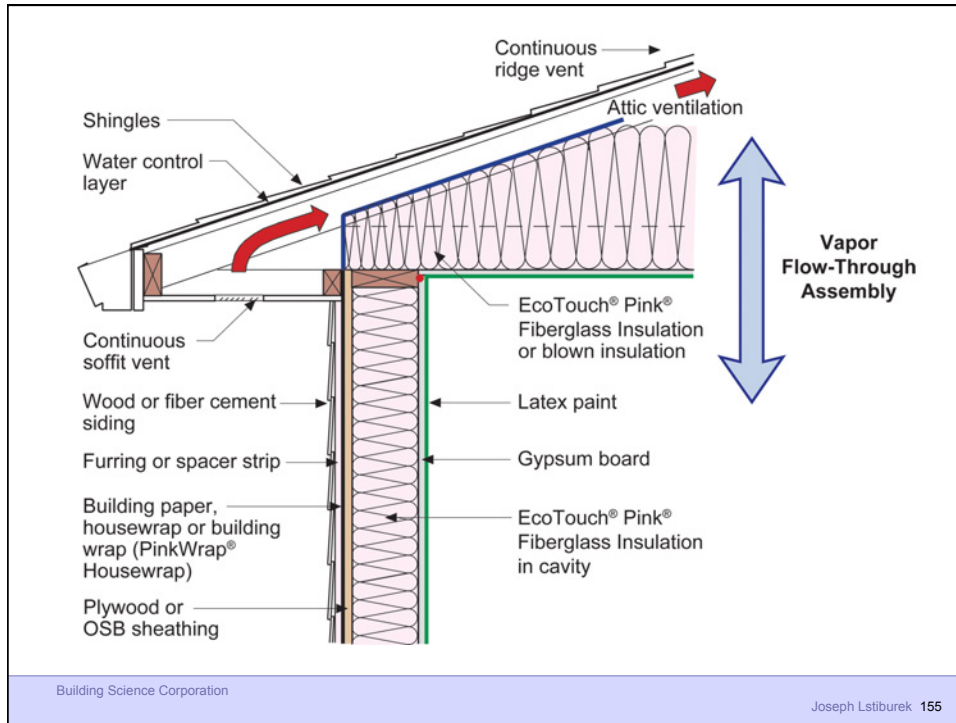
**Cladding Ventilation/ Sheathing Ventilation**

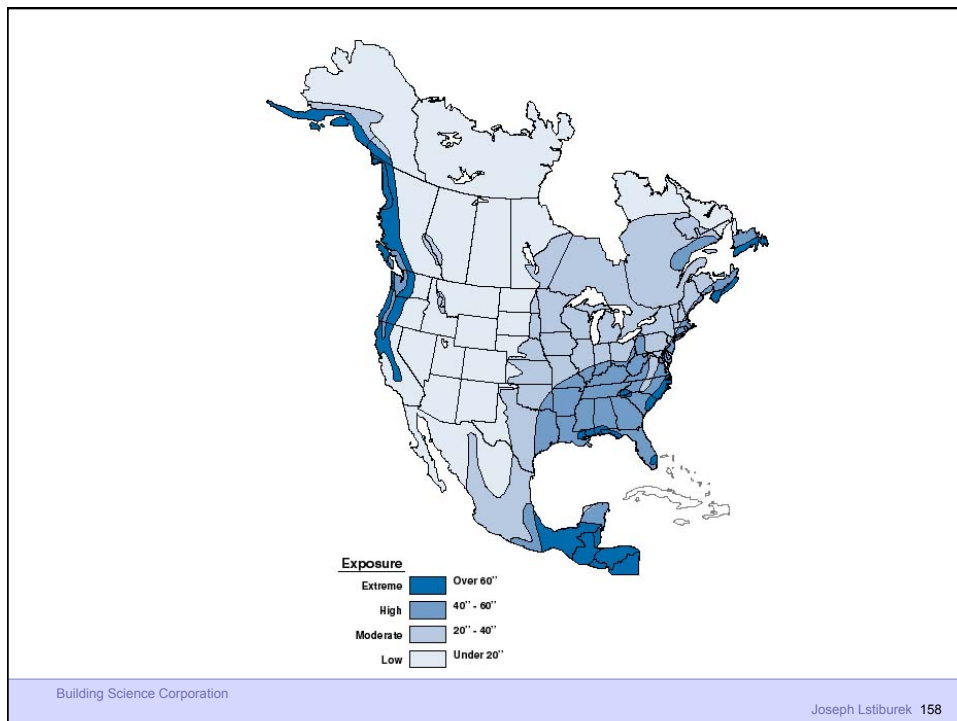
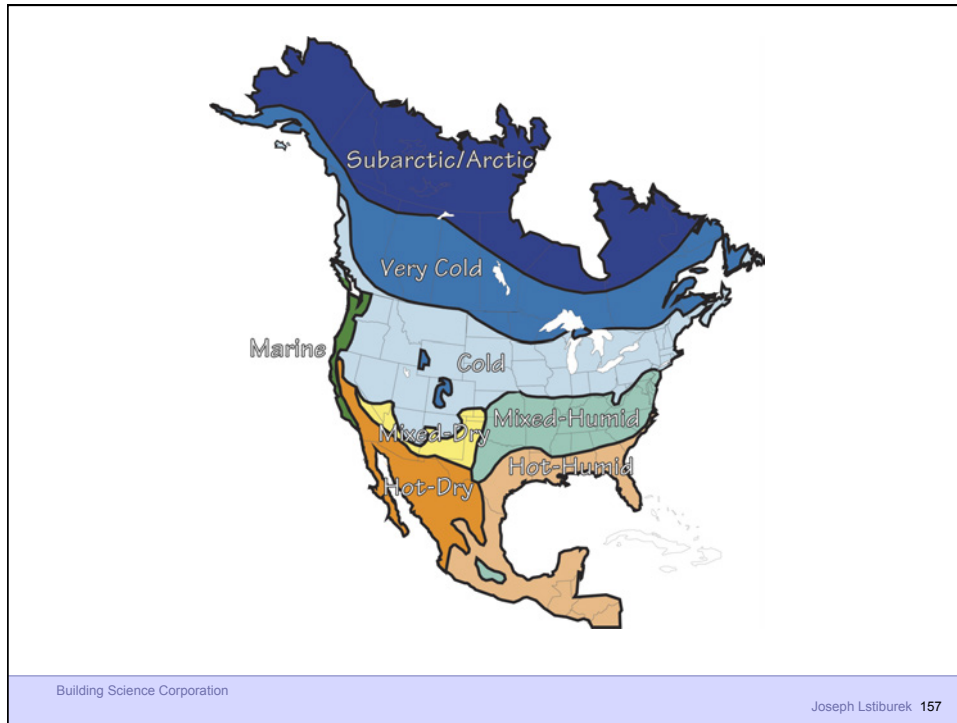
	Flow Rate	Gap	ACH
Wood Siding	0.1 cfm/sf	3/16"	20
Vinyl Siding	0.5 cfm/sf	3/16"	200
Brick Veneer	0.15 cfm/sf	1"	10
Stucco (vented)	0.1 cfm/sf	3/8"	10
Stucco (direct applied)	none	none	0
Sheathing flanking flow	0.05 cfm/sf	3/16"	10

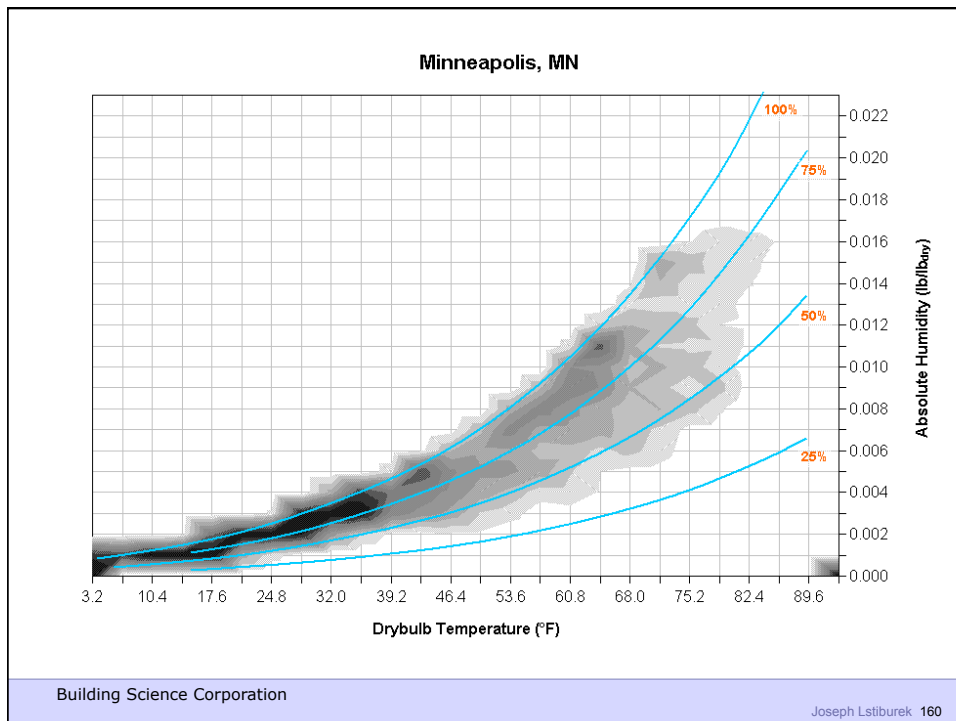
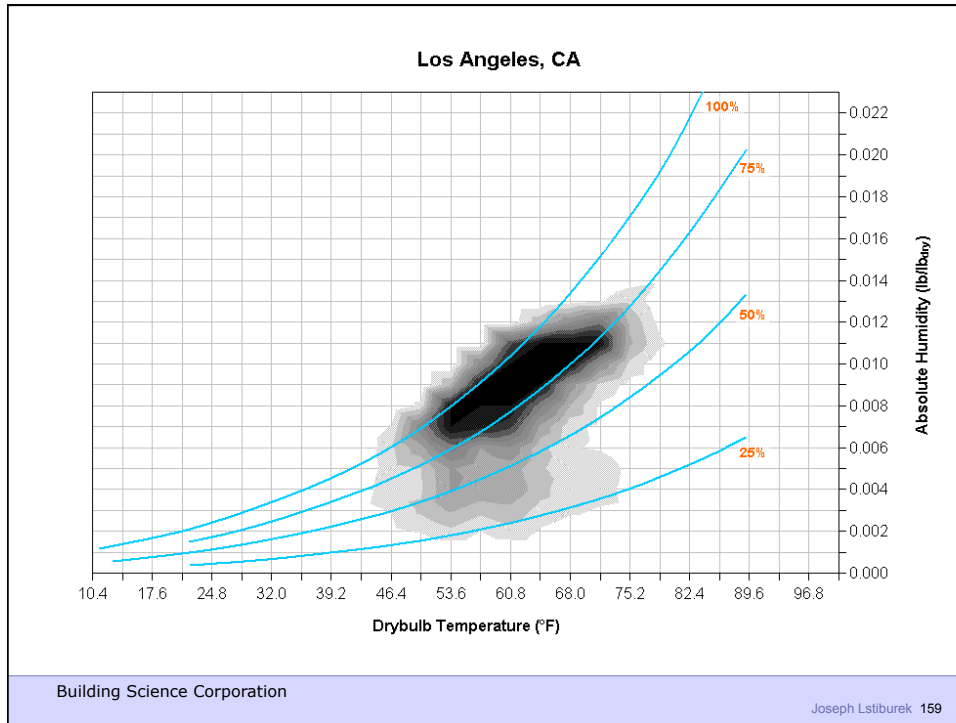
Building Science Corporation

Joseph Lstiburek 152

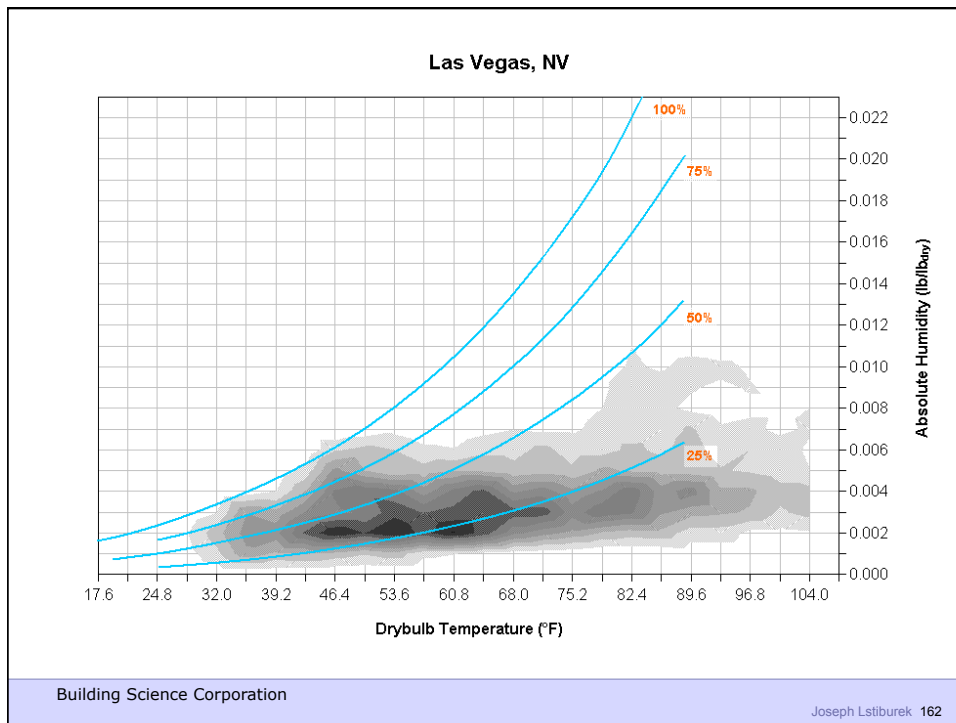
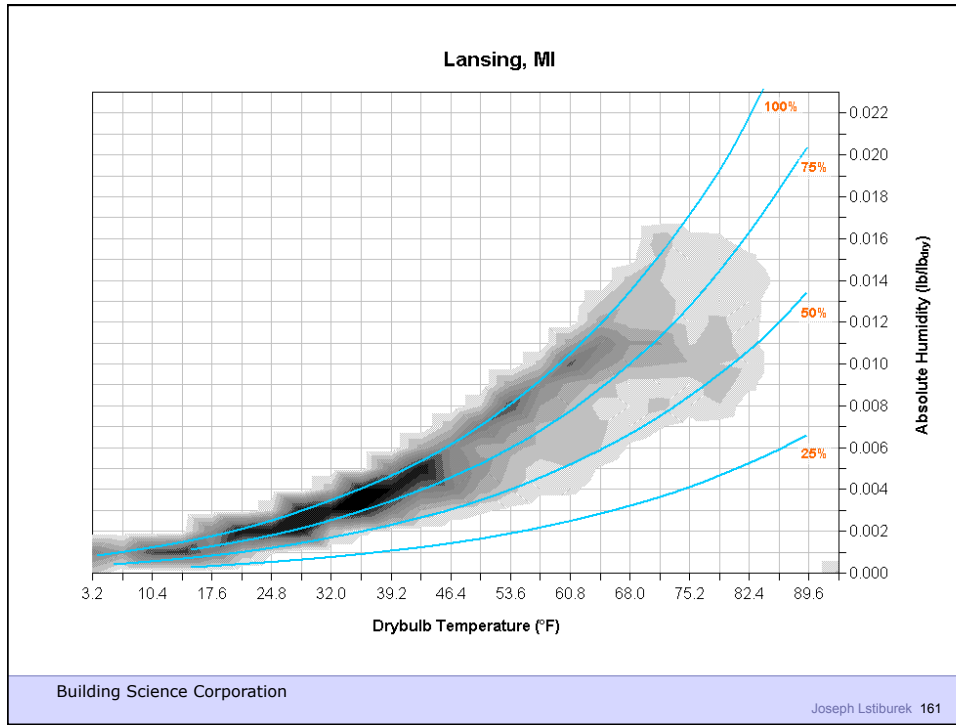


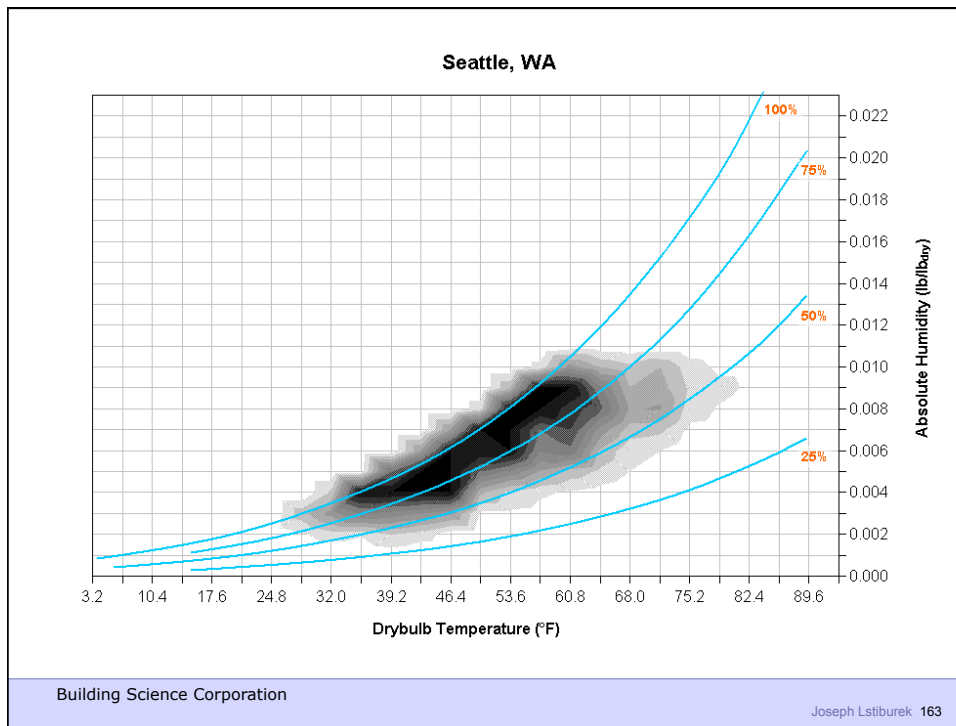












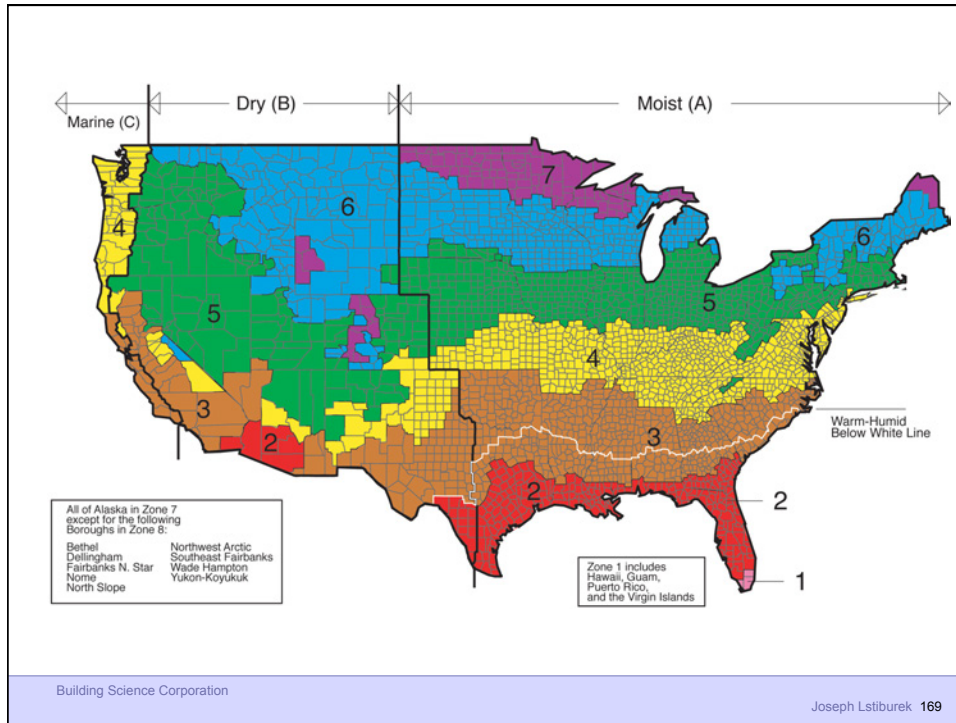
Don't Do Stupid Things

Building Science Corporation

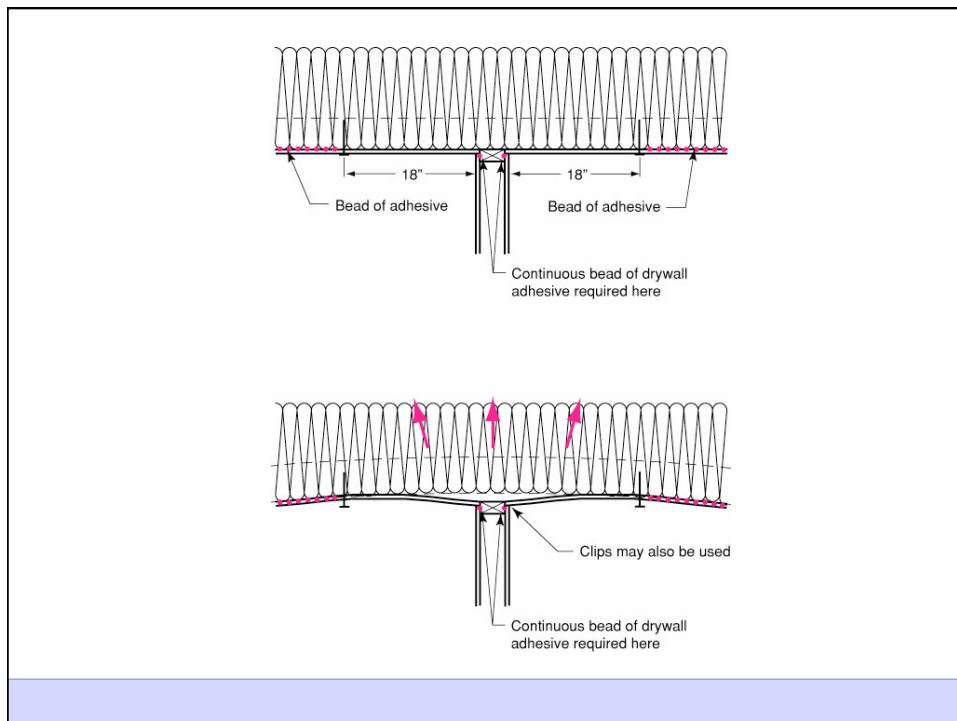
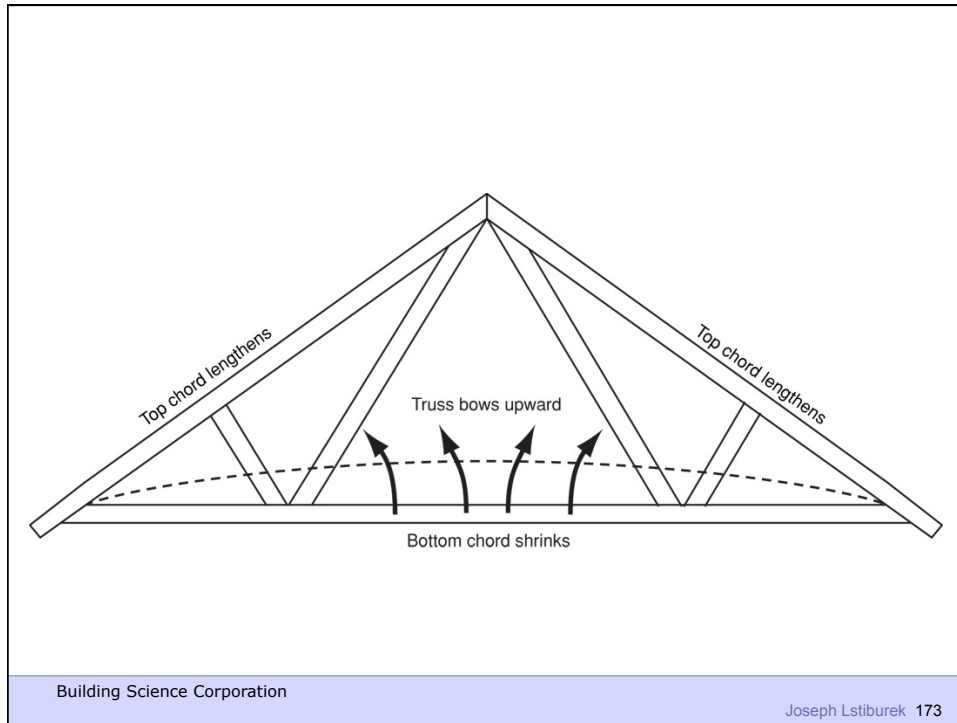
Joseph Lstiburek 164

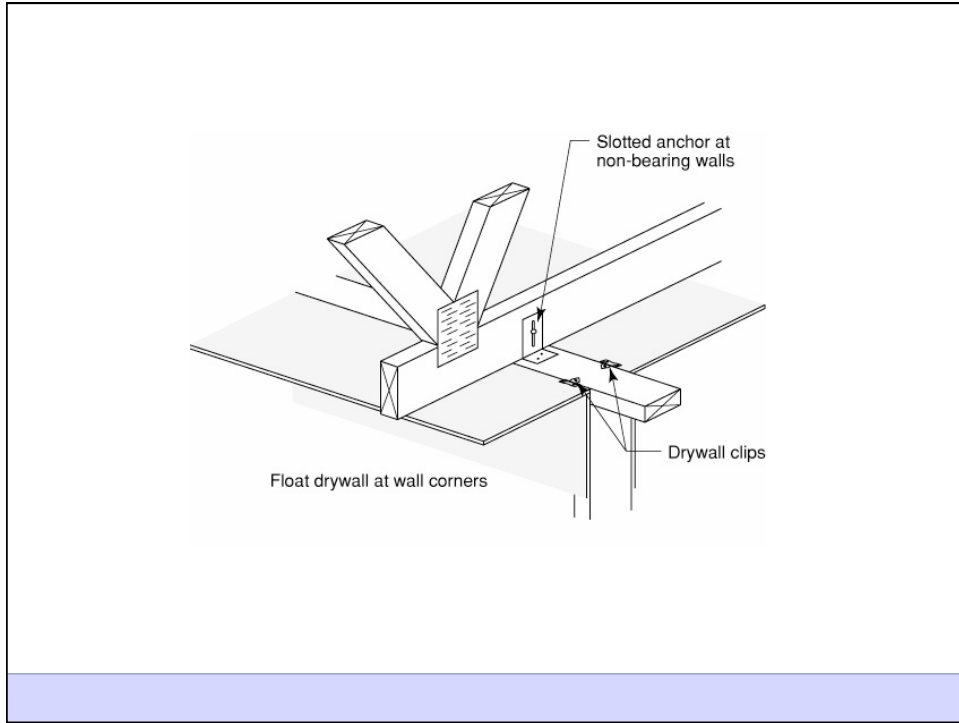
















Exterior Conditions	Conditions within Cavity:	Interior Conditions
Temperature: 80°F Relative humidity: 75% Vapor pressure: 2.49 kPa	Temperature: 100°F Relative humidity: 100% Vapor pressure: 6.45 kPa	Temperature: 75°F Relative humidity: 60% Vapor pressure: 1.82 kPa

Solar radiation strikes wall

Brick veneer is saturated with rainwater

1-inch air space

Felt paper

Fiberboard sheathing

Fiberglass insulation

Polyethylene

Interior gypsum board

Vapor is driven both inward and outward by a high vapor pressure differential between the brick and the interior and the brick and the exterior.

- It is not a good idea to install a vapor barrier (polyethylene) on the inside of an air conditioned assembly. Vinyl wall coverings and foil-backed batt cavity insulation should also be avoided.
- Vapor permeable exterior sheathings, housewraps or building papers should not be used with absorptive claddings such as brick veneers unless a ventilated cavity is provided in conjunction with high inward drying potentials (i.e. no interior polyethylene vapor barriers).
- Failure will occur when brick is installed over a frame wall constructed with felt paper, fiberboard sheathing and an interior polyethylene vapor barrier. Kraft-faced fiberglass batts should be used in place of unfaced batts and a polyethylene vapor barrier. OSB, plywood or foam sheathing should be used in place of the fiberboard sheathing.
- Similar problems occur with stucco.

Building Science Corporation

Joseph Lstiburek 178

Brick veneer back-ventilated to flush inward-driven moisture out of assembly

Air outlet

Drainage plane

Clear 1" air space open at both bottom and top

Air inlet

Seat in foundation acting as flashing

- To effectively uncouple a brick veneer from a wall system by using back ventilation, a clear cavity must be provided along with both air inlets at the bottom and air outlets at the top

Building Science Corporation

Joseph Lstiburek 179

Brick veneer

Drainage plane

Impermeable rigid insulation

Drainage space (1/4" or greater)

Drainage or weep opening

Seat in foundation acting as flashing

- To effectively uncouple a brick veneer from a wall system by using a condensing surface, the drainage plane must also be a vapor barrier or a vapor impermeable layer (i.e. rigid insulation) must be installed between the drainage plane and the brick veneer. Alternatively, the rigid insulation can be configured to act as both the drainage plane and vapor impermeable layer.
- When a condensing surface is used to uncouple a brick veneer from a wall system, a ventilated air space is no longer necessary — i.e. the presence of mortar droppings is no longer an issue. Additionally, the width of the drainage space is almost irrelevant.

Building Science Corporation

Joseph Lstiburek 180



Building Science Corporation

Joseph Lstiburek 181



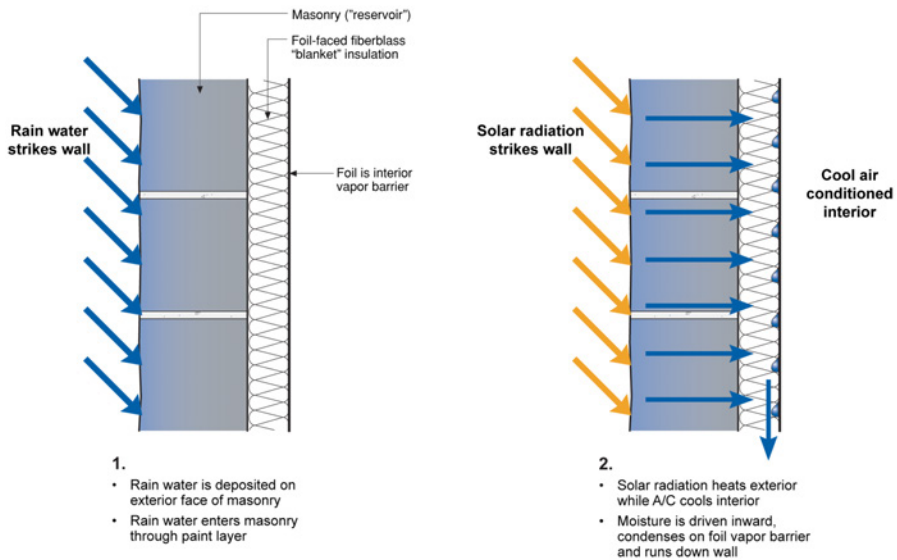
Building Science Corporation

Joseph Lstiburek 182



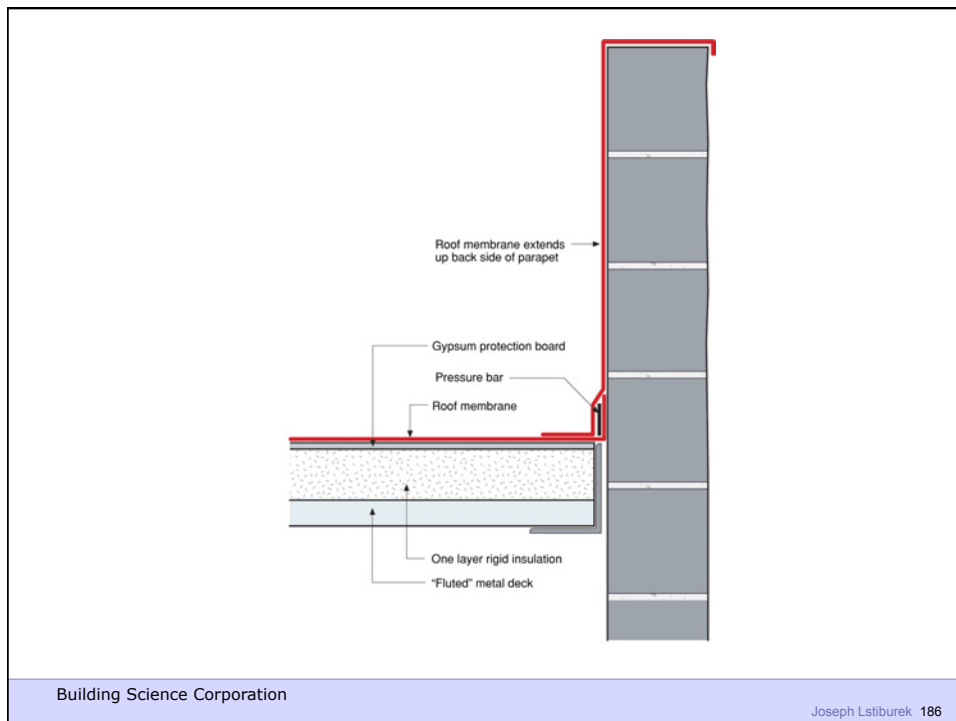
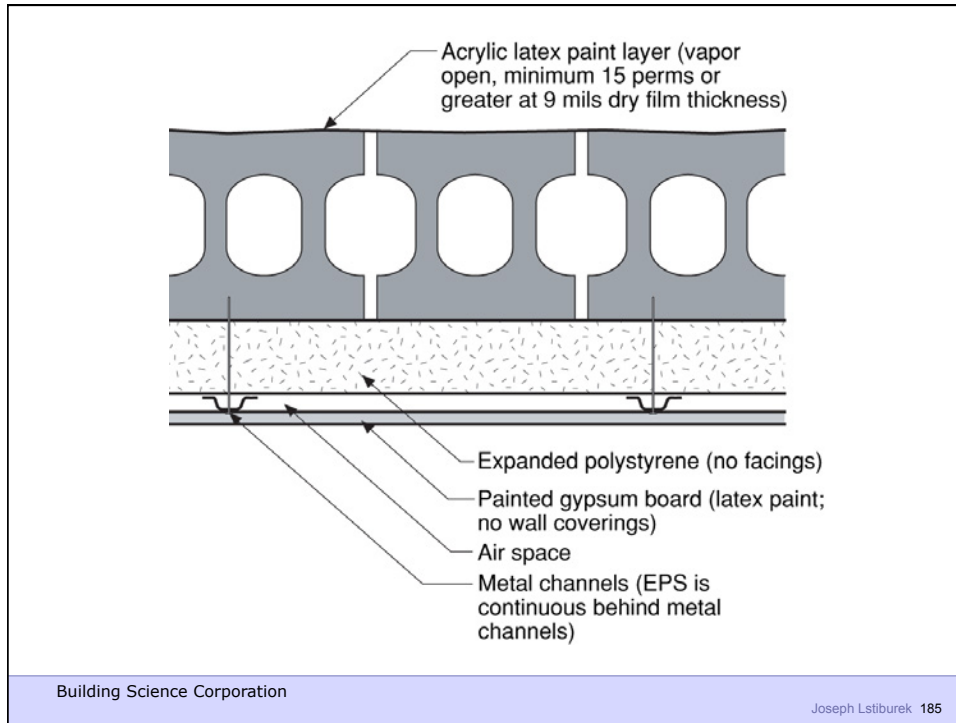
Building Science Corporation

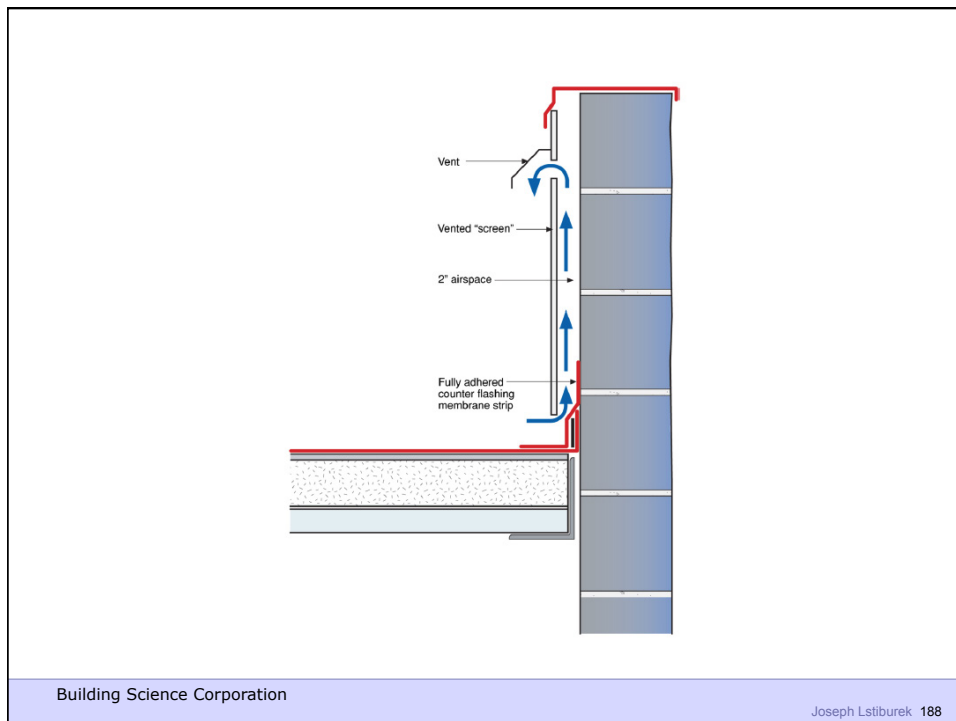
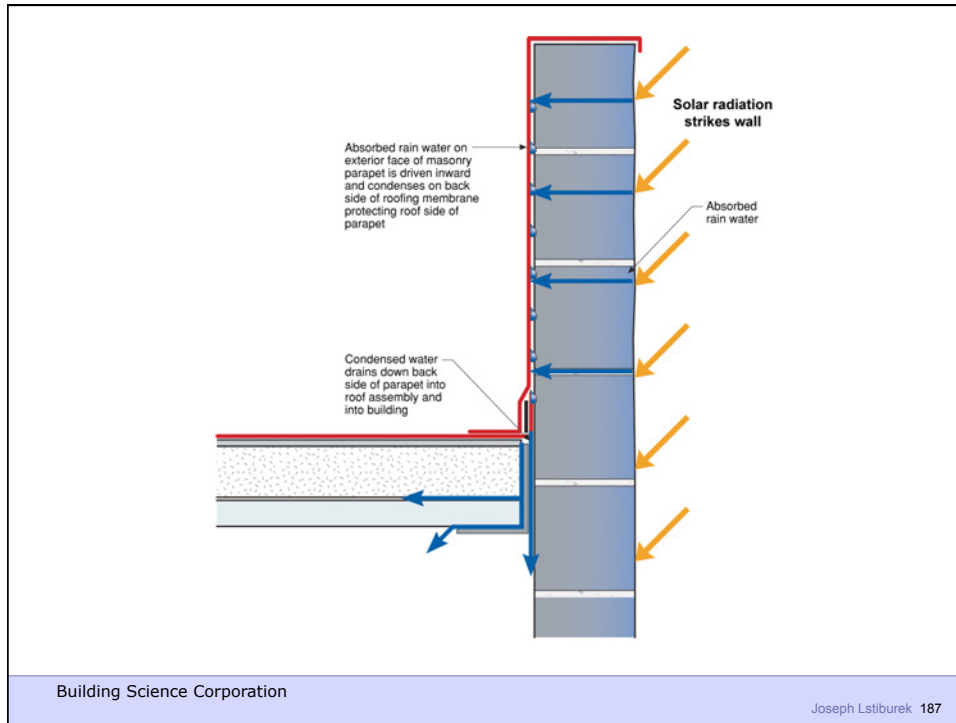
Joseph Lstiburek 183



Building Science Corporation

Joseph Lstiburek 184





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

# Building Science

## Rain Control

[www.buildingscience.com](http://www.buildingscience.com)



Building Science Corporation

Joseph Lstiburek – Rain Control 2



Building Science Corporation

Joseph Lstiburek – Rain Control 3



Building Science Corporation

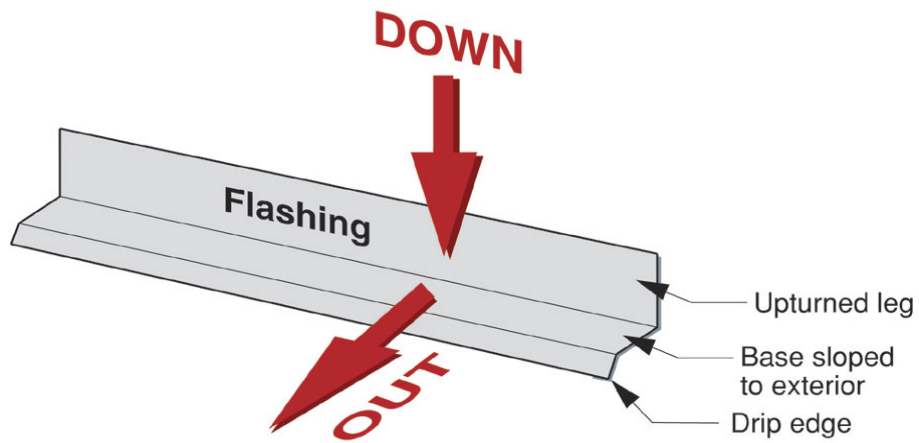
Joseph Lstiburek – Rain Control 4





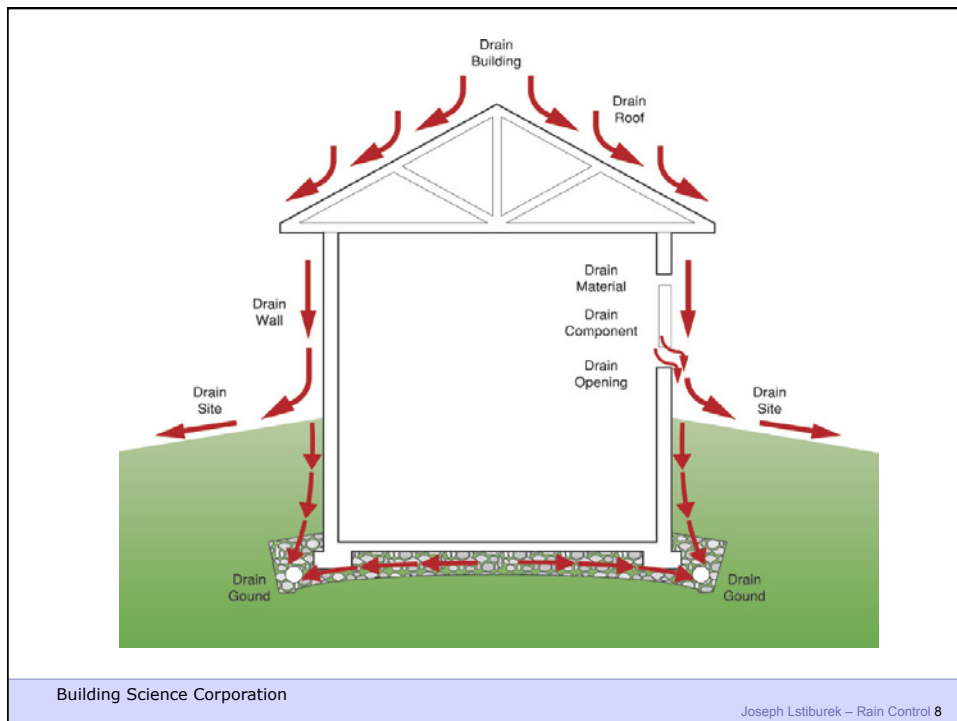
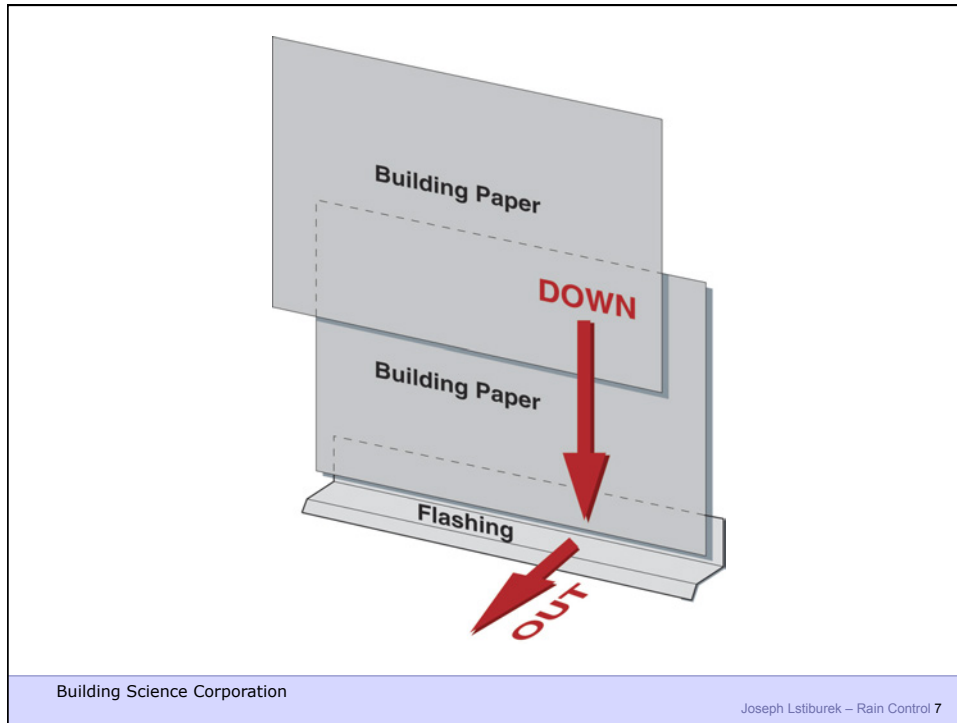
Building Science Corporation

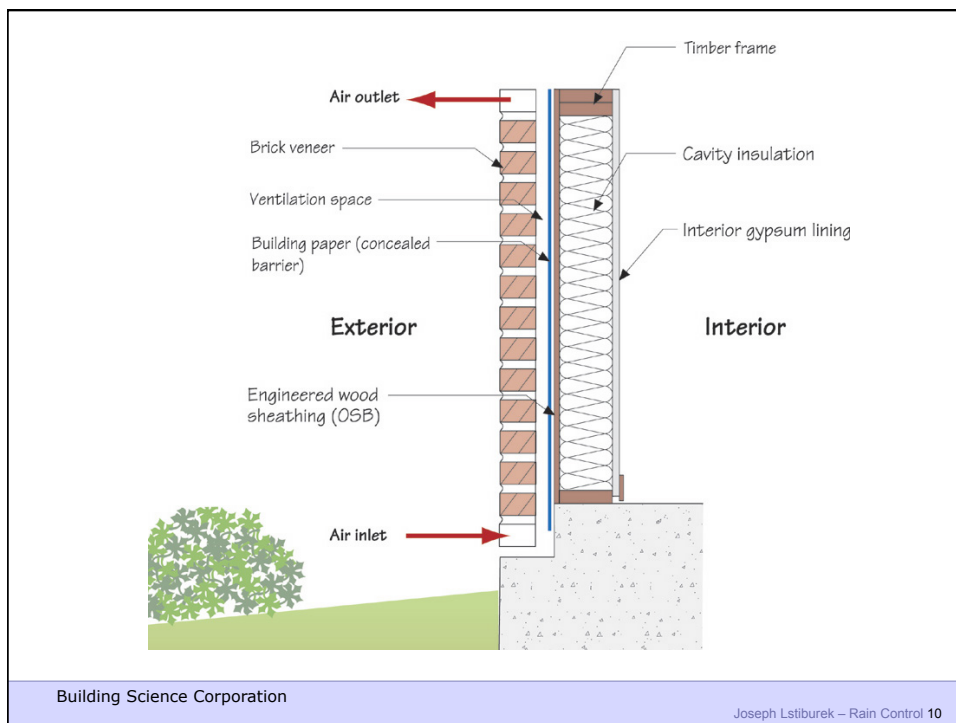
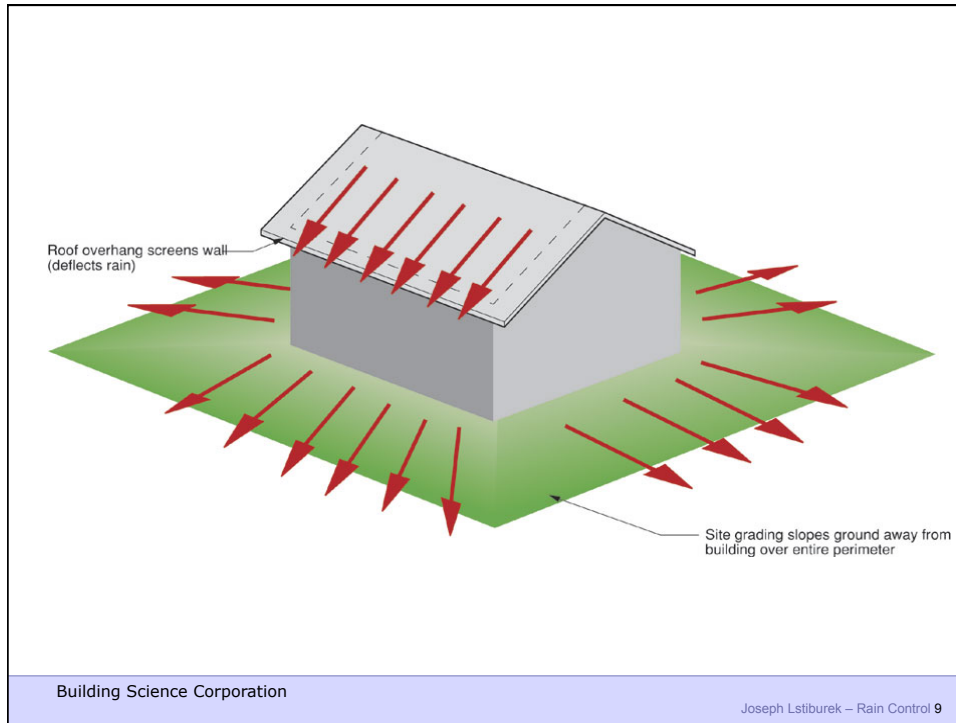
Joseph Lstiburek – Rain Control 5



Building Science Corporation

Joseph Lstiburek – Rain Control 6







Building Science Corporation

Joseph Lstiburek – Rain Control 11



Building Science Corporation

Joseph Lstiburek – Rain Control 12



Building Science Corporation



Building Science Corporation



Building Science Corporation

Joseph Lstiburek – Rain Control 15



Building Science Corporation

Joseph Lstiburek – Rain Control 16



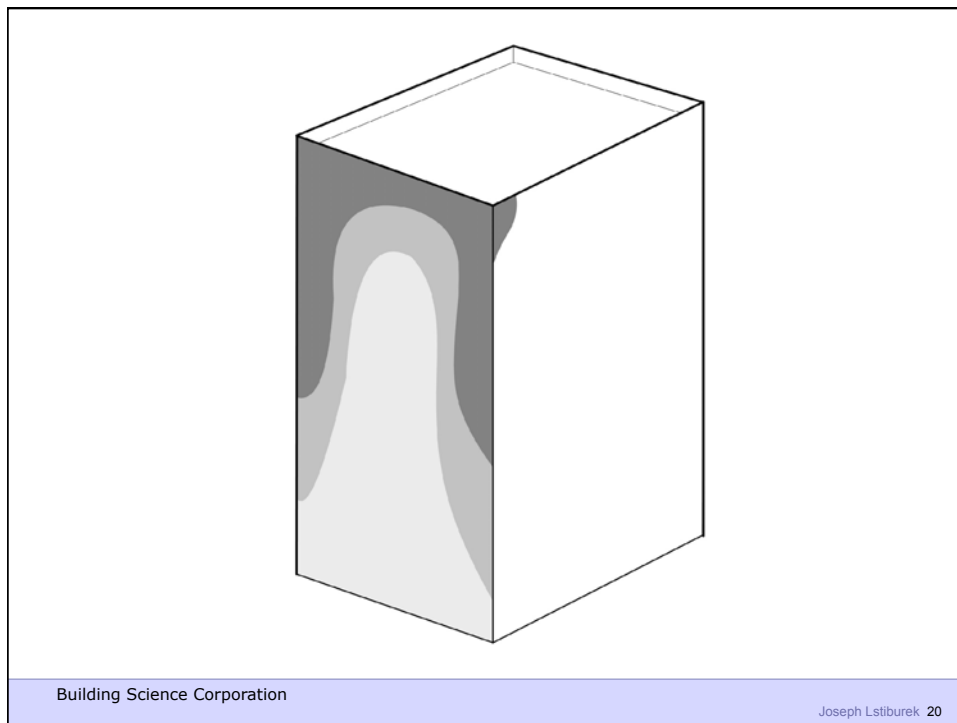
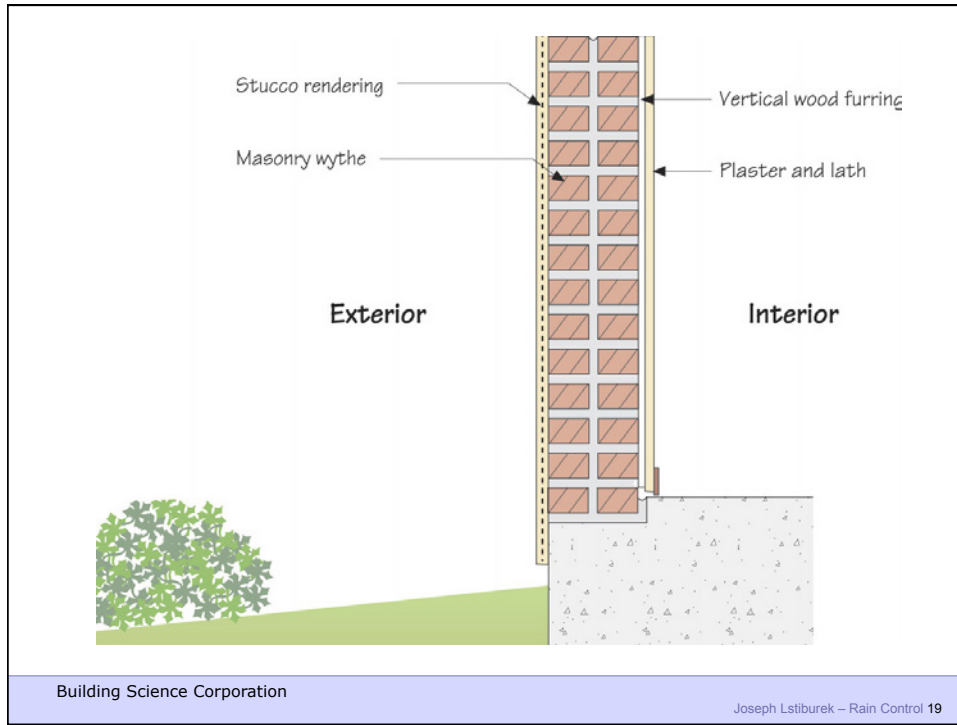
Building Science Corporation

Joseph Lstiburek – Rain Control 17



Building Science Corporation

Joseph Lstiburek 18







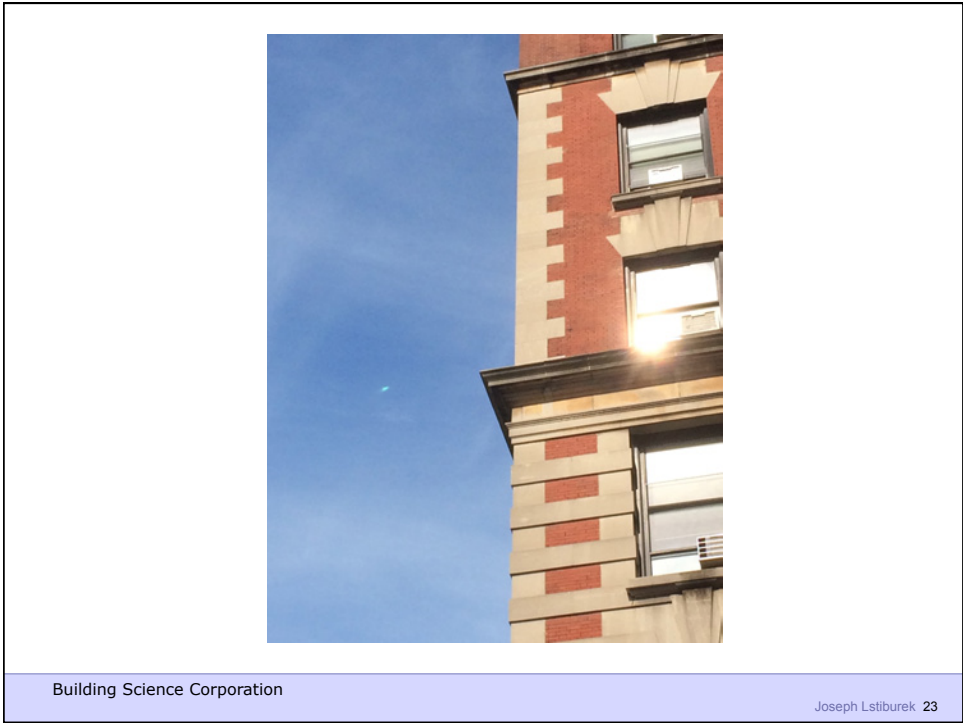
Building Science Corporation

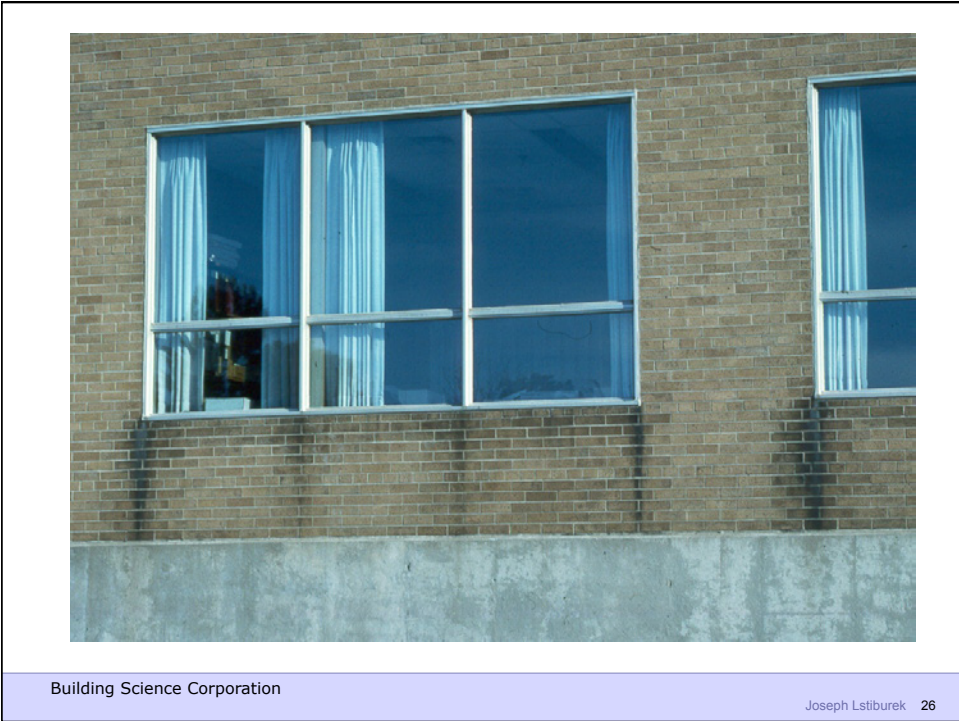
Joseph Lstiburek 21

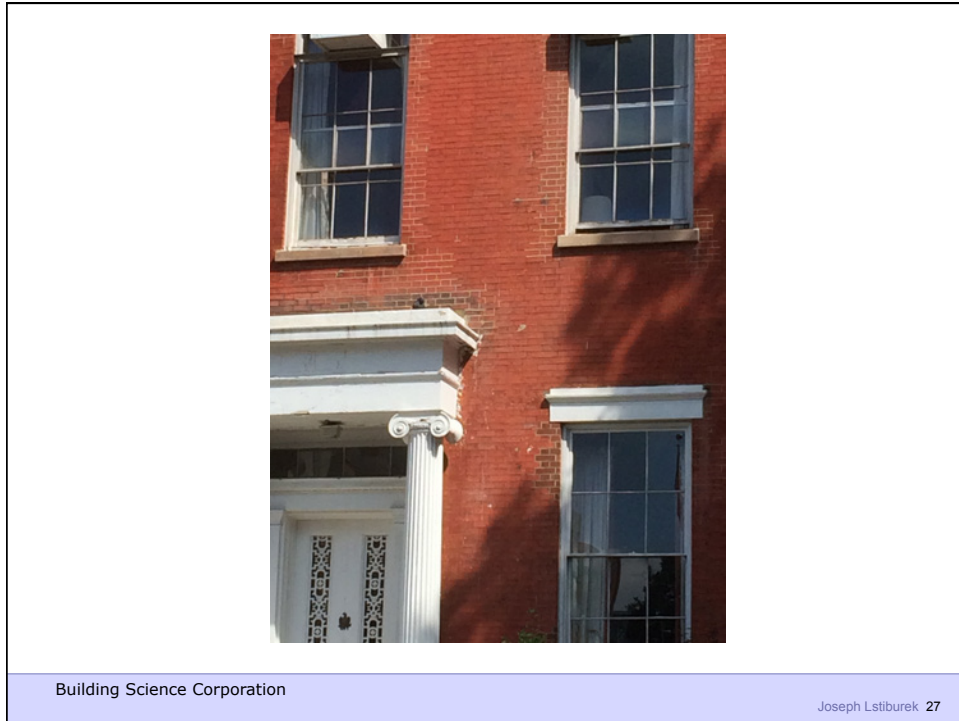


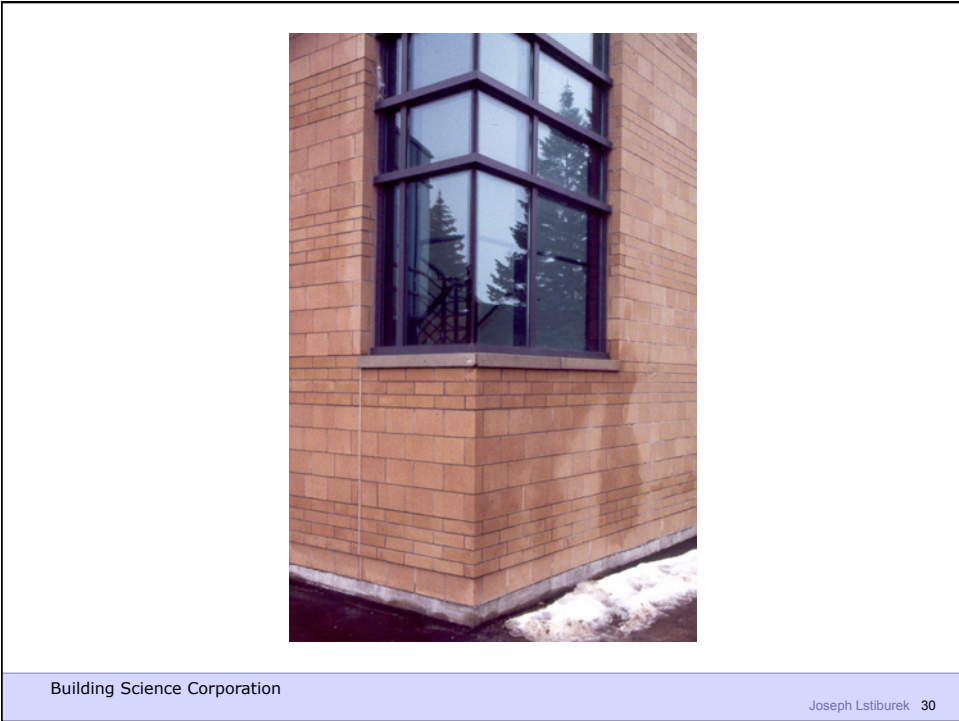
Building Science Corporation

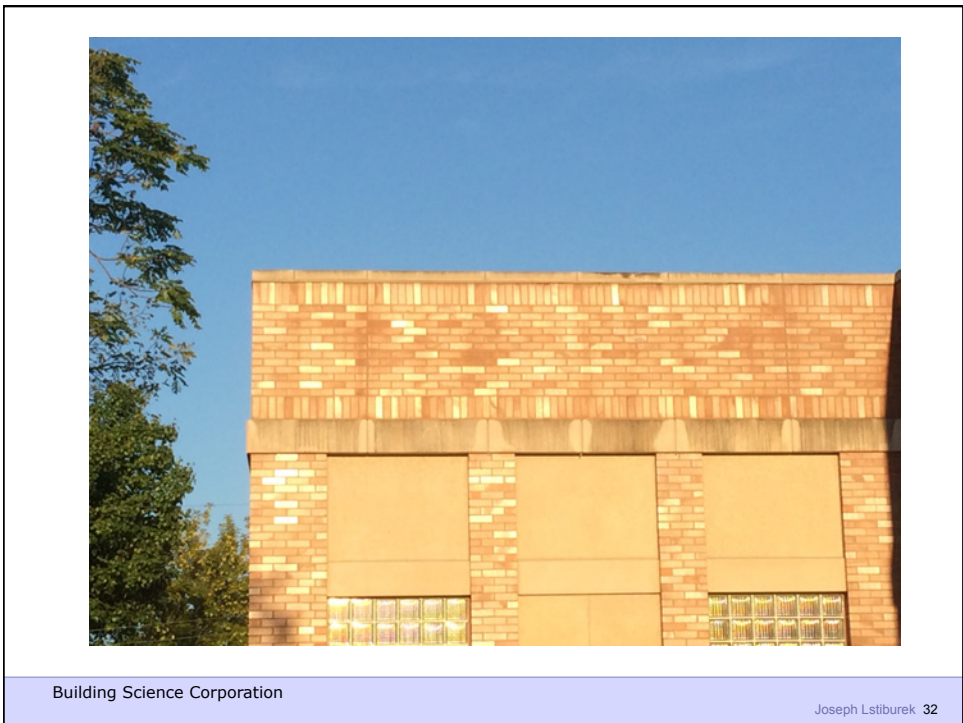
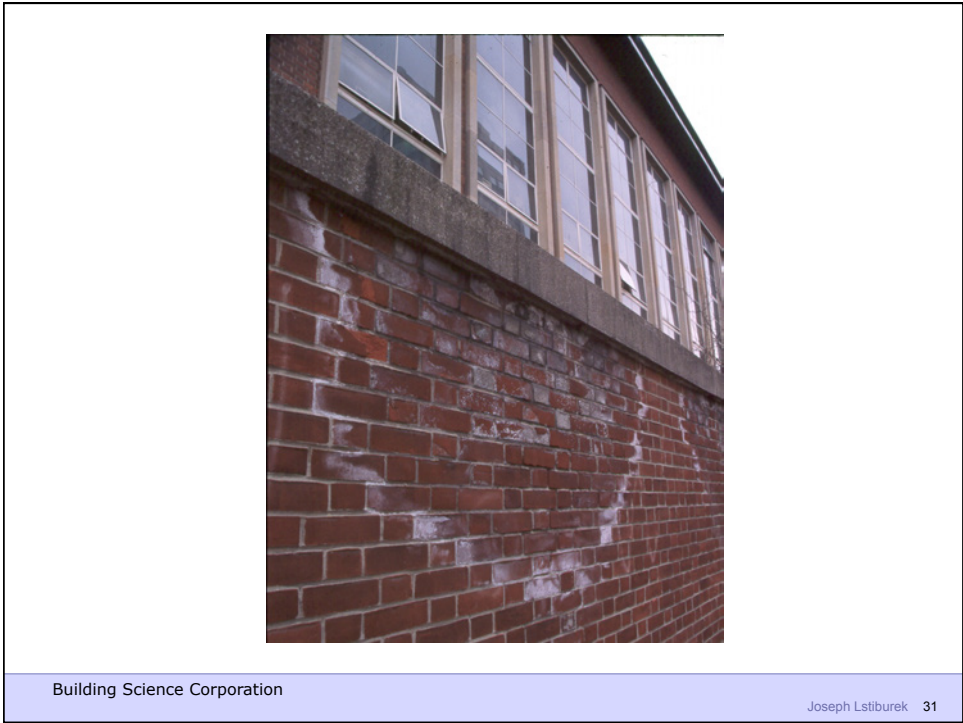
Joseph Lstiburek 22













Building Science Corporation

Joseph Lstiburek 33



Building Science Corporation

Joseph Lstiburek 34



Building Science Corporation



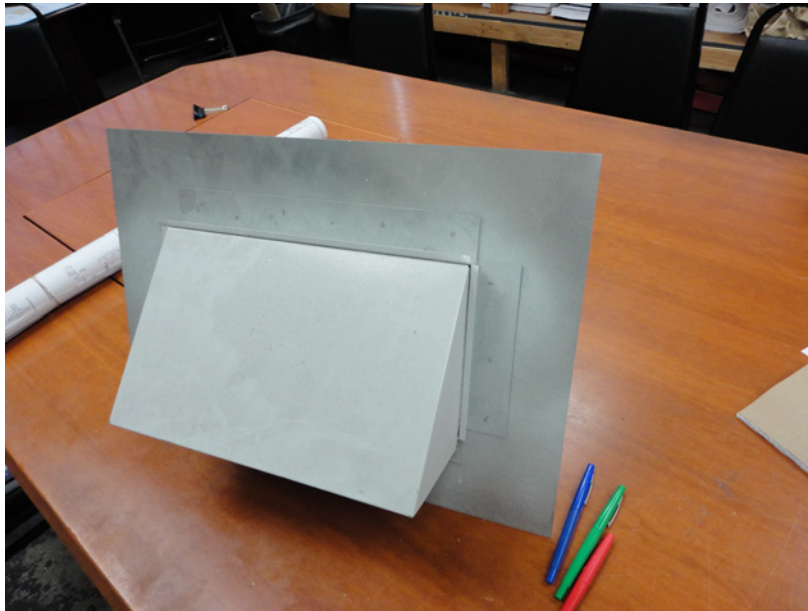
Building Science Corporation





Building Science Corporation

Joseph Lstiburek – Rain Control 37



Building Science Corporation

Joseph Lstiburek 38



Building Science Corporation

Joseph Lstiburek – Rain Control 39



Building Science Corporation

Joseph Lstiburek 40



Building Science Corporation

Joseph Lstiburek 41



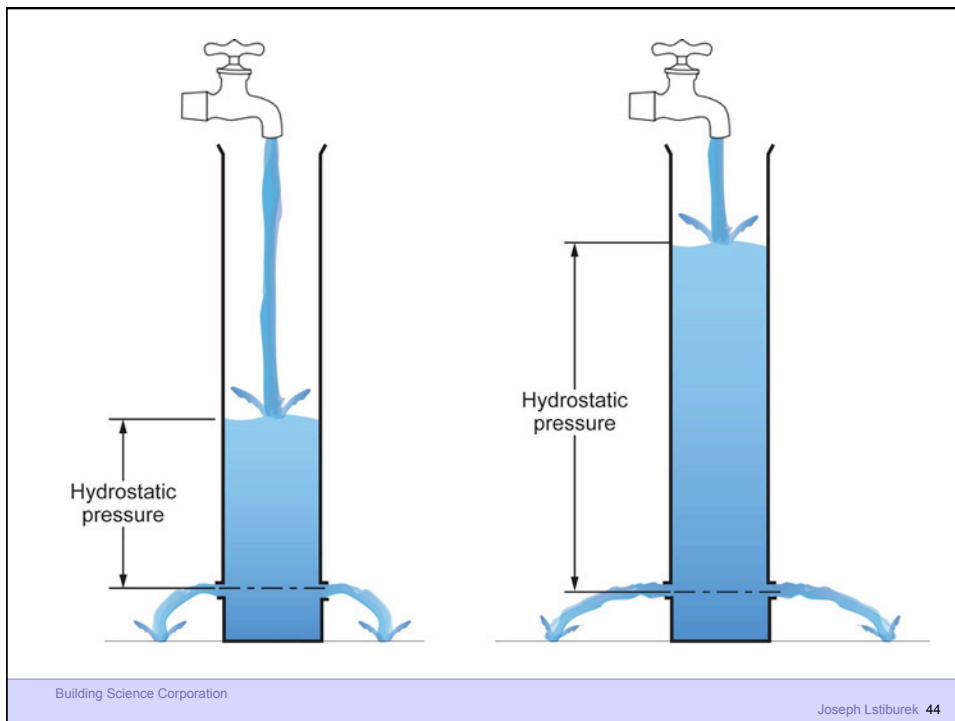
Building Science Corporation

Joseph Lstiburek 42



Building Science Corporation

Joseph Lstiburek 43



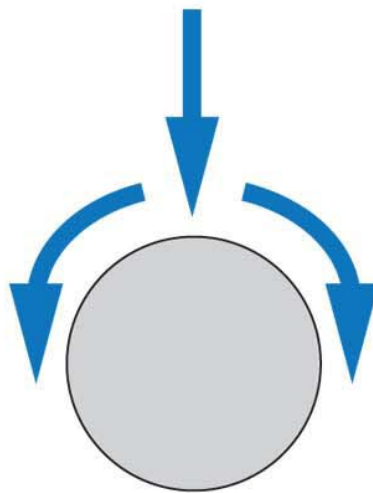
Building Science Corporation

Joseph Lstiburek 44



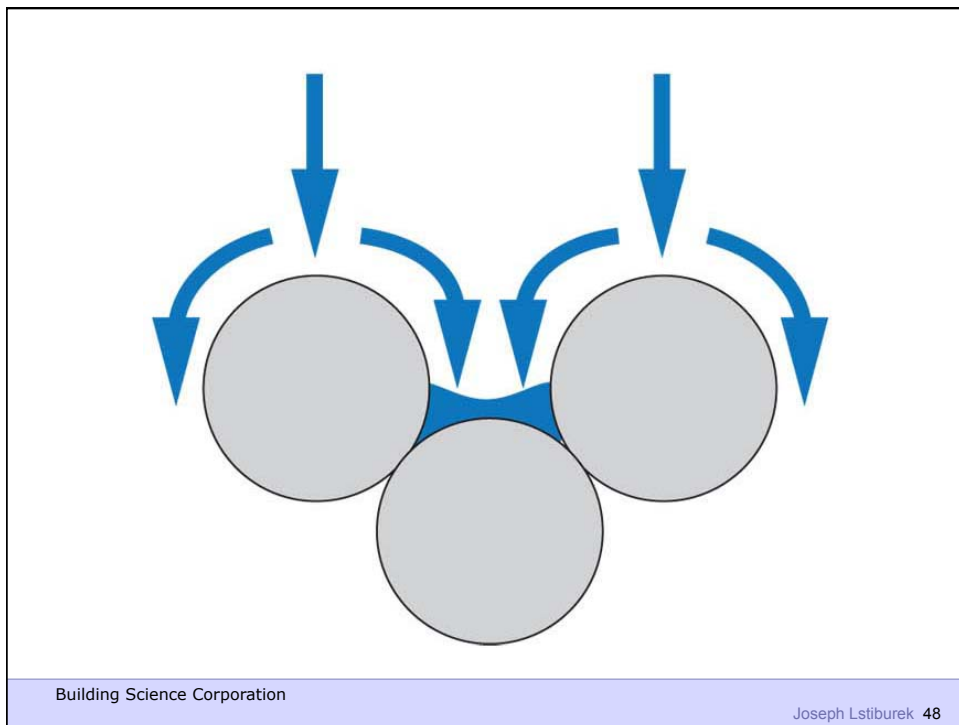
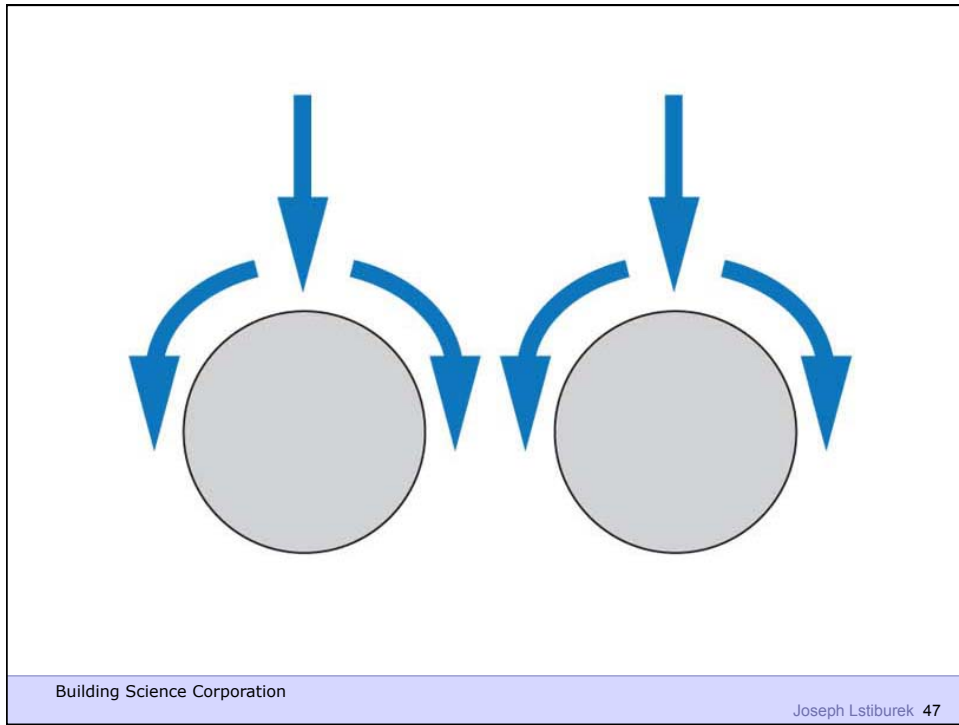
Building Science Corporation

Joseph Lstiburek 45



Building Science Corporation

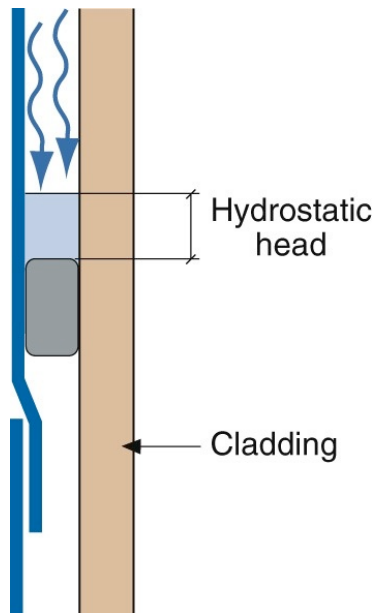
Joseph Lstiburek 46





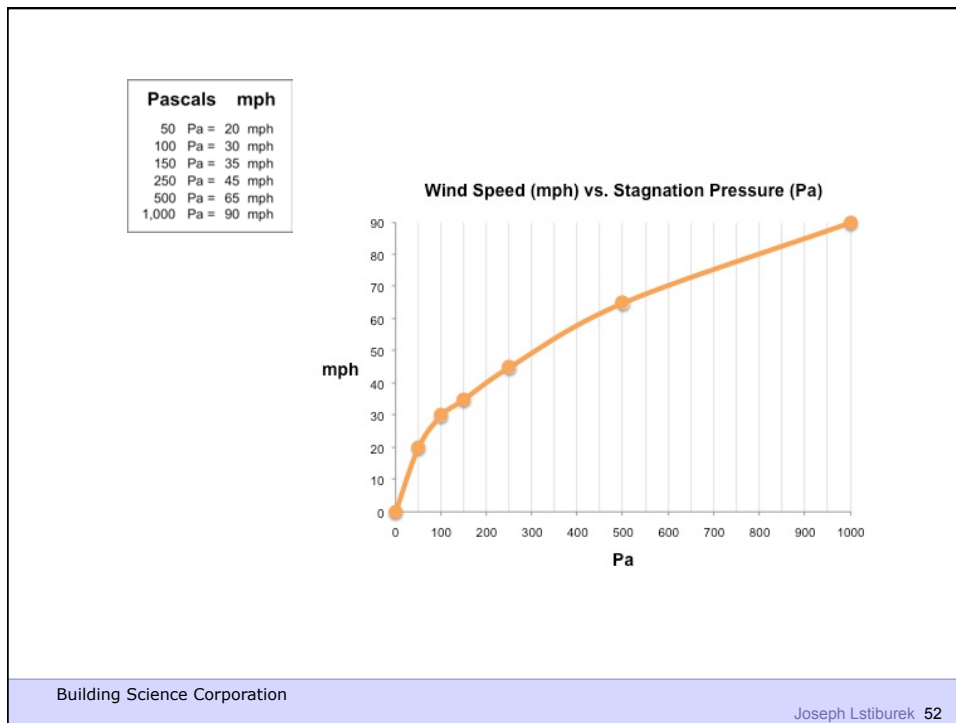
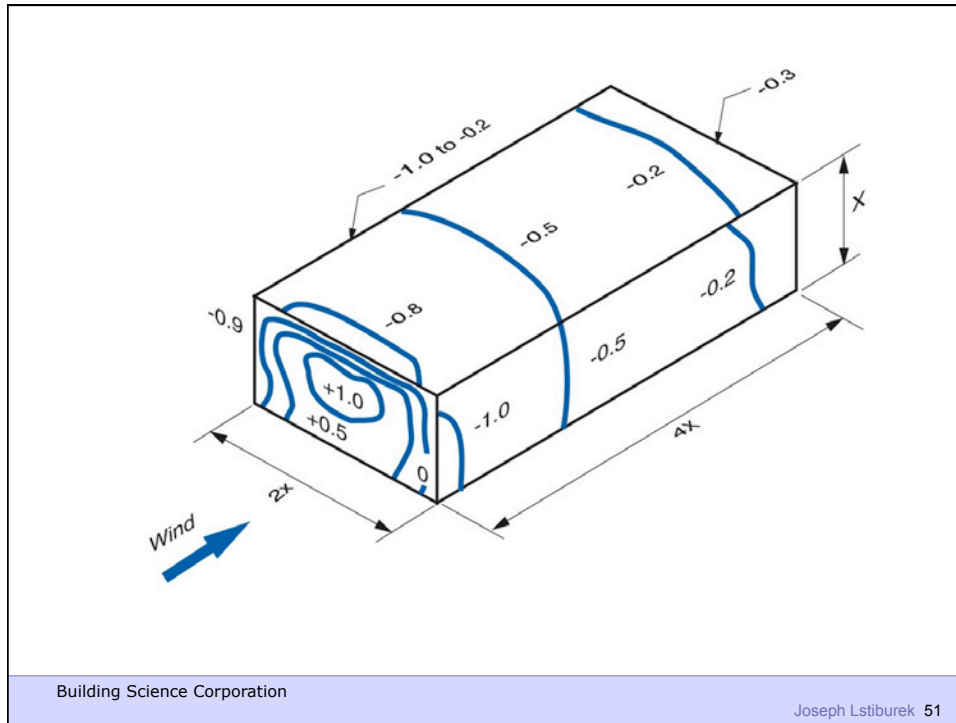
Building Science Corporation

Joseph Lstiburek 49



Building Science Corporation

Joseph Lstiburek 50

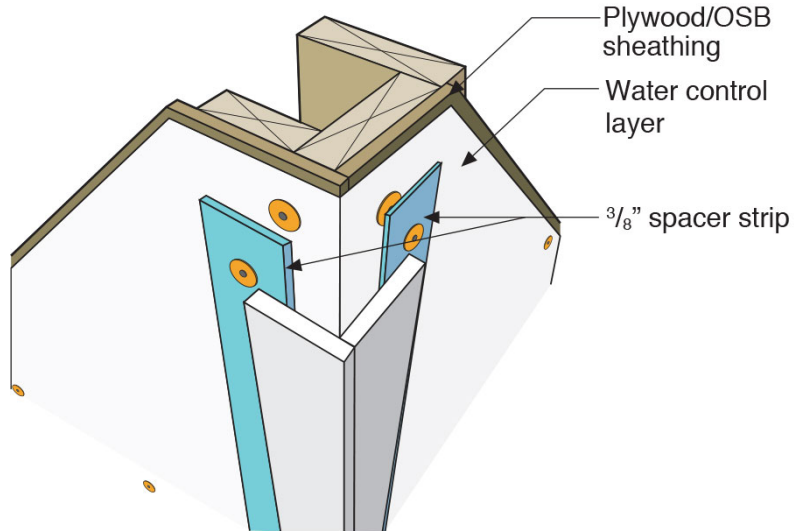






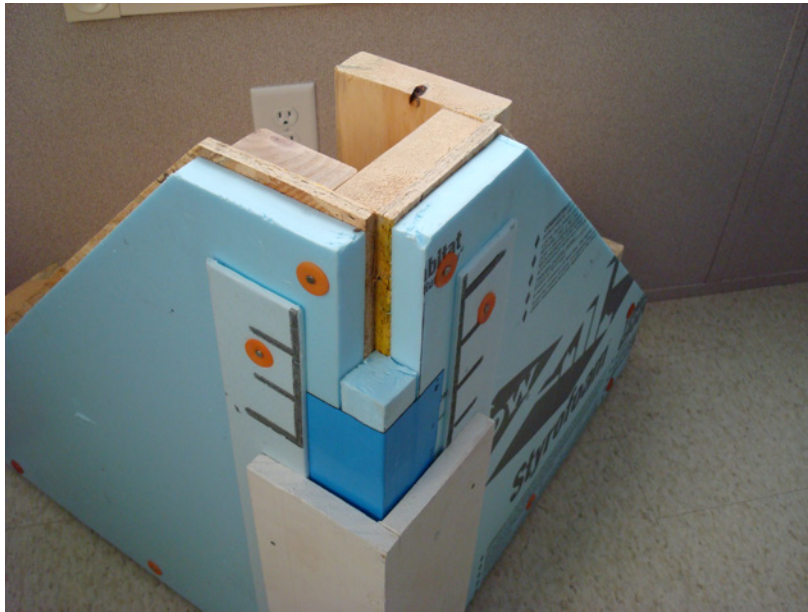
Building Science Corporation

Joseph Lstiburek 53



Building Science Corporation

Joseph Lstiburek 54



Building Science Corporation

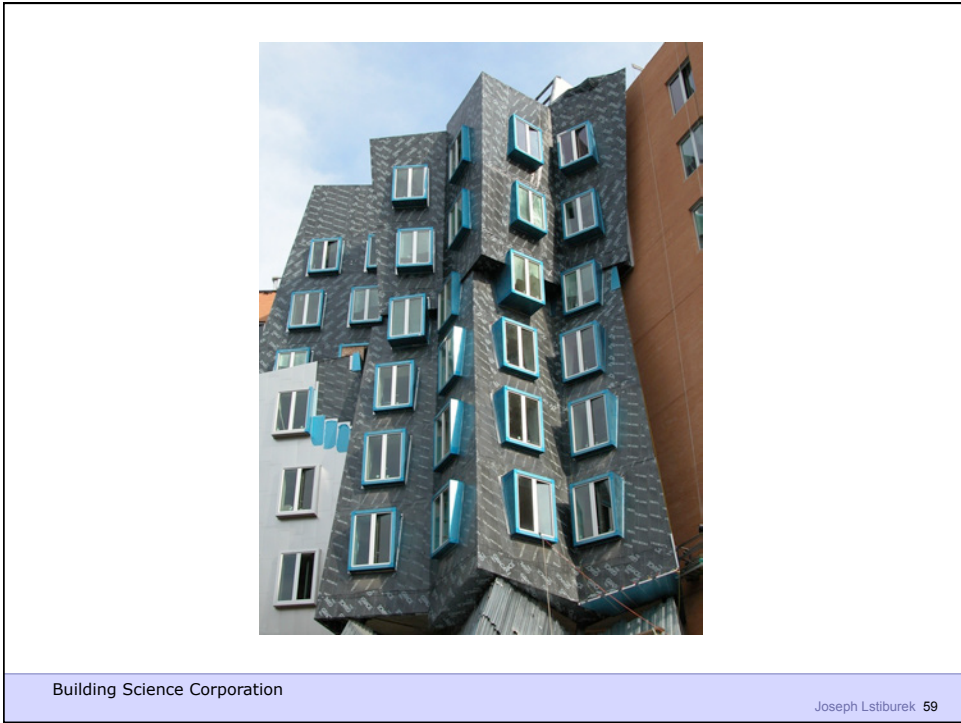
Joseph Lstiburek 55



Building Science Corporation

Joseph Lstiburek 56



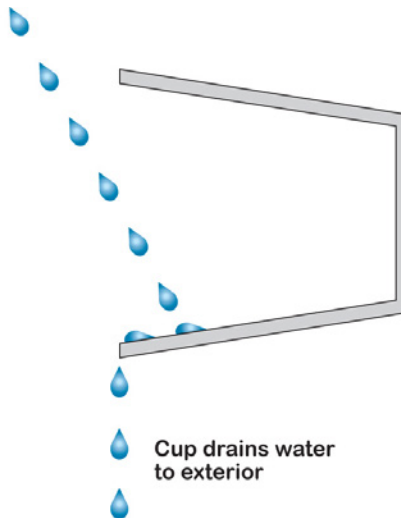




Building Science Corporation

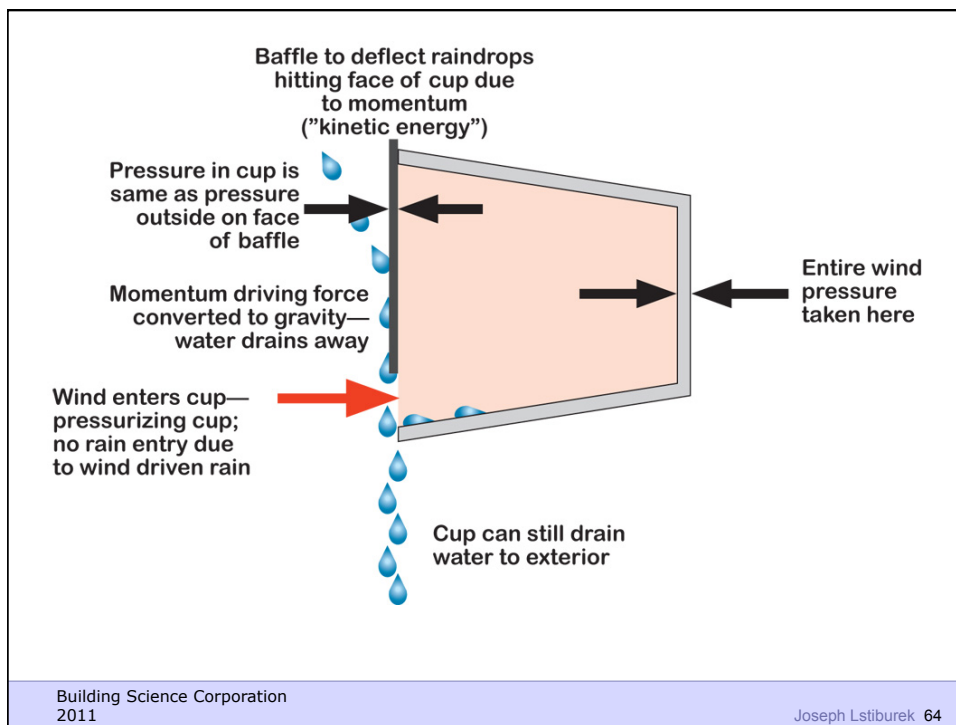
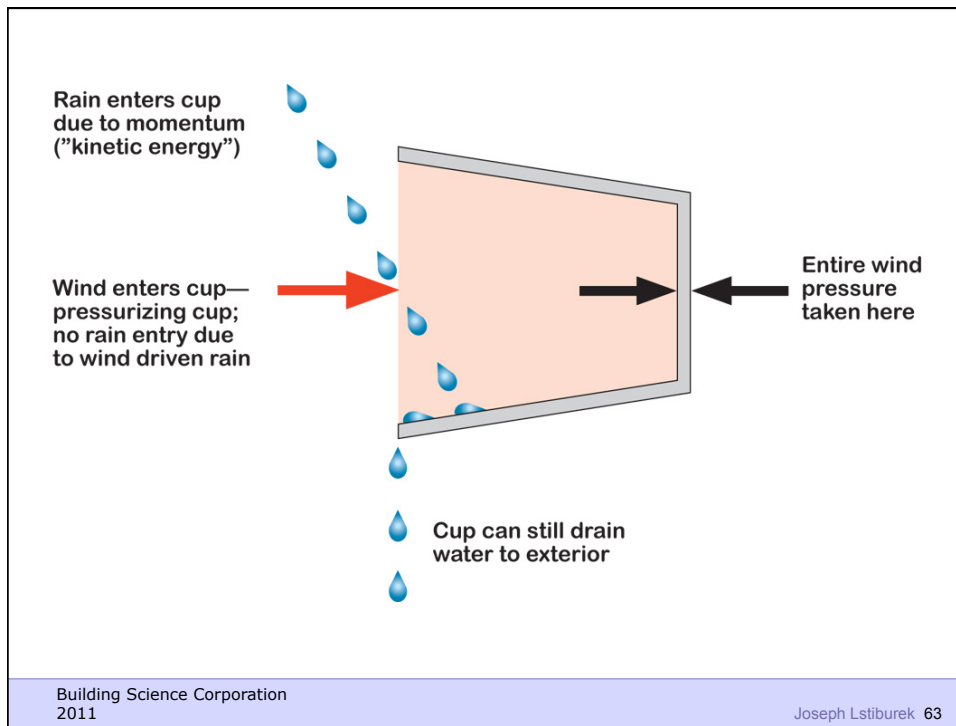
Joseph Lstiburek – Rain Control 61

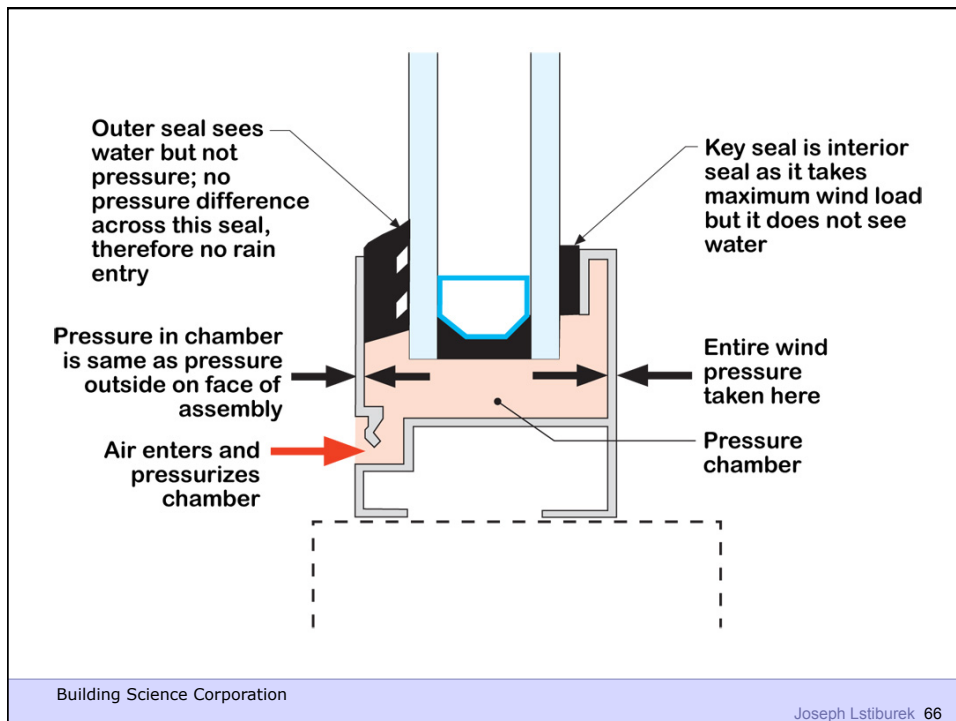
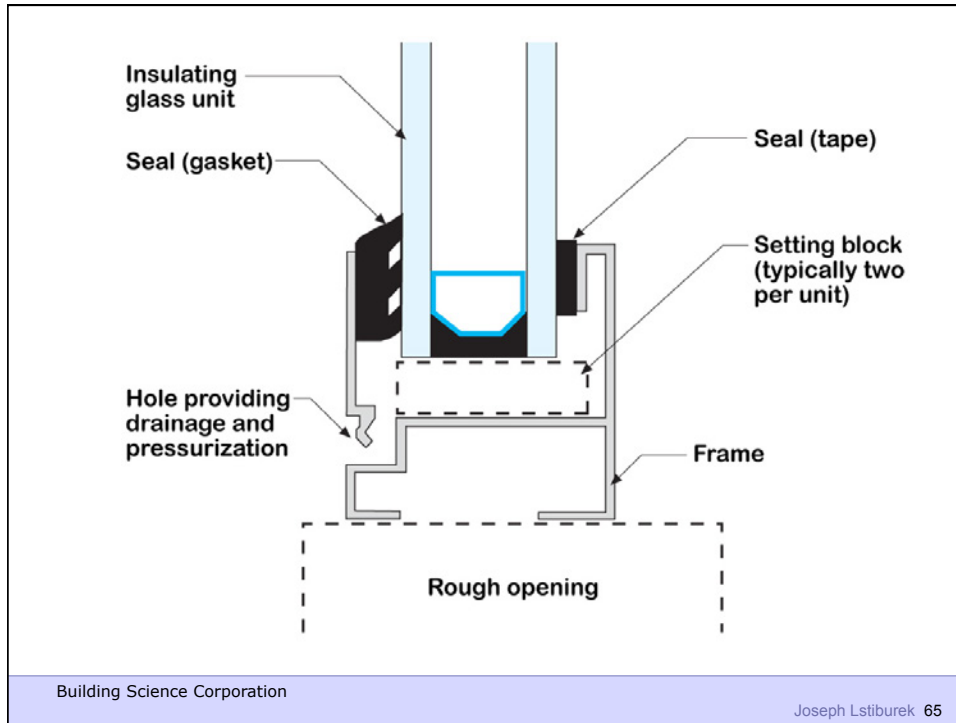
Rain enters cup  
due to momentum  
("kinetic energy")

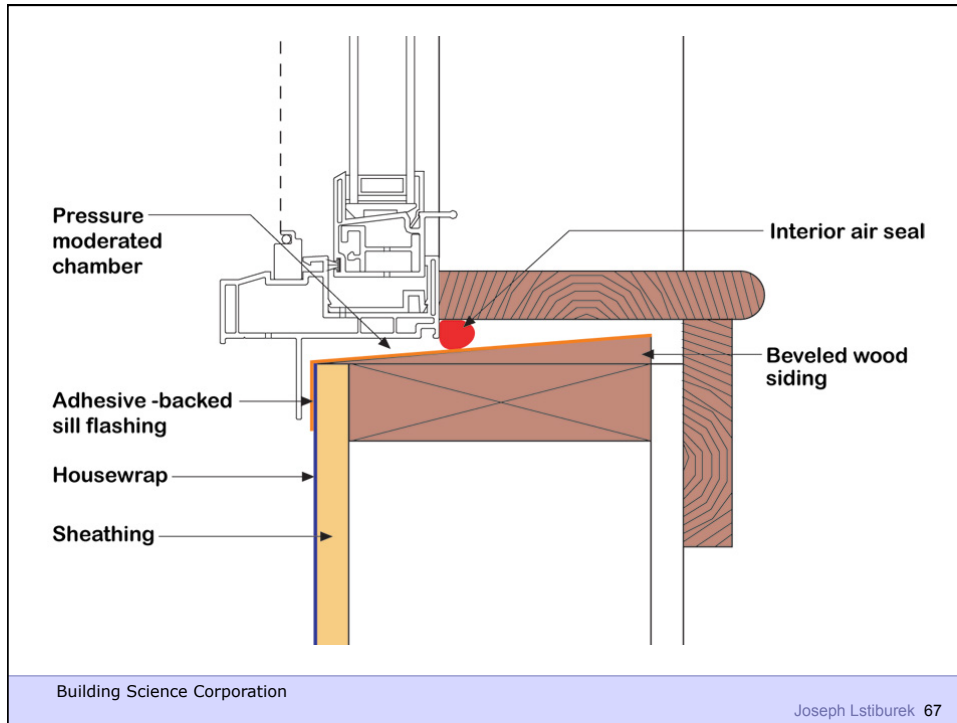


Building Science Corporation  
2011

Joseph Lstiburek 62

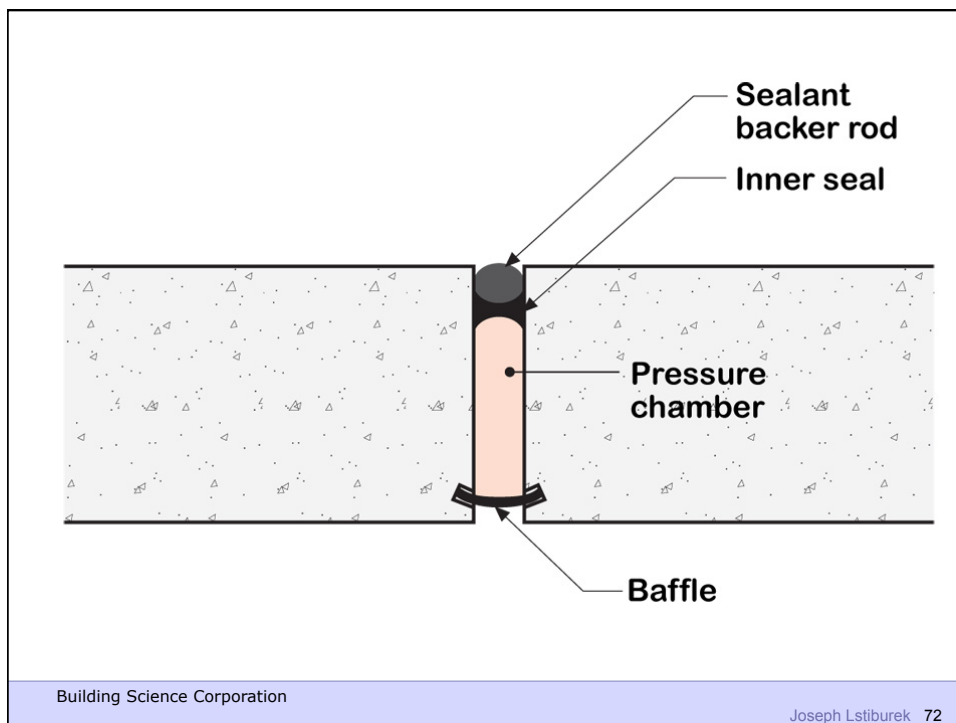
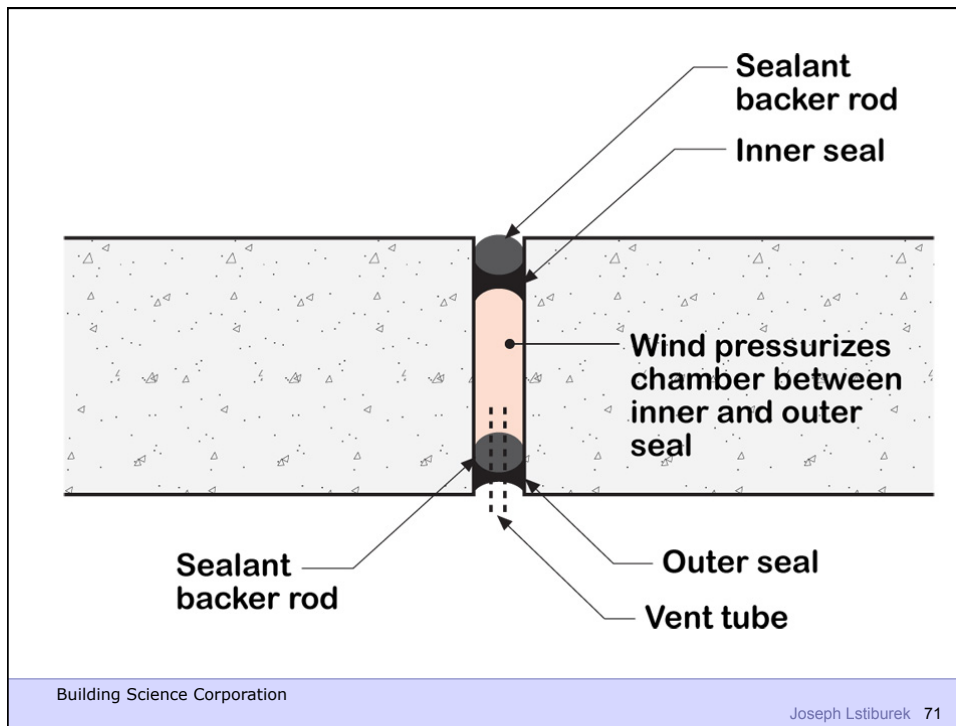


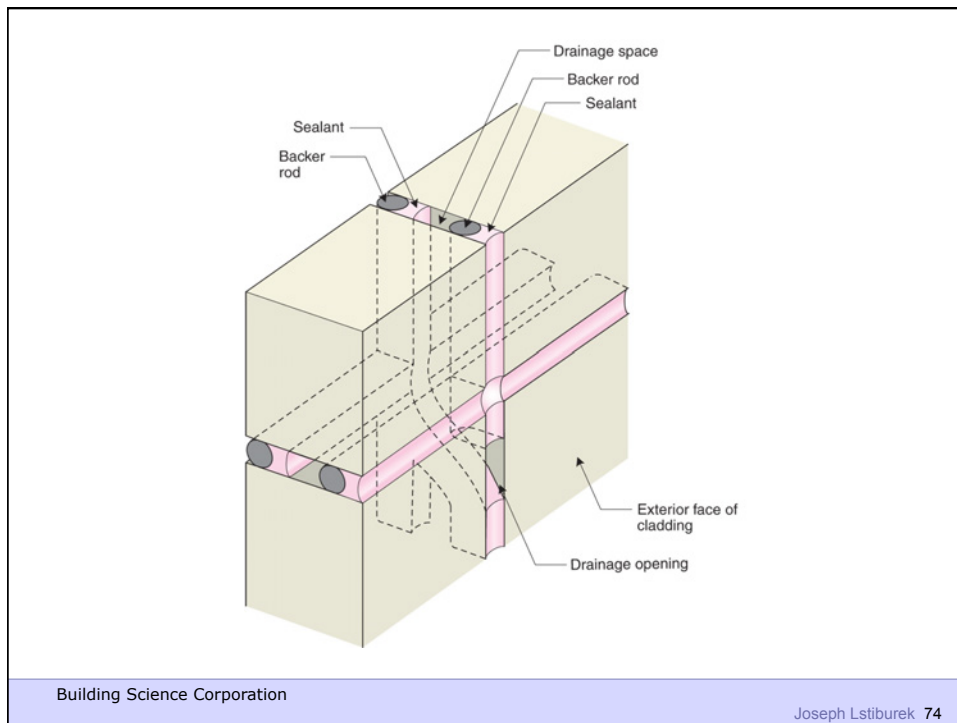
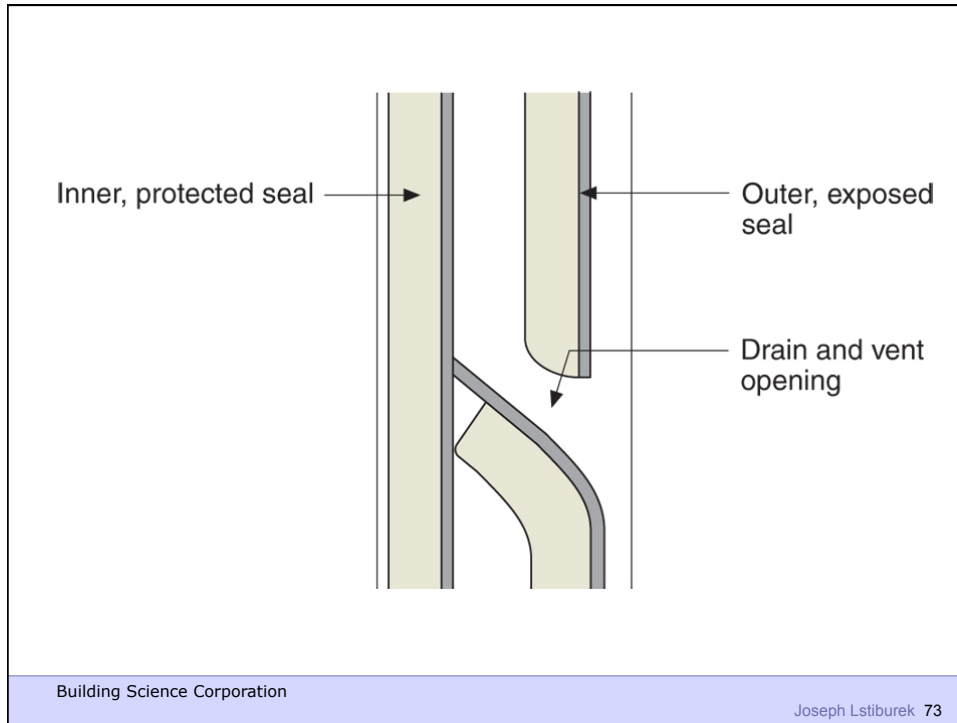














Building Science Corporation

Joseph Lstiburek 75

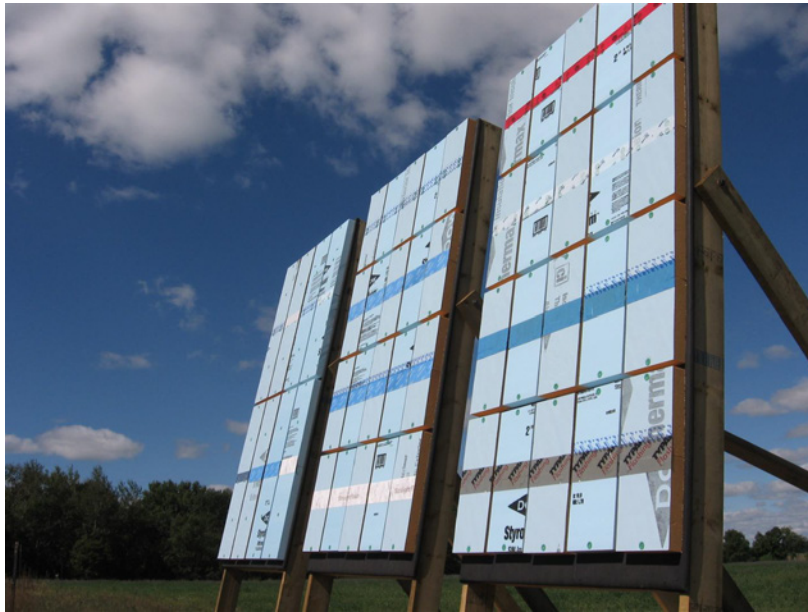


Building Science Corporation

Joseph Lstiburek 76







Building Science Corporation

Joseph Lstiburek 81



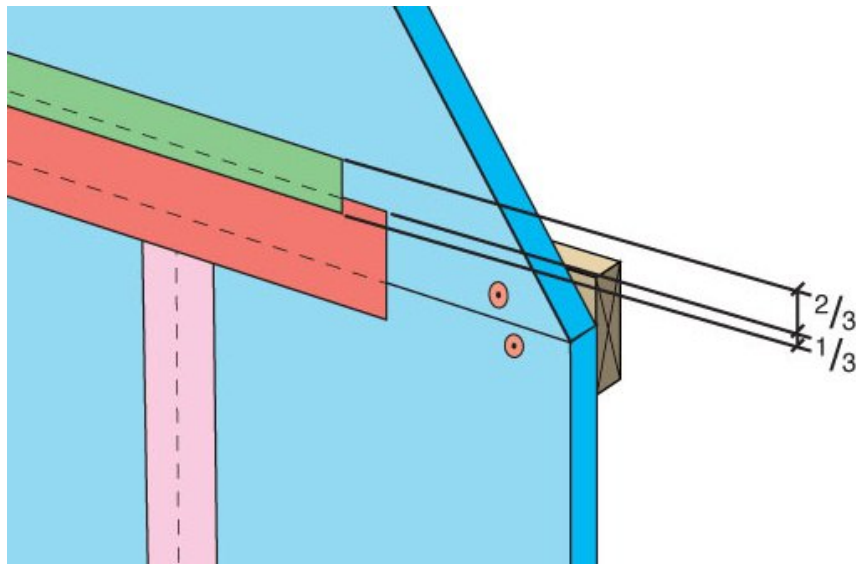
Building Science Corporation

Joseph Lstiburek 82



Building Science Corporation

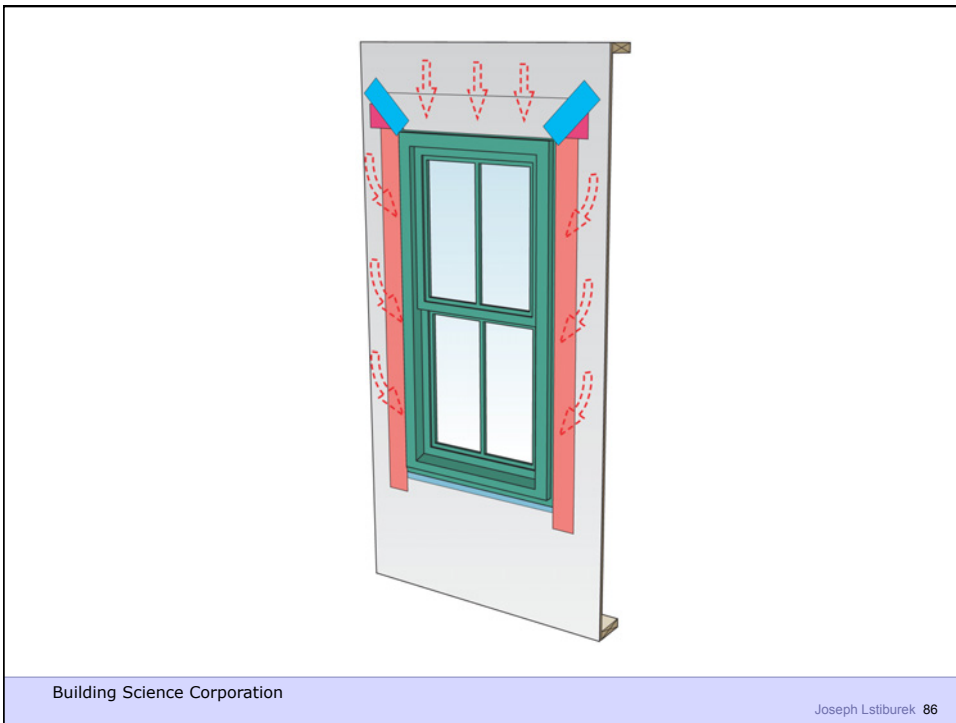
Joseph Lstiburek 83

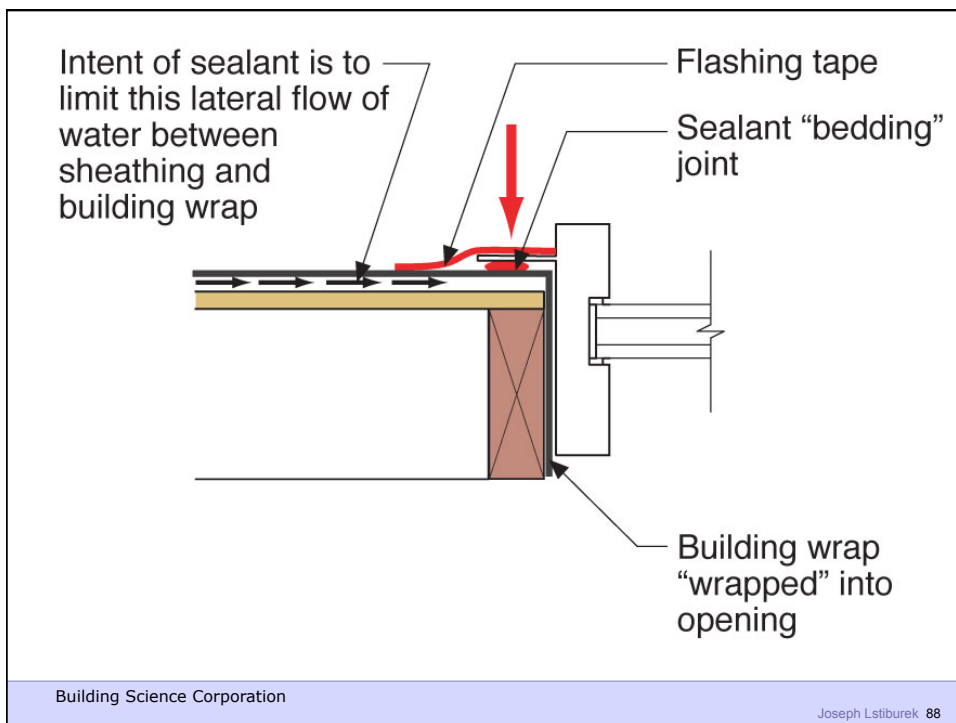


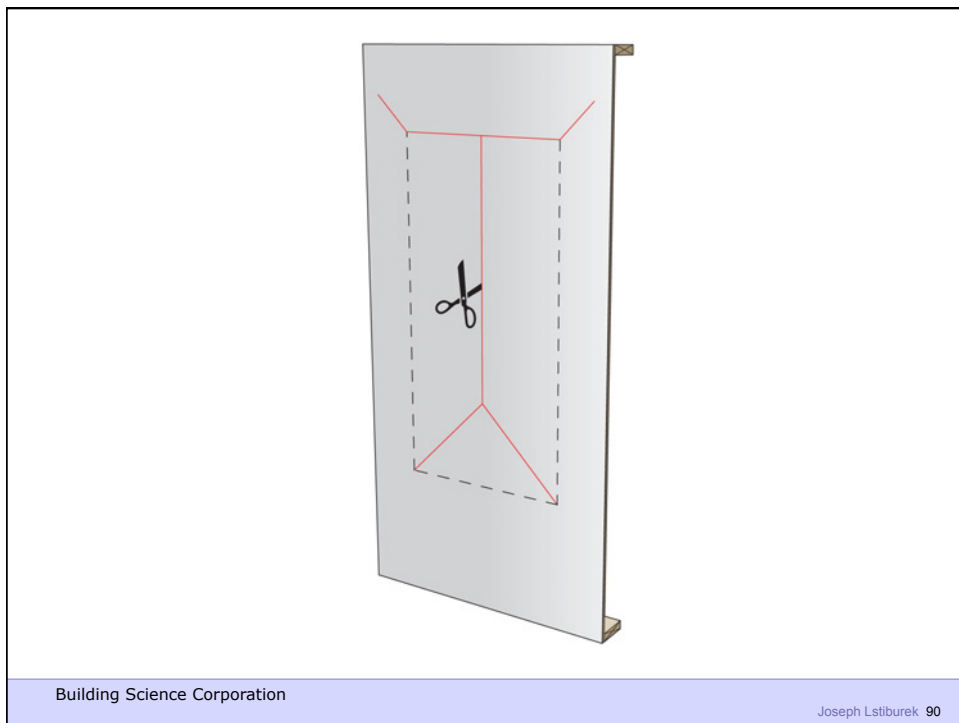
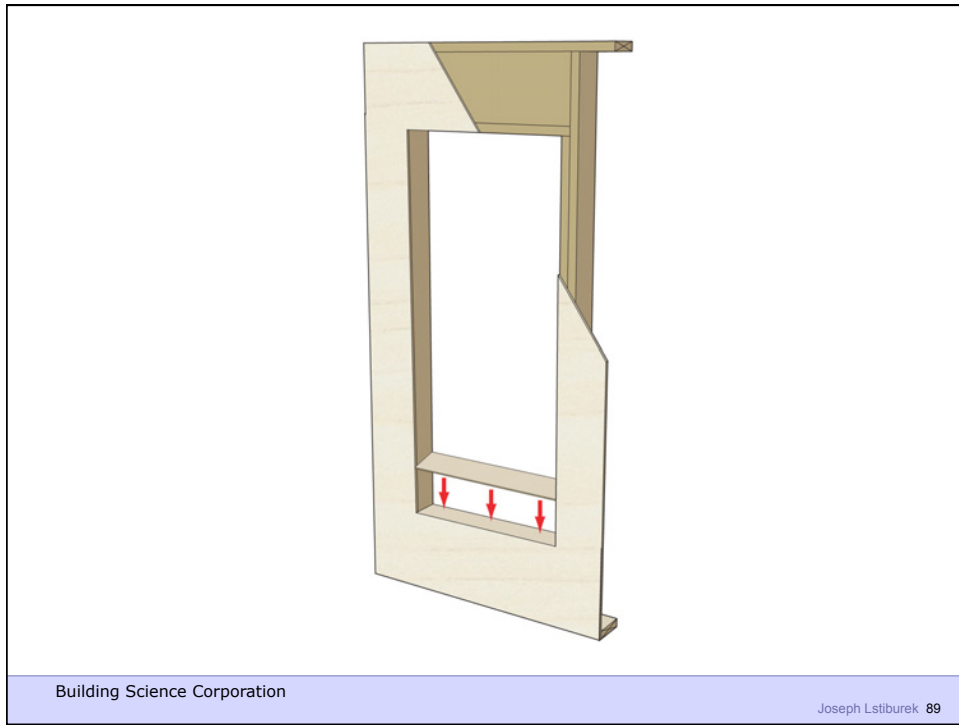
Building Science Corporation

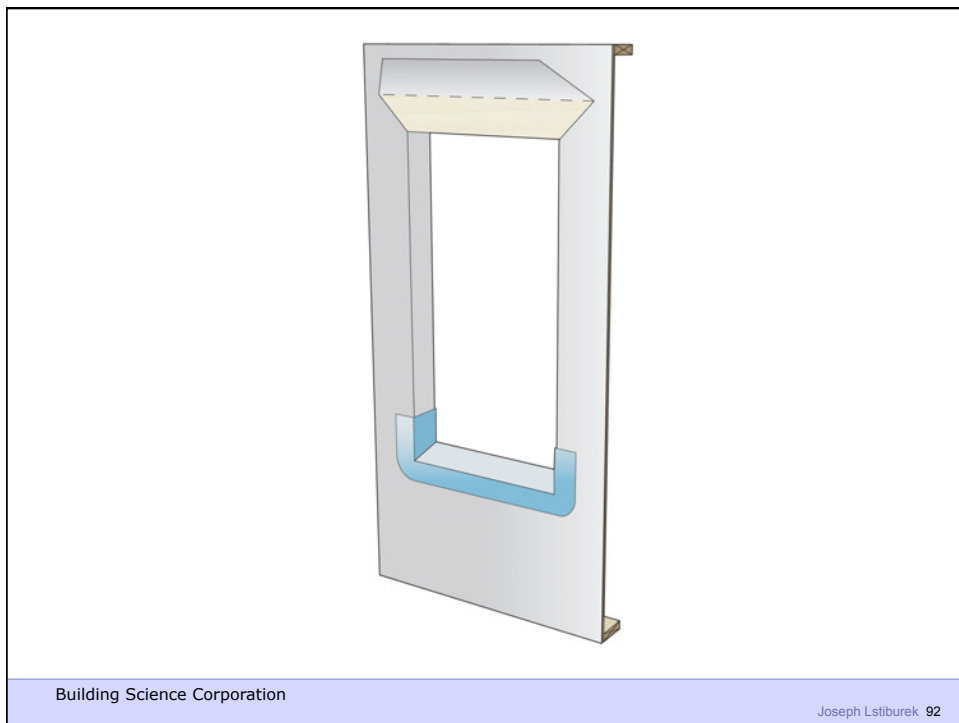
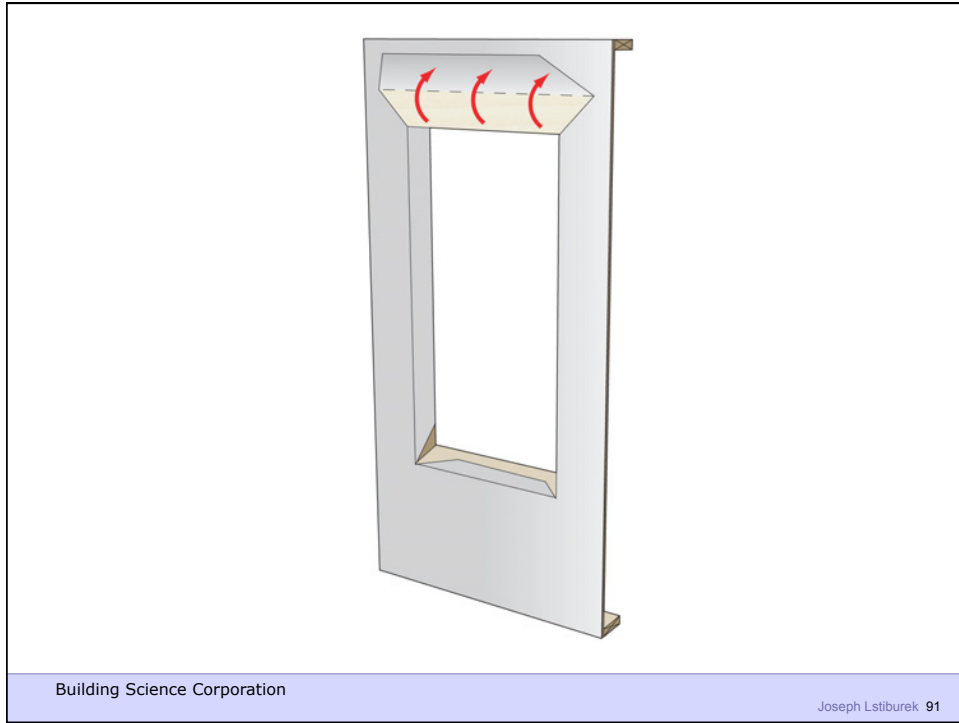
Joseph Lstiburek 84

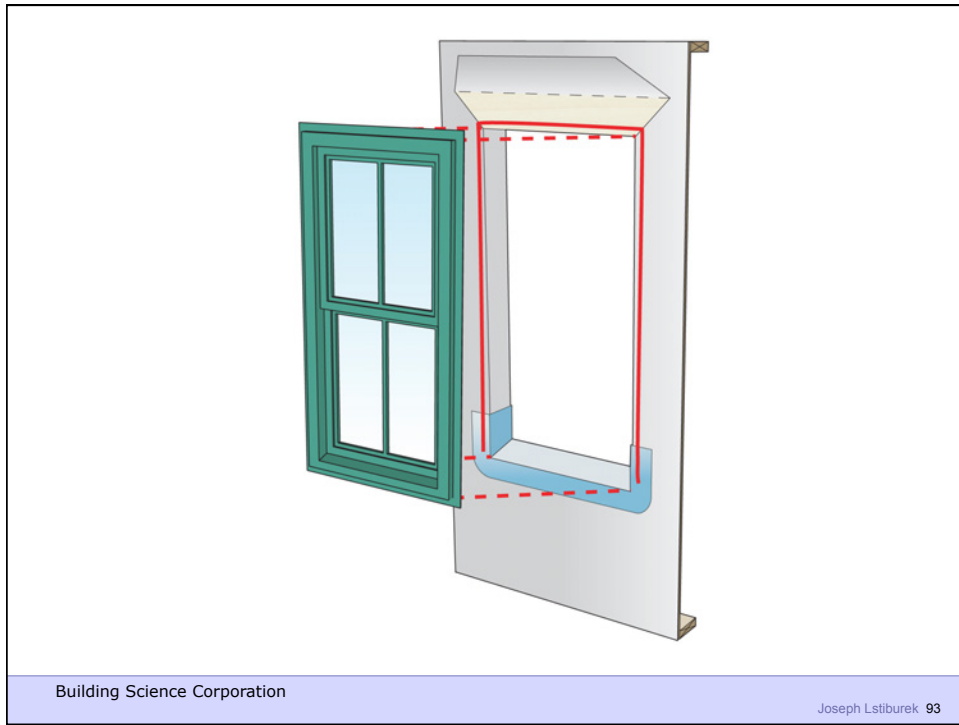


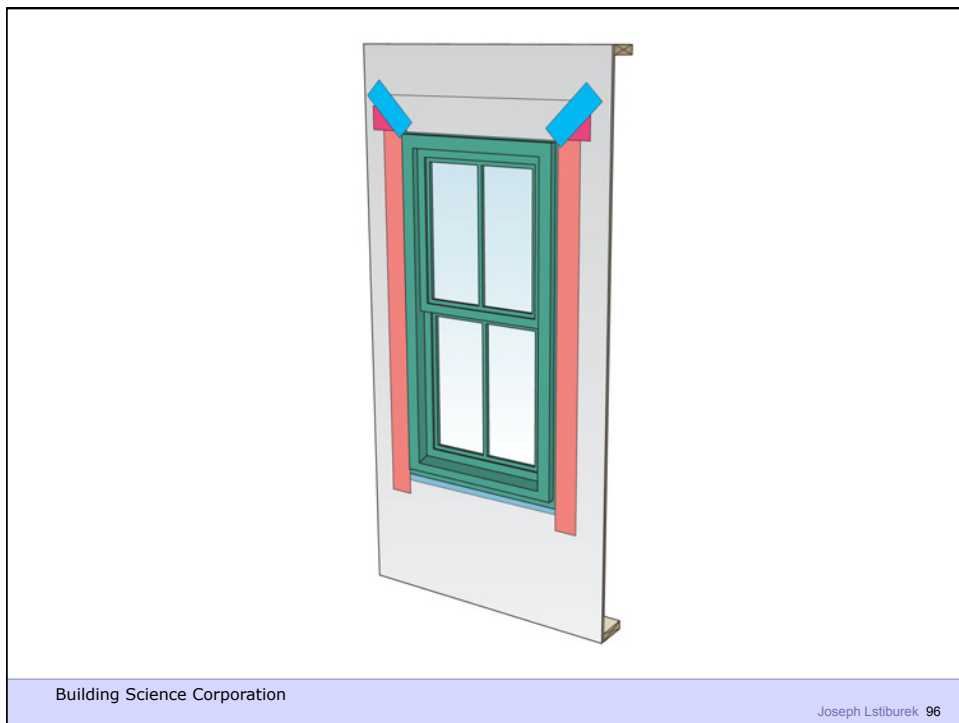
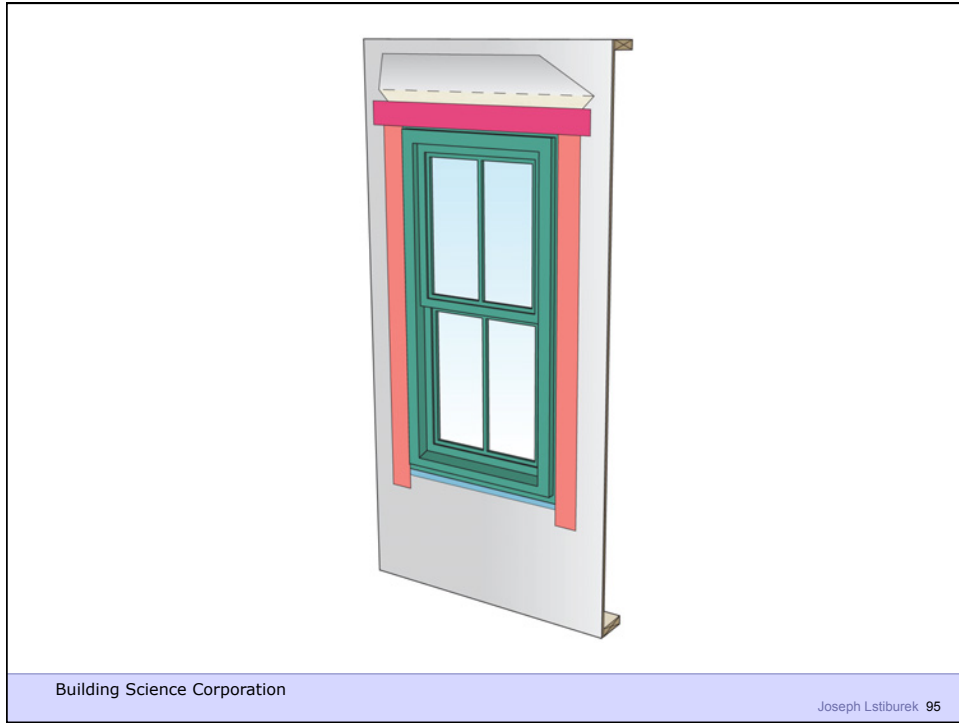


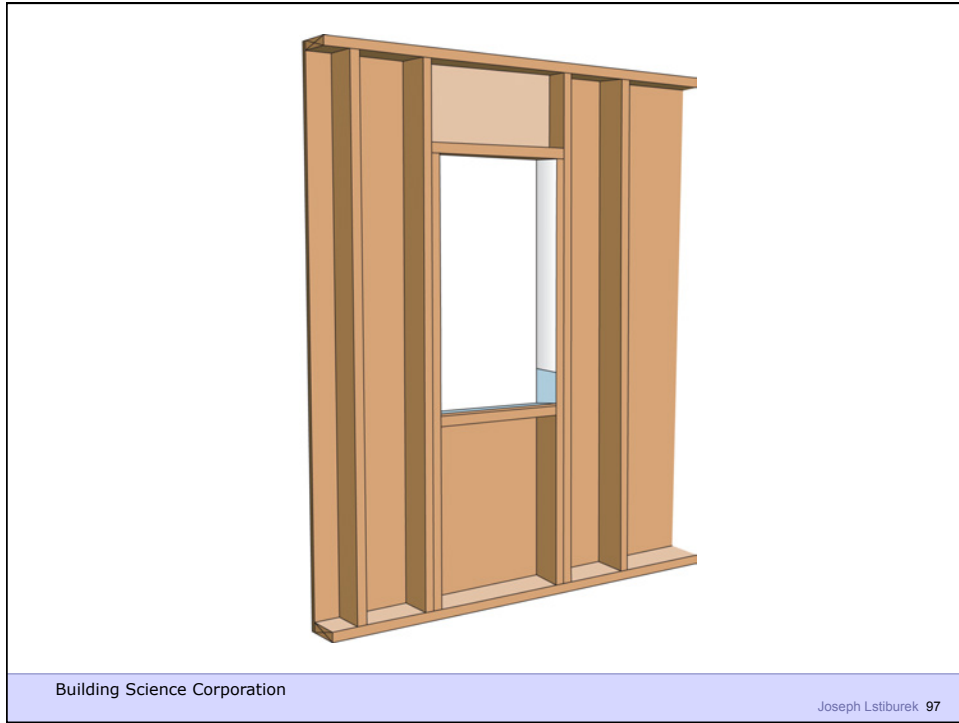


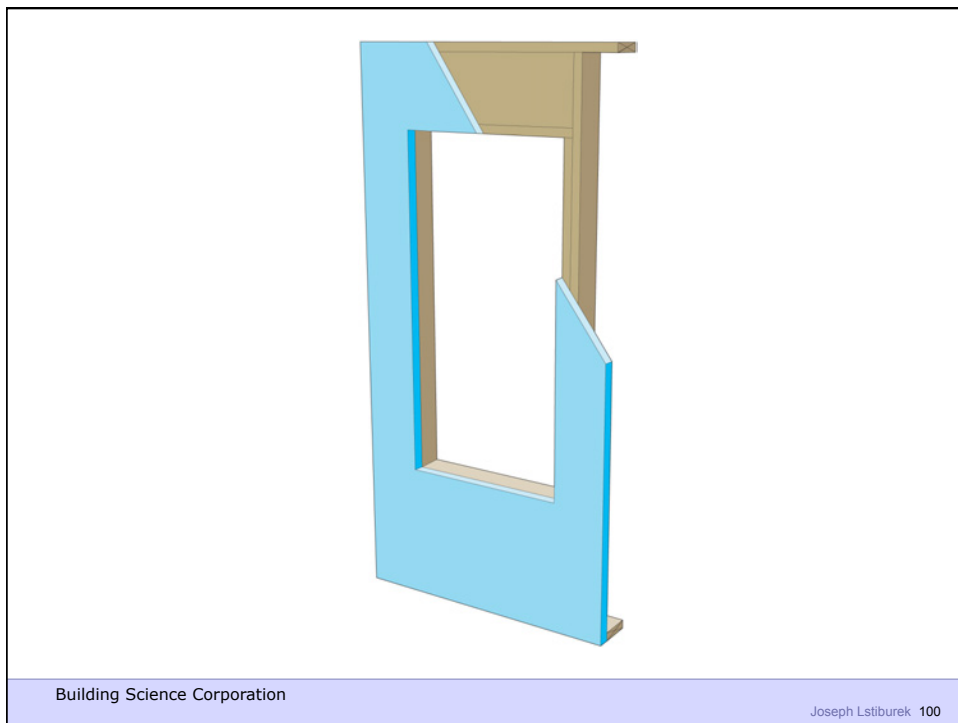




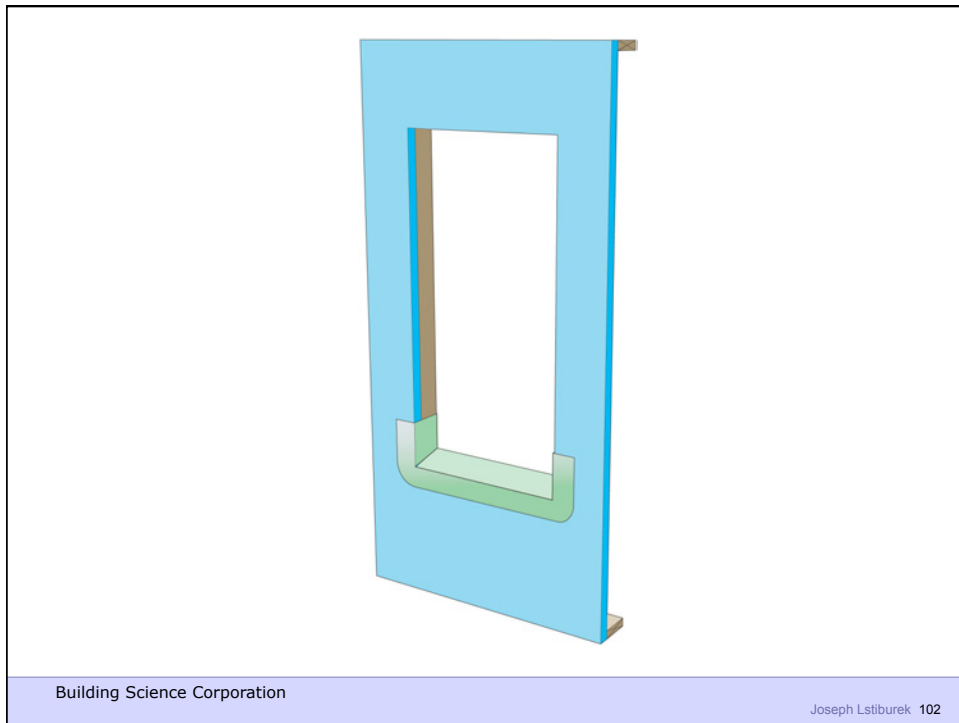
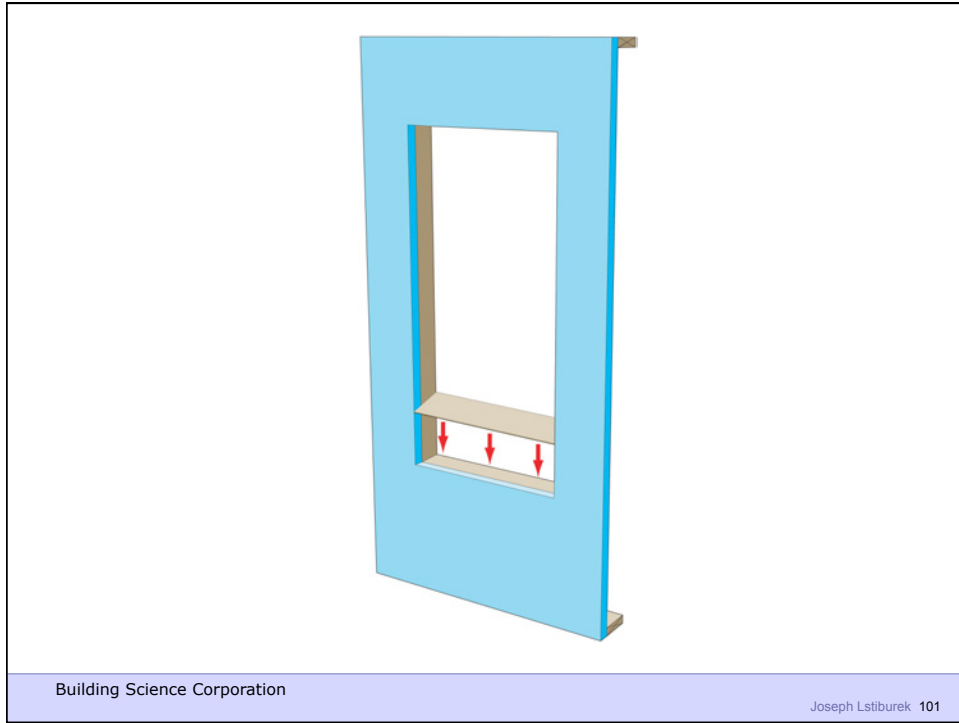


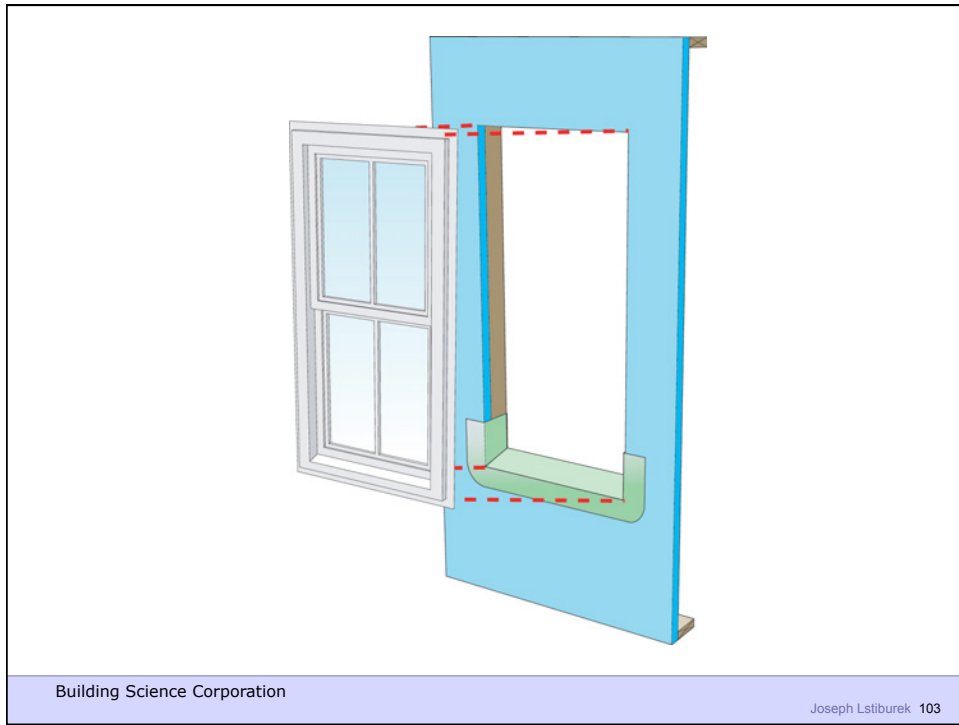




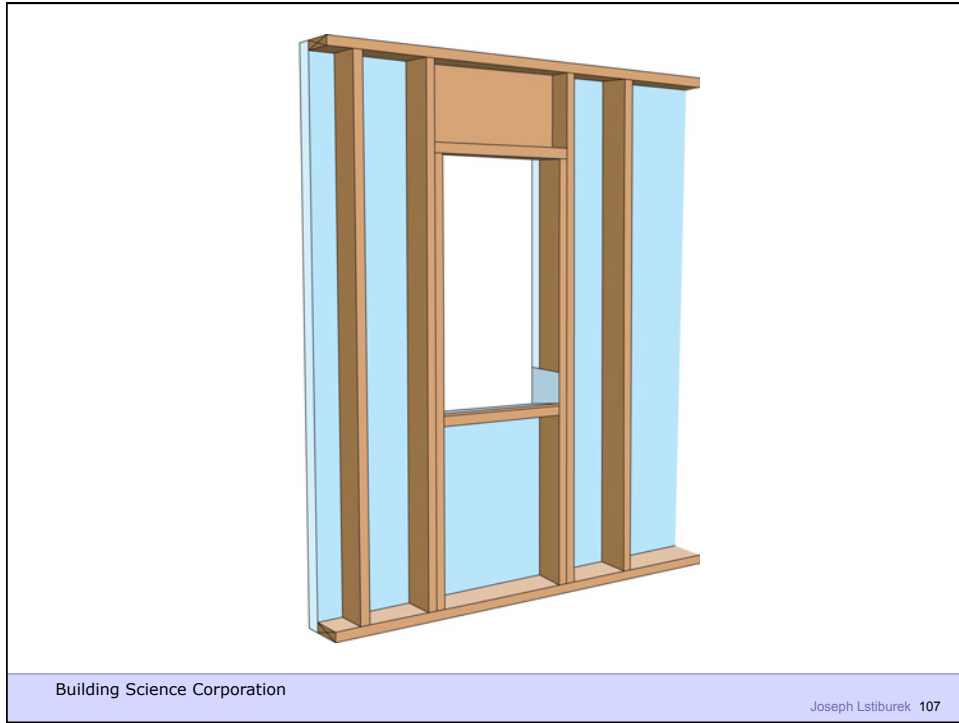
















Building Science Corporation

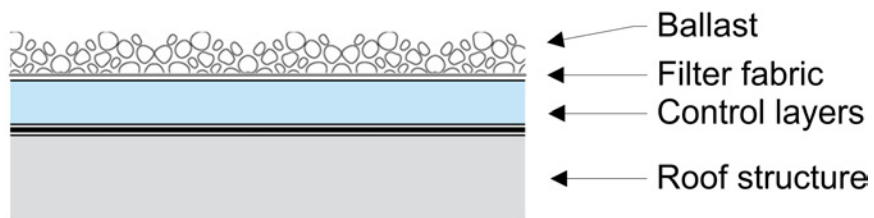
Joseph Lstiburek 111

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

# Building Science

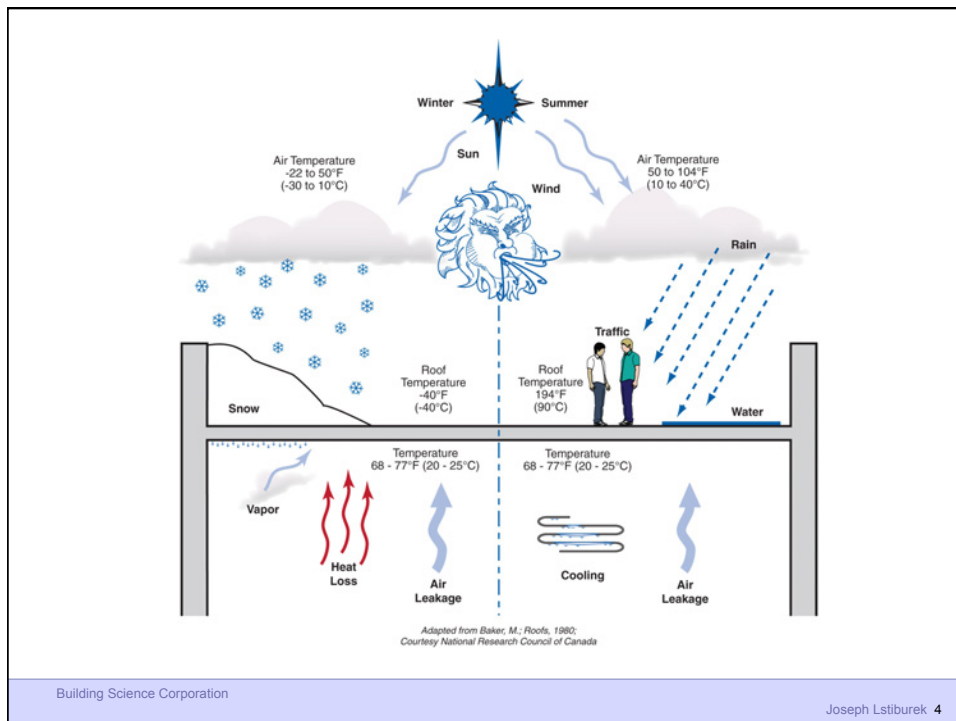
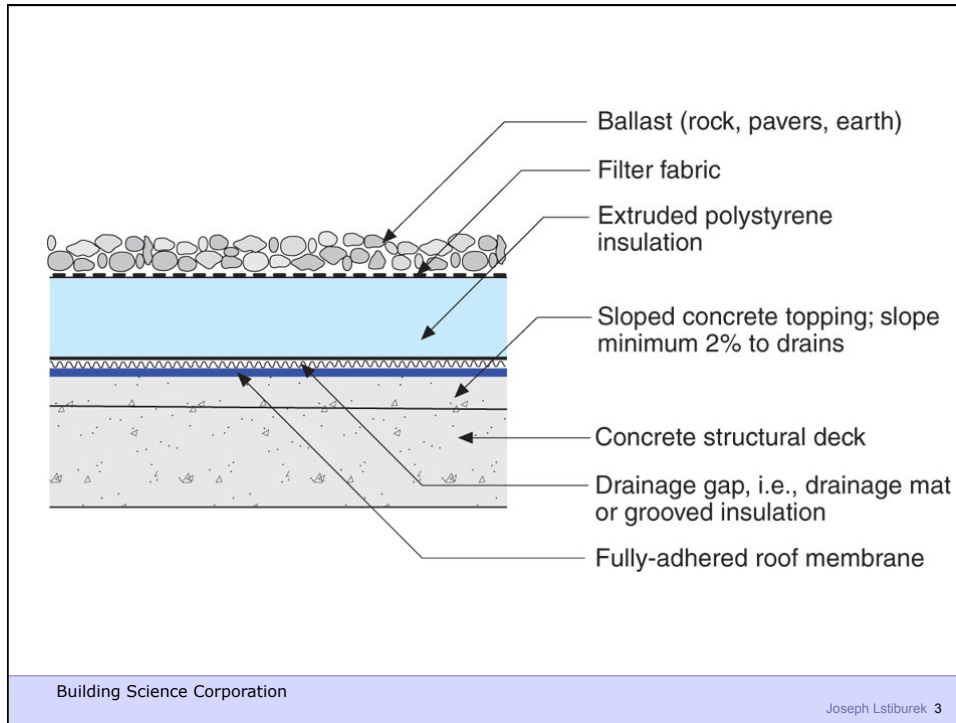
Adventures In Building Science

[www.buildingscience.com](http://www.buildingscience.com)

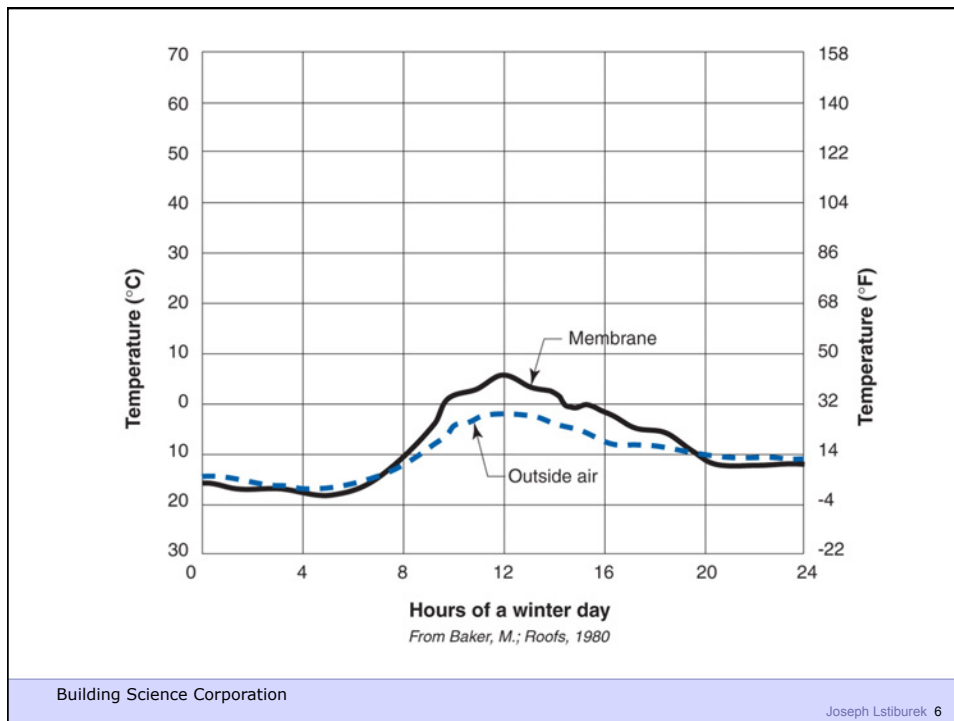
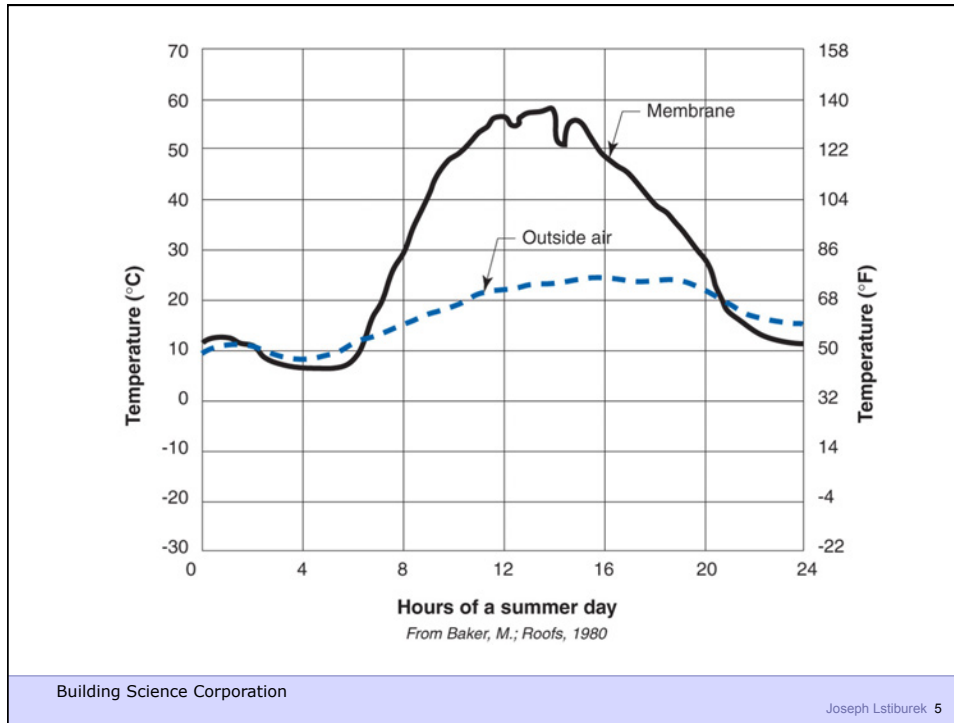


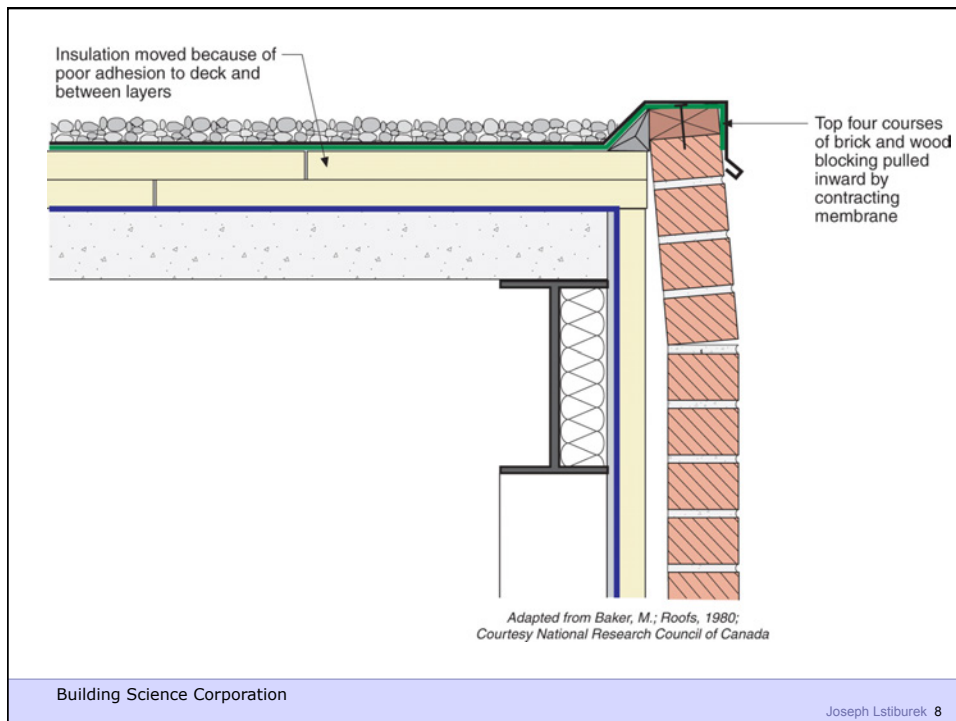
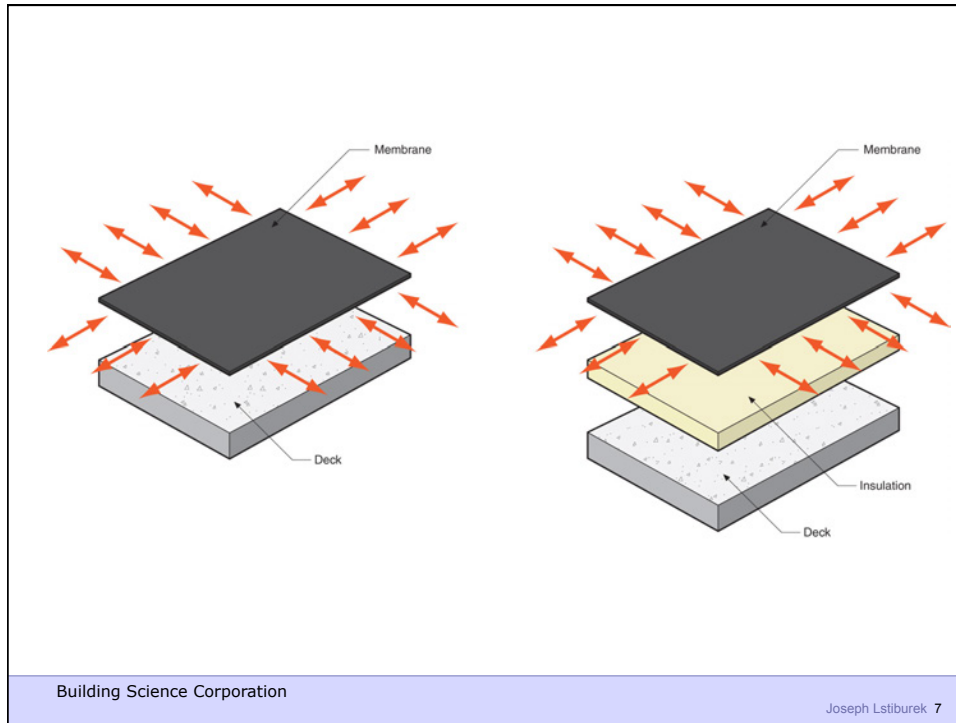
Building Science Corporation

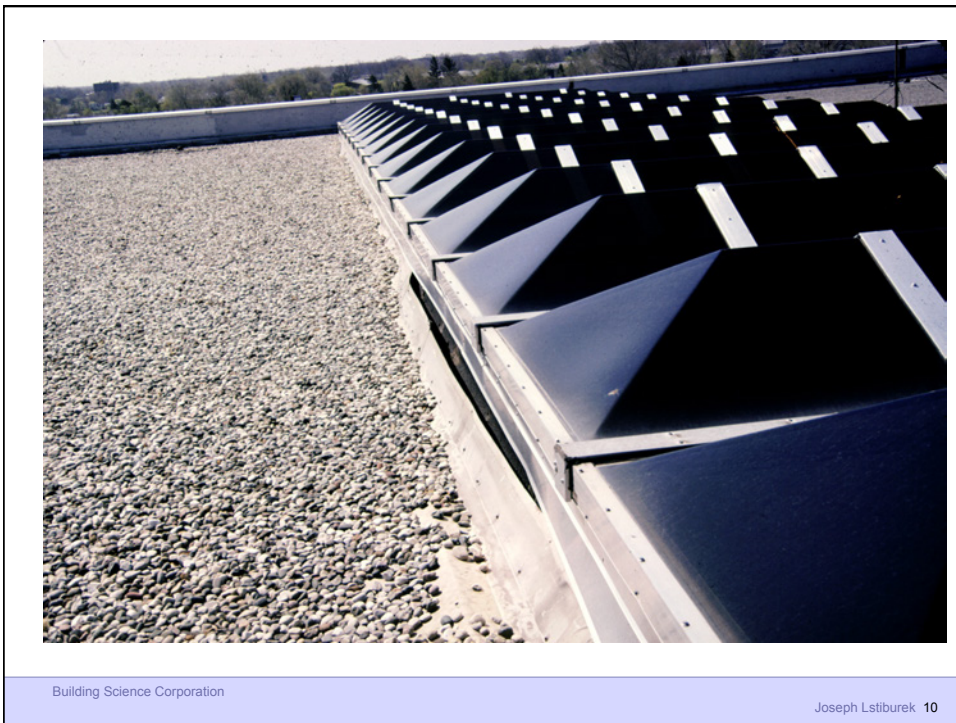
Joseph Lstiburek 2



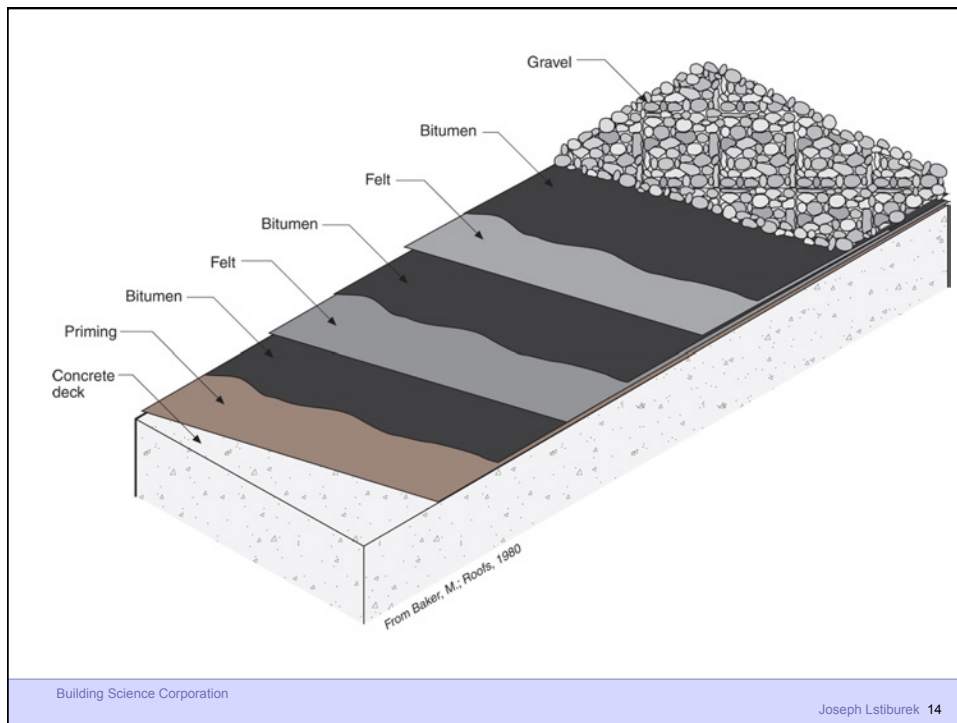
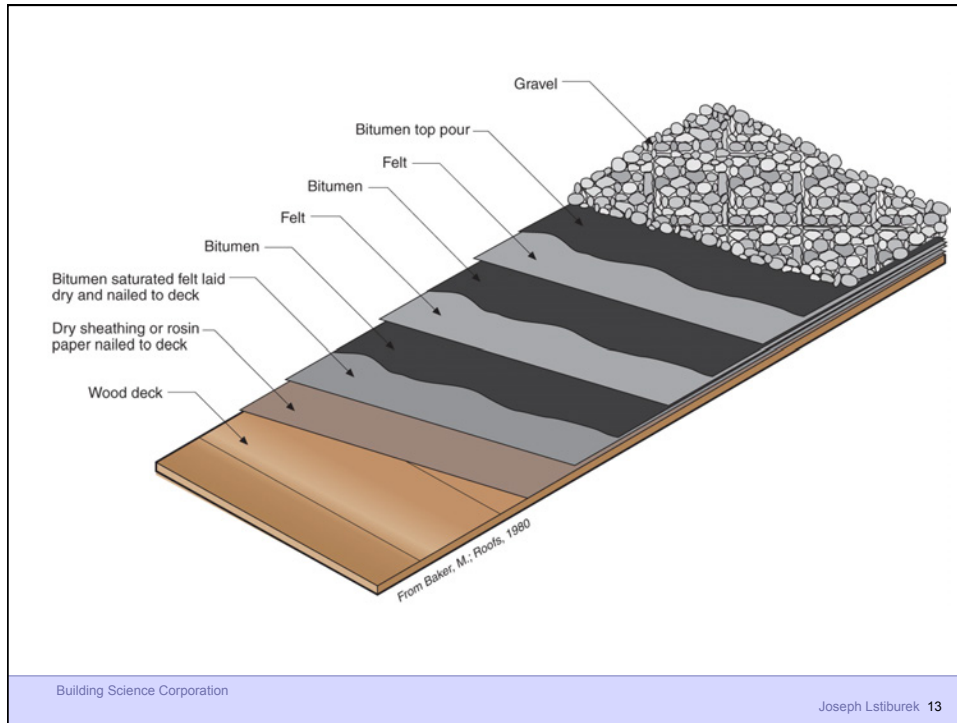


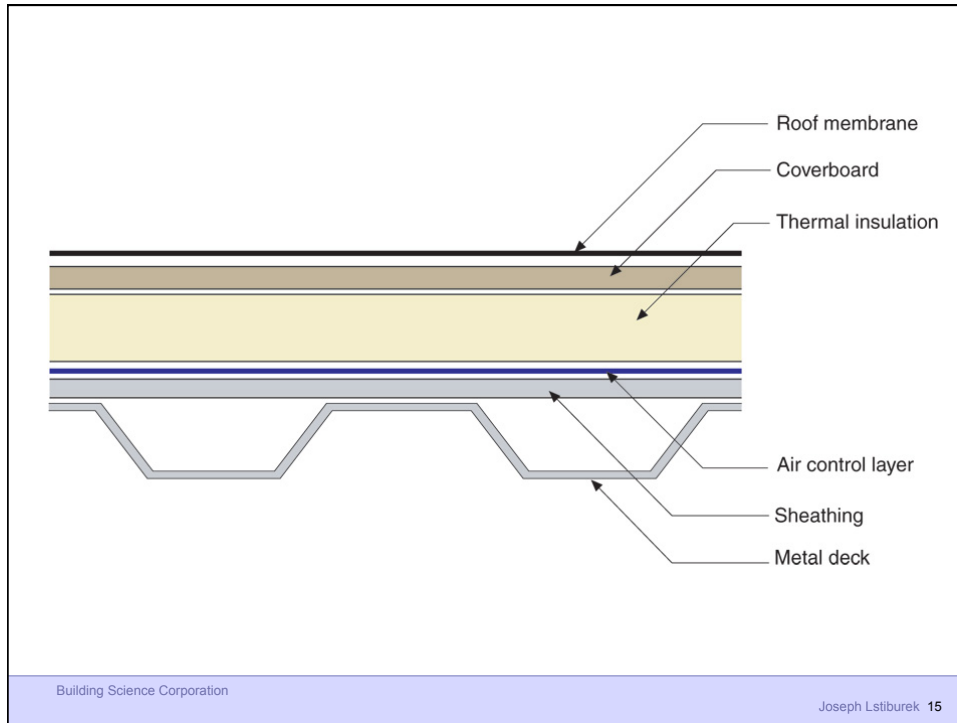


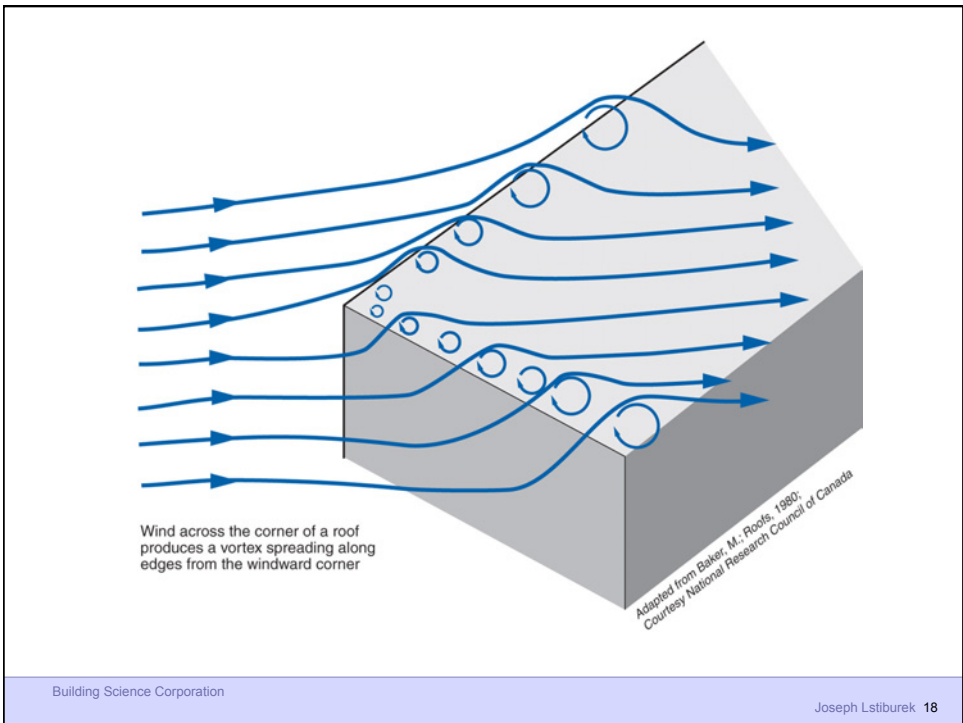
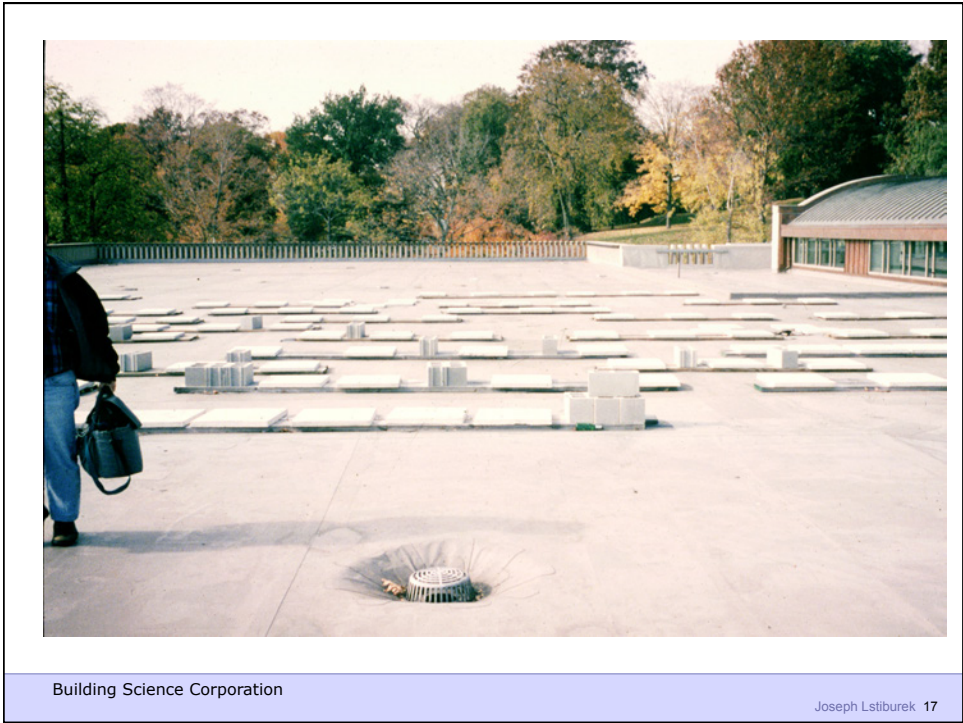


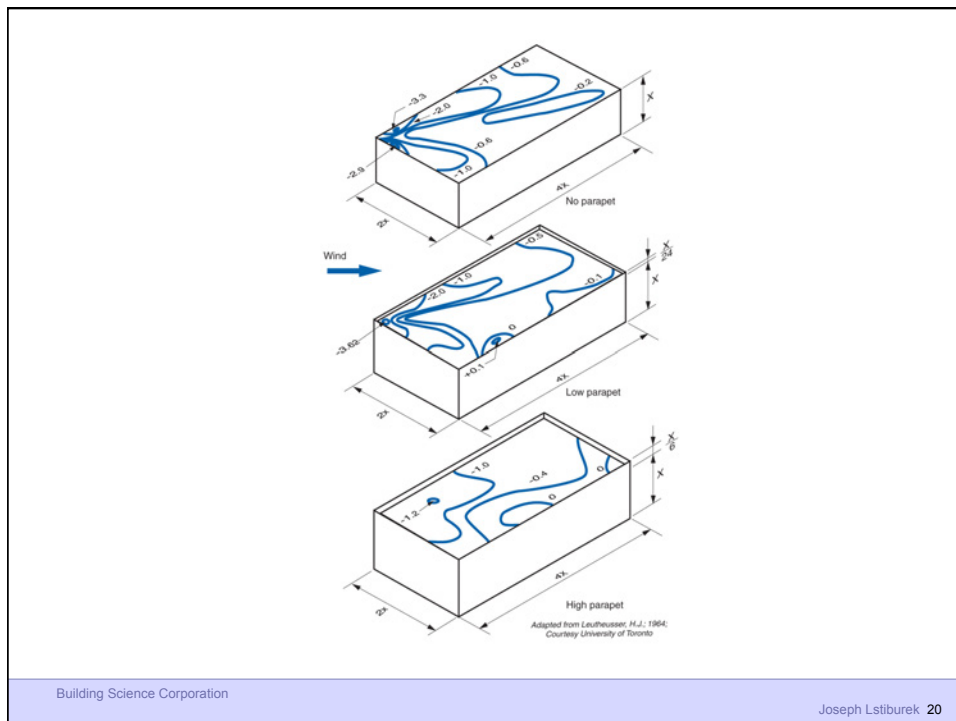
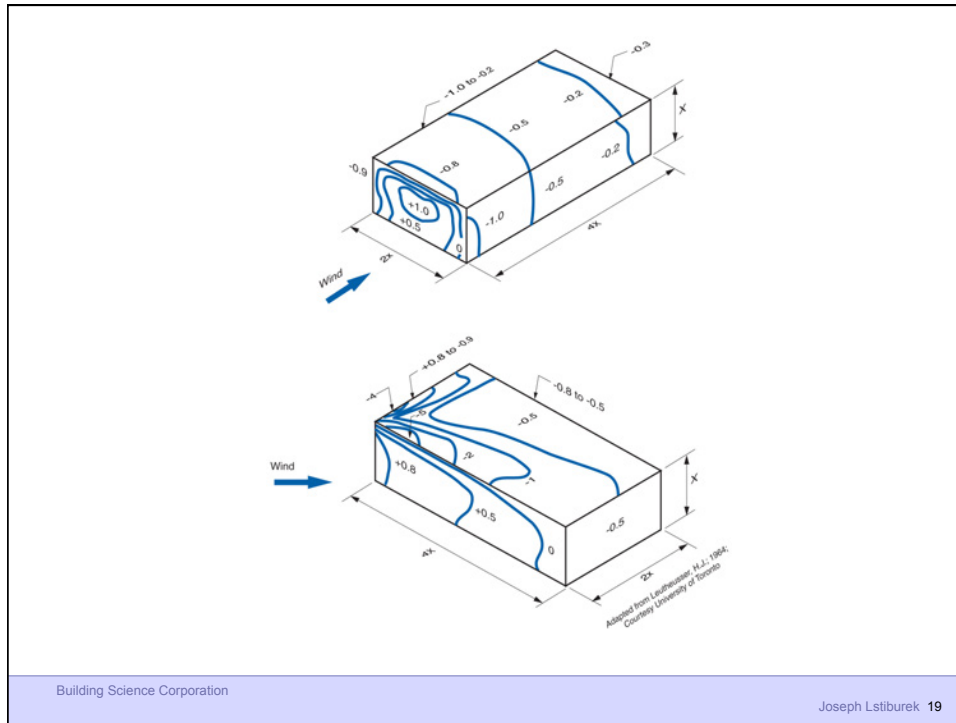




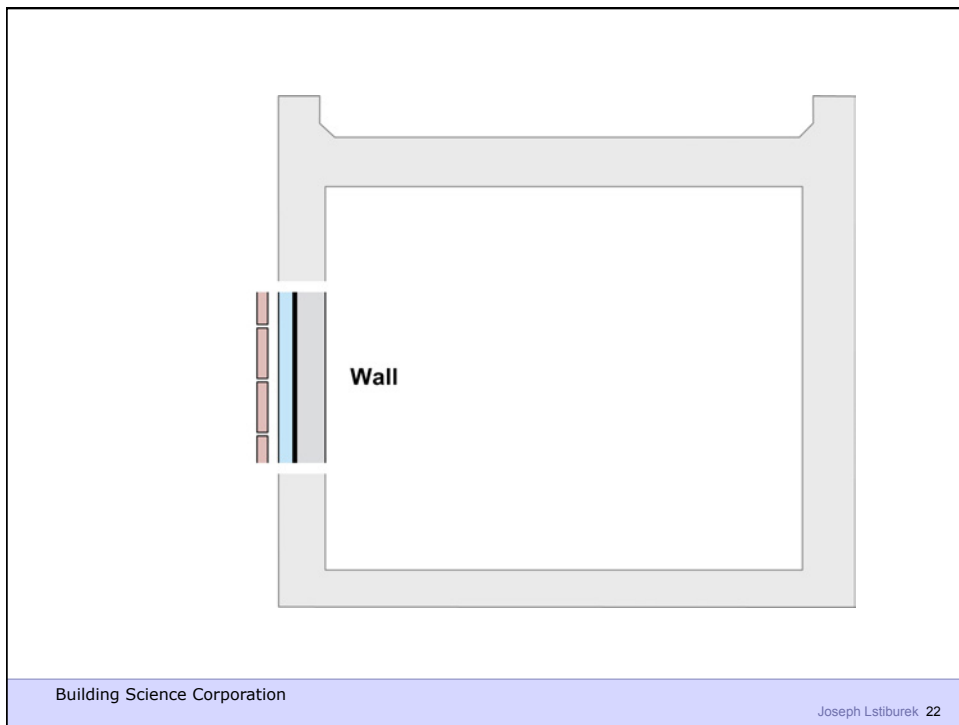
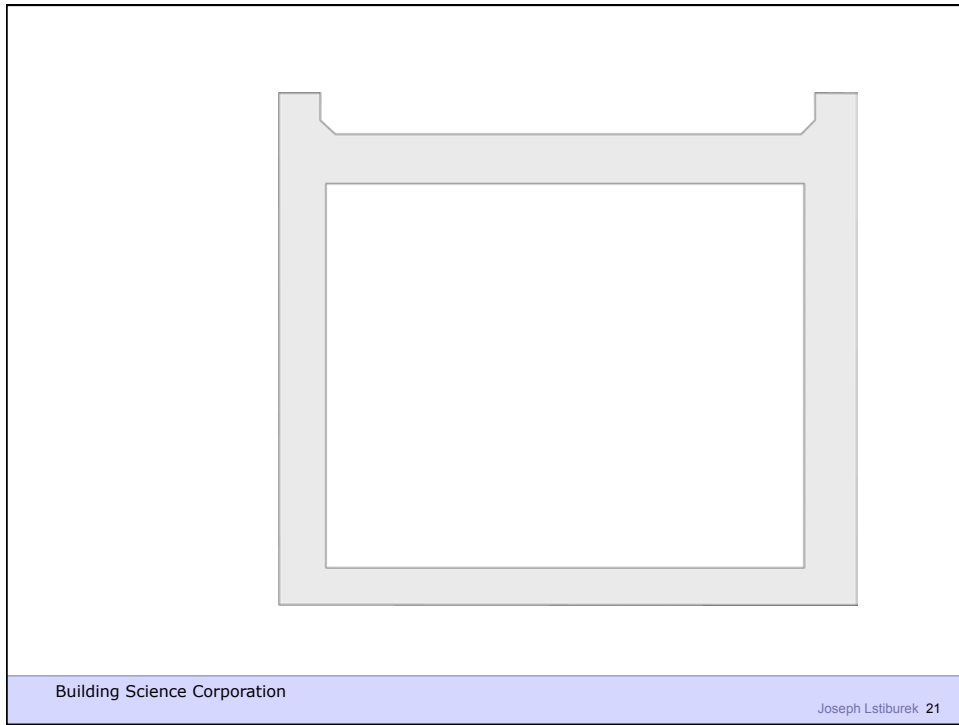


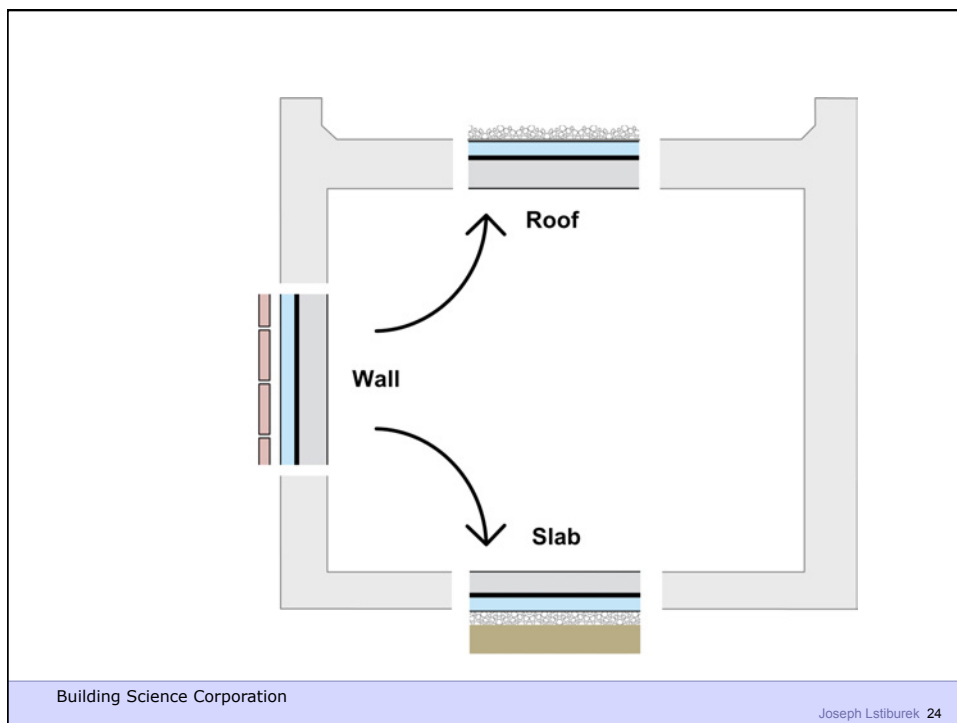
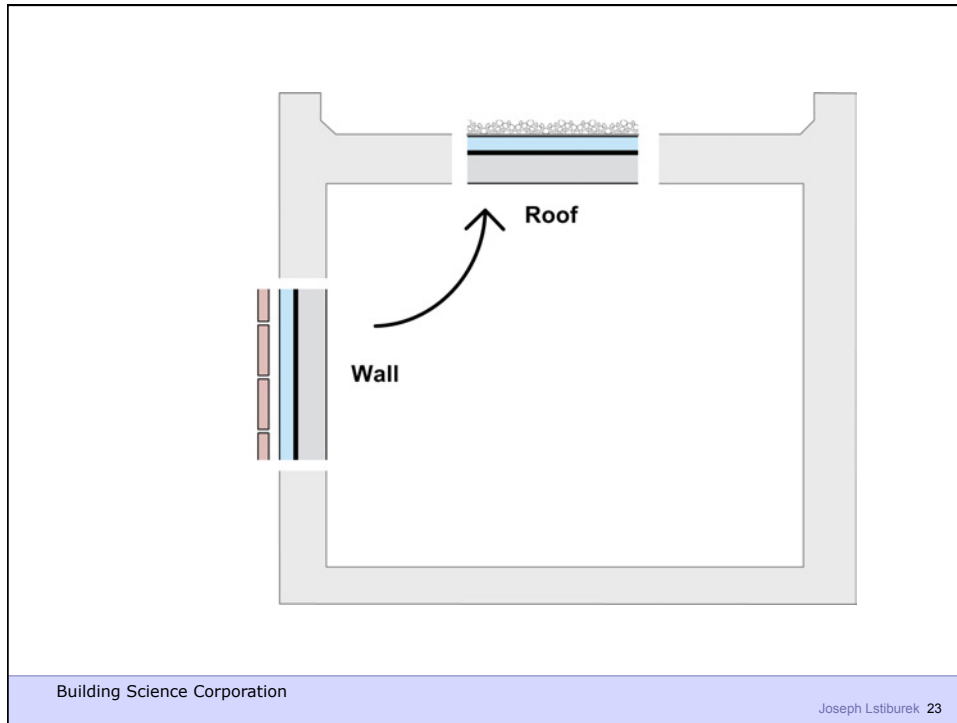


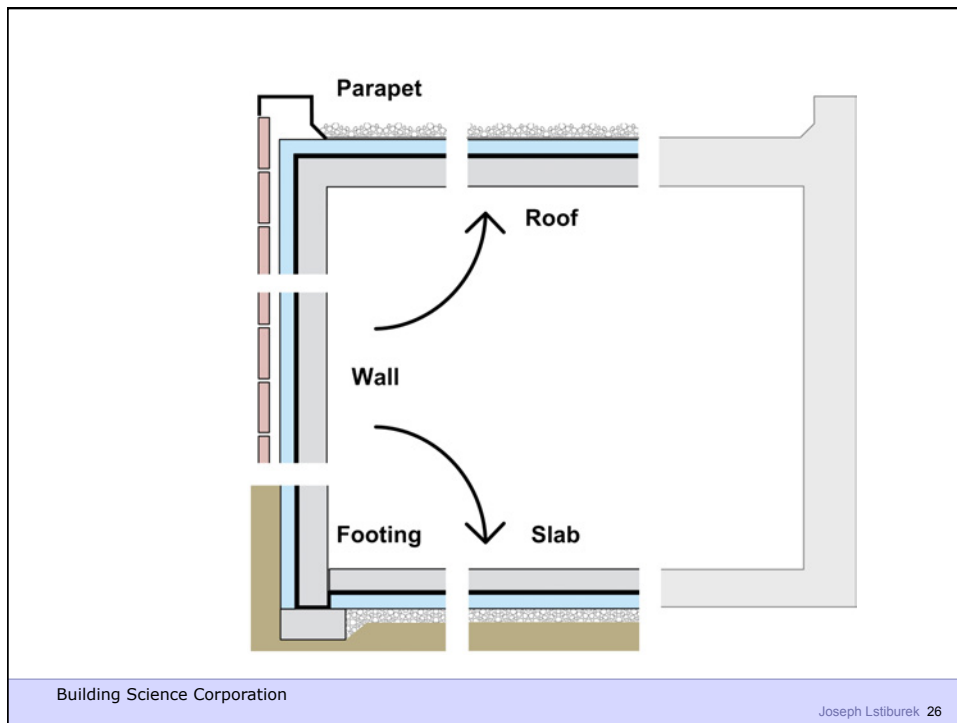
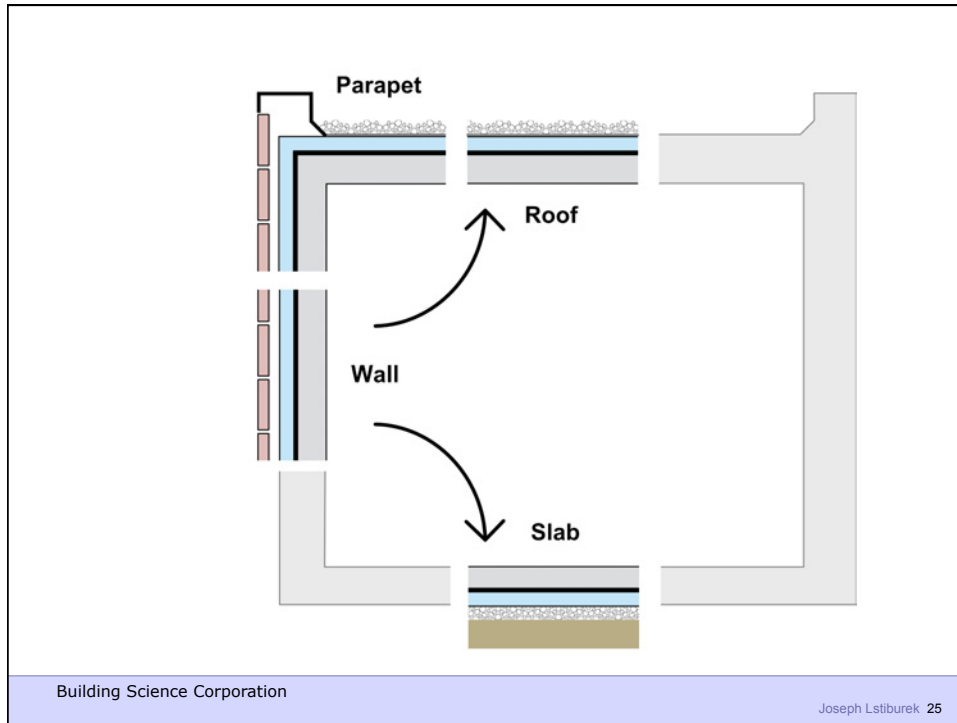


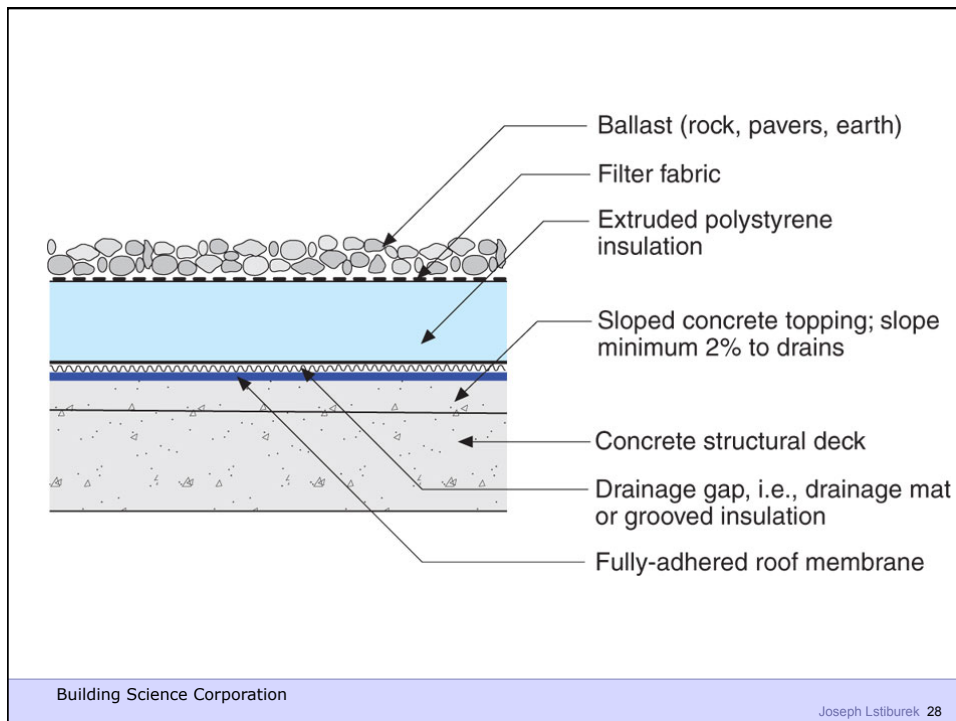
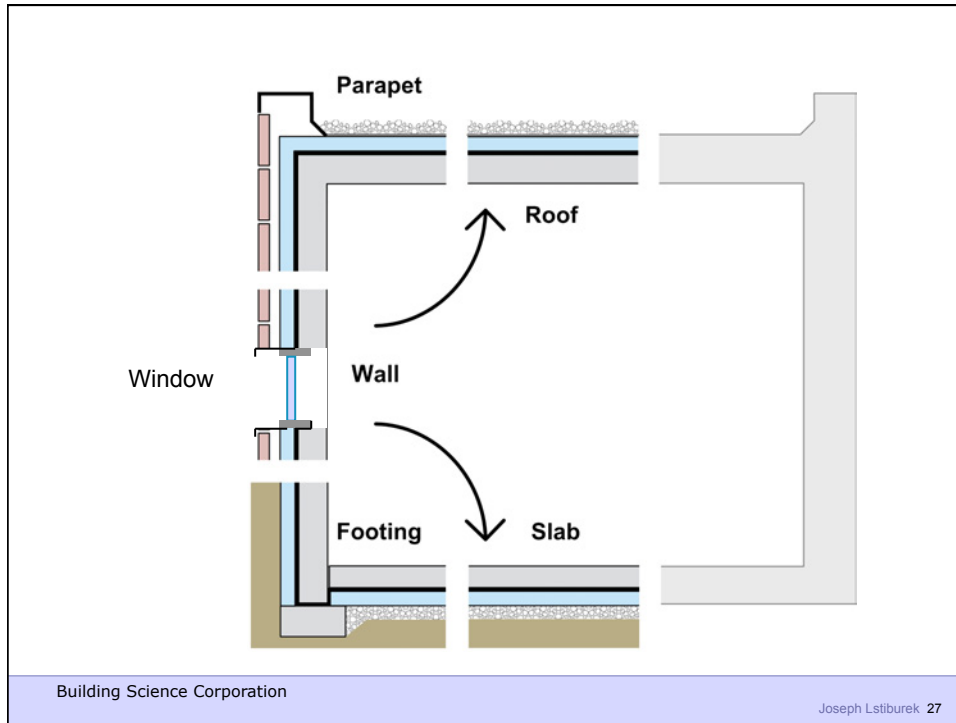


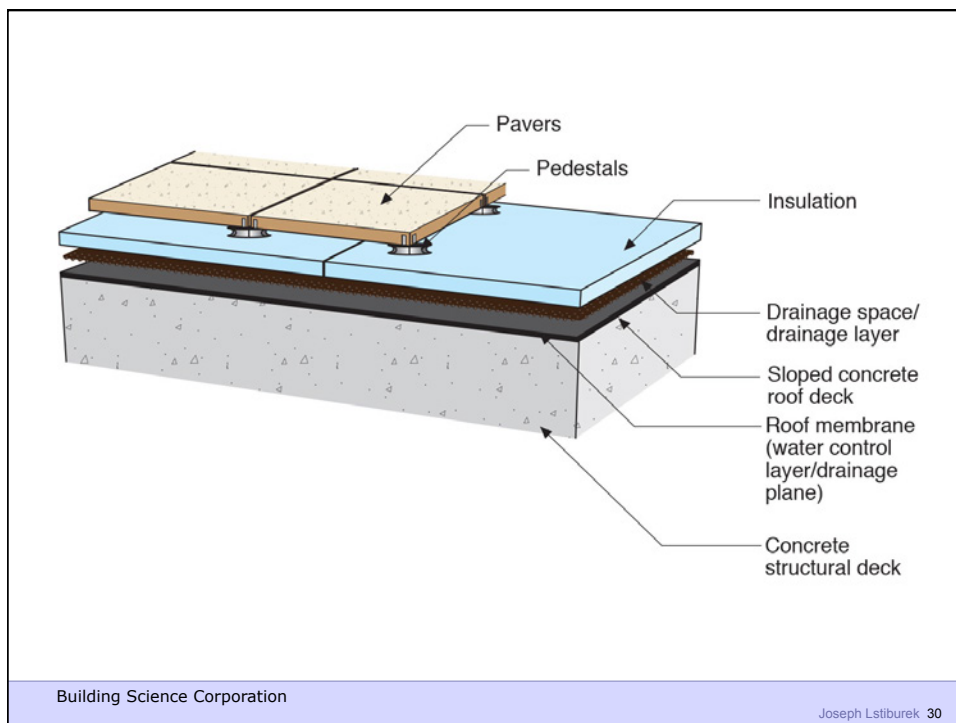
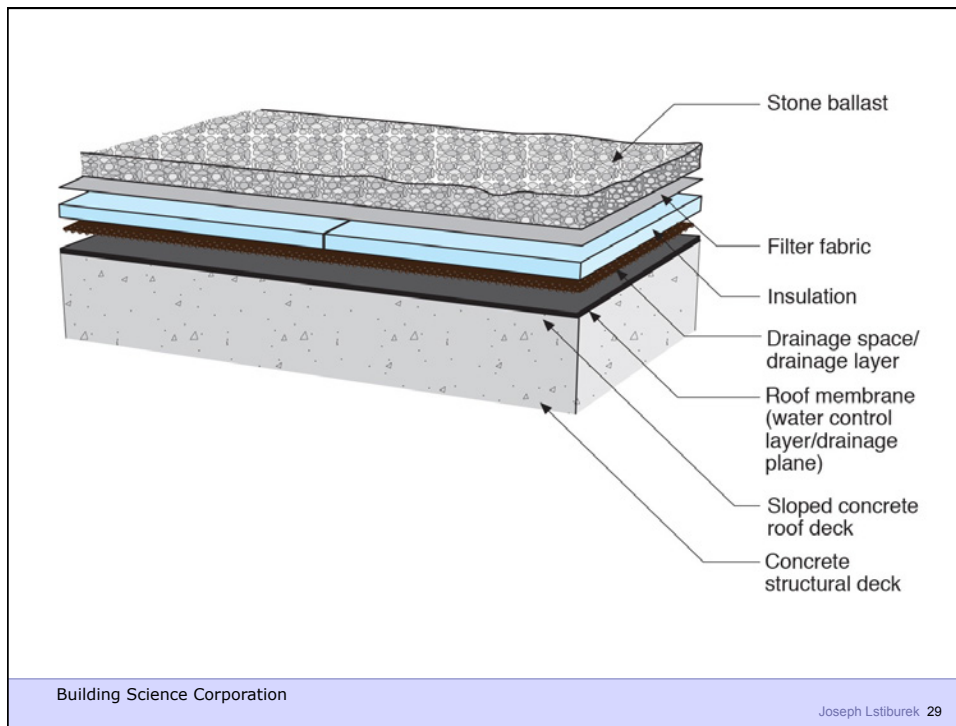


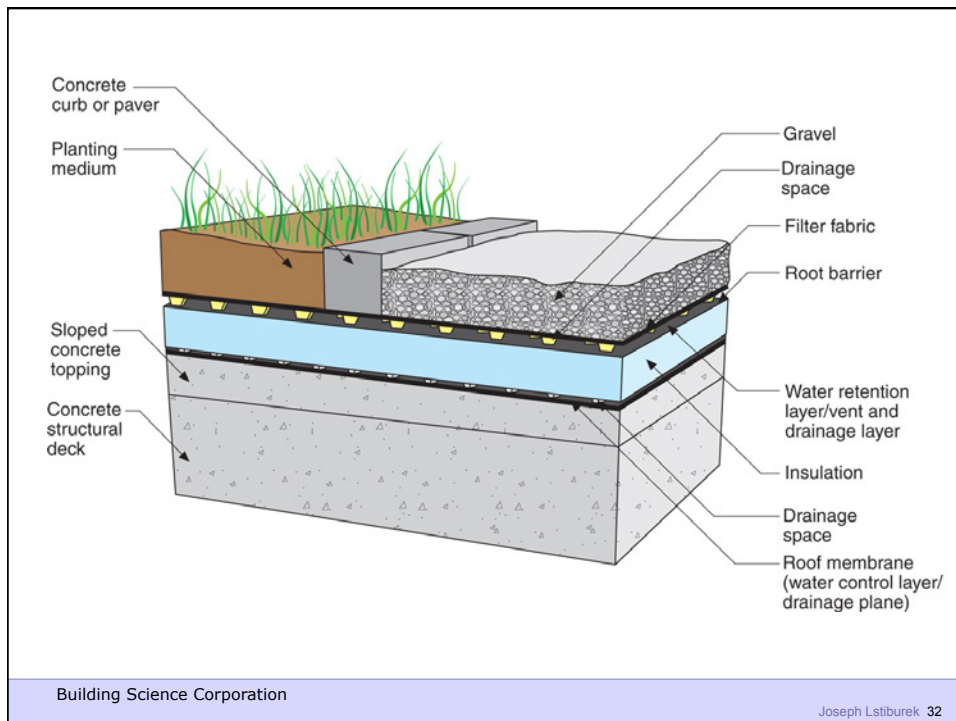
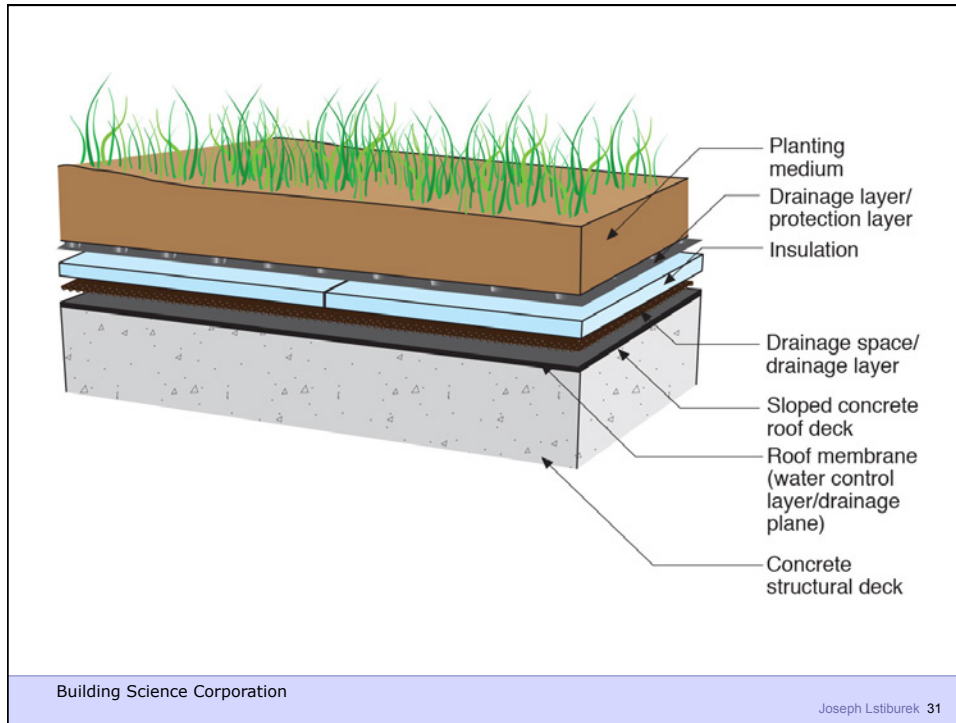














Building Science Corporation

Joseph Lstiburek 33



Building Science Corporation

Joseph Lstiburek 34



Building Science Corporation

Joseph Lstiburek 35



Building Science Corporation

Joseph Lstiburek 36





Building Science Corporation

Joseph Lstiburek 37



Building Science Corporation

Joseph Lstiburek 38

## Plaza Decks

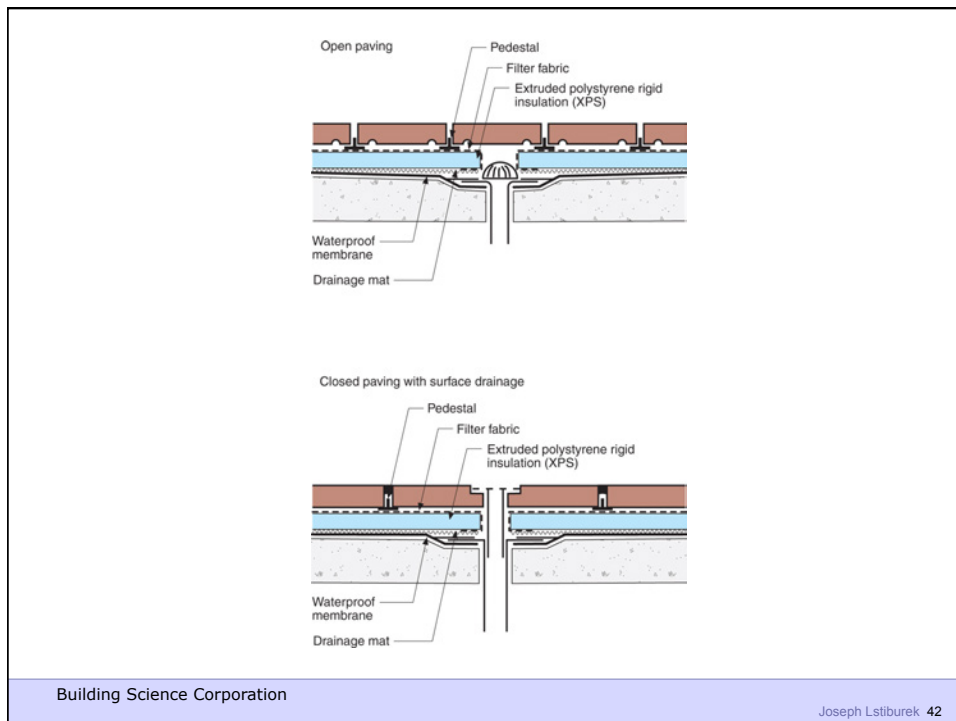
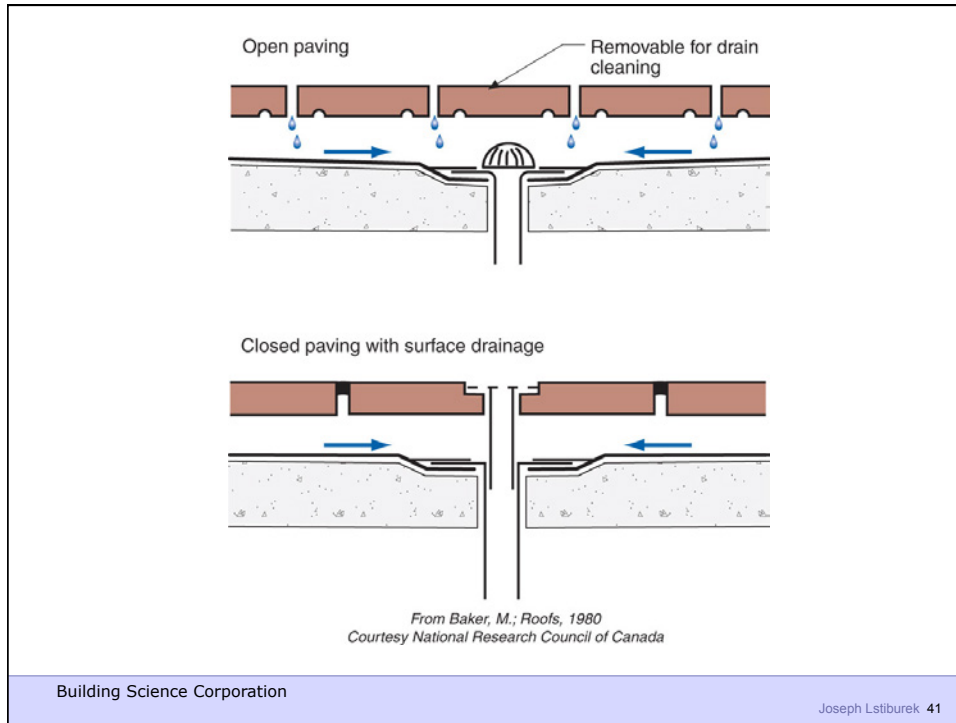
Building Science Corporation

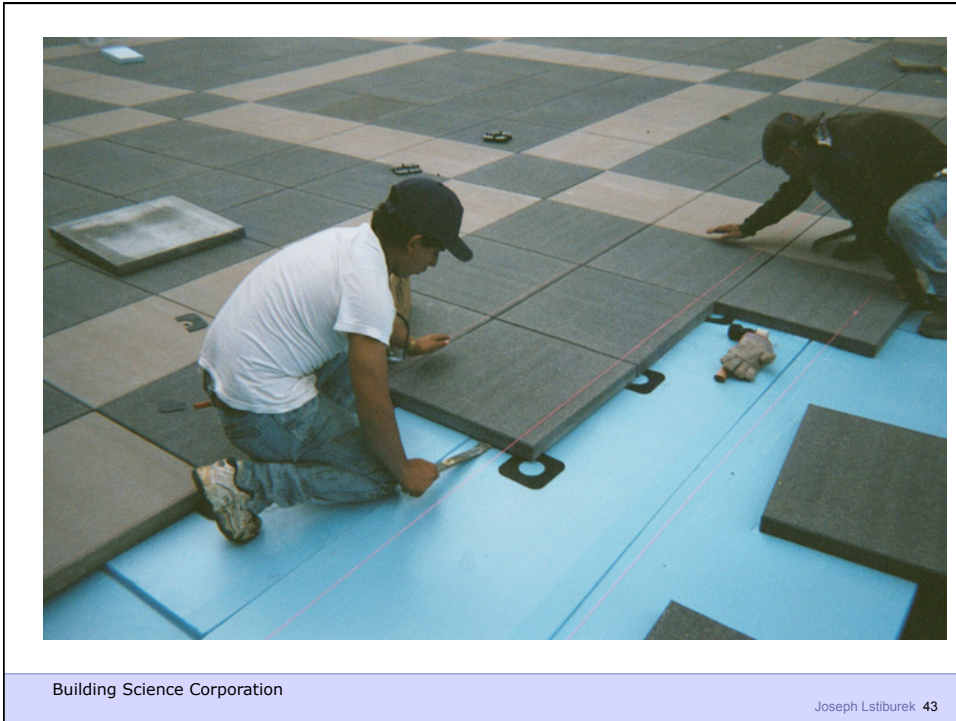
Joseph Lstiburek 39



Building Science Corporation

Joseph Lstiburek 40







Building Science Corporation

Joseph Lstiburek 45



Building Science Corporation

Joseph Lstiburek 46



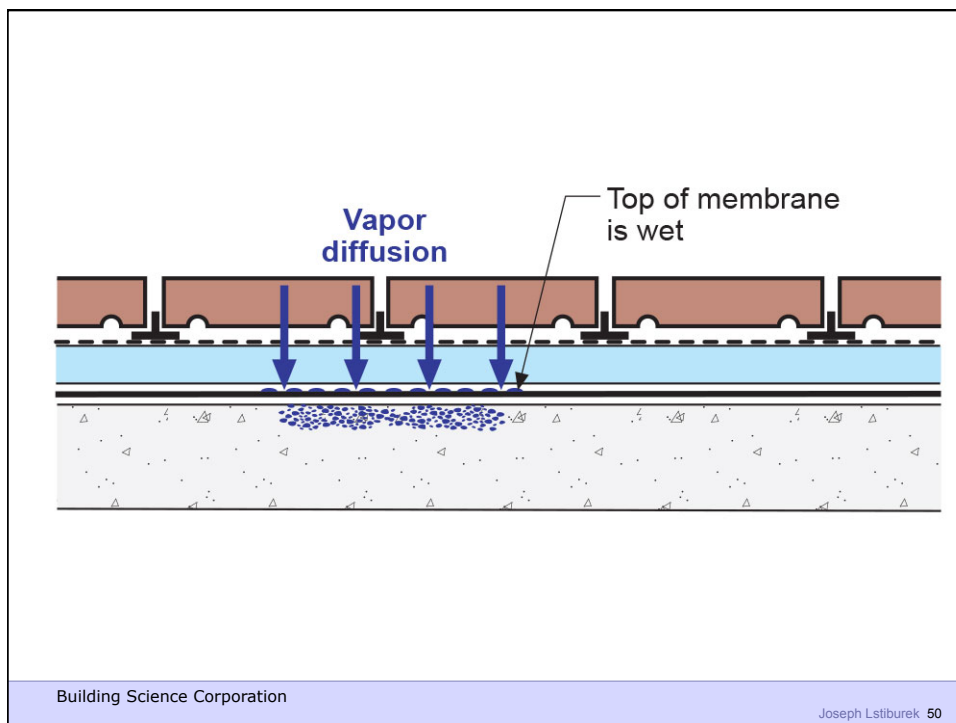
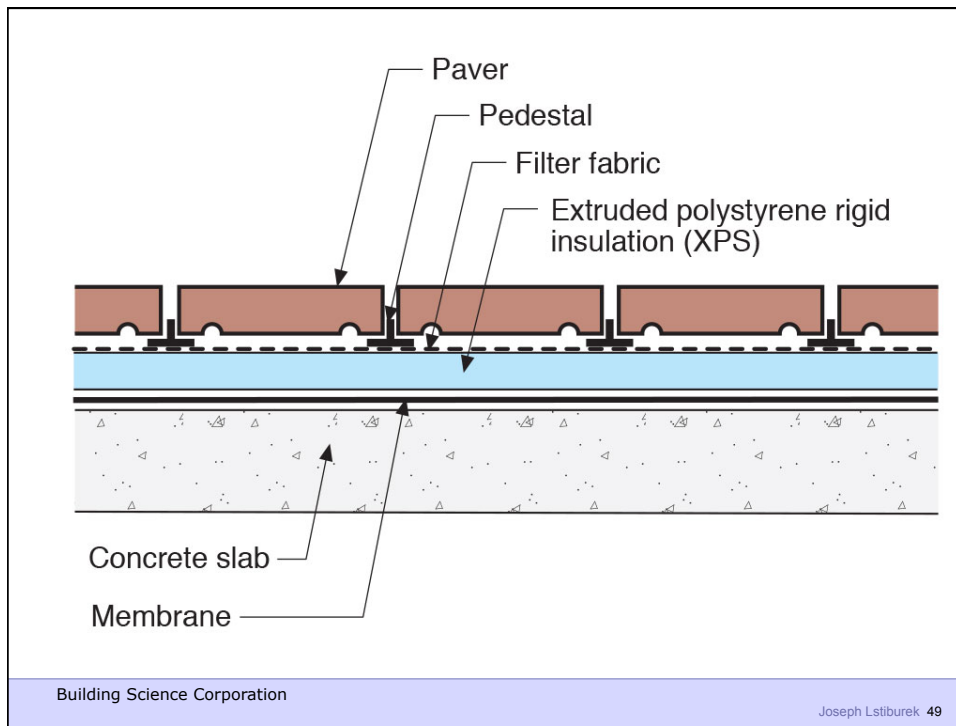
Building Science Corporation

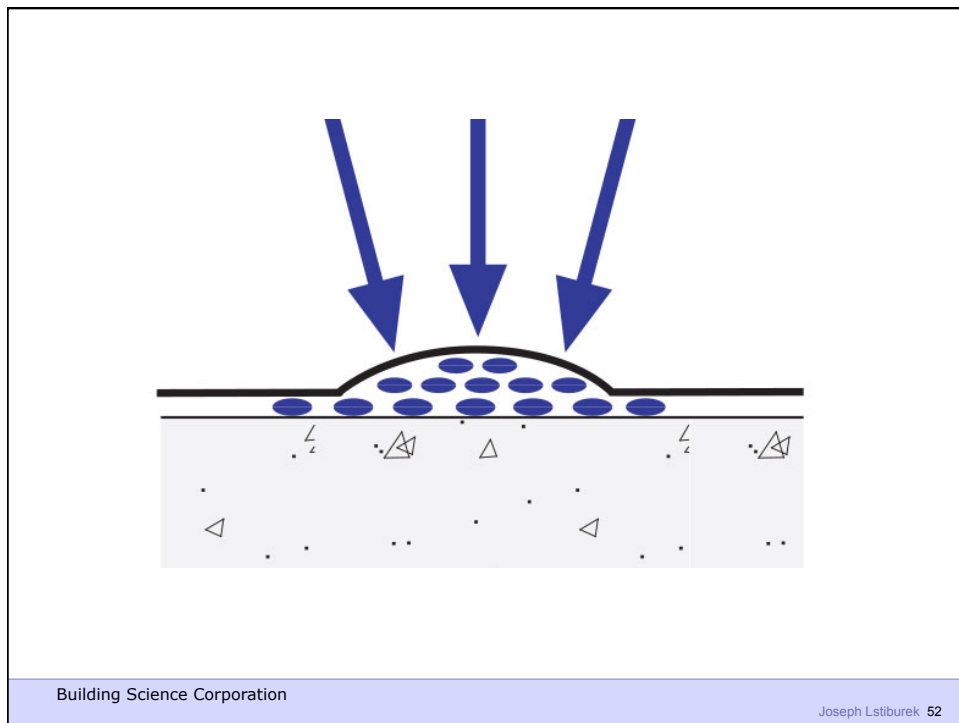
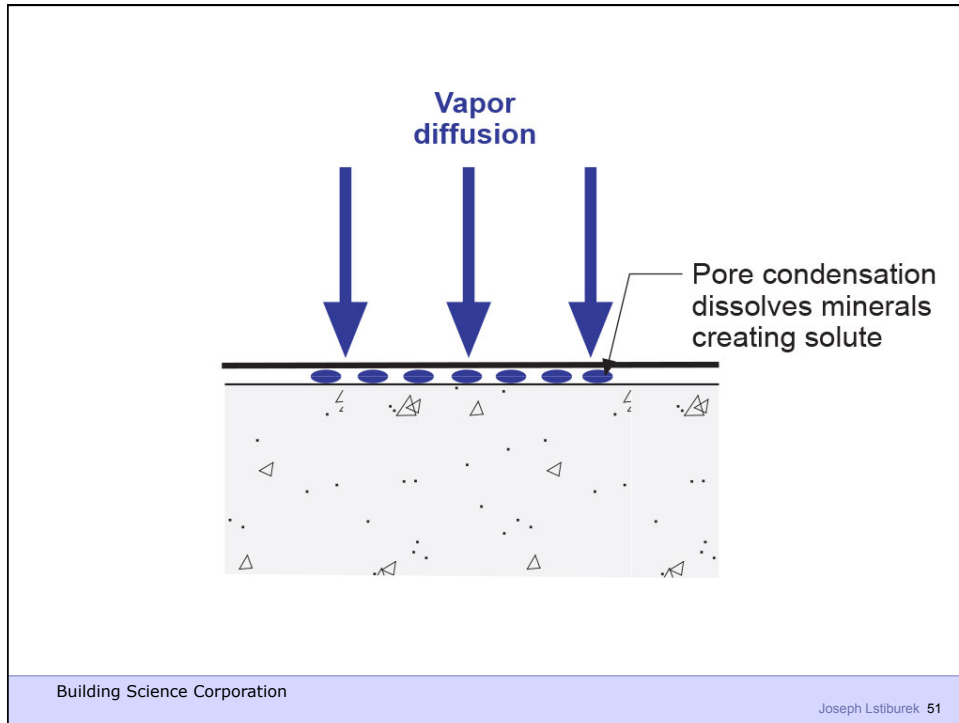
Joseph Lstiburek 47

## Osmosis

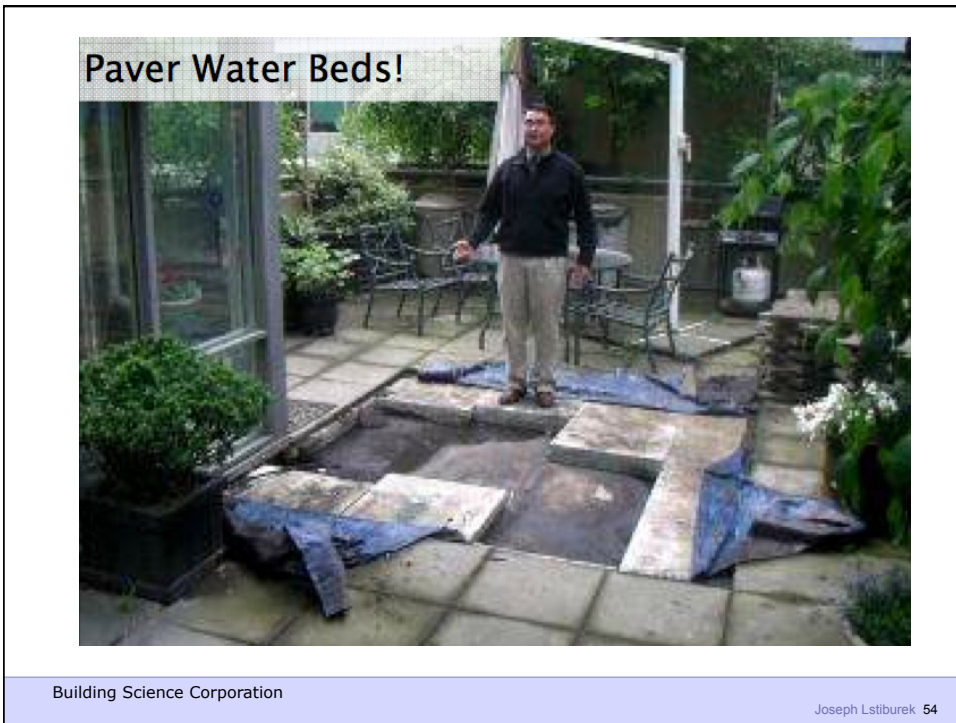
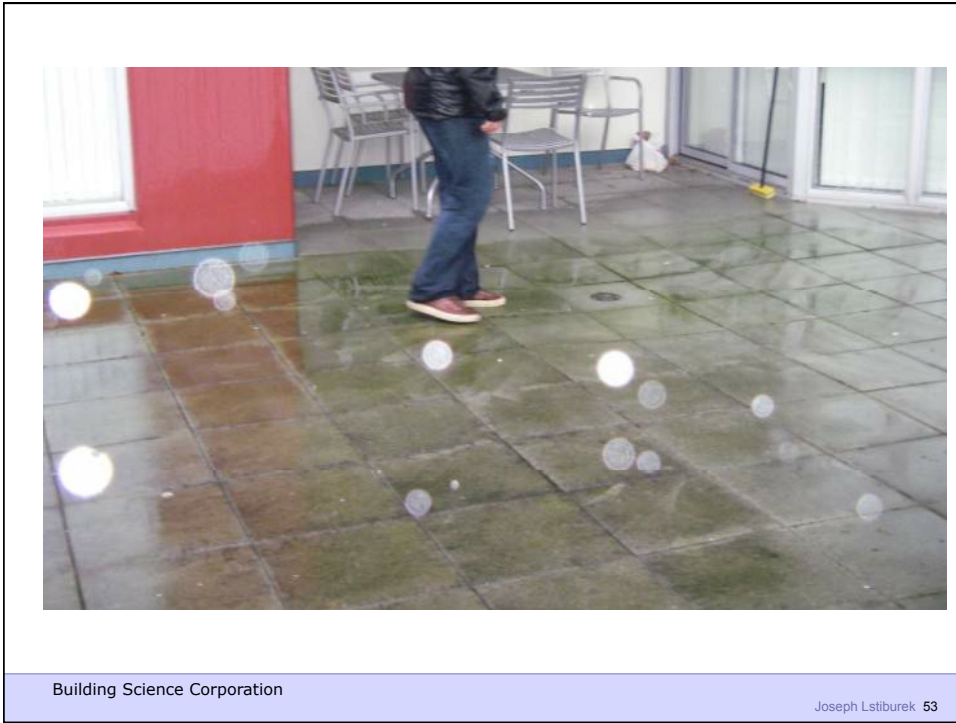
Building Science Corporation

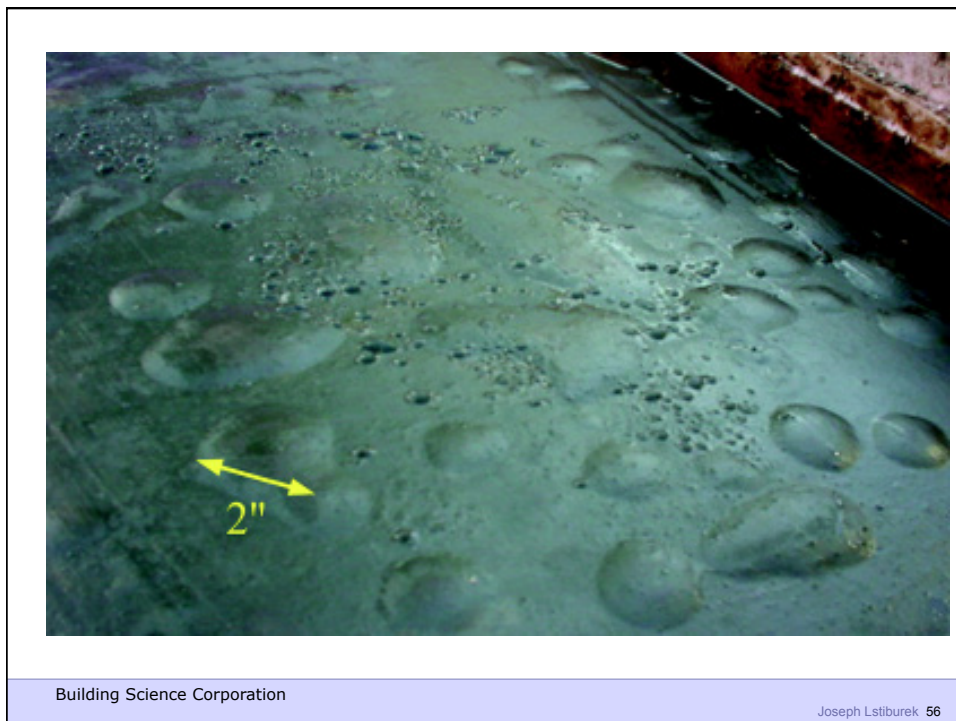
Joseph Lstiburek 48









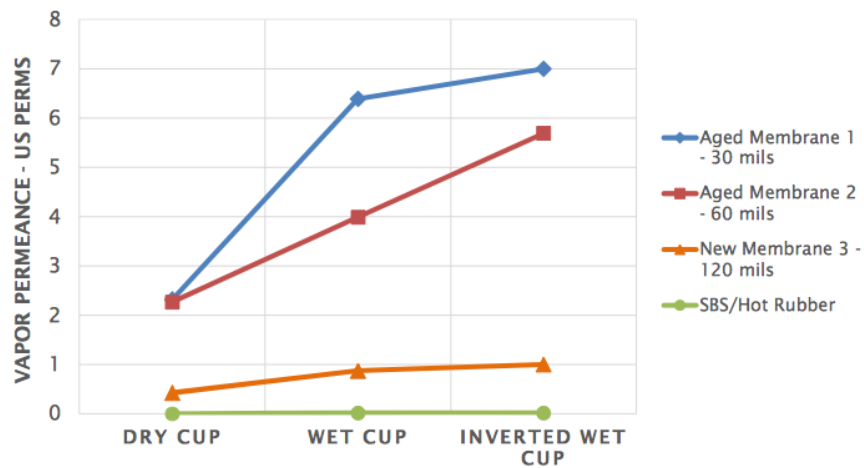




Building Science Corporation

Joseph Lstiburek 57

### VAPOR PERMEANCE OF LIQUID MEMBRANES



Building Science Corporation

Joseph Lstiburek 58

## What Is Important For Long Term Performance?

Building Science Corporation

Joseph Lstiburek 59

## What Is Important For Long Term Performance? Provide a Protection Layer and Drainage Mat

Building Science Corporation

Joseph Lstiburek 60

## What Is Important For Long Term Performance?

Provide a Protection Layer and Drainage Mat

Isolate the System From Other Building Elements Such as Planters, Pools and Landscaping

## What Is Important For Long Term Performance?

Provide a Protection Layer and Drainage Mat

Isolate the System From Other Building Elements Such as Planters, Pools and Landscaping

Provide Curbs at Penetrations







Building Science Corporation

Joseph Lstiburek 67



Building Science Corporation

Joseph Lstiburek 68







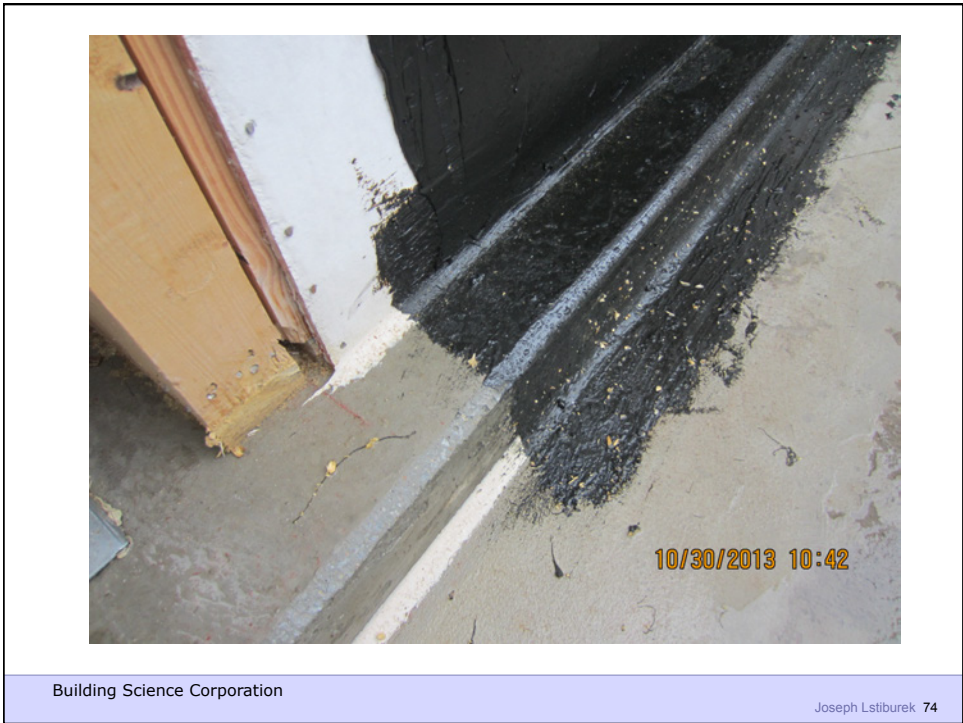
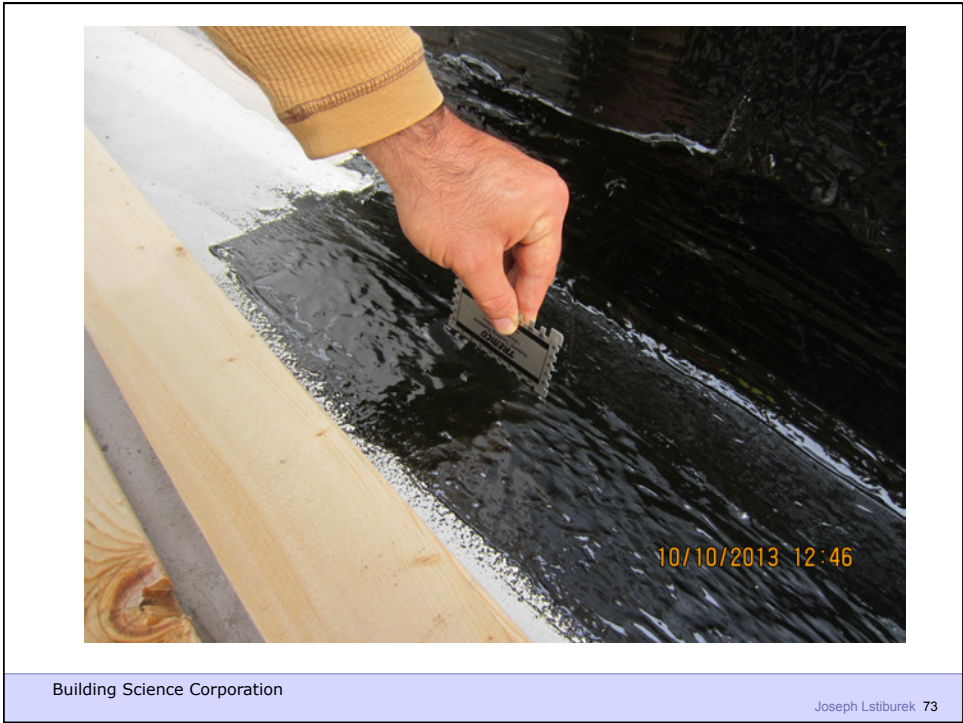
Building Science Corporation

Joseph Lstiburek 71



Building Science Corporation

Joseph Lstiburek 72





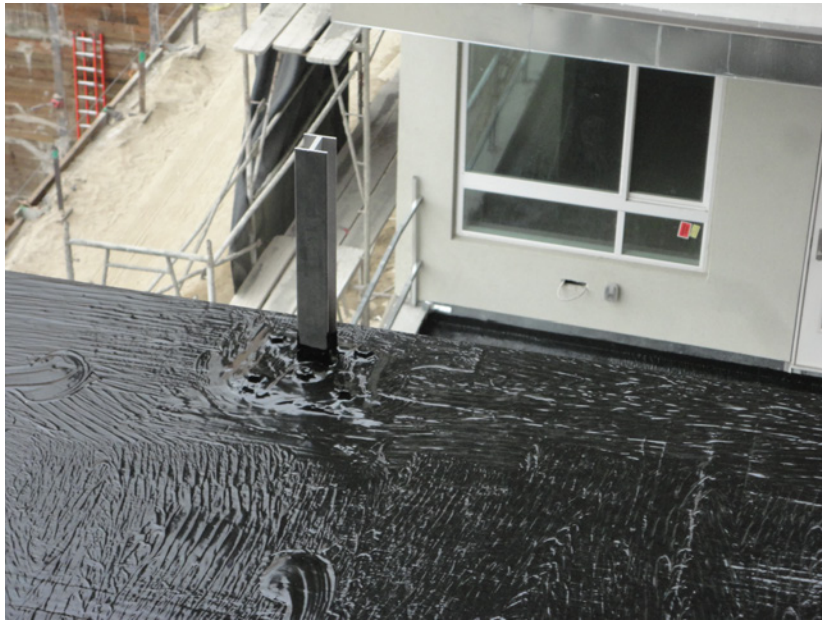
Building Science Corporation

Joseph Lstiburek 75



Building Science Corporation

Joseph Lstiburek 76



Building Science Corporation

Joseph Lstiburek 77



Building Science Corporation

Joseph Lstiburek 78







Building Science Corporation

Joseph Lstiburek 83



Building Science Corporation

Joseph Lstiburek 84





Building Science Corporation

Joseph Lstiburek 85



Building Science Corporation

Joseph Lstiburek 86

## It's a Case of Black or White

Building Science Corporation

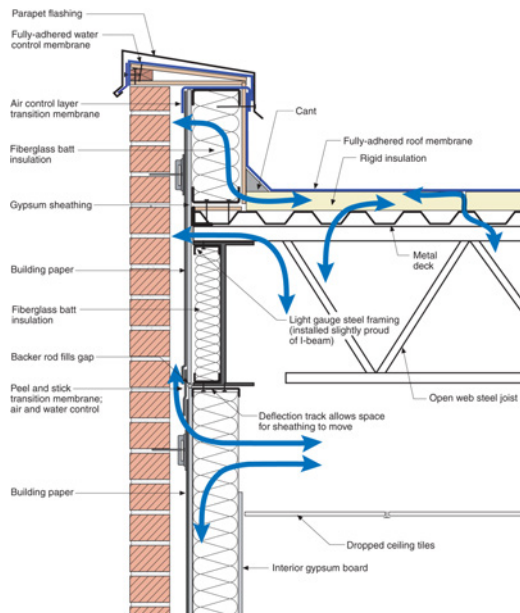
Joseph Lstiburek 87

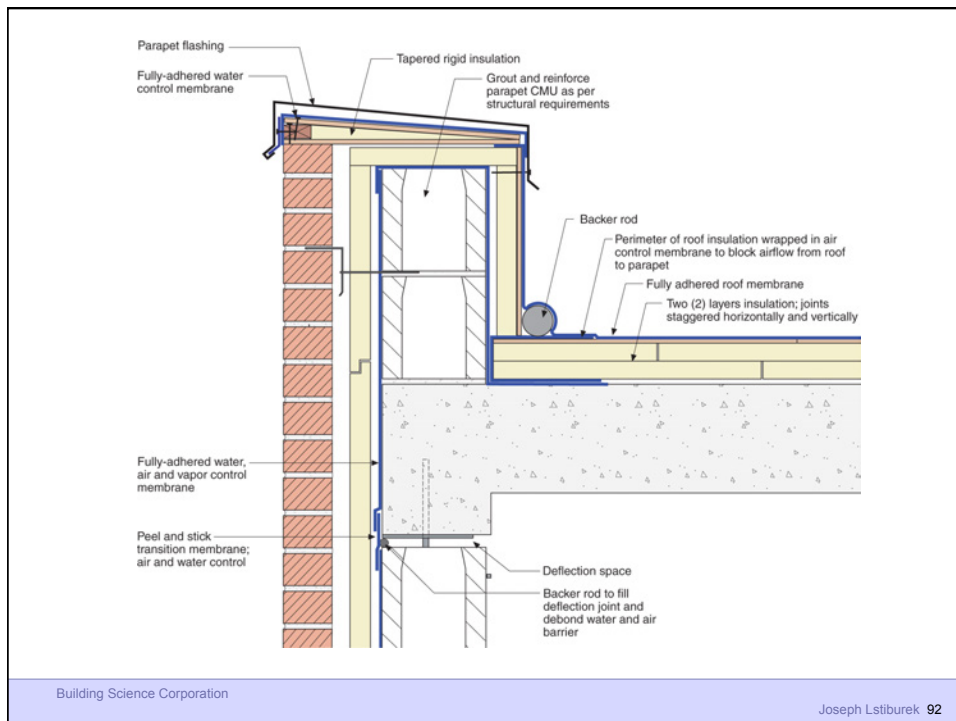
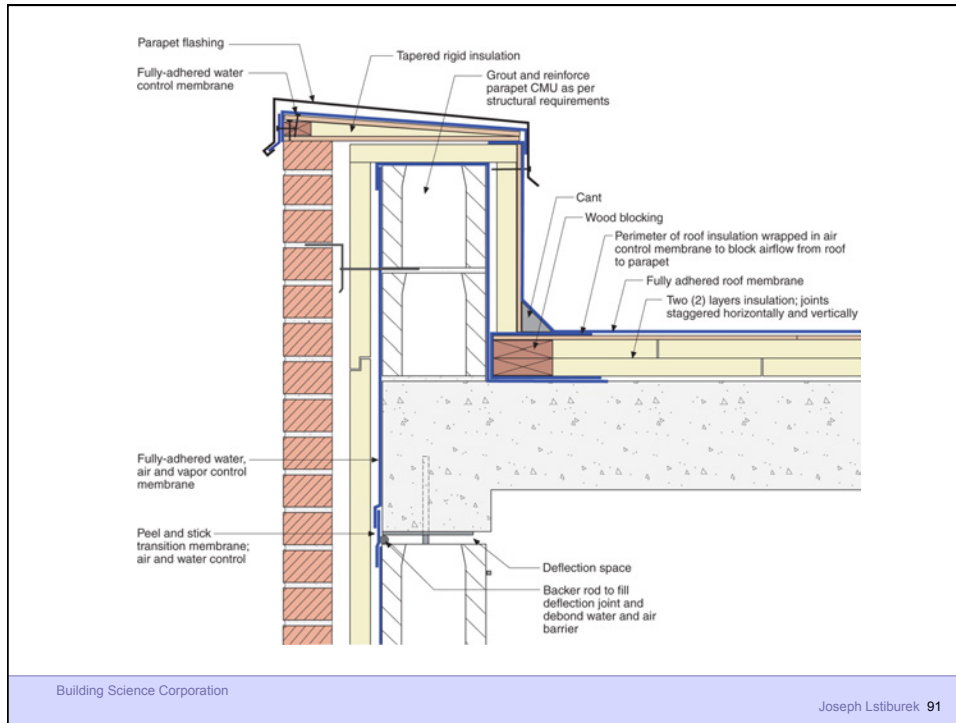
## It's a Case of Black or White Arrhenius

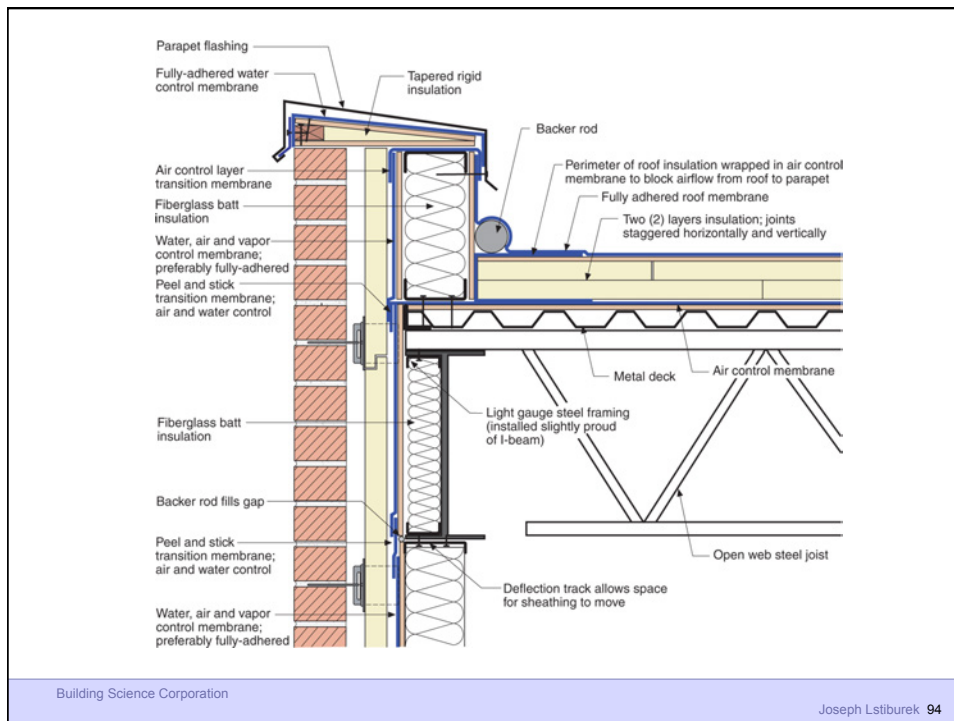
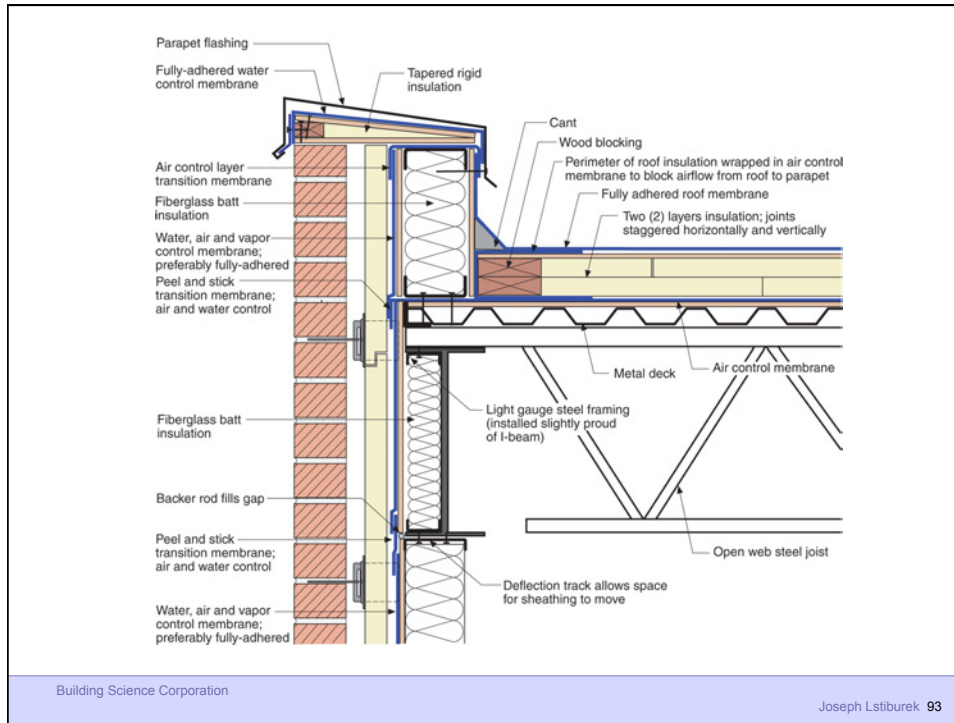
Building Science Corporation

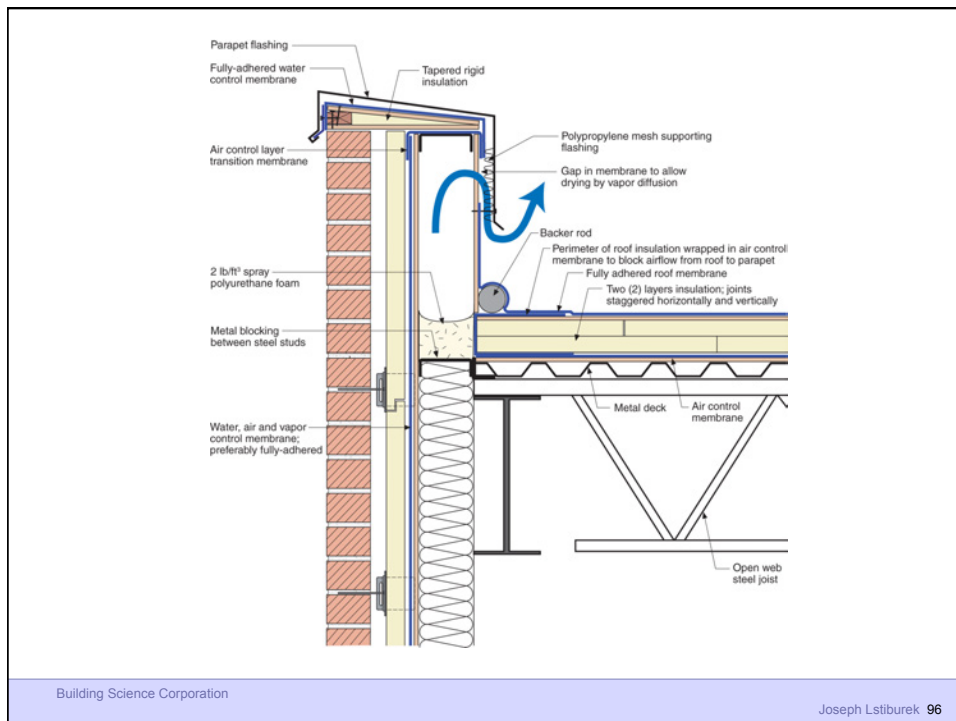
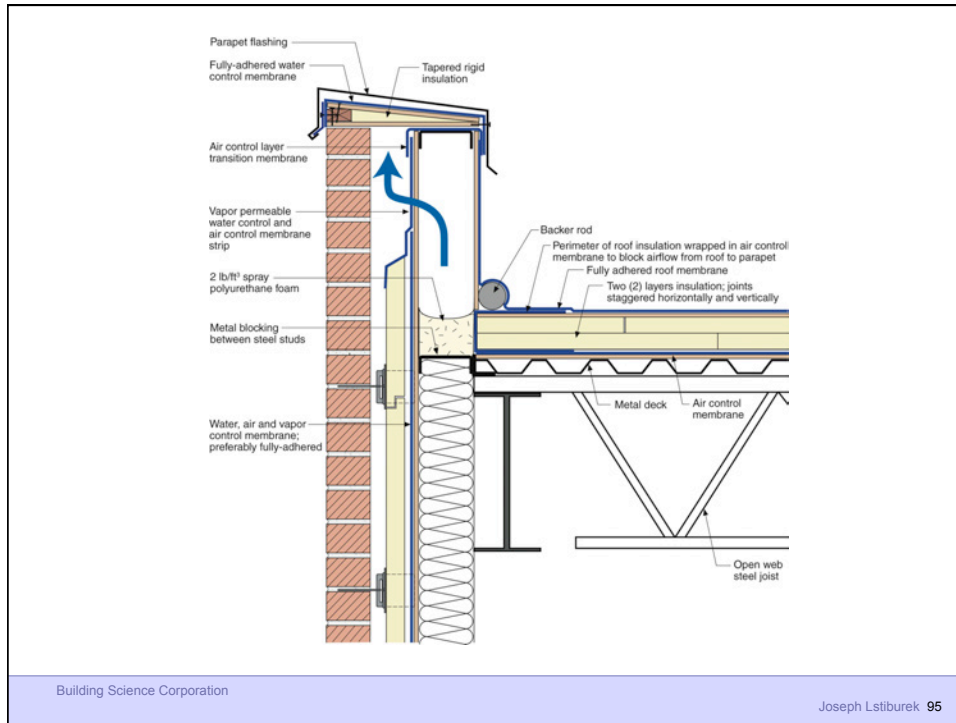
Joseph Lstiburek 88

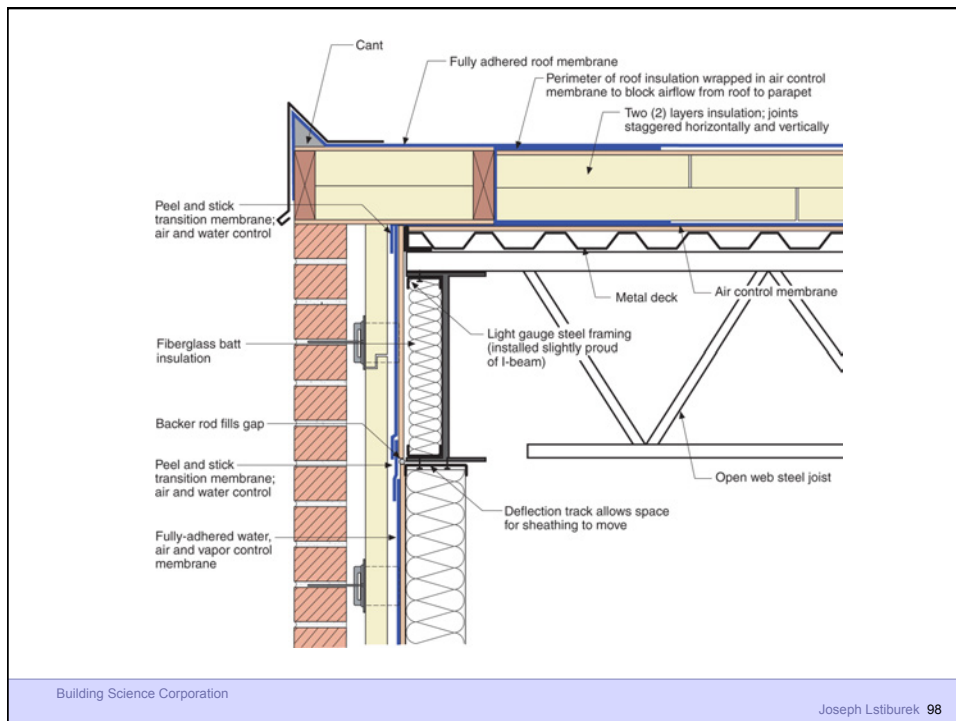
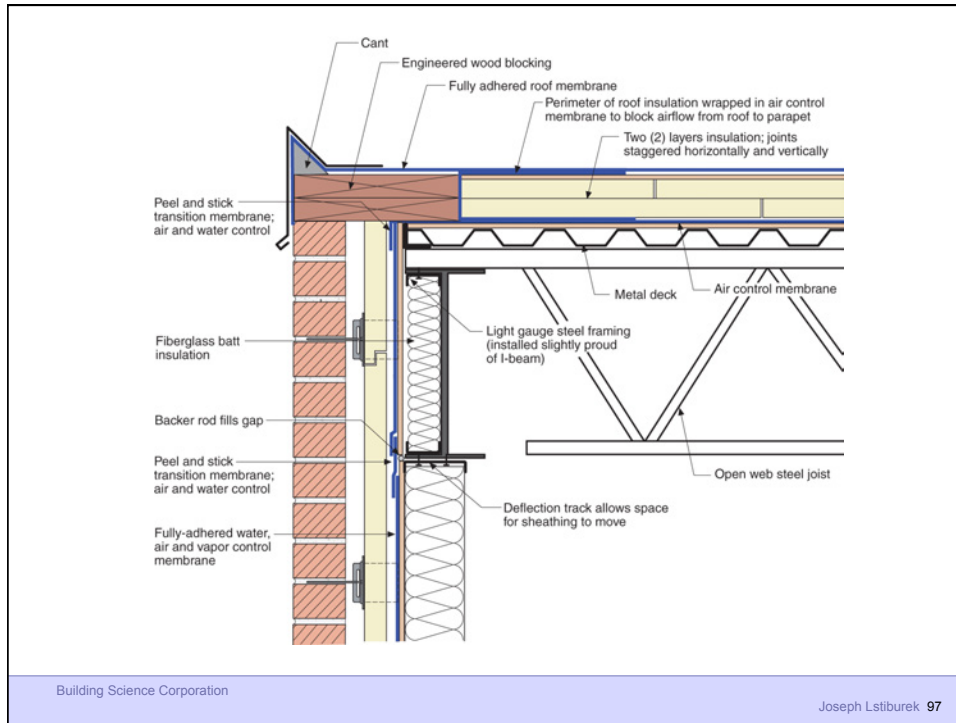
It's a Case of Black or White  
Arrhenius  
Every 10 degrees C – double the “badness”

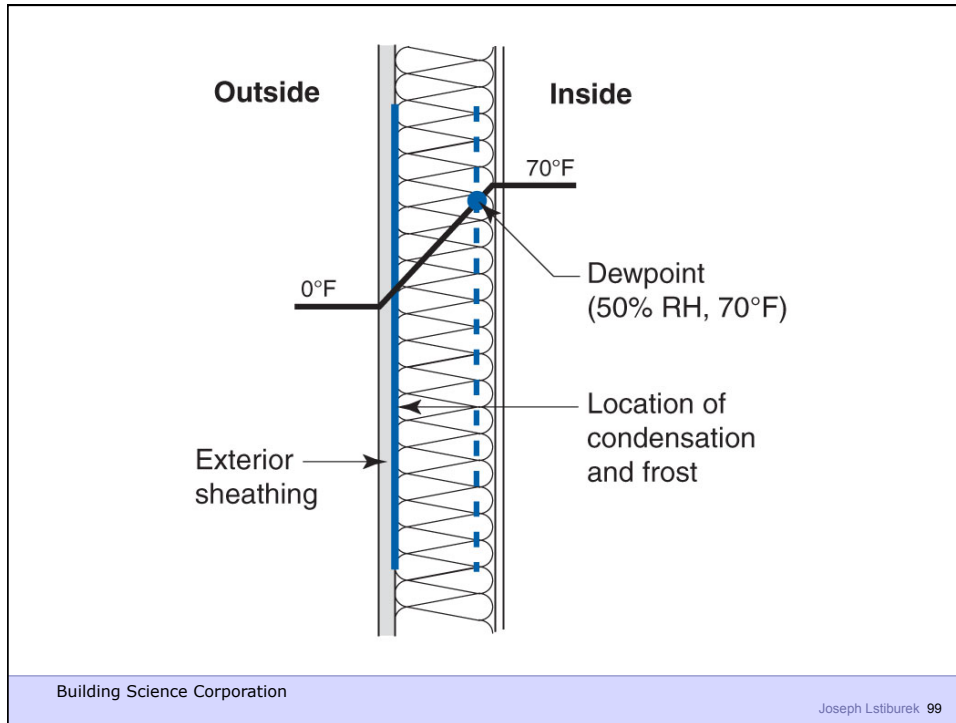




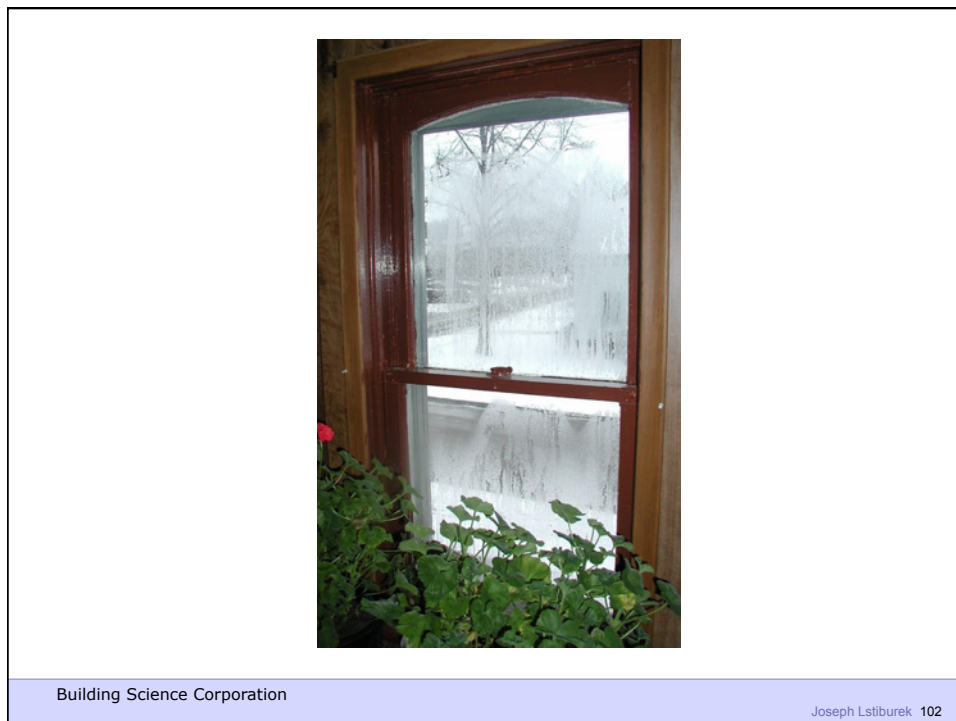
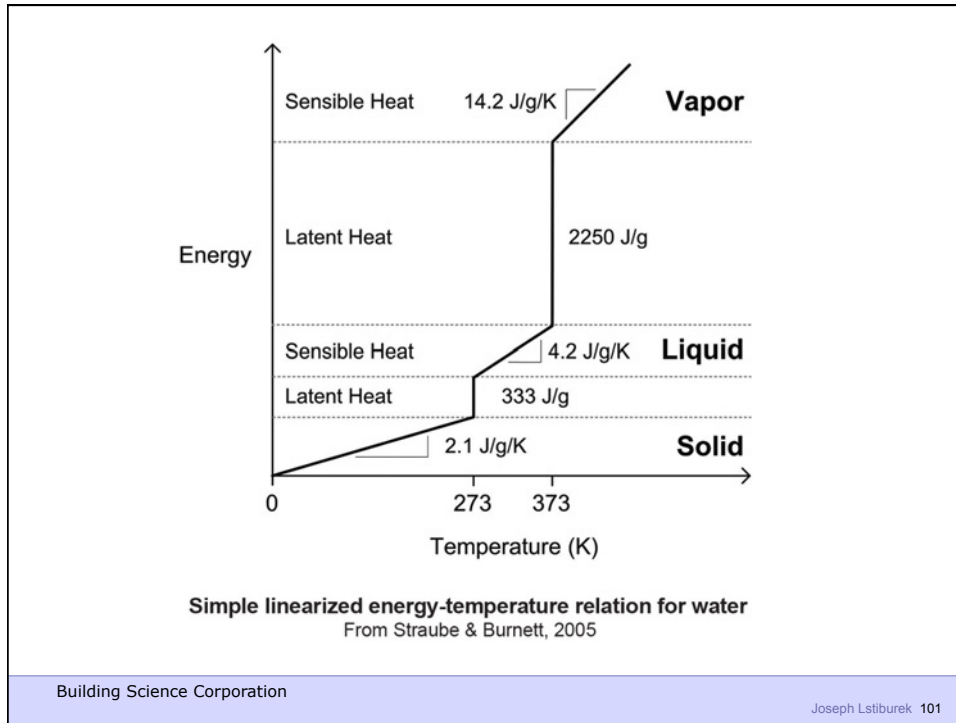


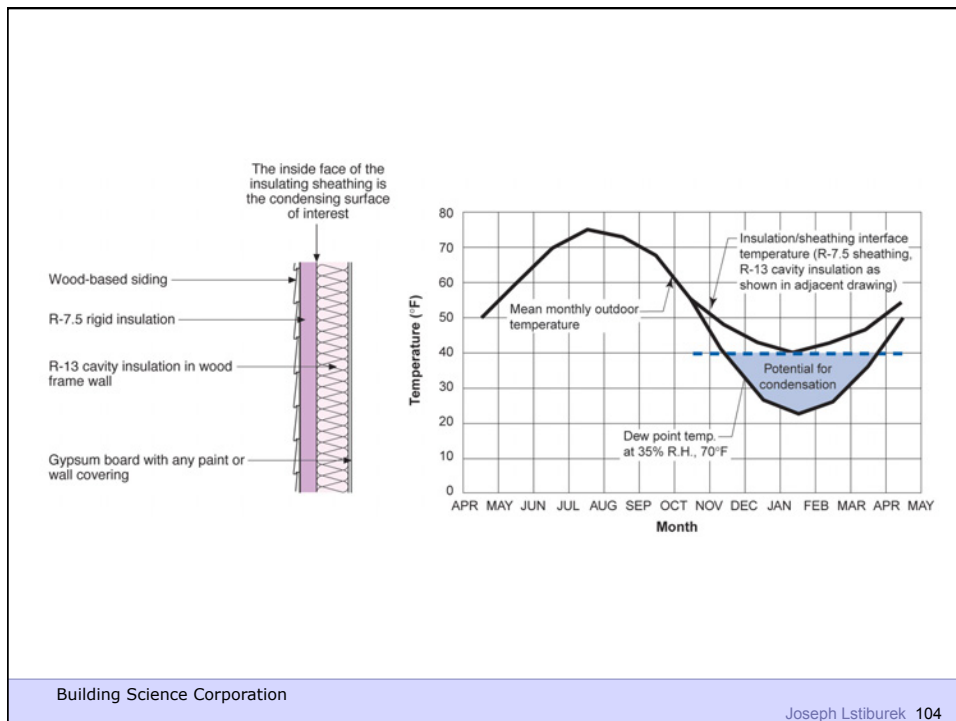
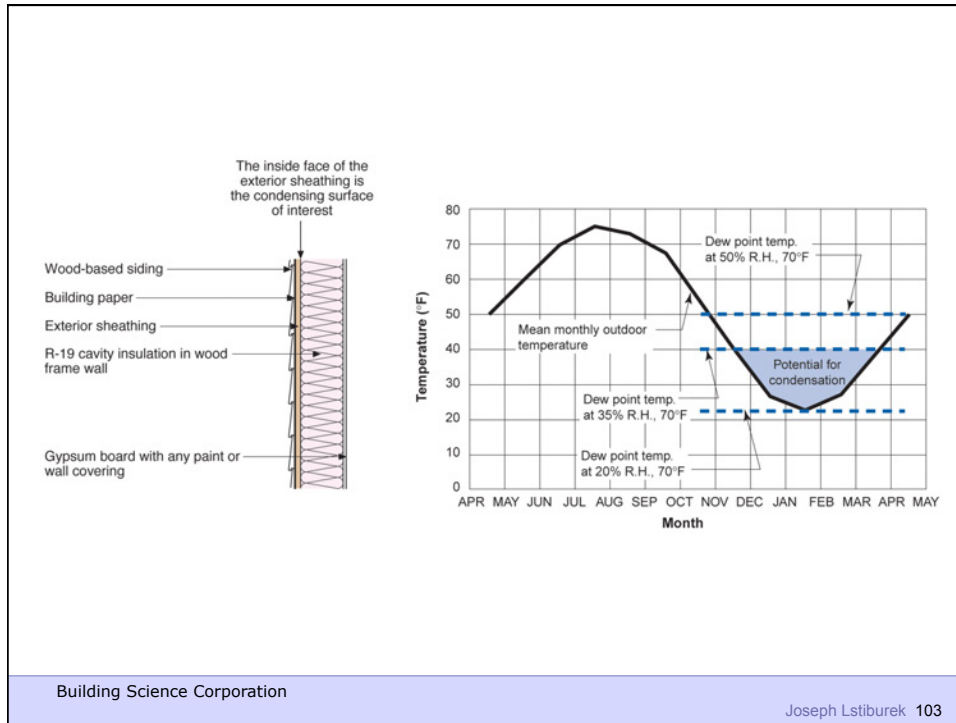


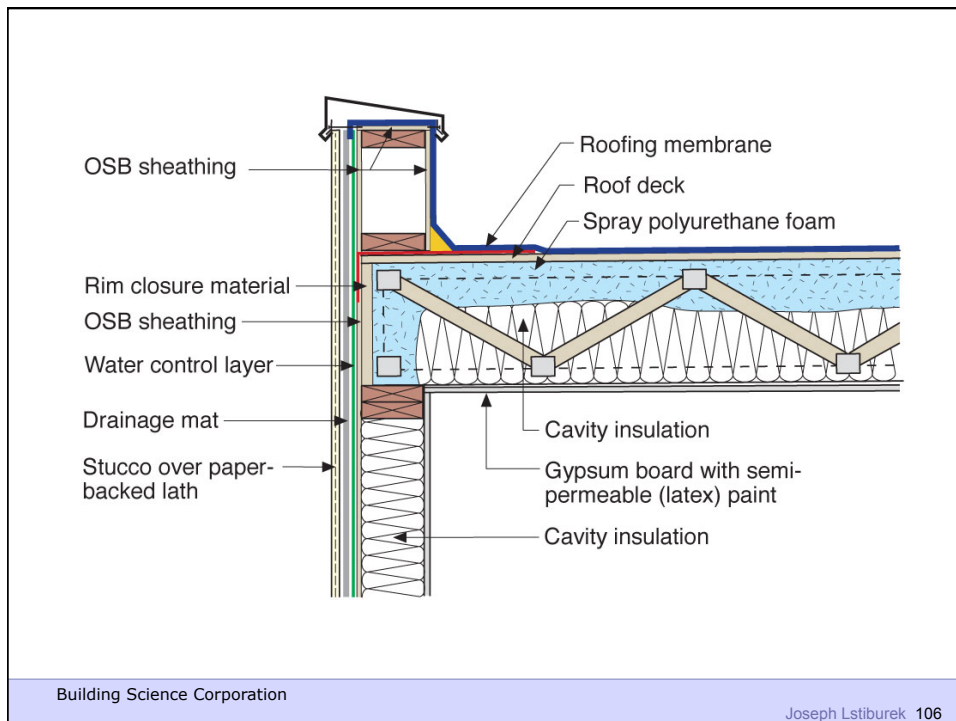
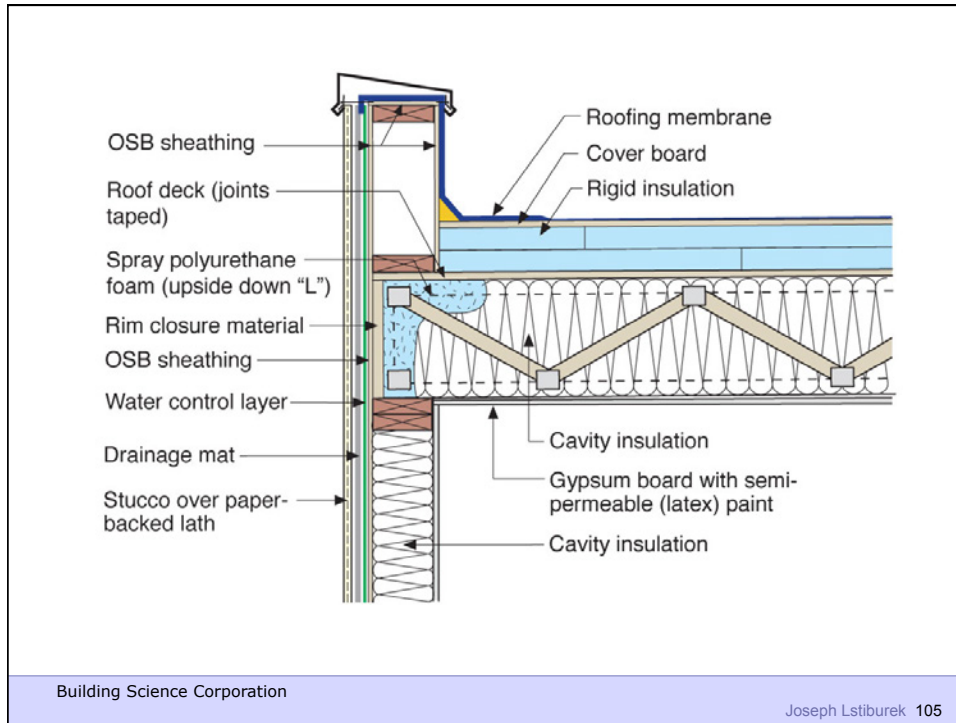


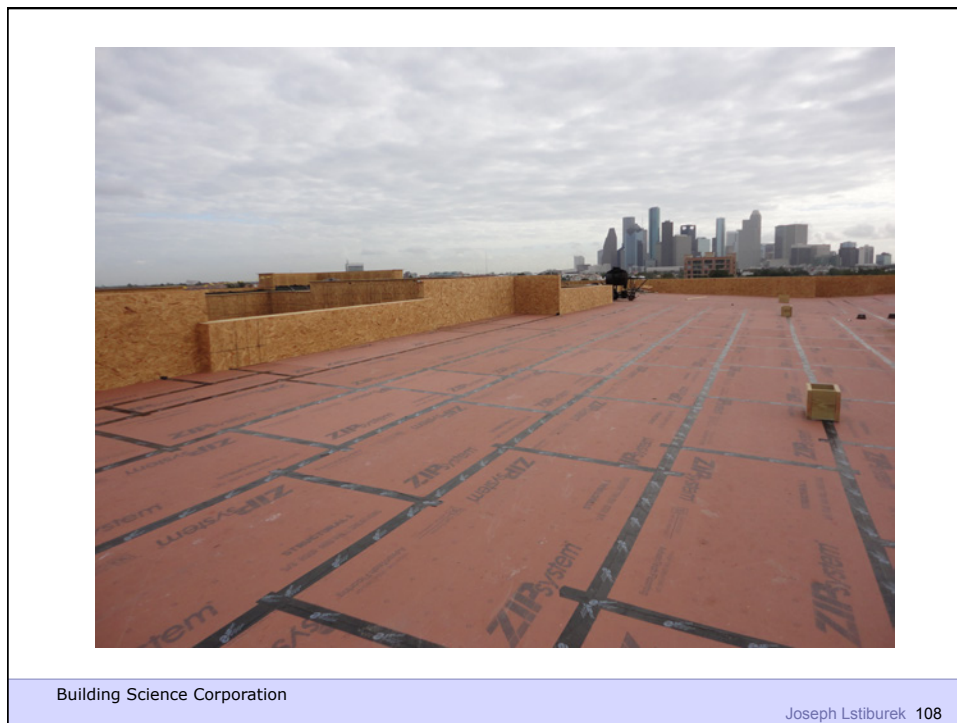
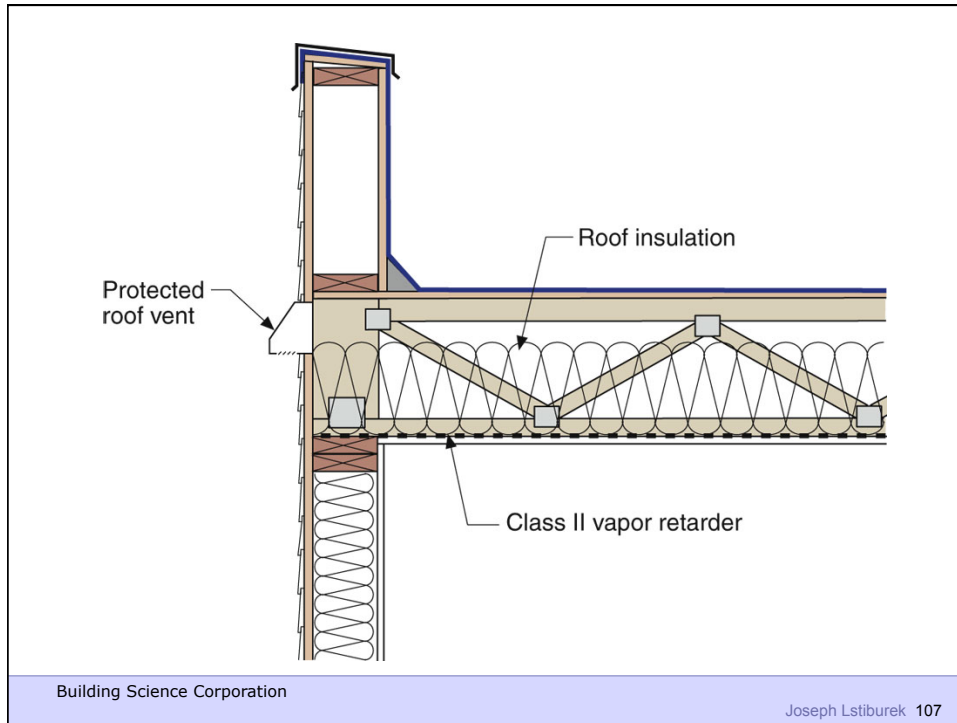














Building Science Corporation

Joseph Lstiburek 109



Building Science Corporation

Joseph Lstiburek 110



Building Science Corporation

Joseph Lstiburek 111



Building Science Corporation

Joseph Lstiburek 112



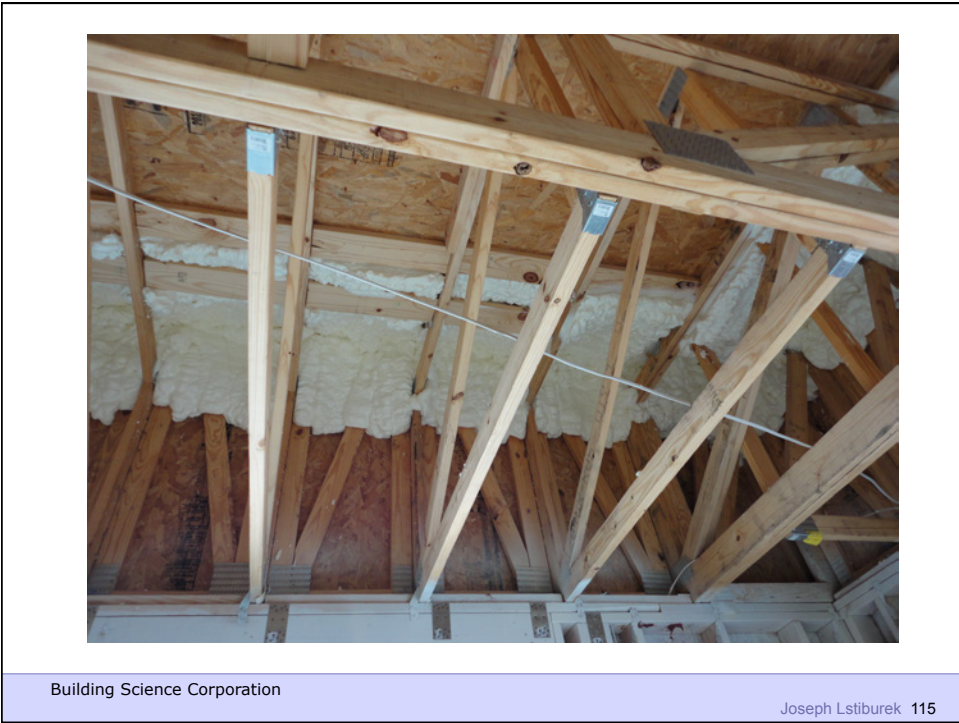
Building Science Corporation

Joseph Lstiburek 113



Building Science Corporation

Joseph Lstiburek 114







Building Science Corporation

Joseph Lstiburek 117



Building Science Corporation

Joseph Lstiburek 118

