

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

Building Science

Adventures In Building Science

www.buildingscience.com

What is a Building?

Building Science Corporation

Joseph Lstiburek 2

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

Order of Magnitude

Building Science Corporation

Joseph Lstiburek 5

Order of Magnitude

1 to 10

10 to 100

100 to 1000

1000 to 10000

First Order Effects, Second Order Effects....

Building Science Corporation

Joseph Lstiburek 6

Arrhenius Equation

Building Science Corporation

Joseph Lstiburek 7

For Every 10 Degree K Rise
Activation Energy Doubles

$$k = Ae^{-E_a/(RT)}$$

Building Science Corporation

Joseph Lstiburek 8

Damage Functions

Building Science Corporation

Joseph Lstiburek 9

Damage Functions
Water
Heat
Ultra Violet Radiation

Building Science Corporation

Joseph Lstiburek 10

Damage Functions

Water

Heat

Ultra Violet Radiation

Oxidization (Ozone)

Fatigue (Creep)

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

80 Percent of all Construction Problems are Related to Water

Building Science Corporation

Joseph Lstiburek 13

Laws of Thermodynamics

Building Science Corporation

Joseph Lstiburek 14

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

2nd 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

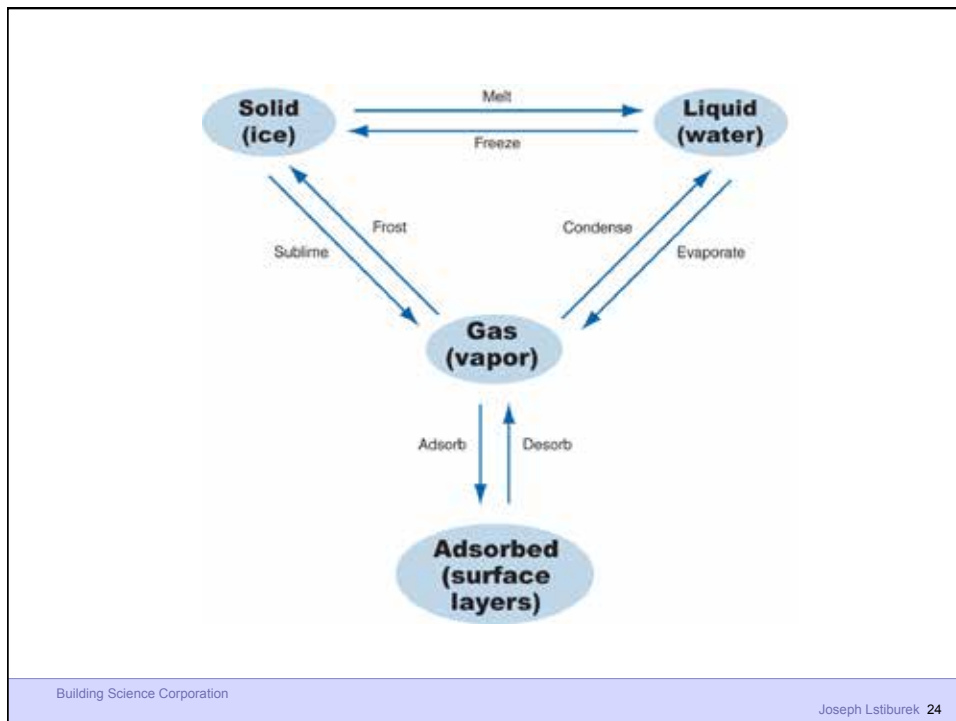
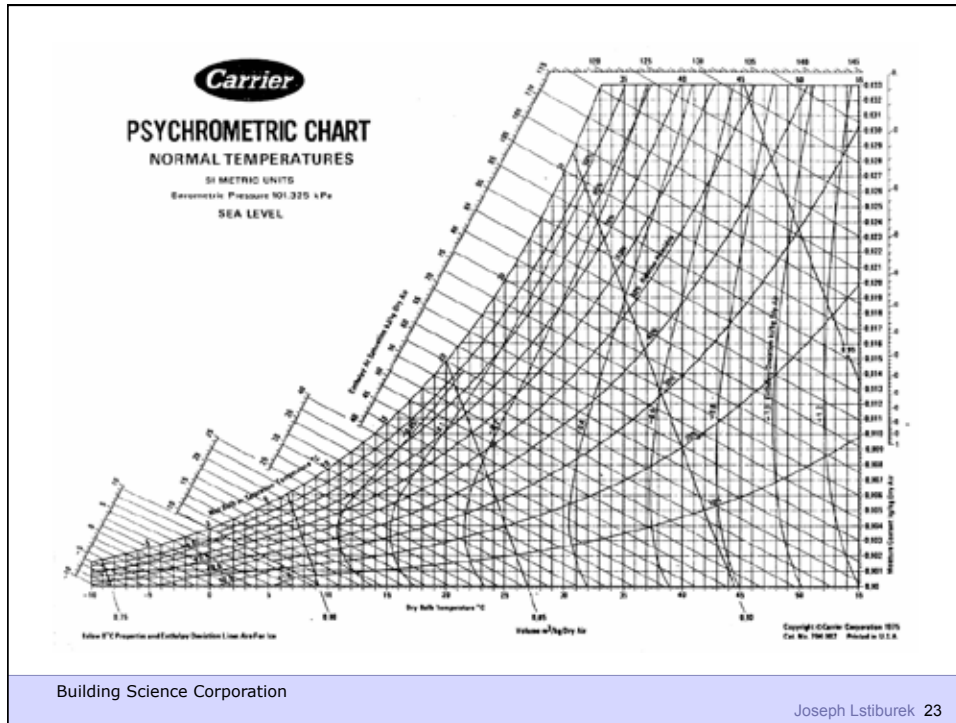
Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

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



Moisture Transport in Porous Media

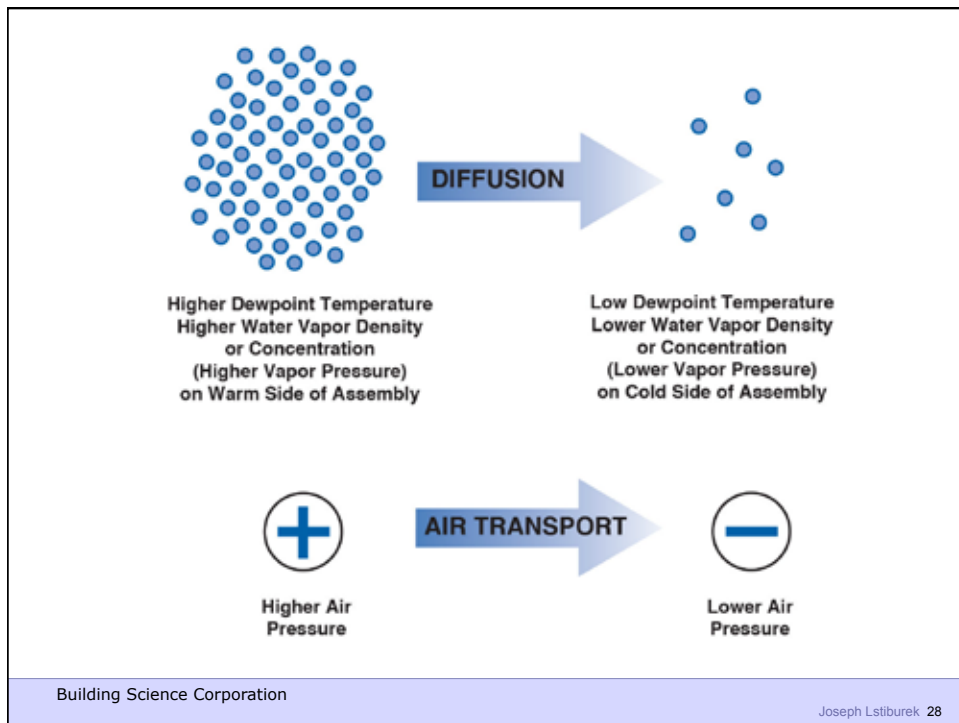
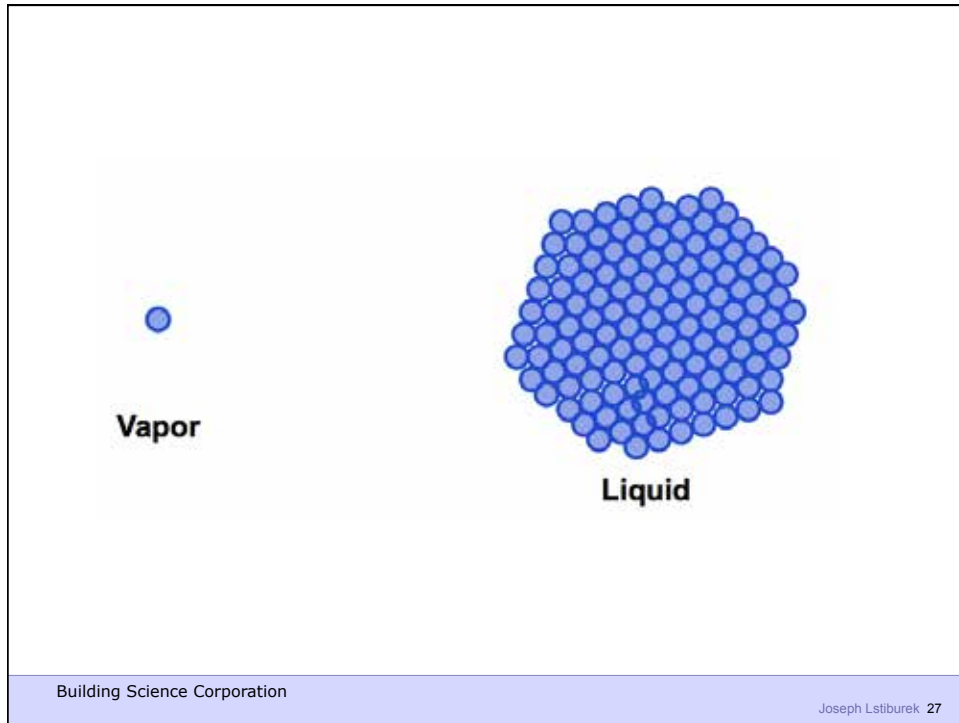
Phase	Transport Process	Driving Potential
Vapor	Diffusion	Vapor Concentration
Adsorbate	Surface Diffusion	Concentration
Liquid	Capillary Flow Osmosis	Suction Pressure Solute Concentration

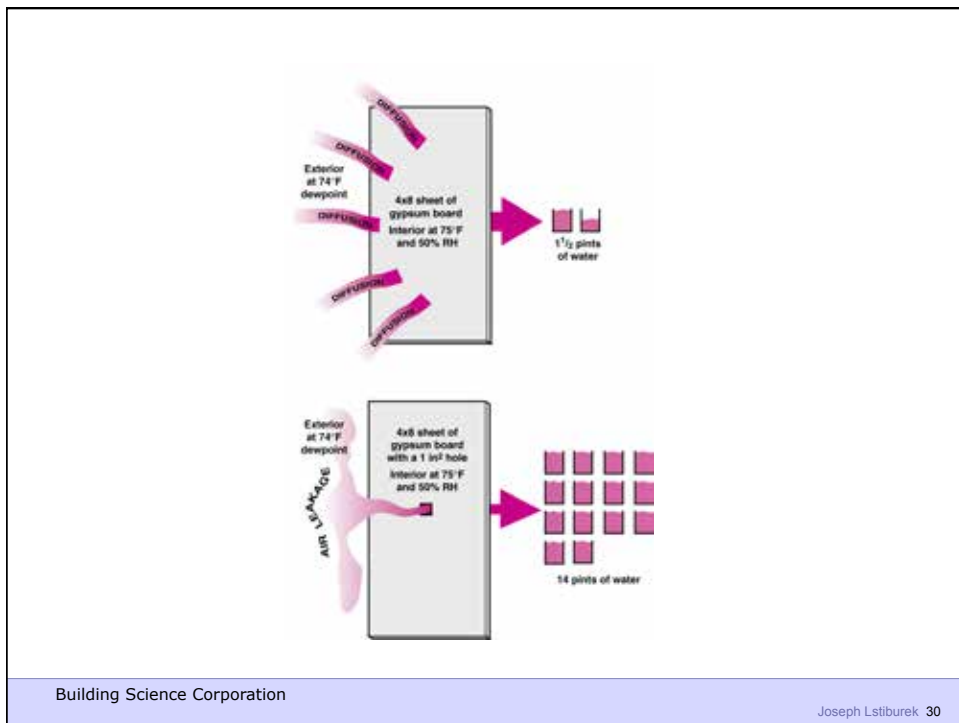
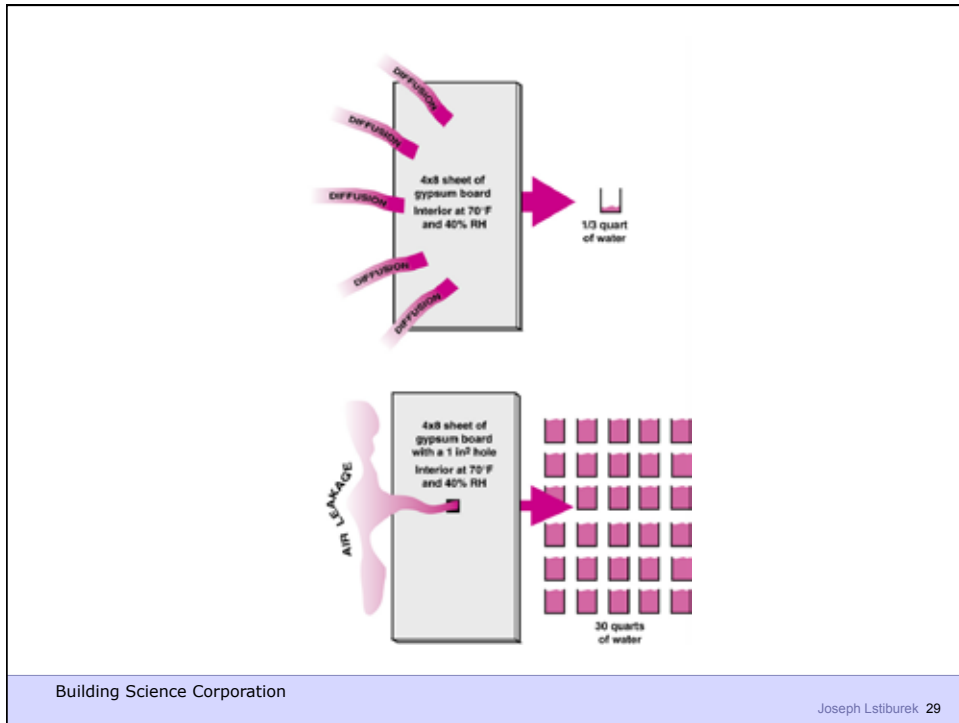
Building Science Corporation Joseph Lstiburek 25

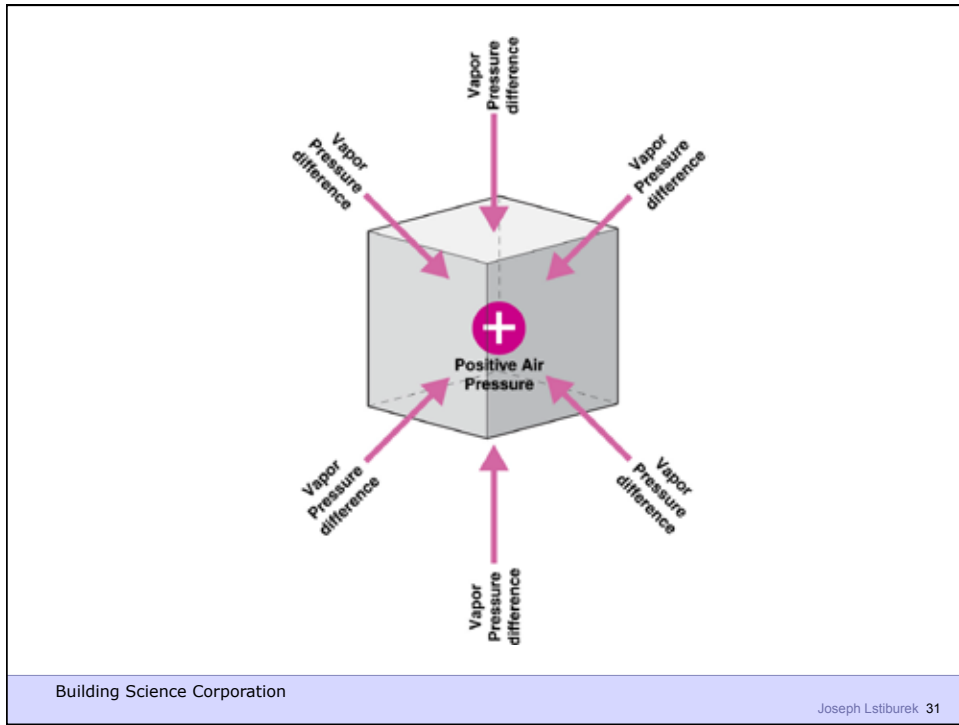
Moisture Transport in Assemblies

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

Building Science Corporation Joseph Lstiburek 26



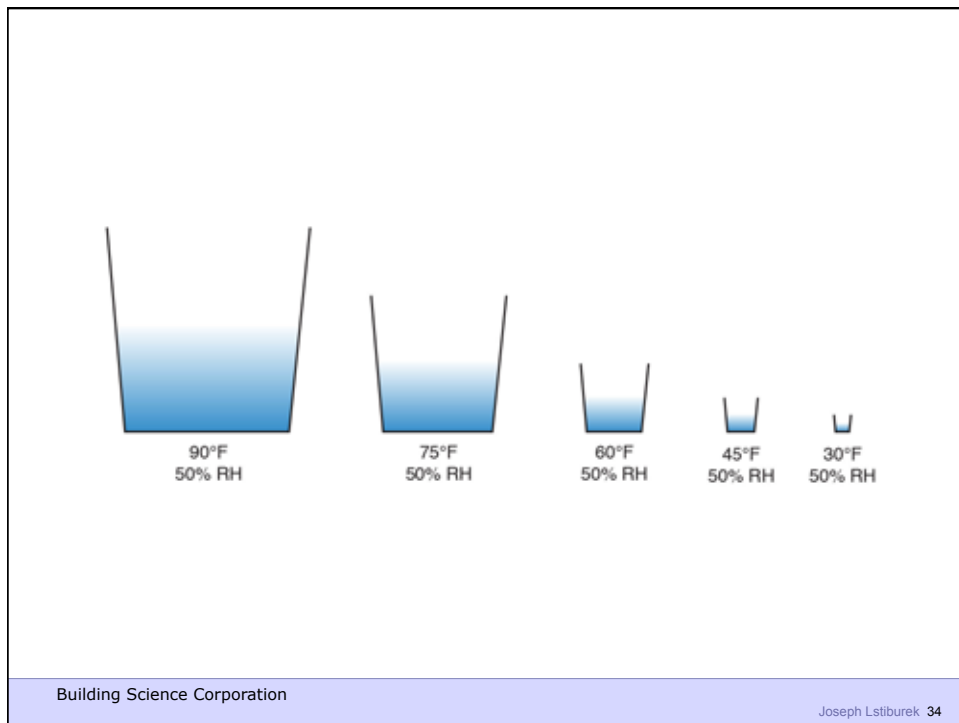
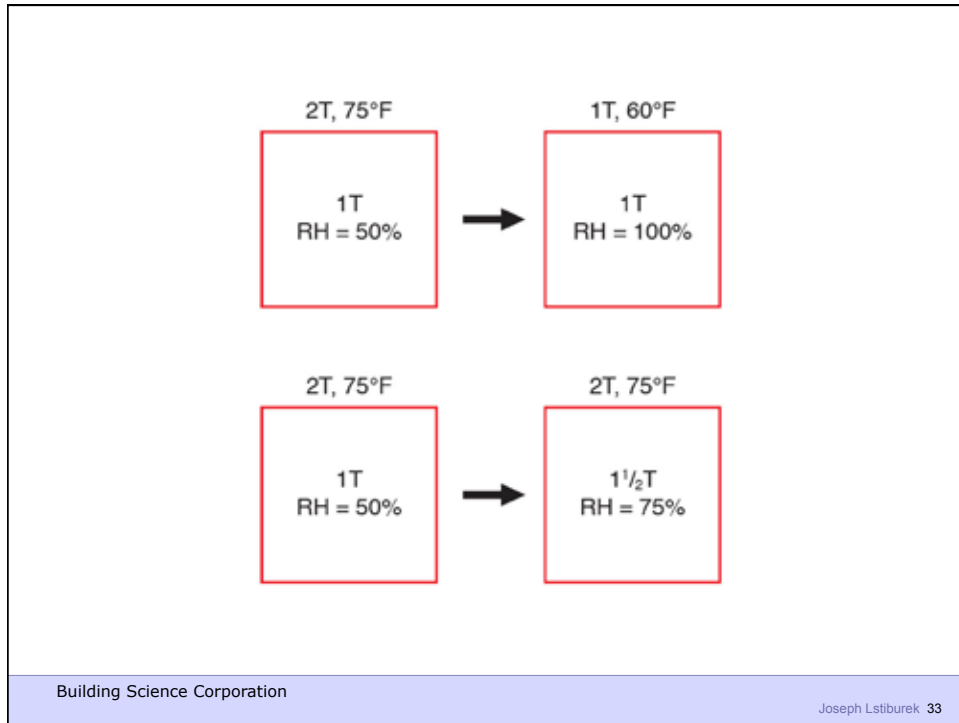


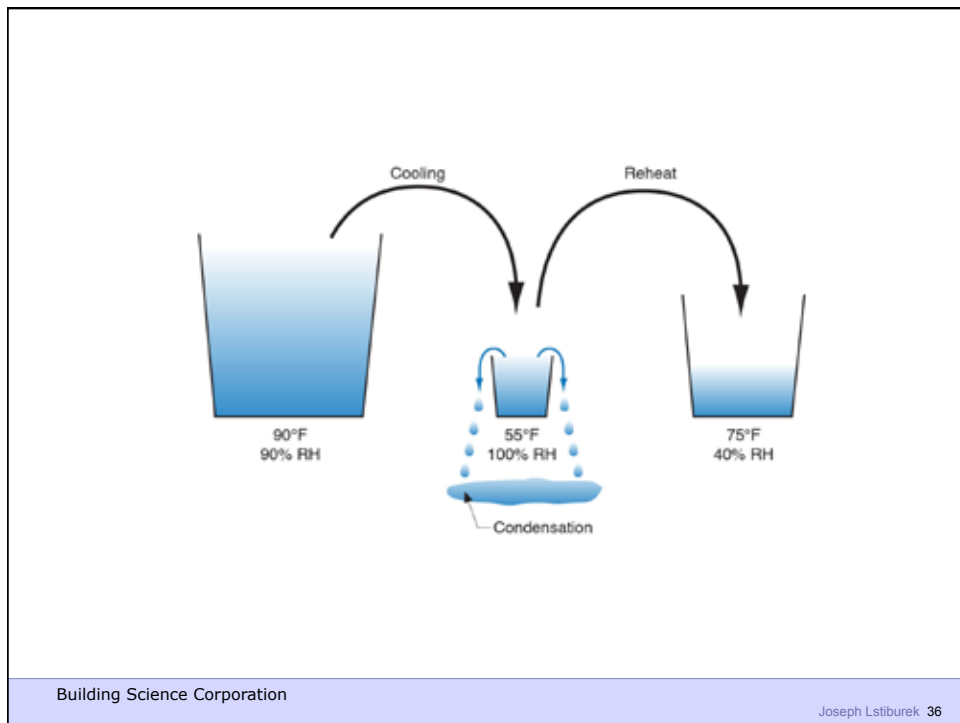
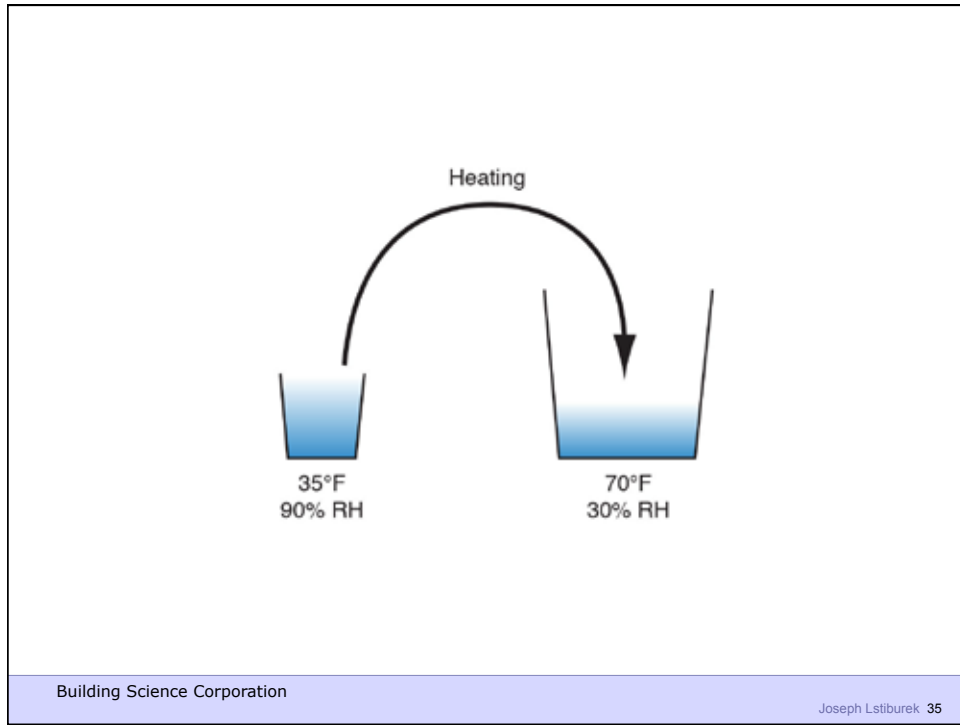


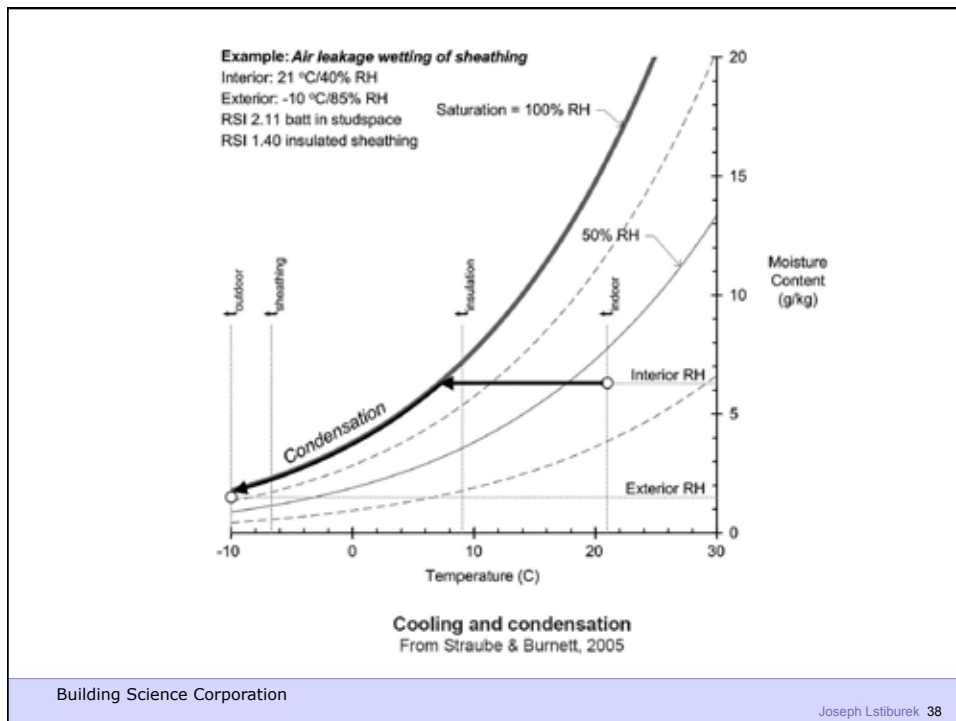
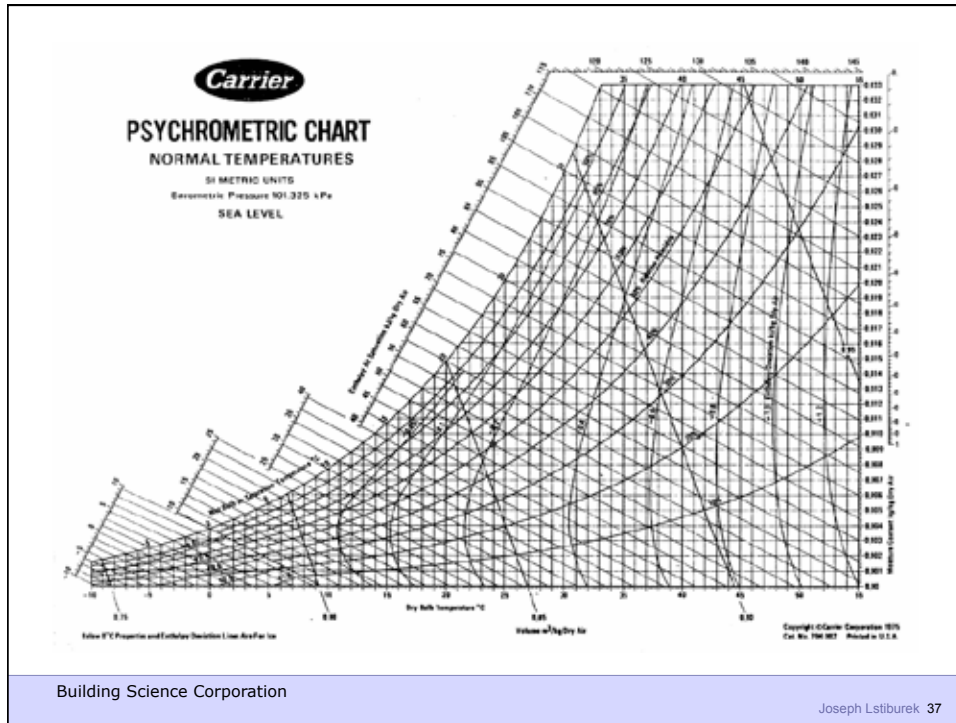
Vapor Pressure and Relative Humidity

Building Science Corporation

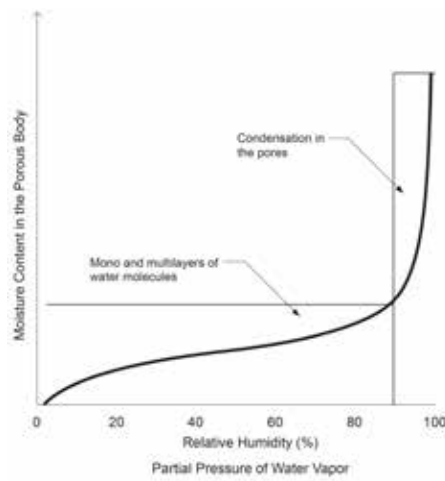
Joseph Lstiburek 32





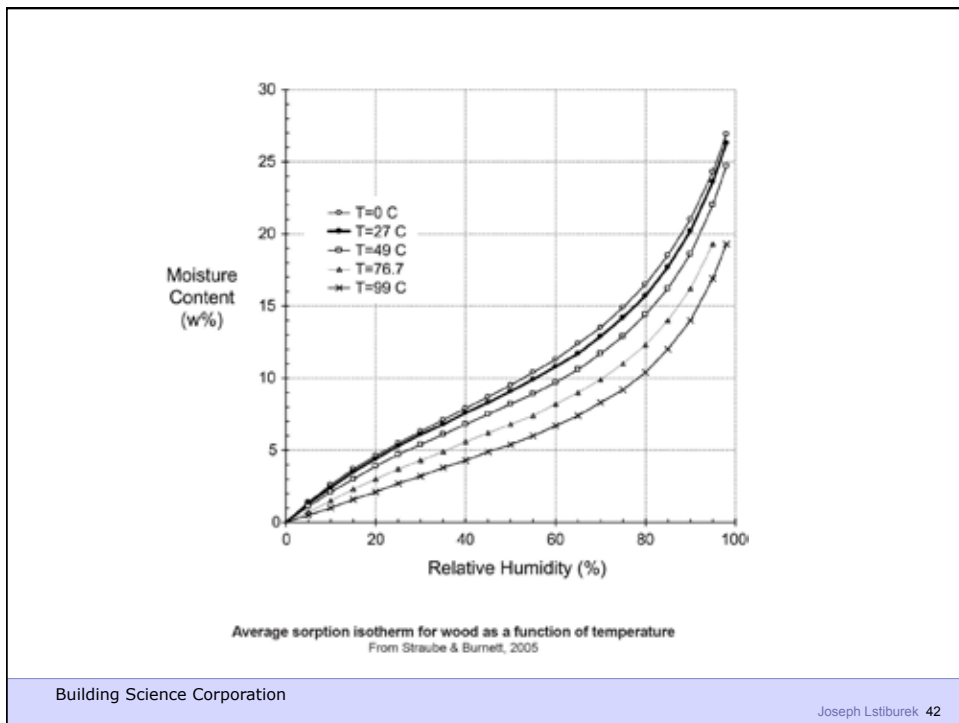
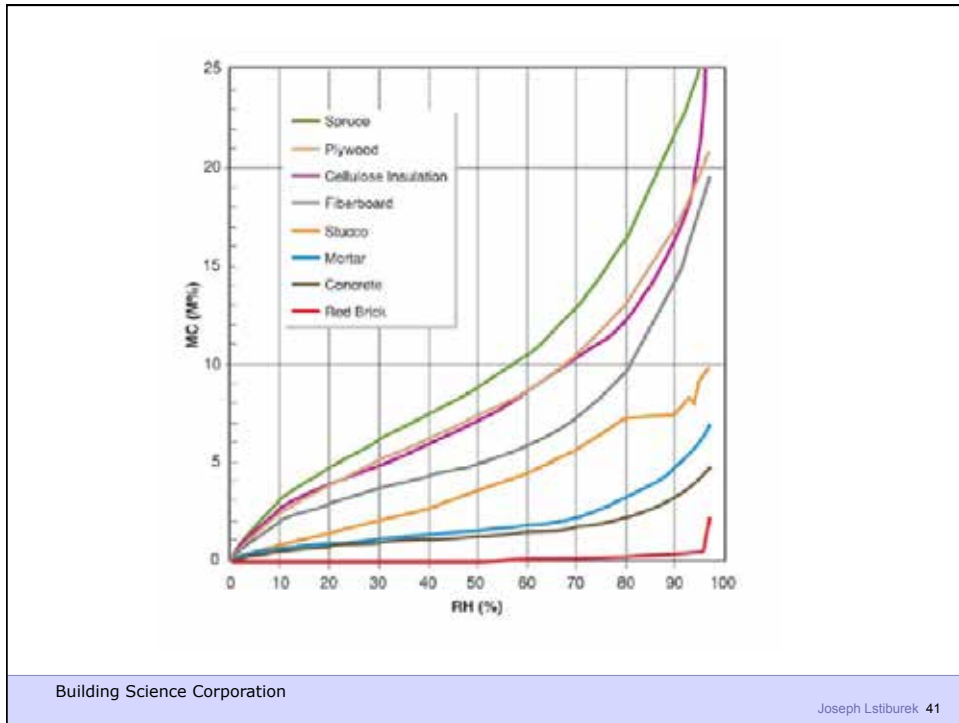


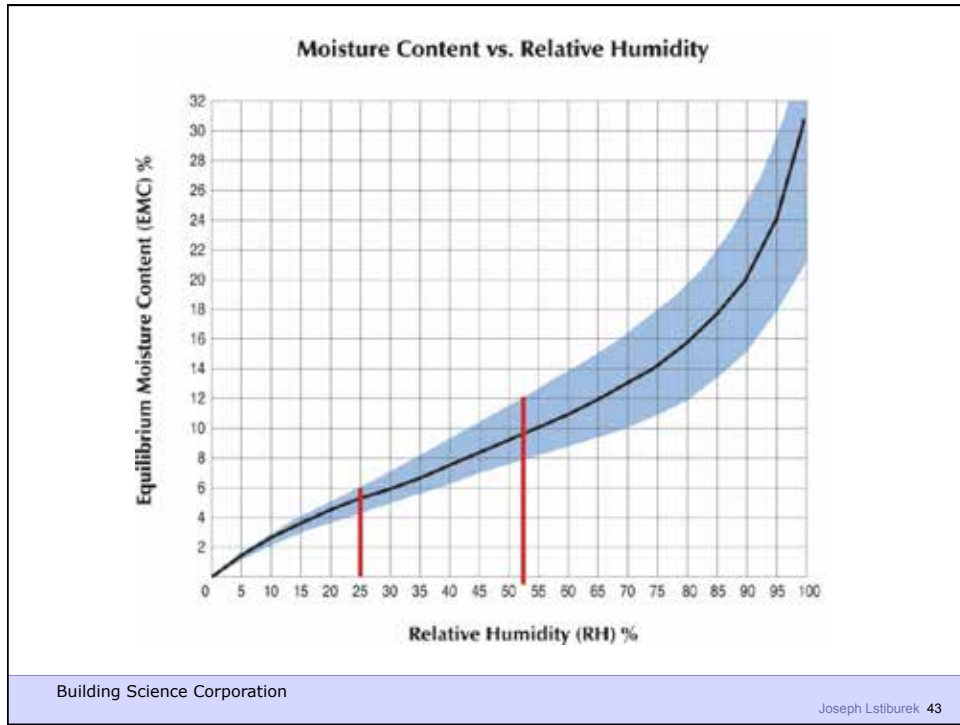
Sorption Isotherms



Change in the storage of moisture in a porous building material as the partial pressure of water vapor in the ambient air increases from zero to full saturation value at a given temperature.

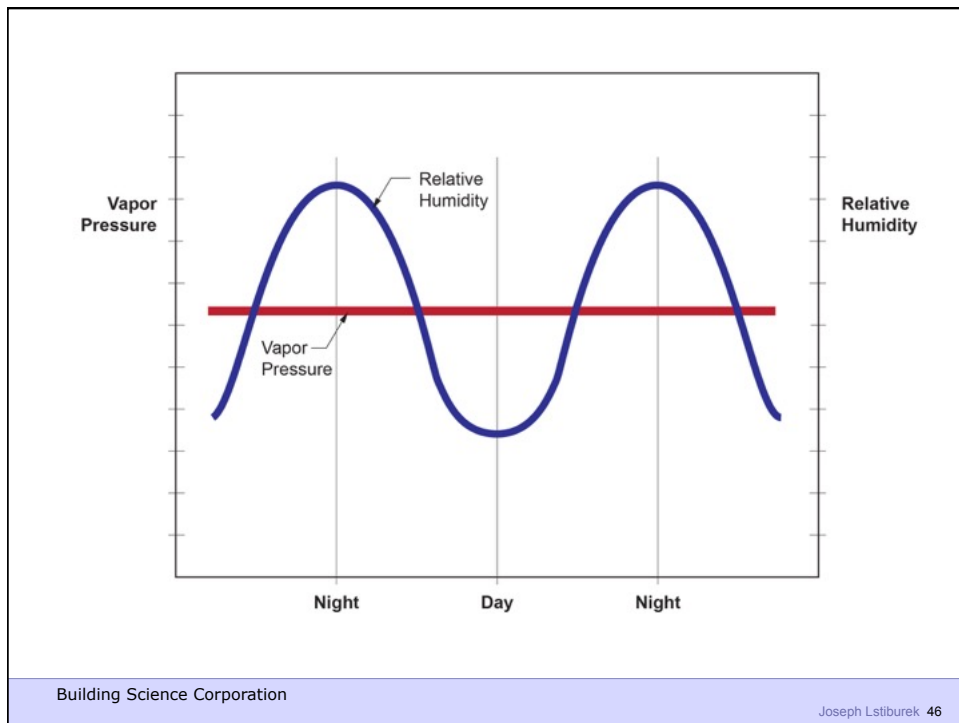
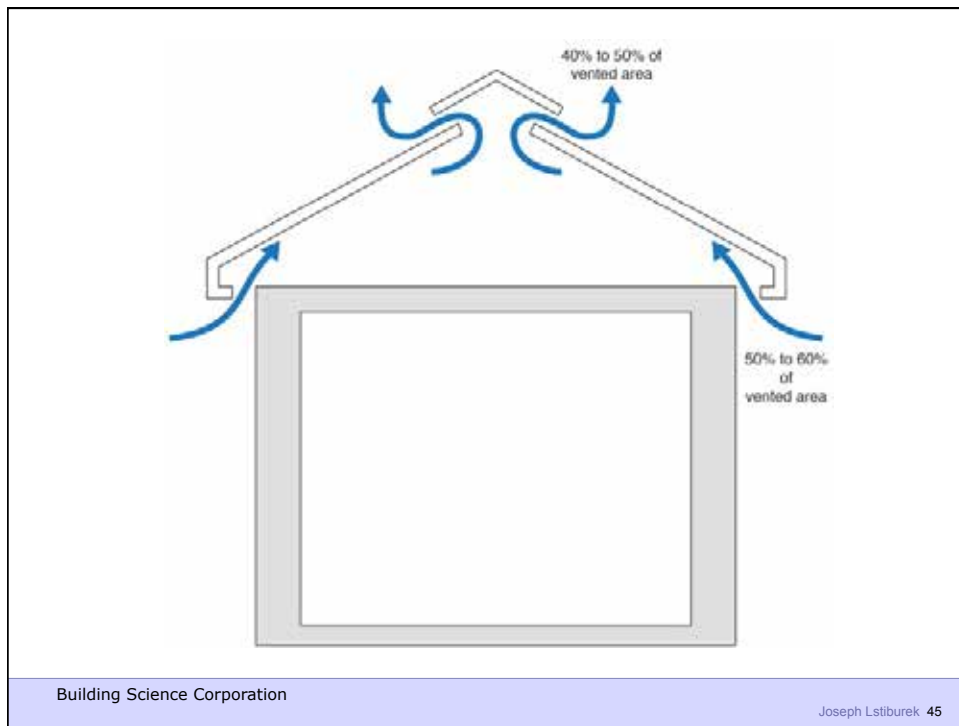
Sorption Curve
From M.K. Kumaran, ASTM MN, 16-2nd Edition,
Moisture Control in Buildings, 2009

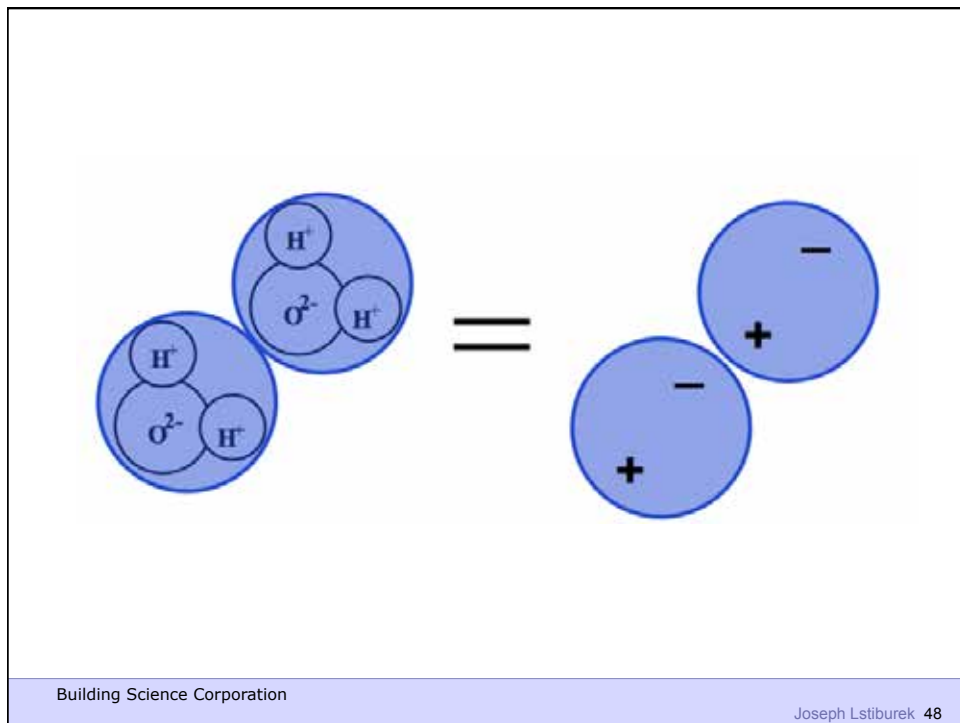
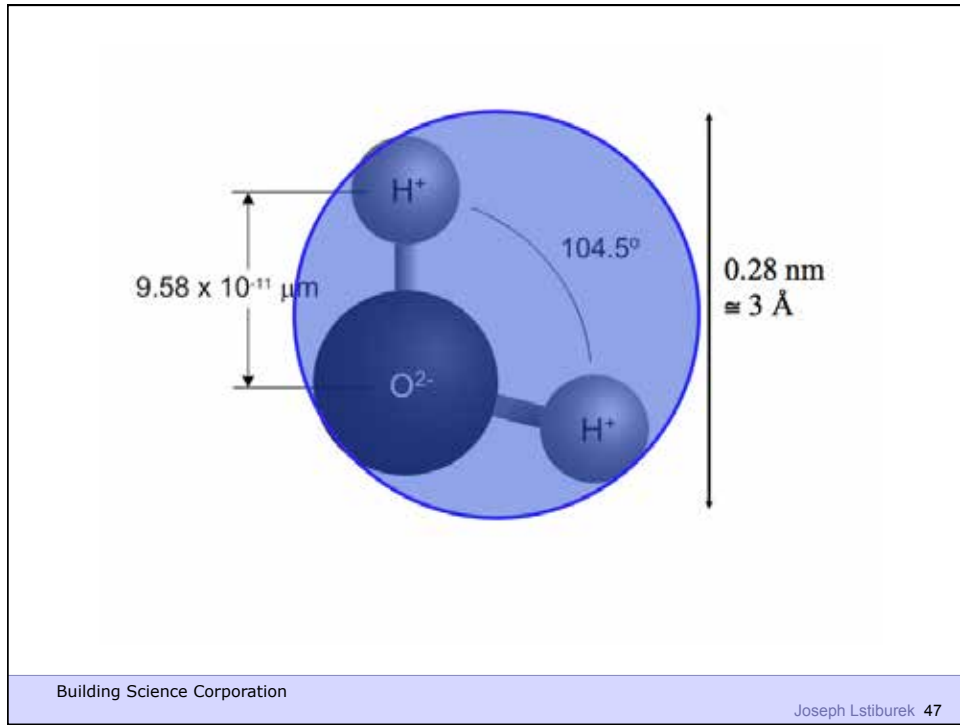


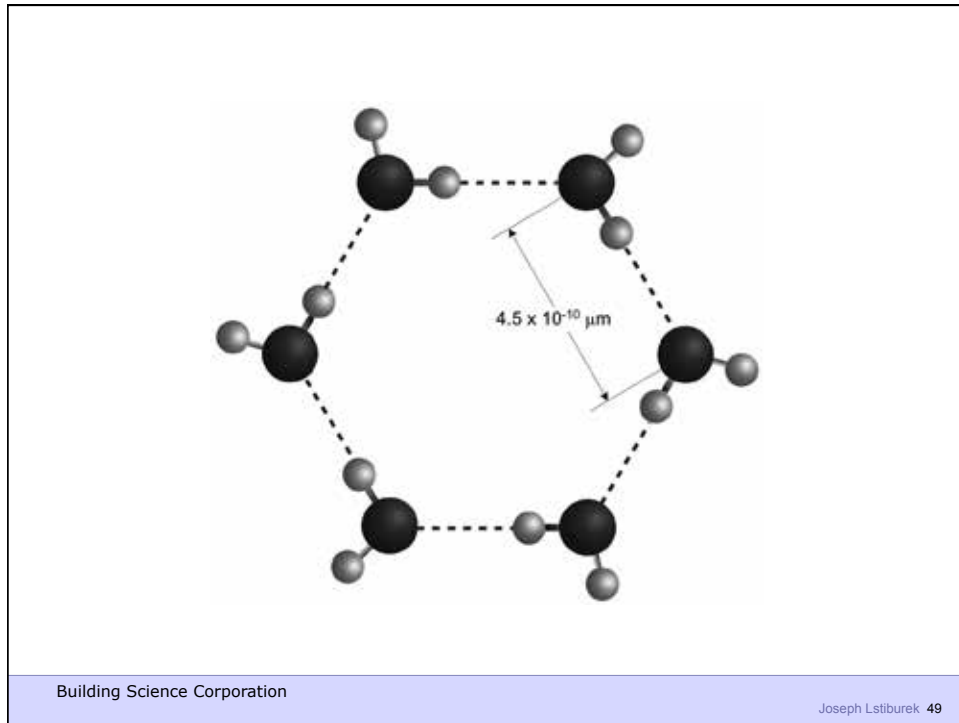


Quick Aside - Vented Attics

Building Science Corporation Joseph Lstiburek 44







Heat
Air
Moisture

Building Science Corporation

Joseph Lstiburek 50

HAM

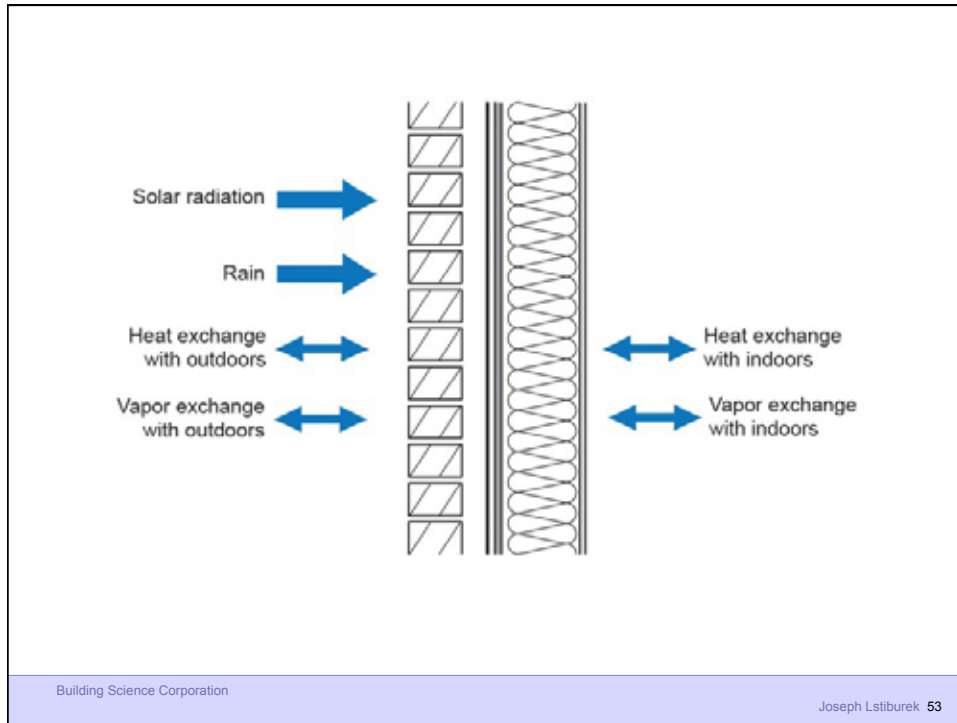
Building Science Corporation

Joseph Lstiburek 51

Hygrothermal Analysis

Building Science Corporation

Joseph Lstiburek 52



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

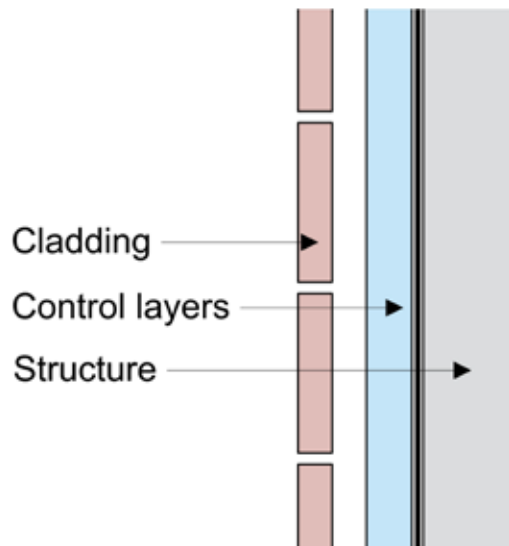
Building Science Corporation

Joseph Lstiburek 54

Perfect Wall

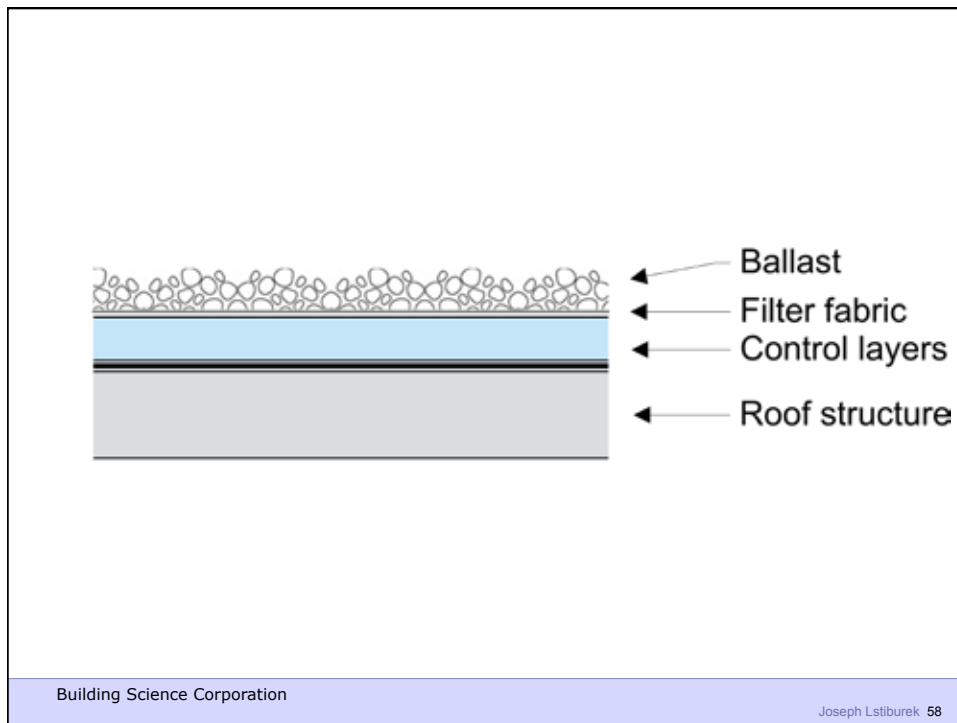
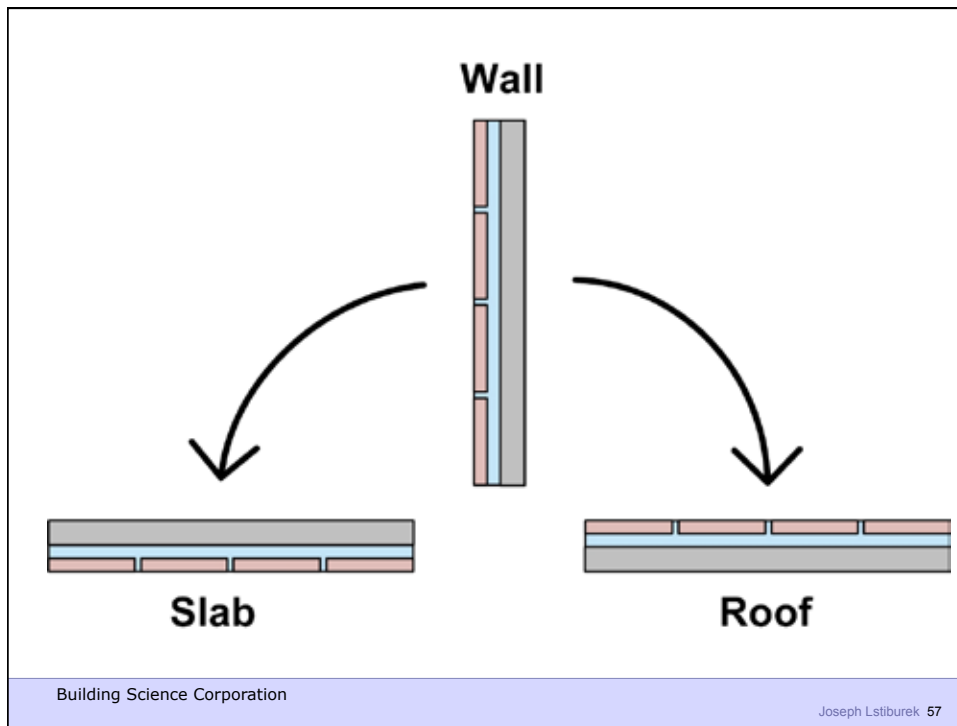
Building Science Corporation

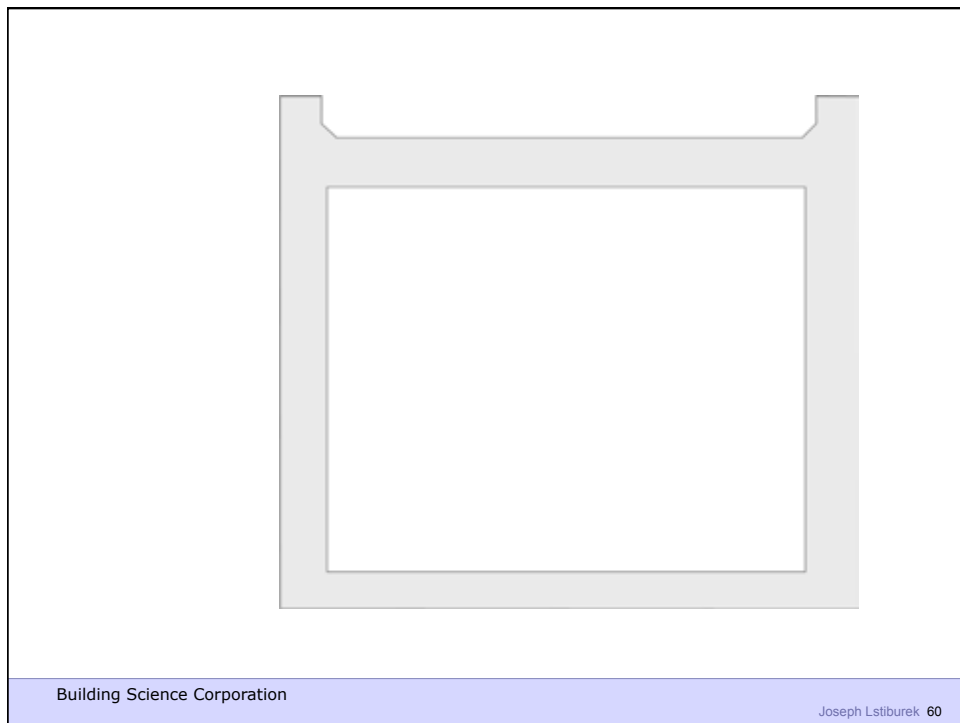
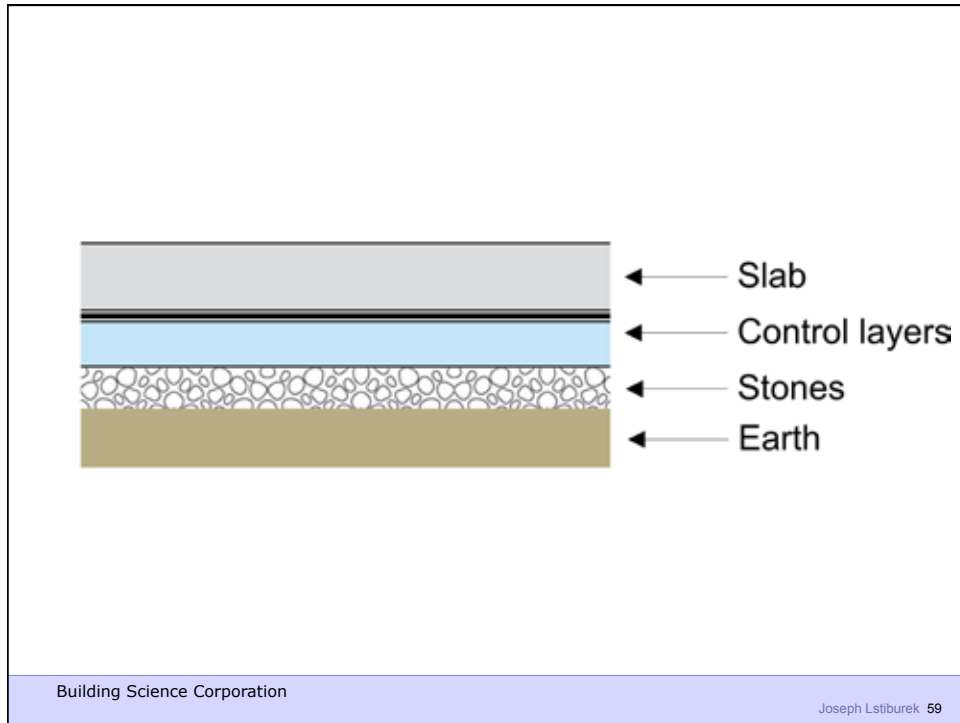
Joseph Lstiburek 55

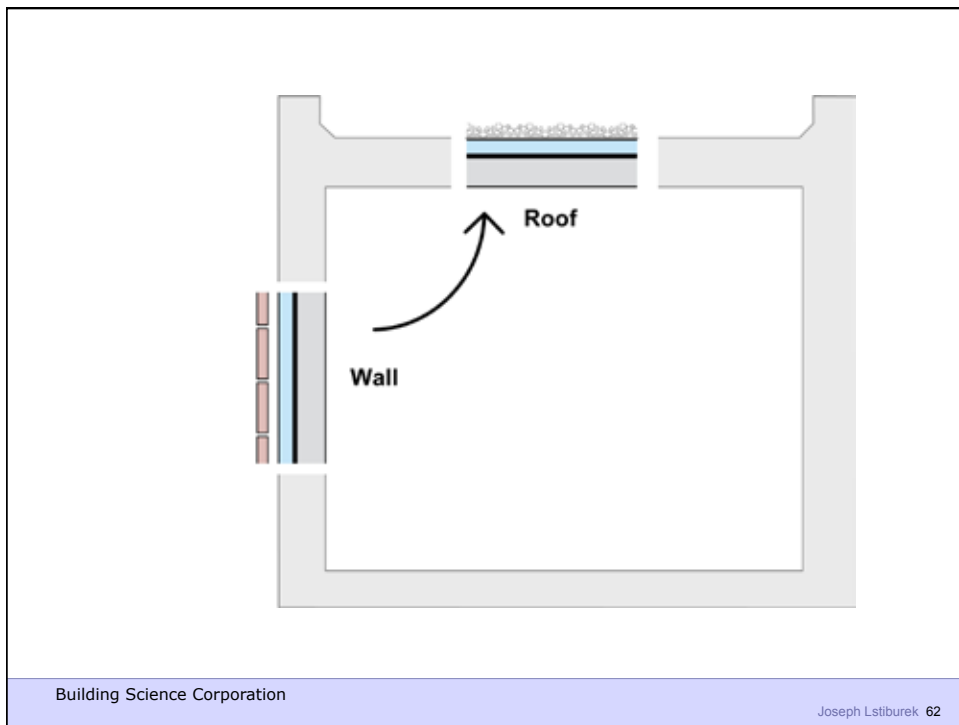
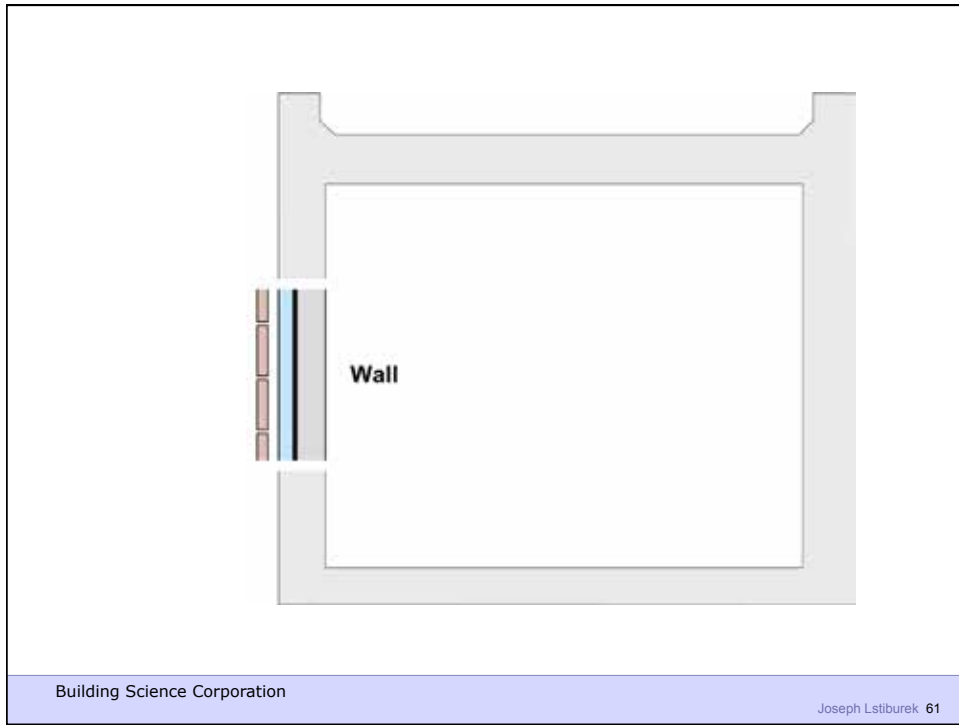


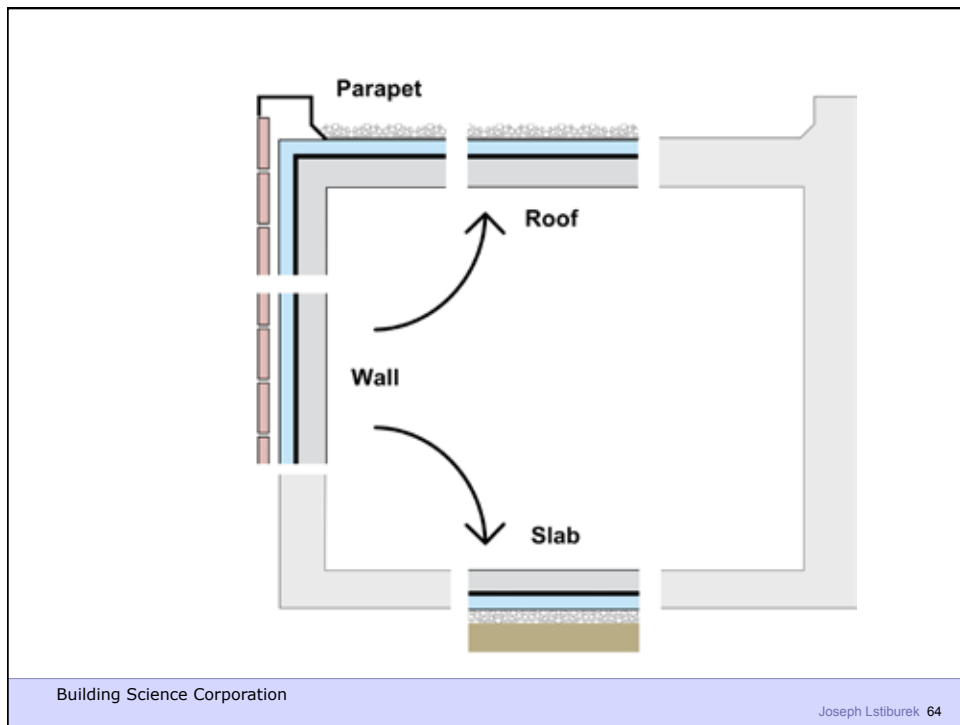
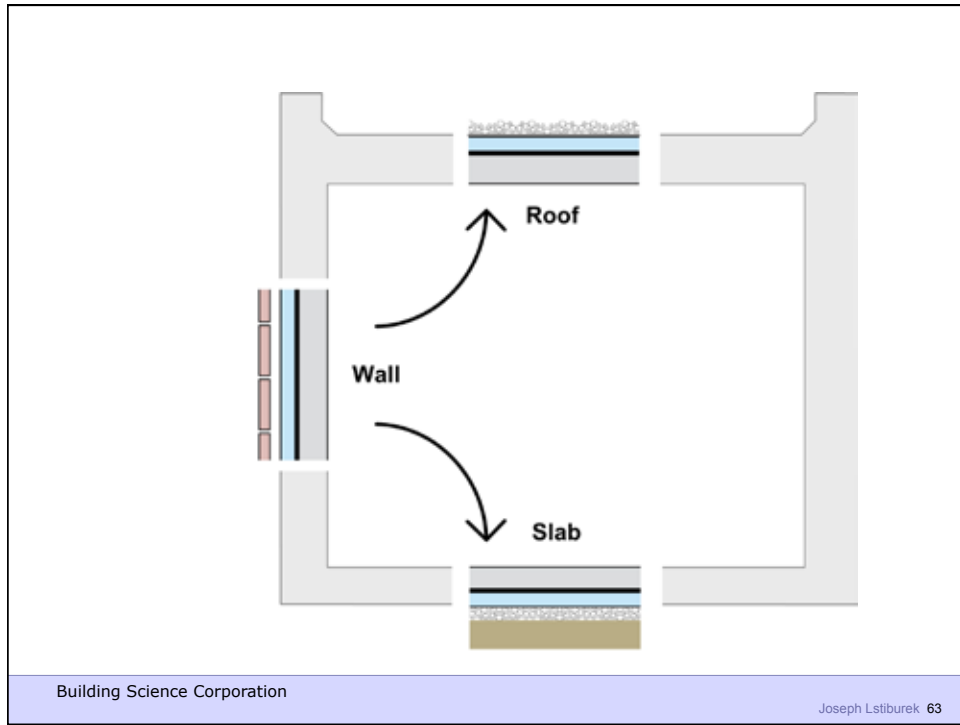
Building Science Corporation

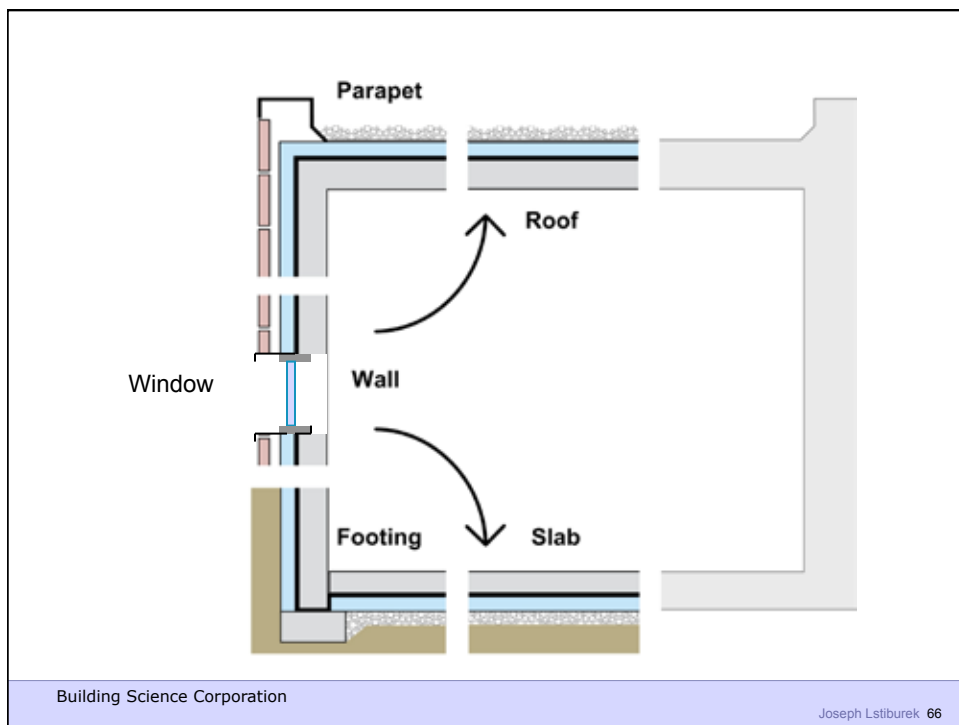
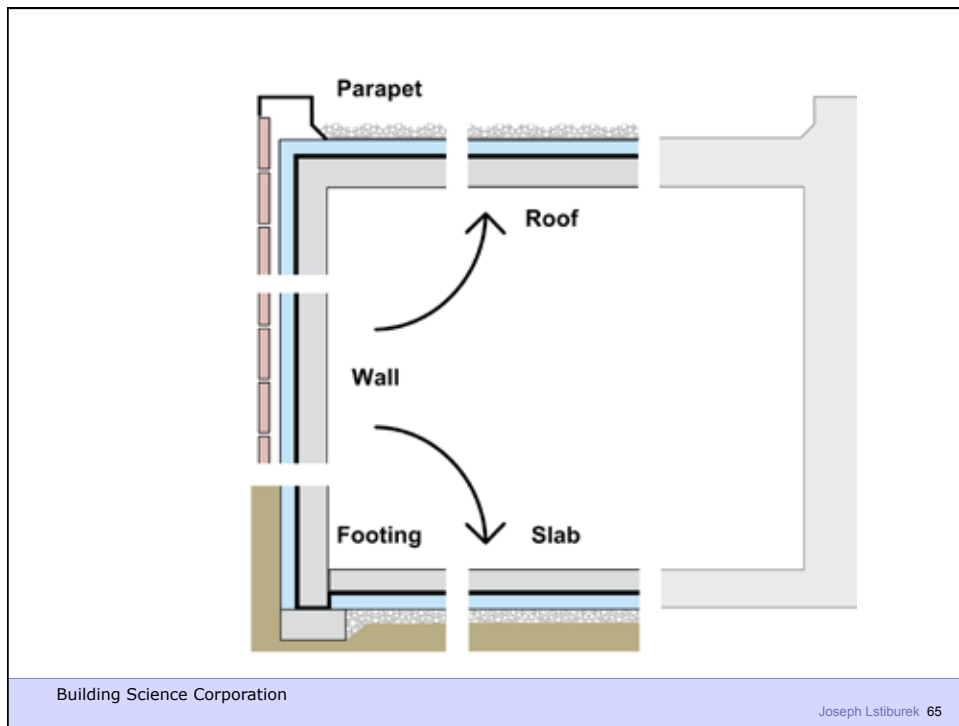
Joseph Lstiburek 56

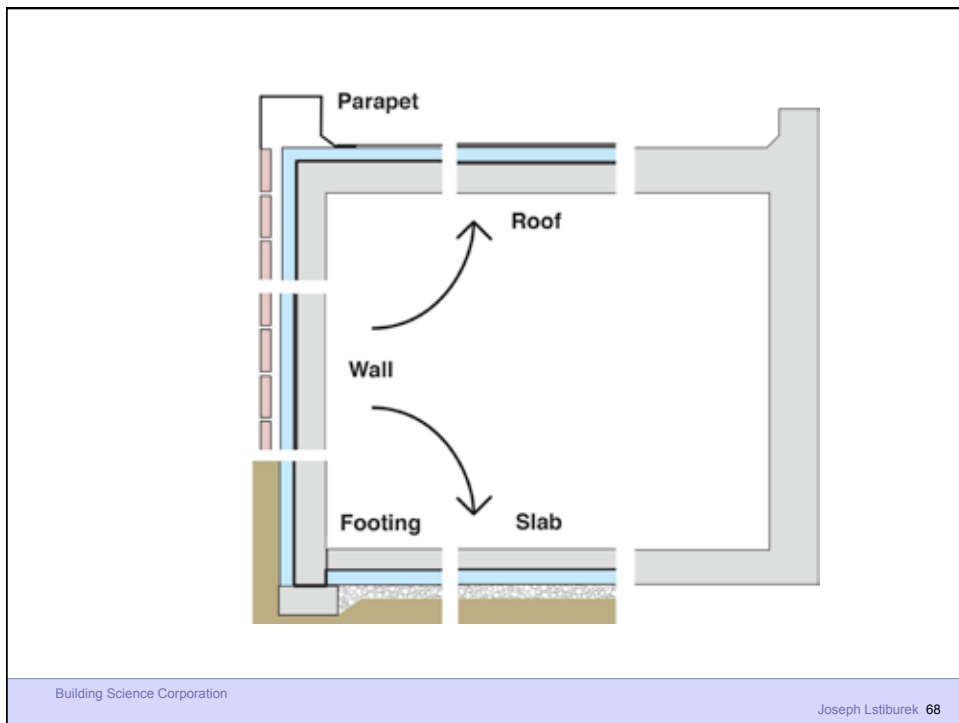
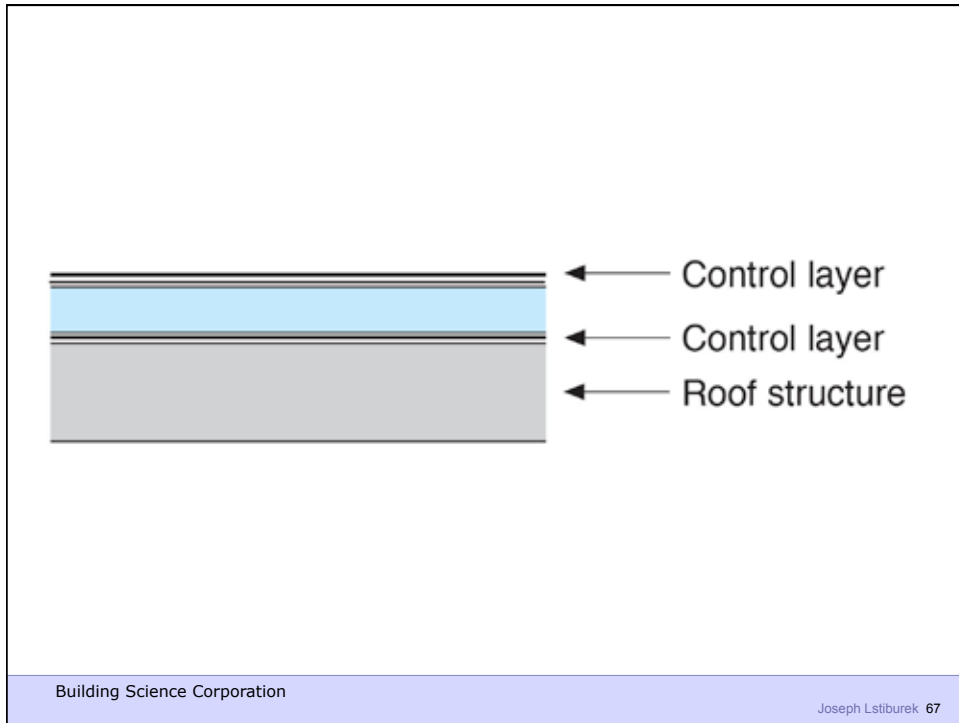


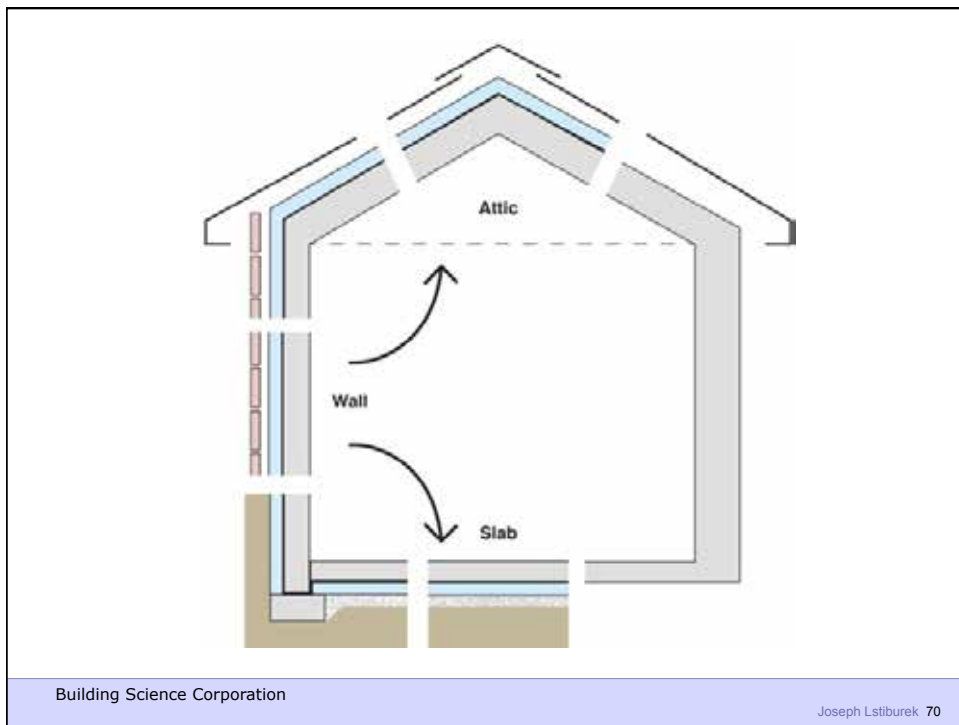
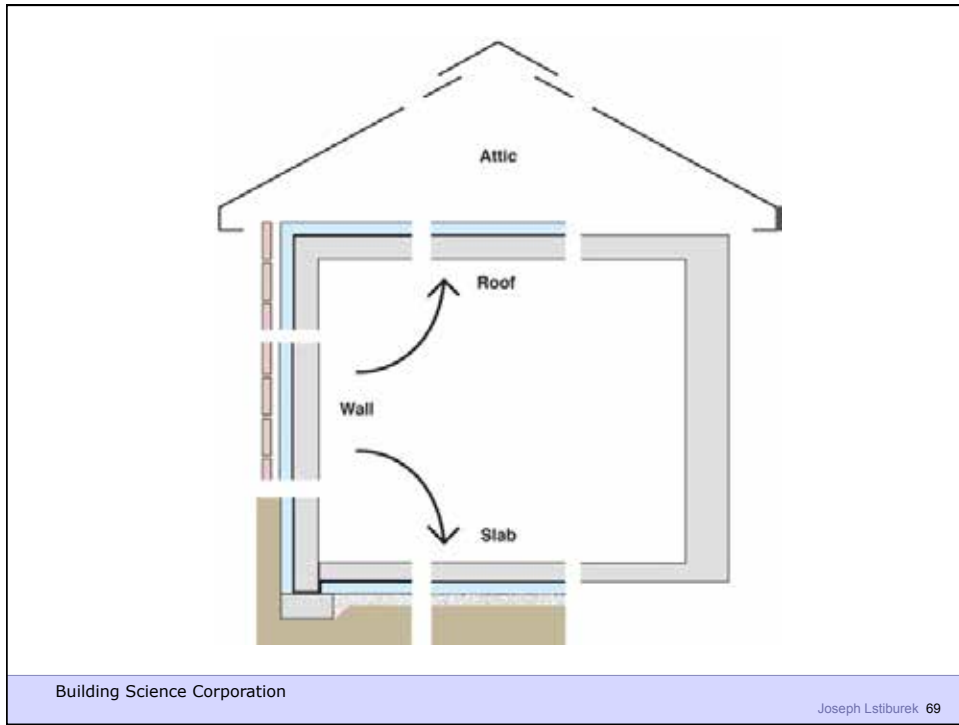


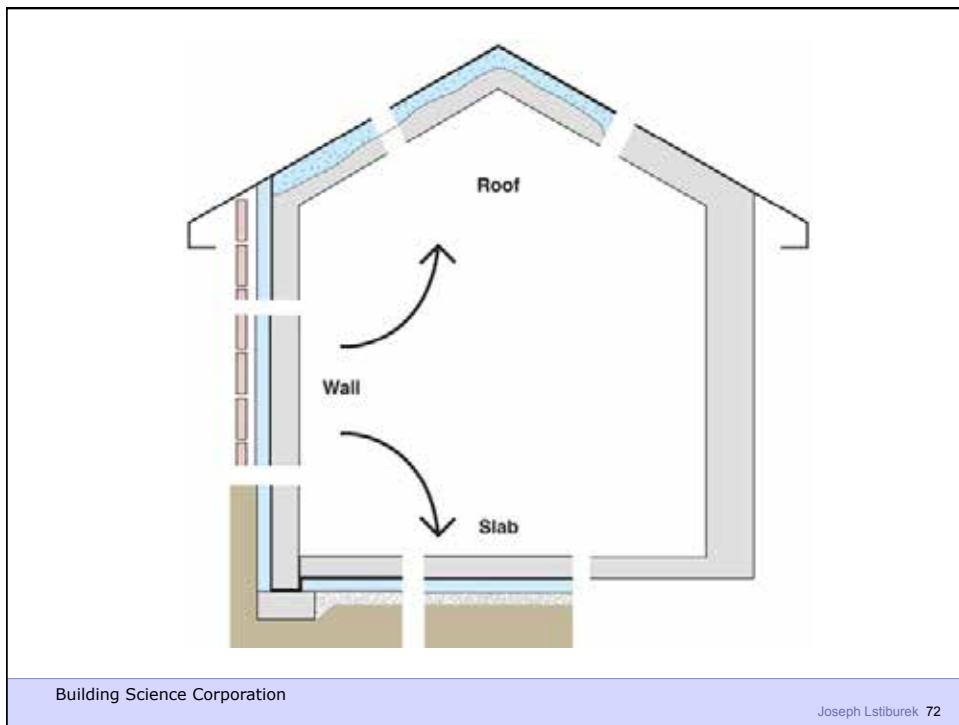
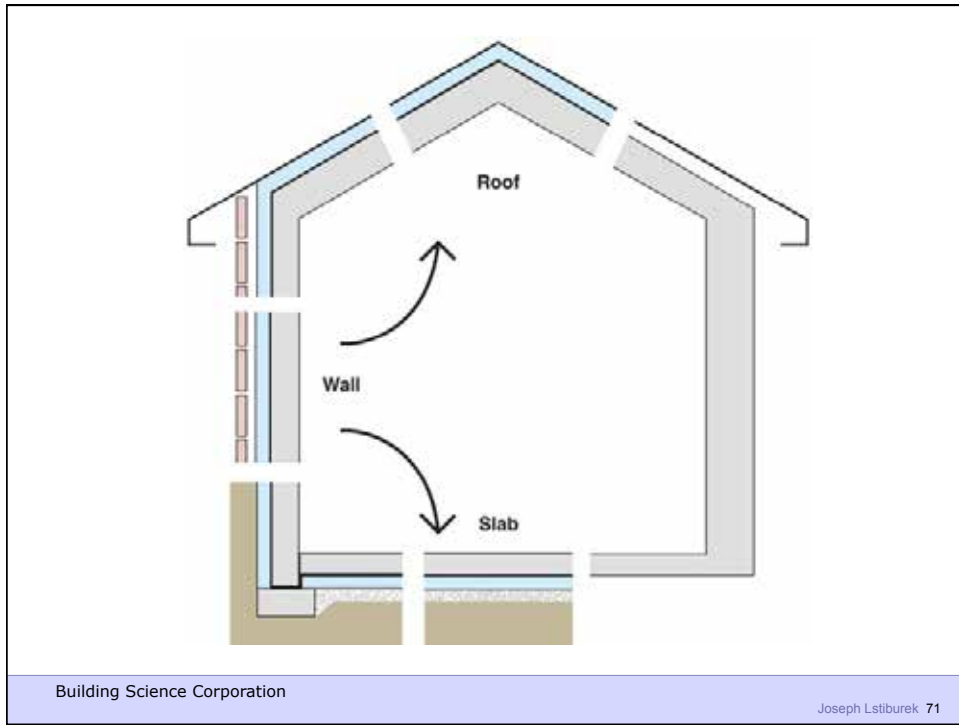








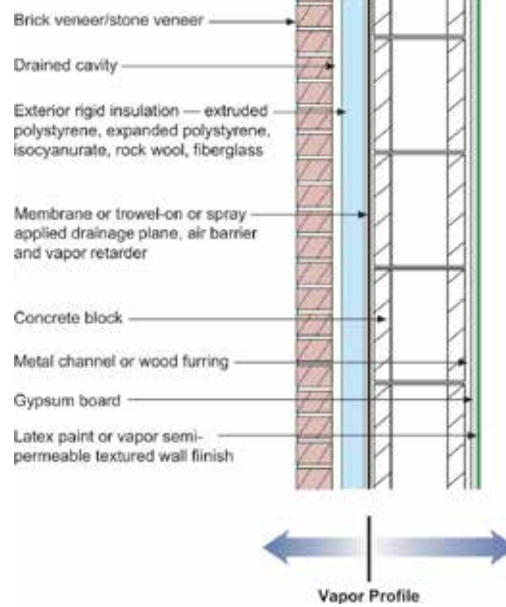




Configurations of the Perfect Wall

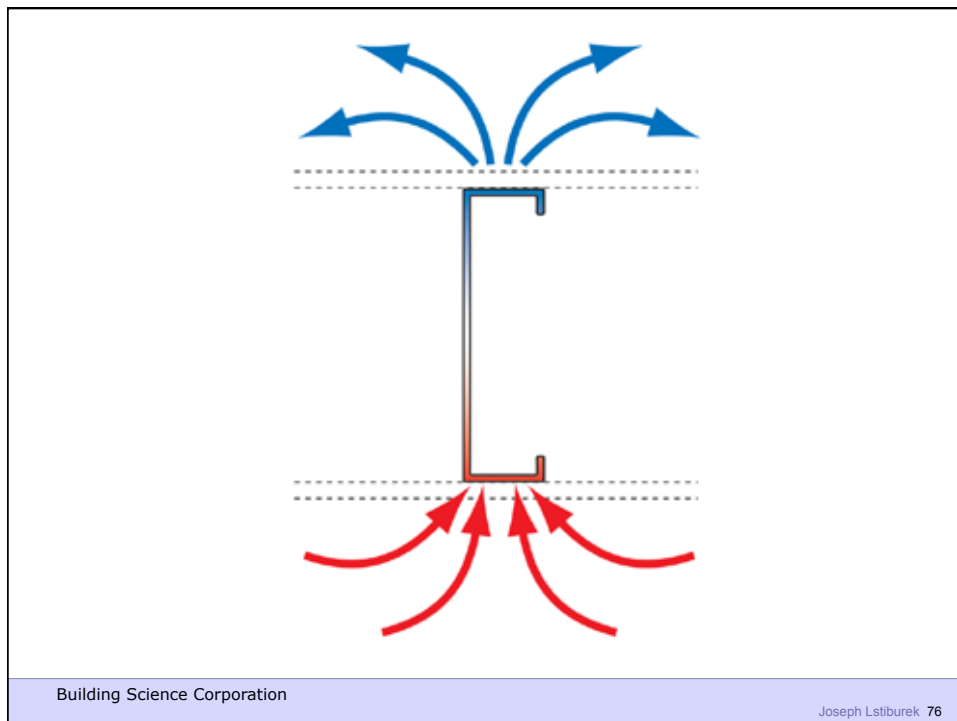
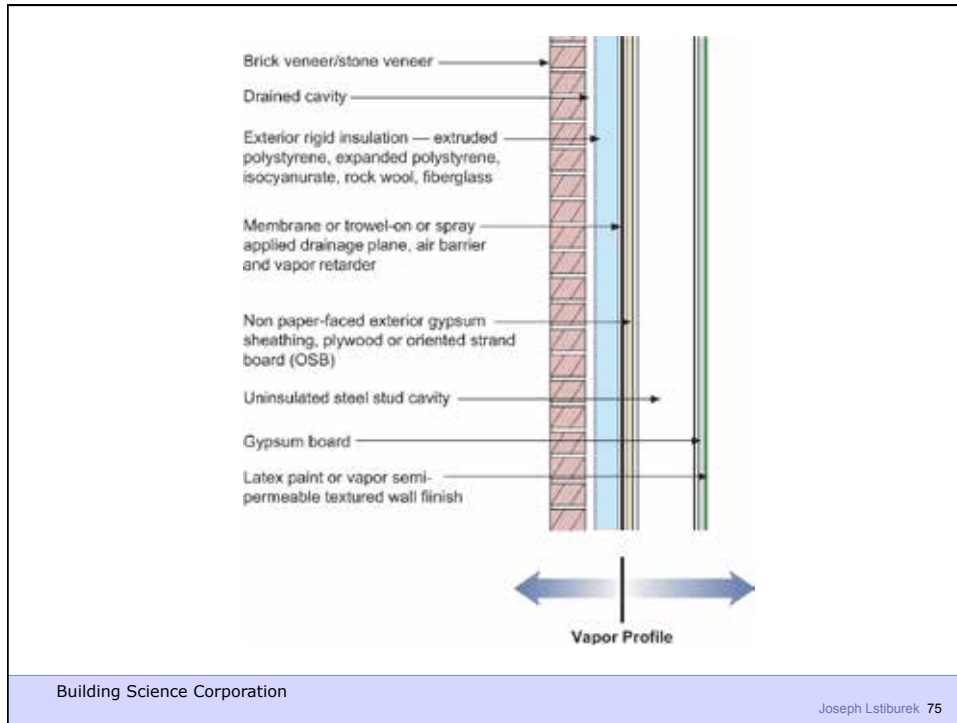
Building Science Corporation

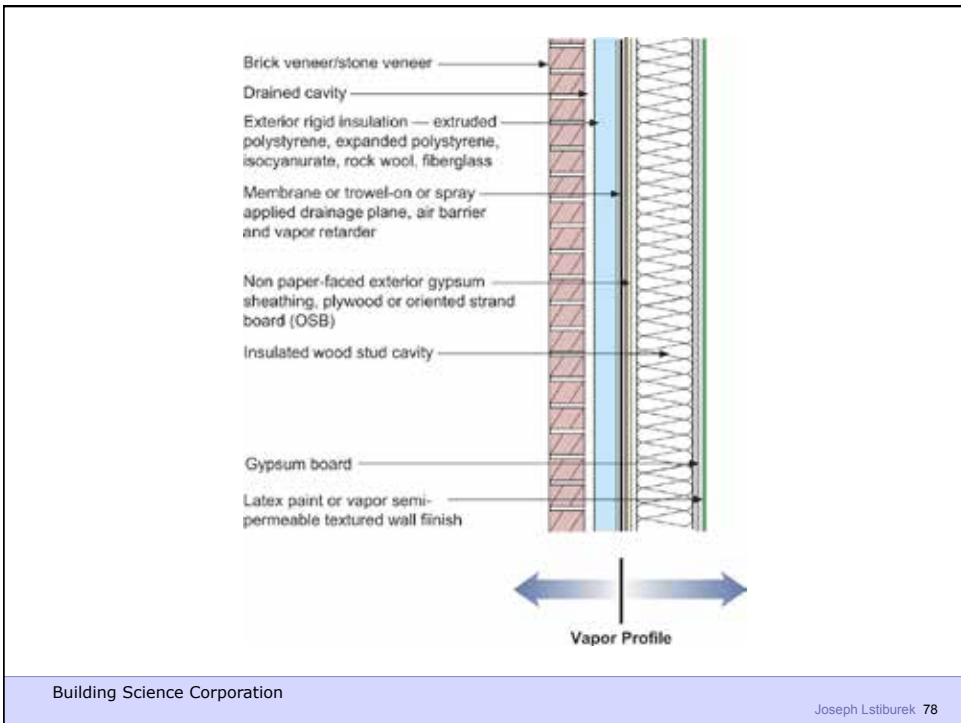
Joseph Lstiburek 73



Building Science Corporation

Joseph Lstiburek 74





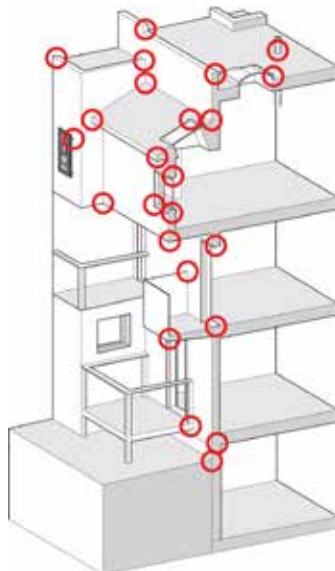
Commercial Enclosure: Simple Layers



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

Building Science Corporation

Joseph Lstiburek 79



Building Science Corporation

Joseph Lstiburek 80





Building Science Corporation

Joseph Lstiburek 83



Building Science Corporation

Joseph Lstiburek 84



Building Science Corporation

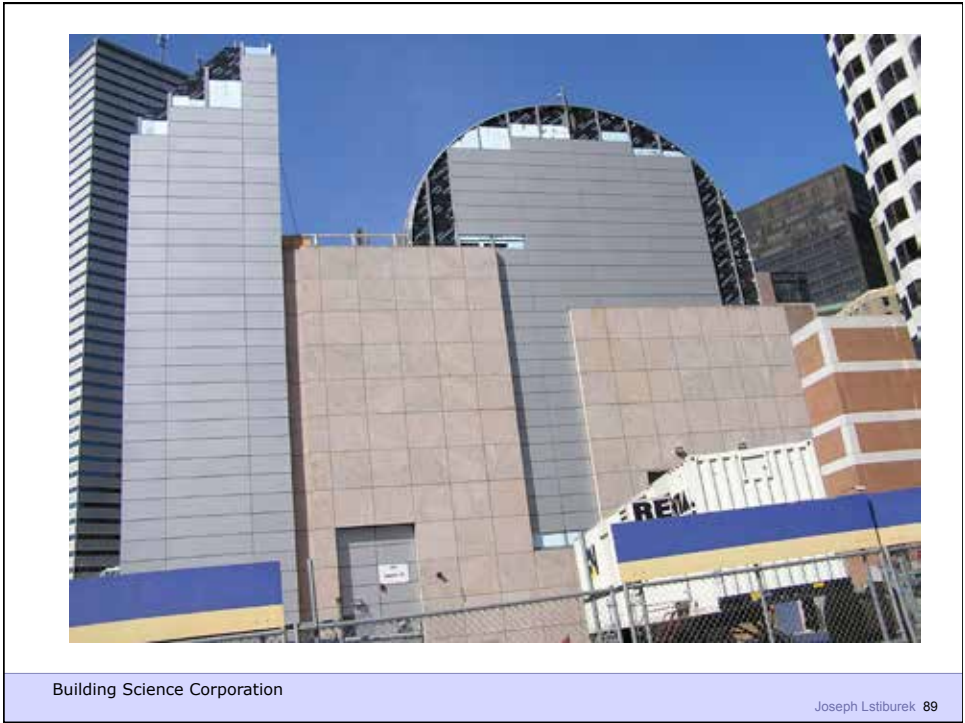
Joseph Lstiburek 85

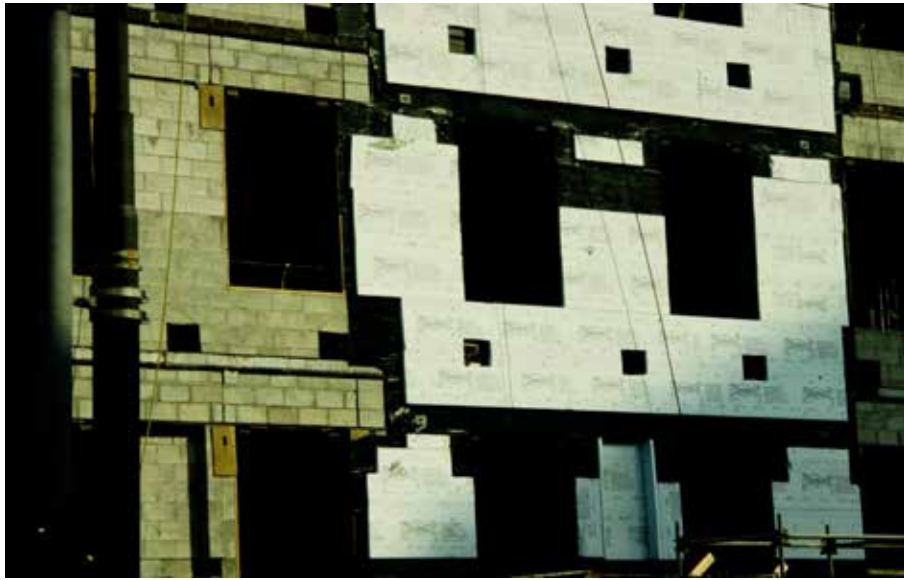


Building Science Corporation

Joseph Lstiburek 86







Building Science Corporation

Joseph Lstiburek 91



Building Science Corporation

Joseph Lstiburek 92



Building Science Corporation

Joseph Lstiburek 93



Building Science Corporation

Joseph Lstiburek 94



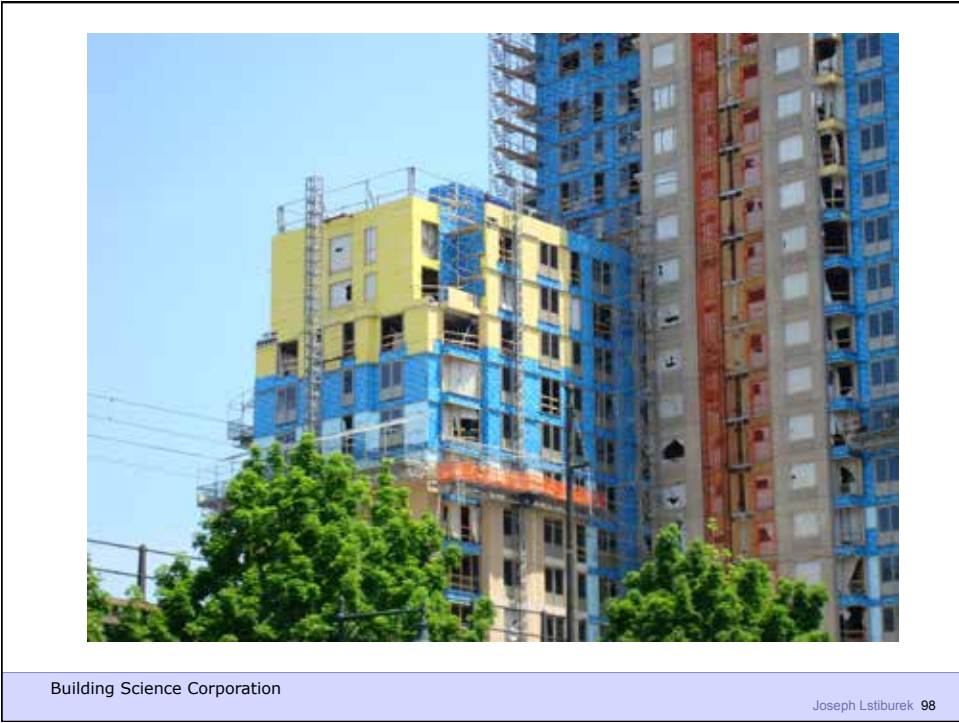
Building Science Corporation

Joseph Lstiburek 95



Building Science Corporation

Joseph Lstiburek 96





Building Science Corporation

Joseph Lstiburek 99



Building Science

Joseph Lstiburek 100





Building Science Corporation

Joseph Lstiburek 103



Building Science Corporation

Joseph Lstiburek 104



Building Science Corporation

Joseph Lstiburek 105



Building Science Corporation

Joseph Lstiburek 106









Building Science Corporation

Joseph Lstiburek 113



Building Science 2009

Joseph Lstiburek – HVAC 114





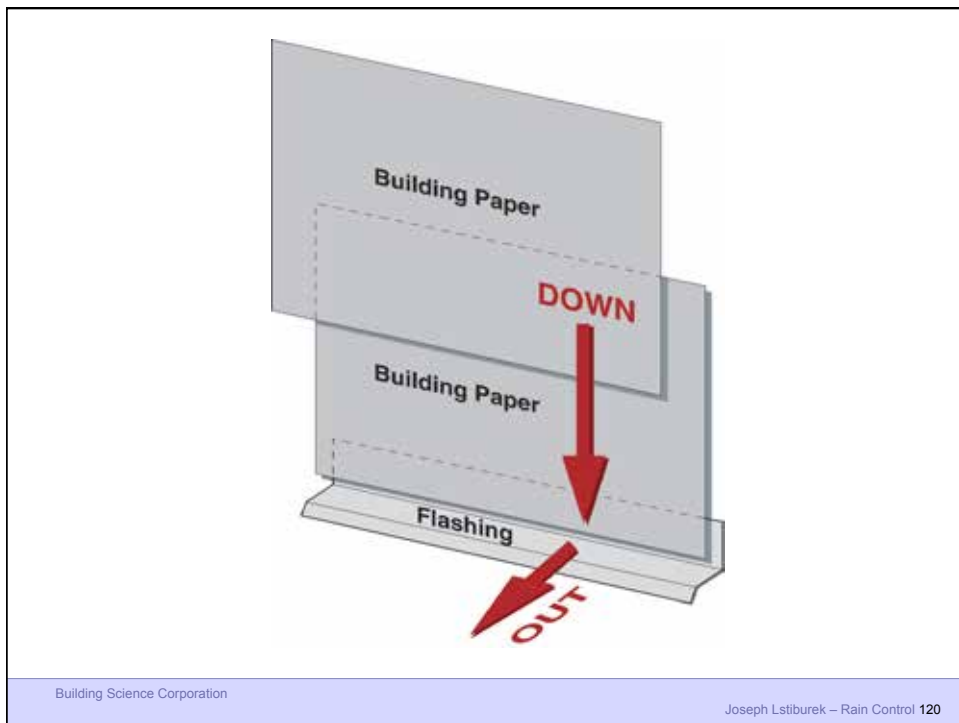
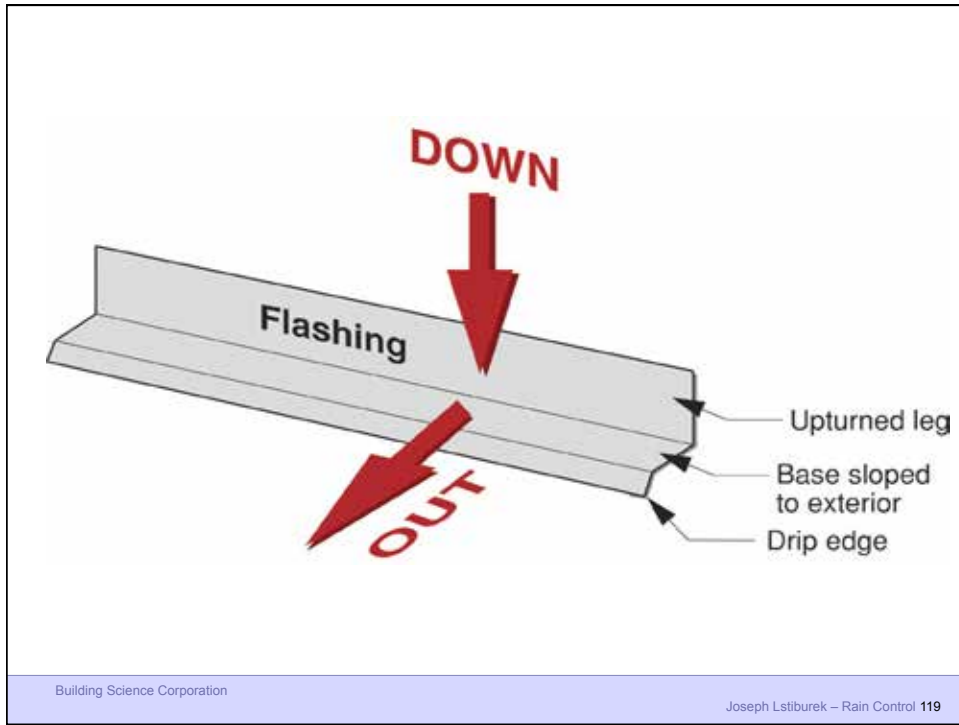
Building Science 2009

Joseph Lstiburek – HVAC 117

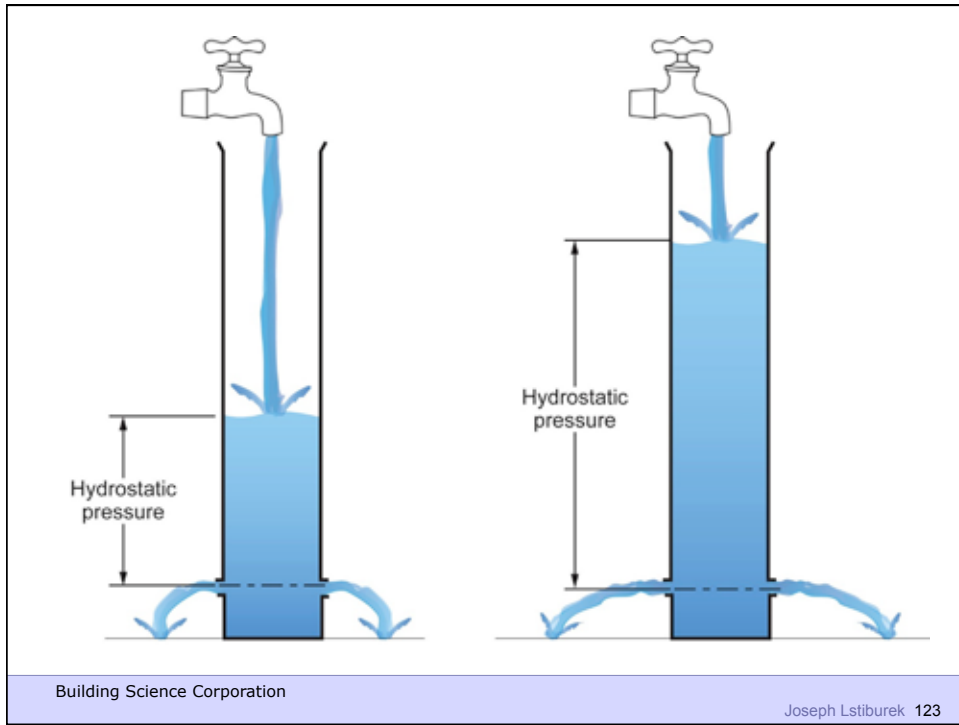


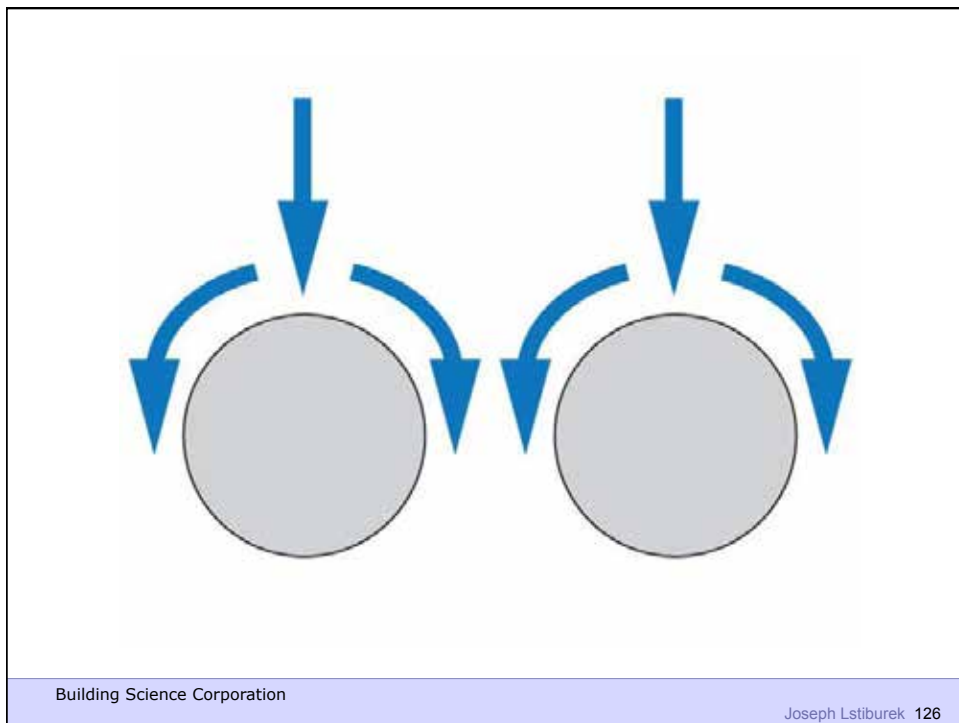
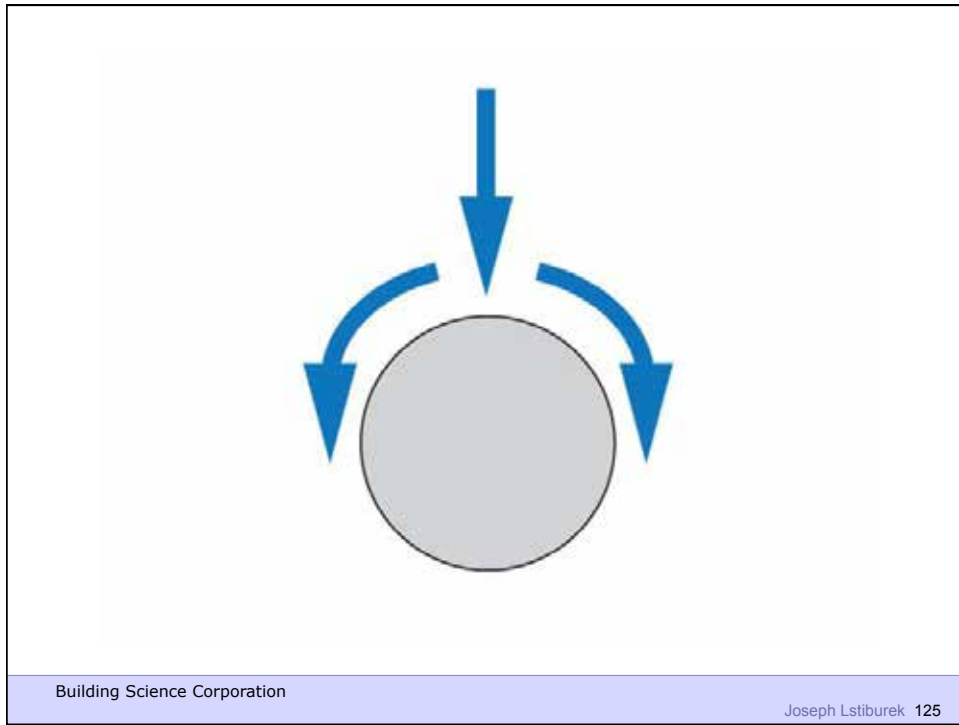
Building Science Corporation

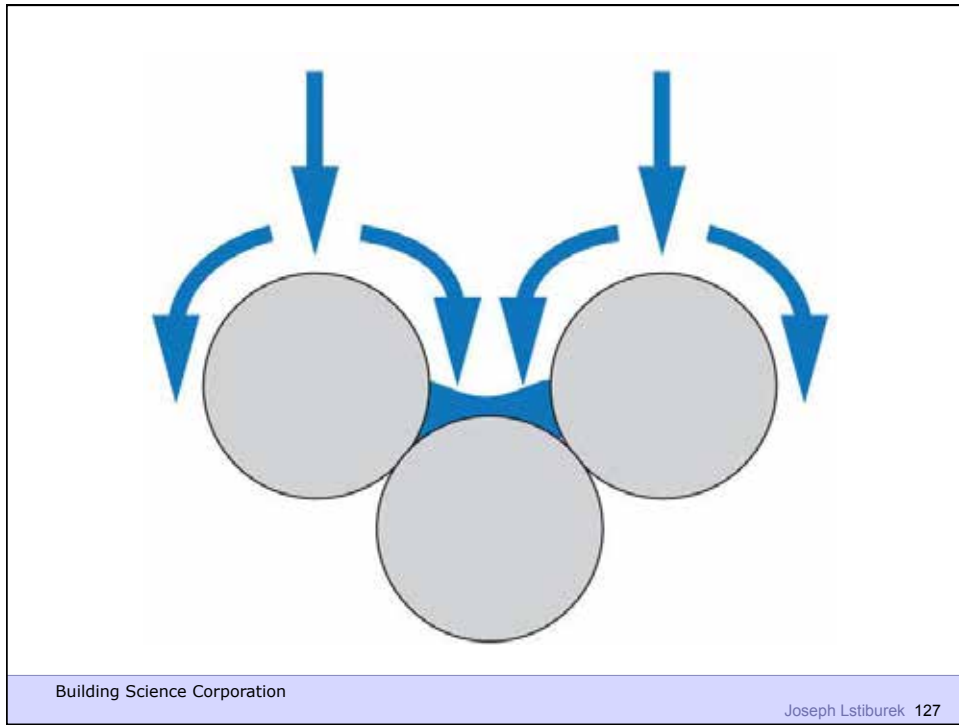
Joseph Lstiburek 118

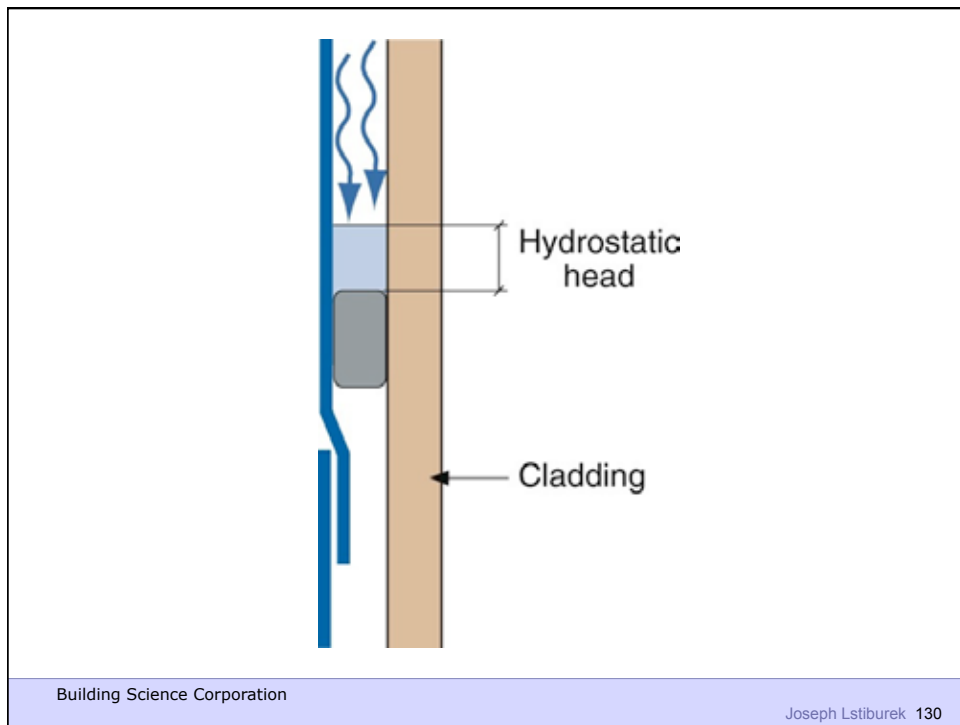
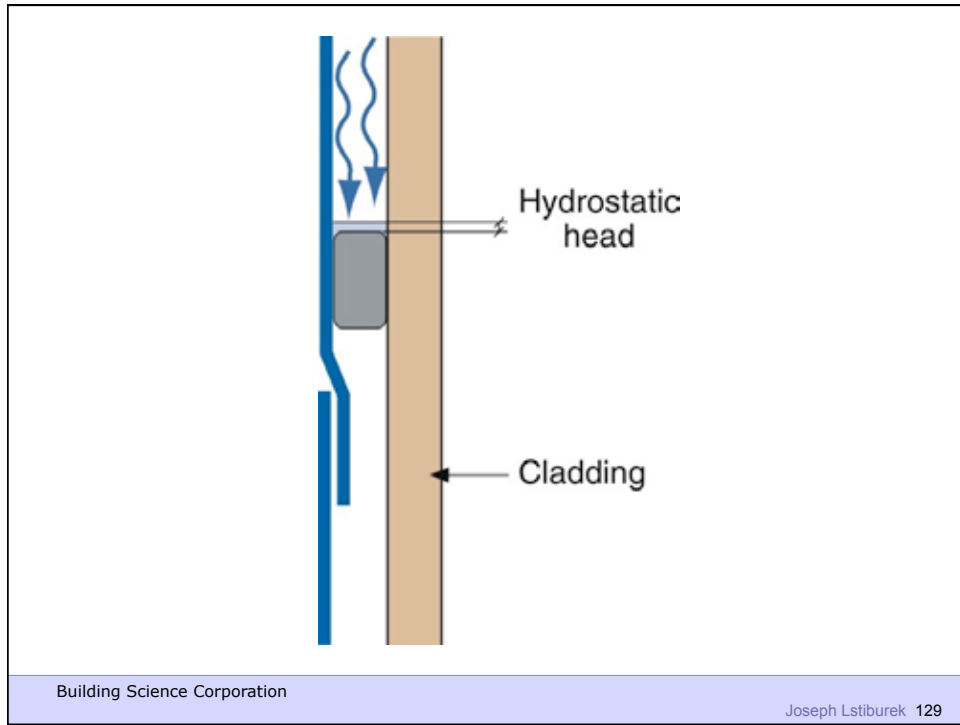


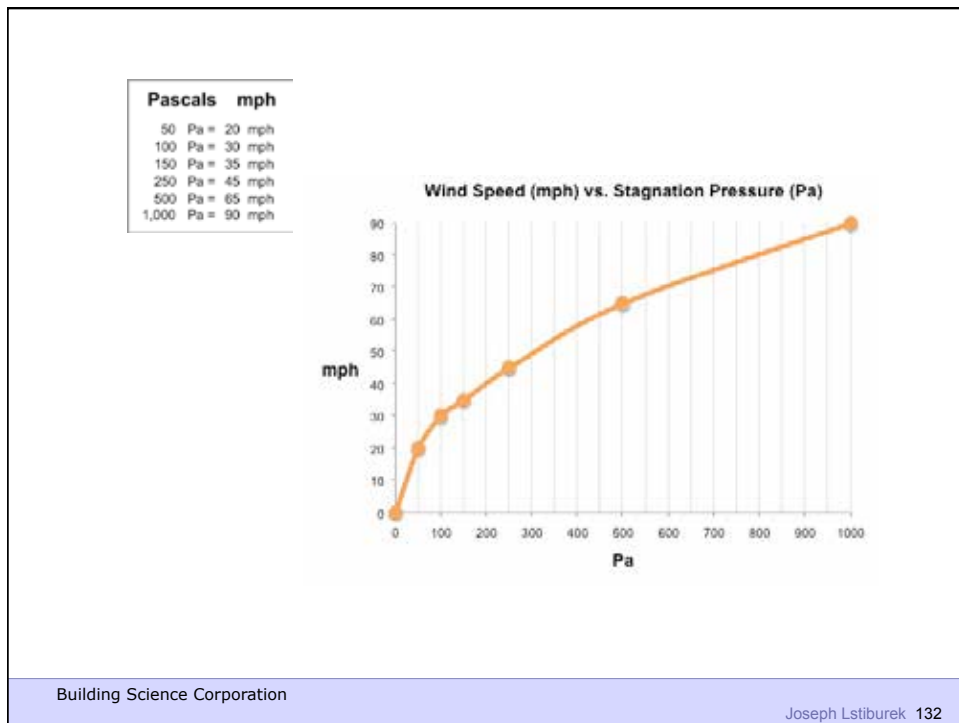
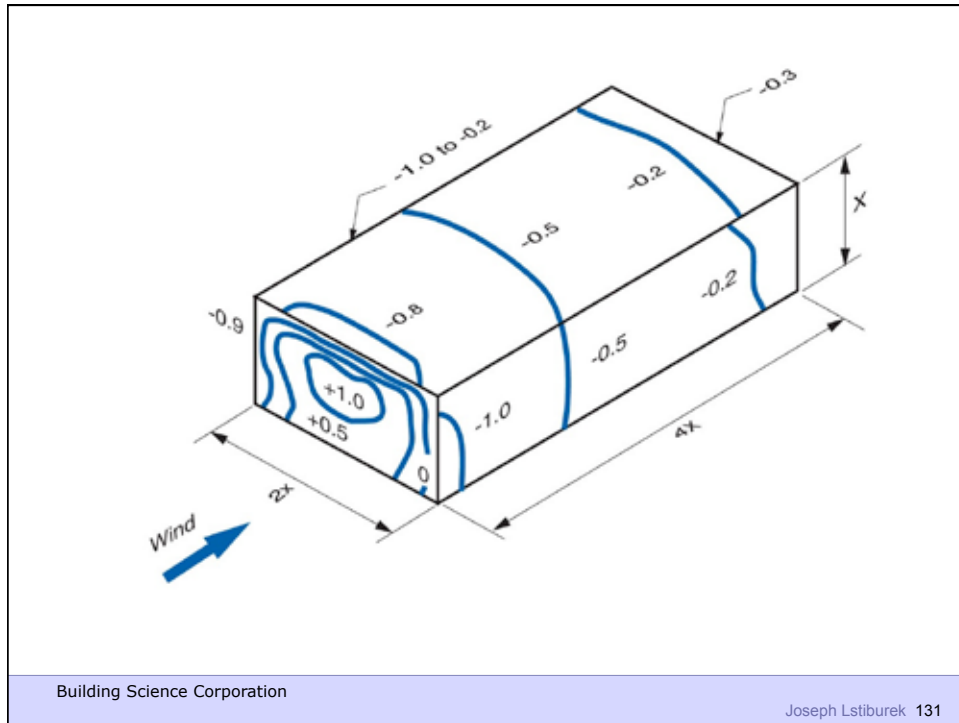














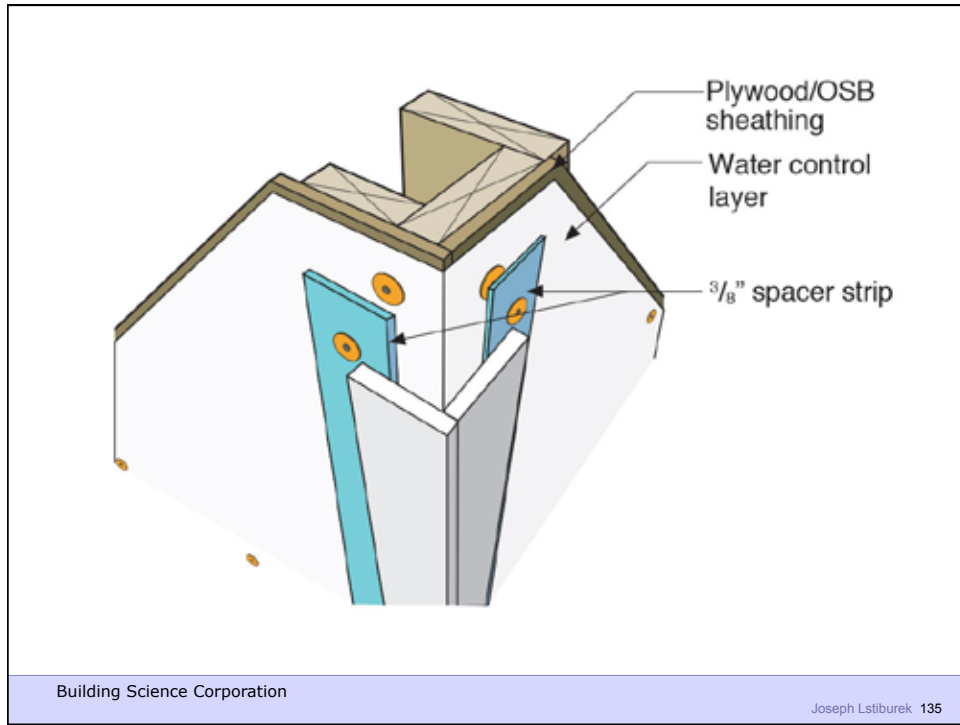
Building Science Corporation

Joseph Lstiburek 133



Building Science Corporation

Joseph Lstiburek – Rain Control 134





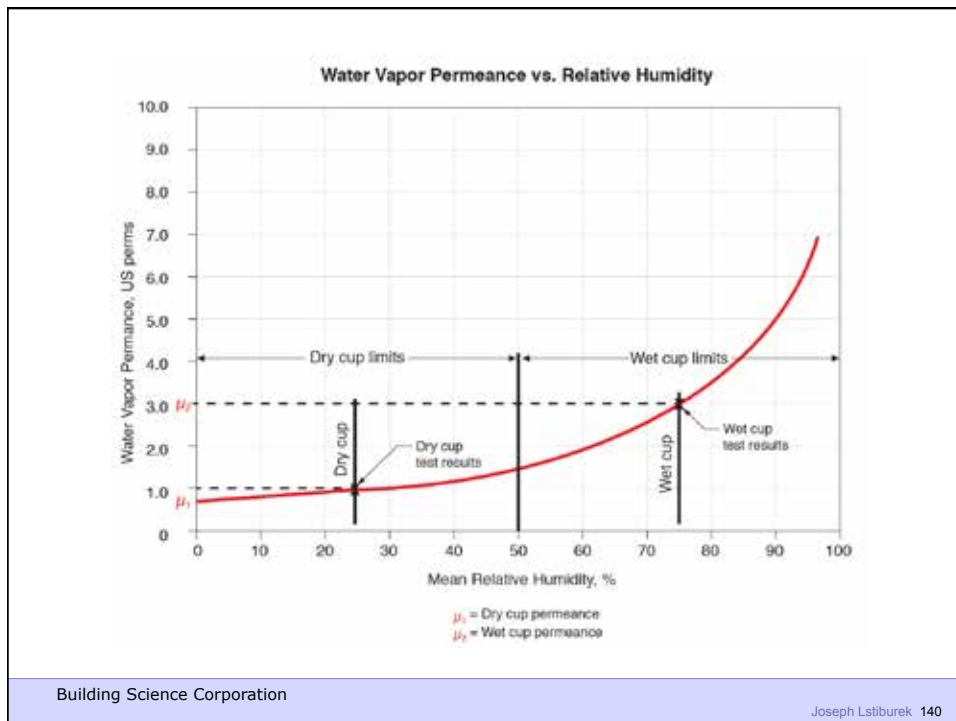
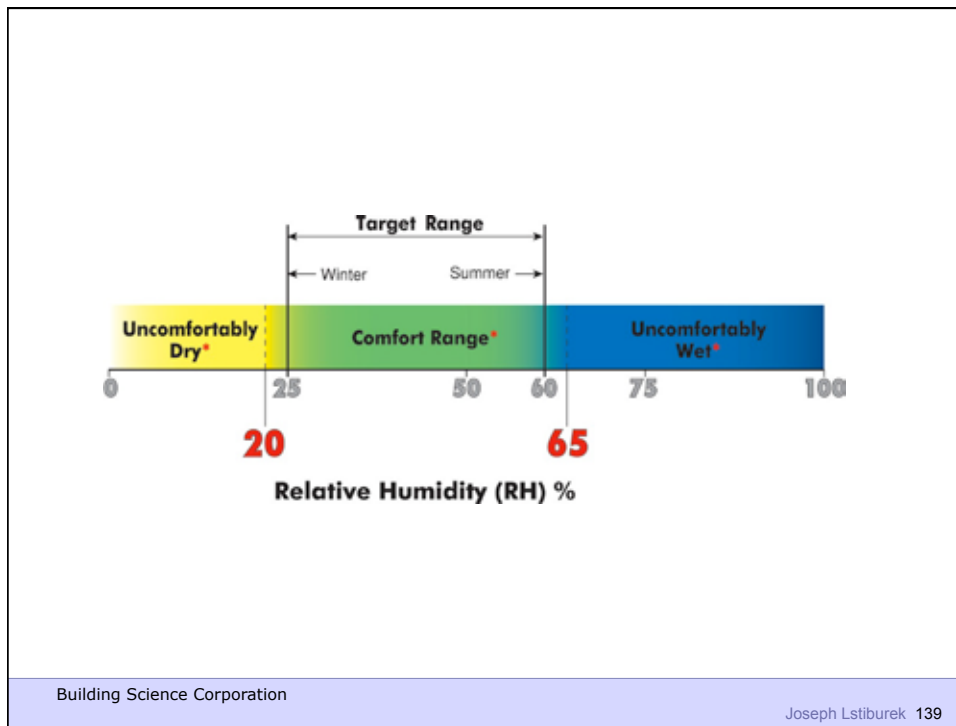
Building Science Corporation

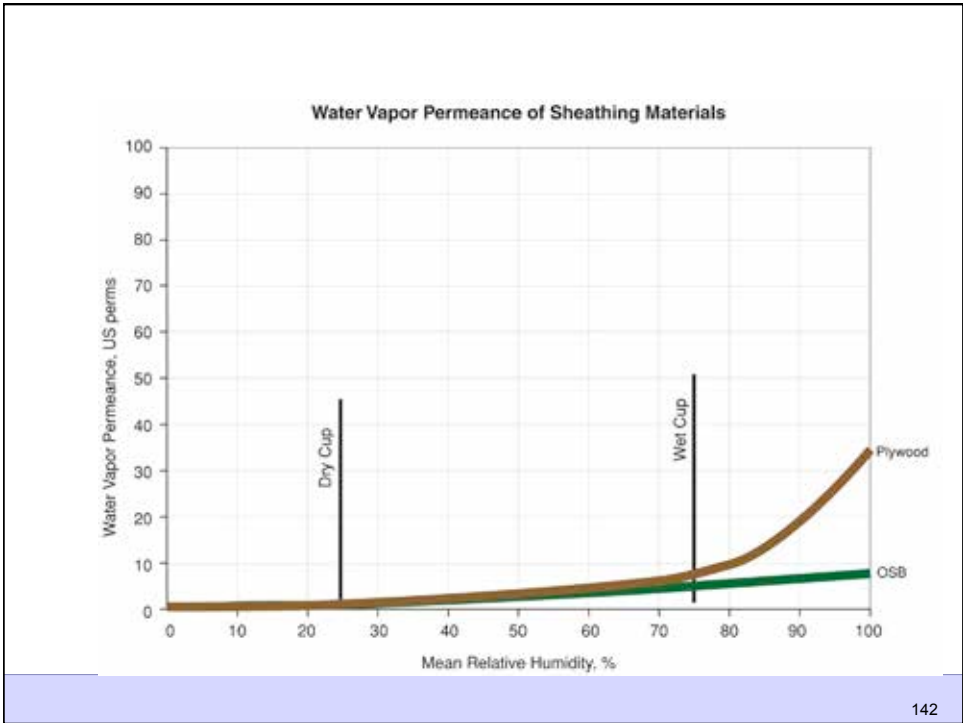
Joseph Lstiburek 137

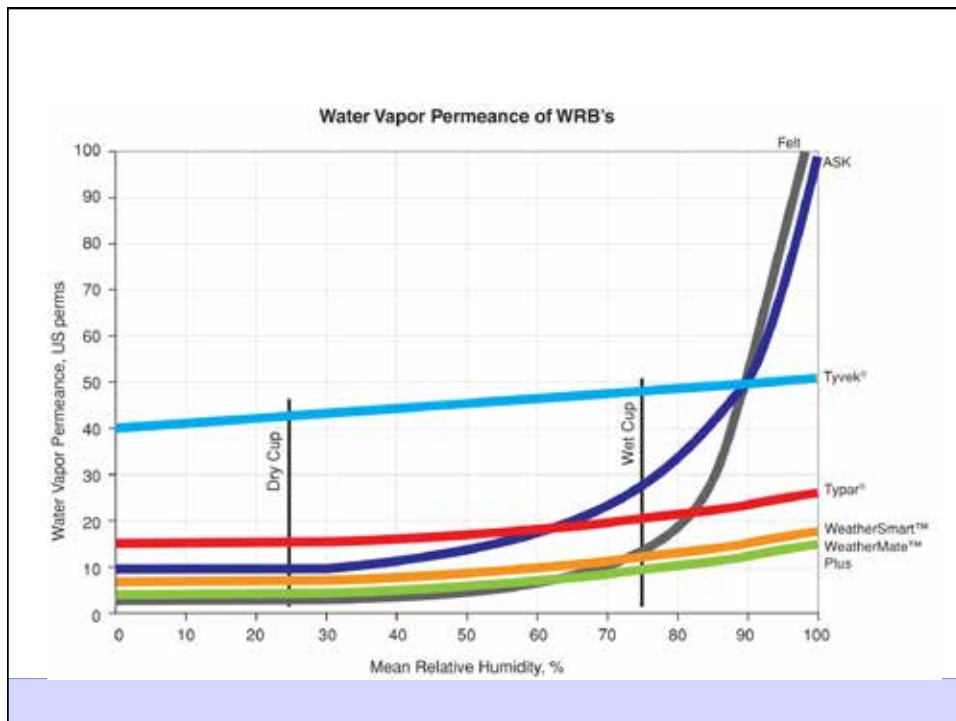
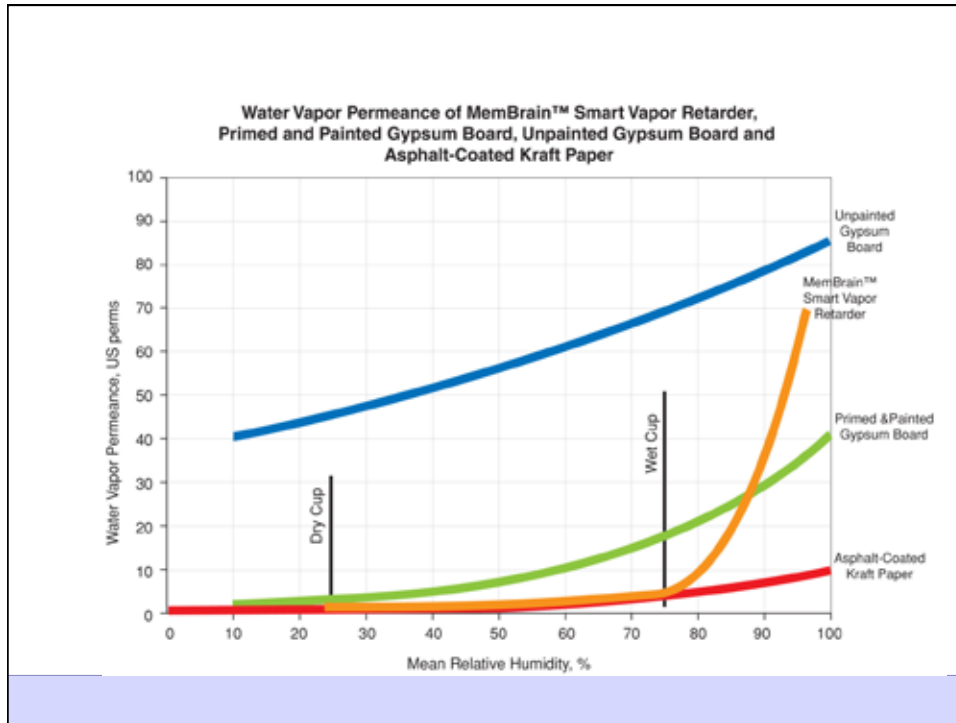


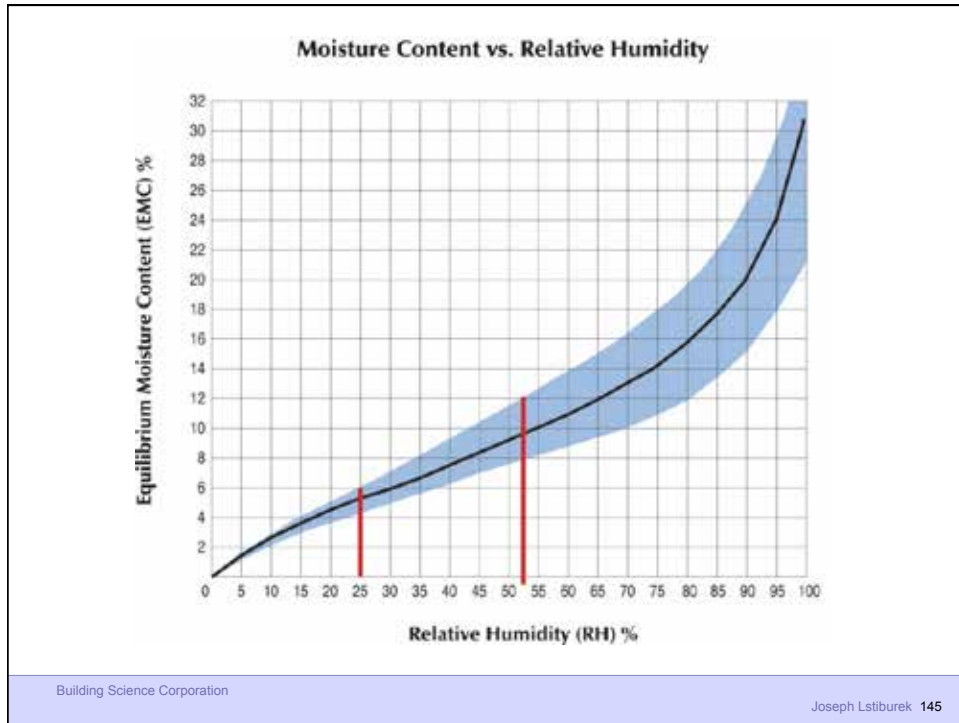
Building Science Corporation

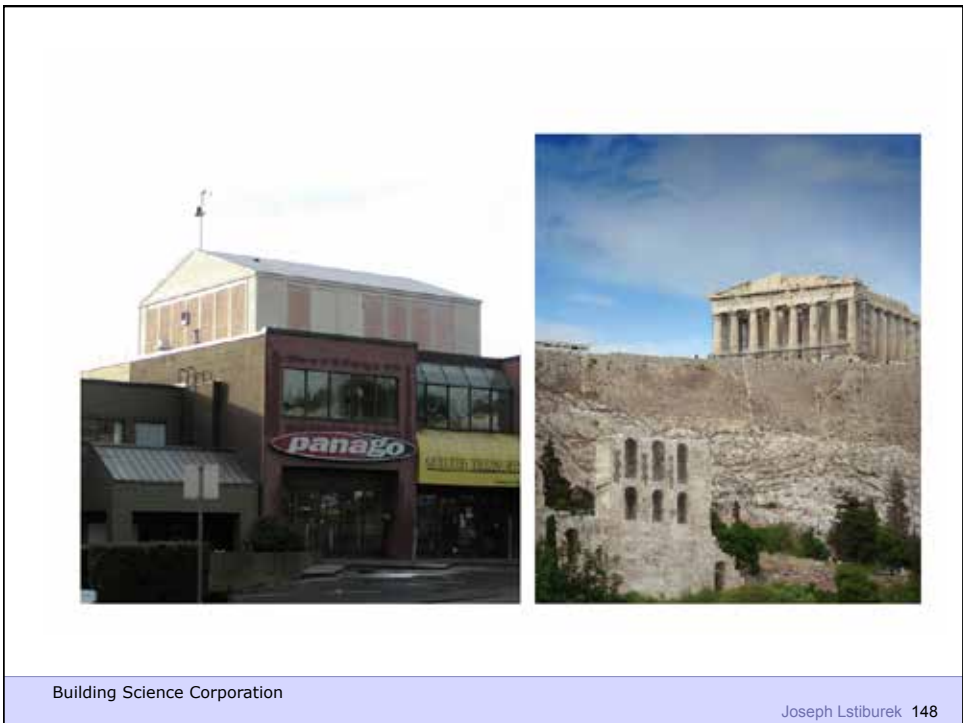
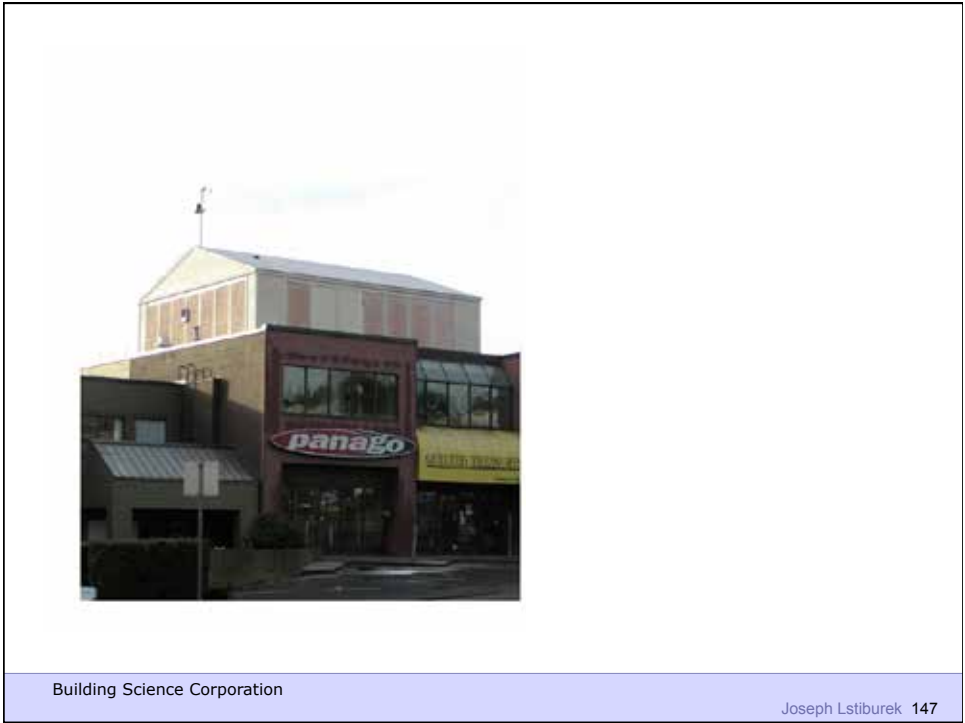
Joseph Lstiburek 138

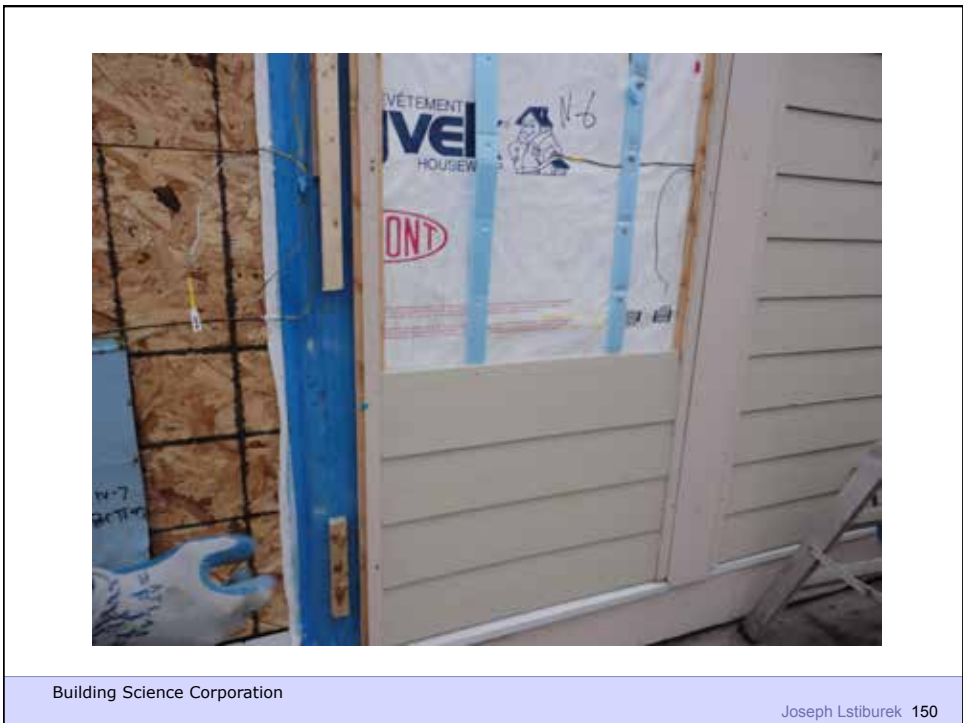














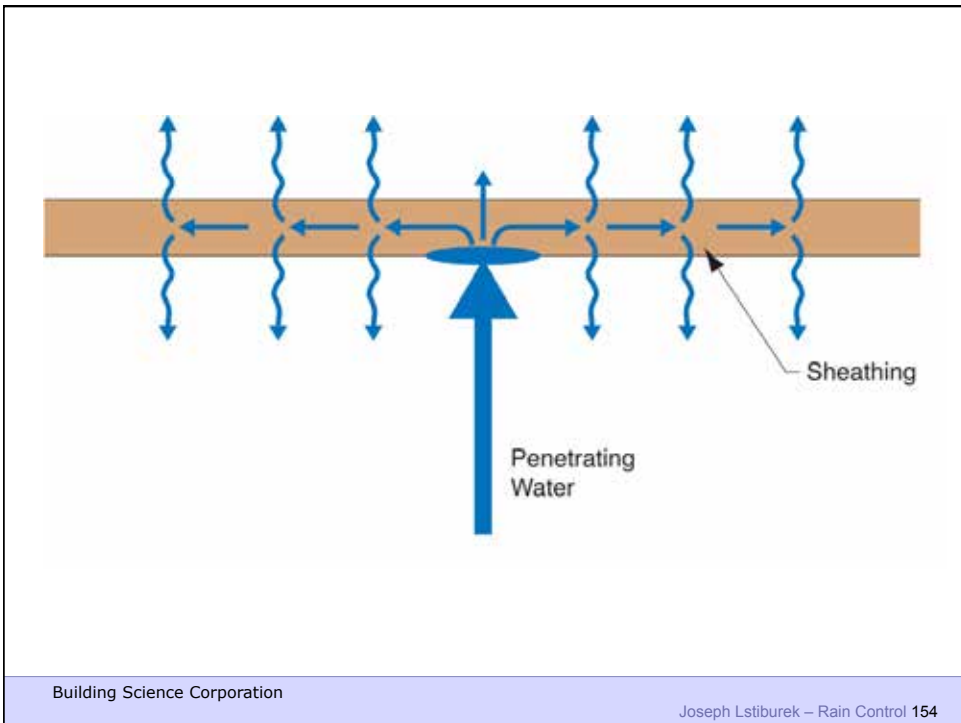
Building Science Corporation

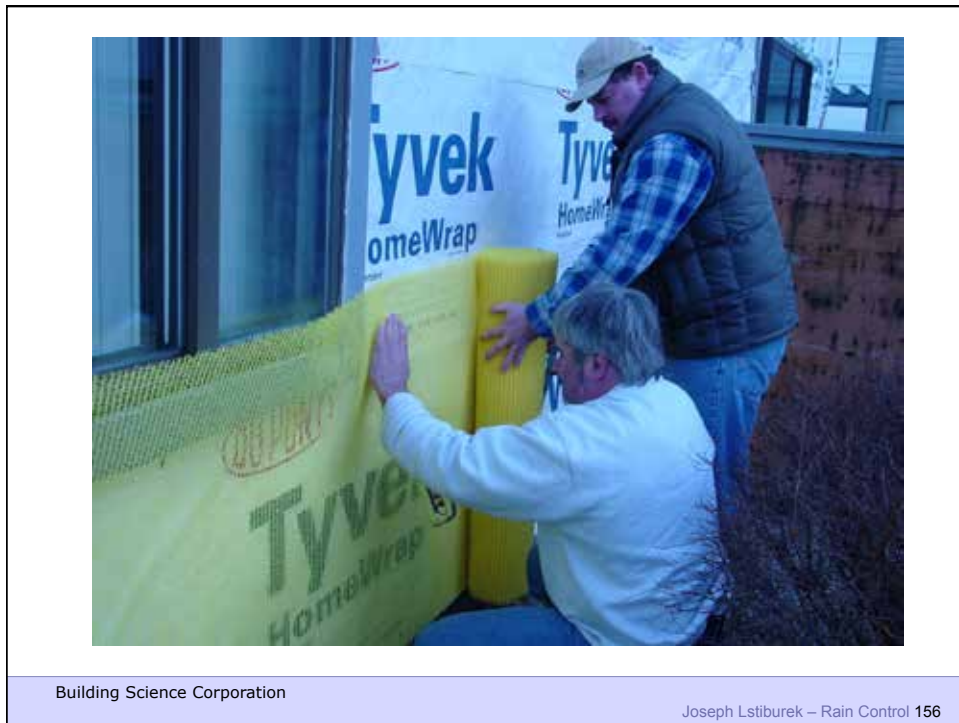
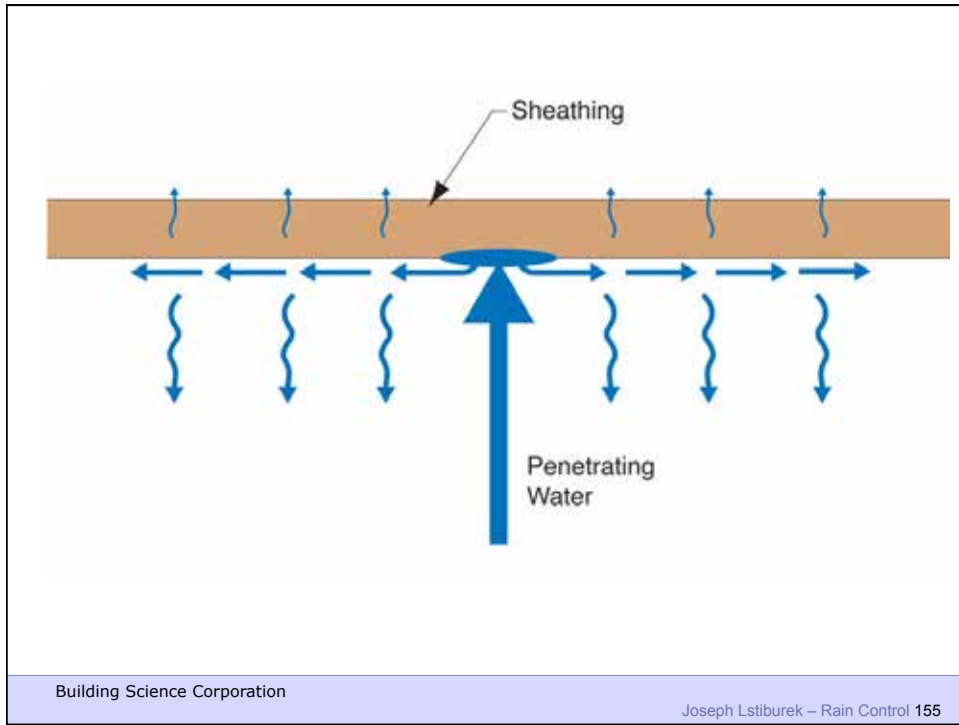
Joseph Lstiburek 151



Building Science Corporation

Joseph Lstiburek 152

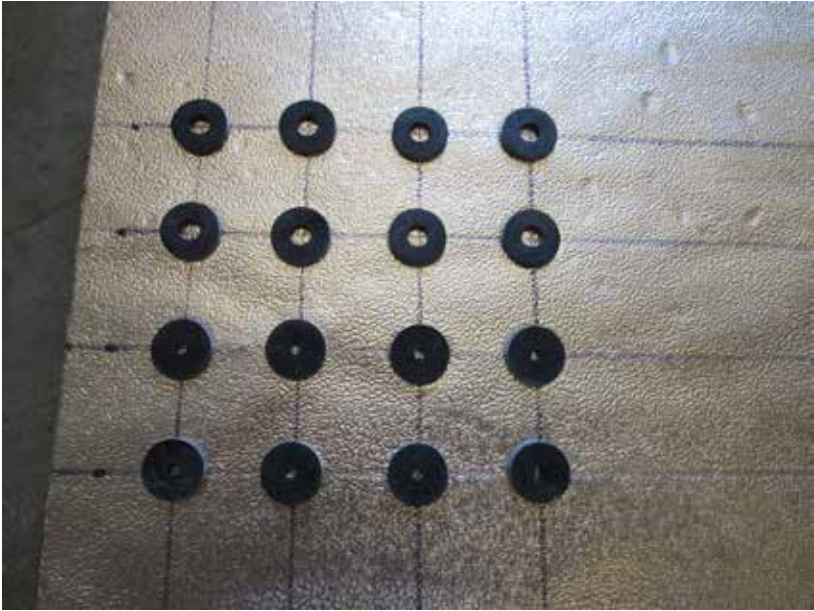




Rain Screen

Building Science Corporation

Joseph Lstiburek 157



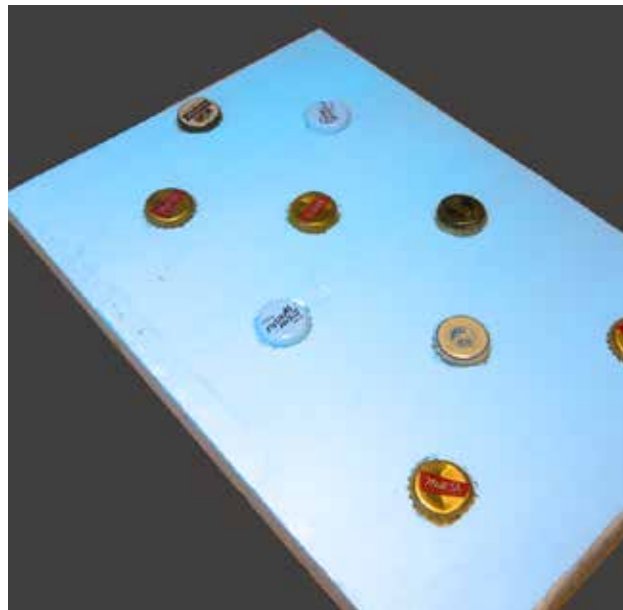
Building Science Corporation

Joseph Lstiburek 158

Beer Screen?

Building Science Corporation

Joseph Lstiburek 159



Building Science Corporation

Joseph Lstiburek 160





Rockwool

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

