

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

Building Science

Adventures In Building Science

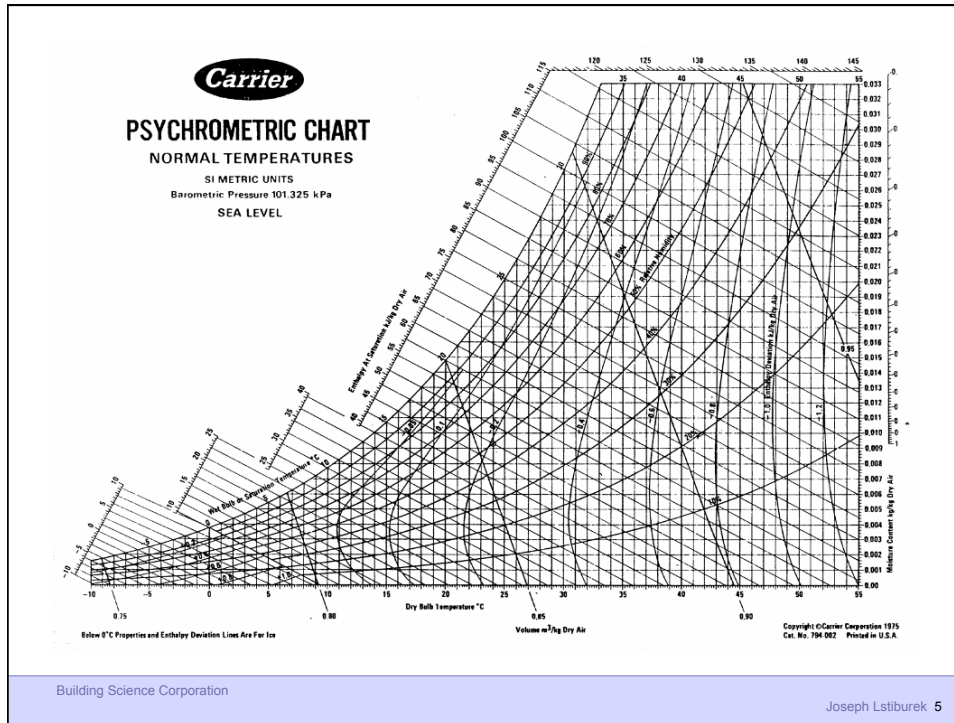
www.buildingscience.com

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



Damage Functions

Building Science Corporation

Joseph Lstiburek 6

Damage Functions
Water
Heat
Ultra Violet Radiation

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

80 Percent of all Construction Problems are Related to Water

Building Science Corporation

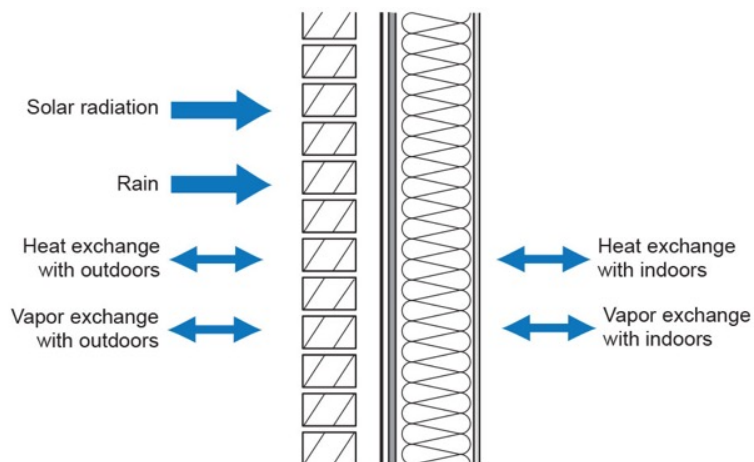
Joseph Lstiburek 9

What is a Building?

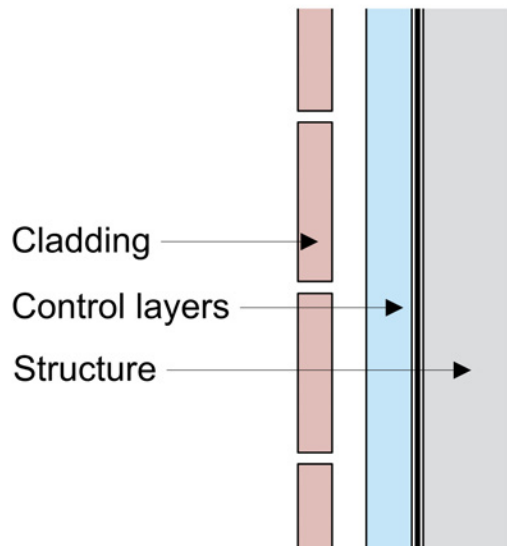
Building Science Corporation

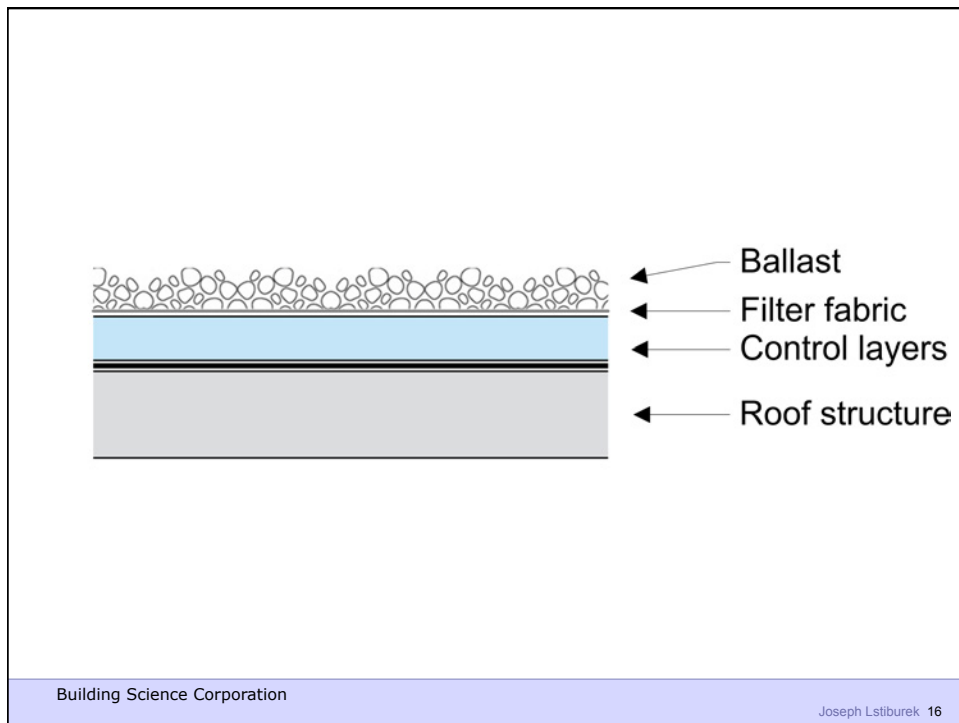
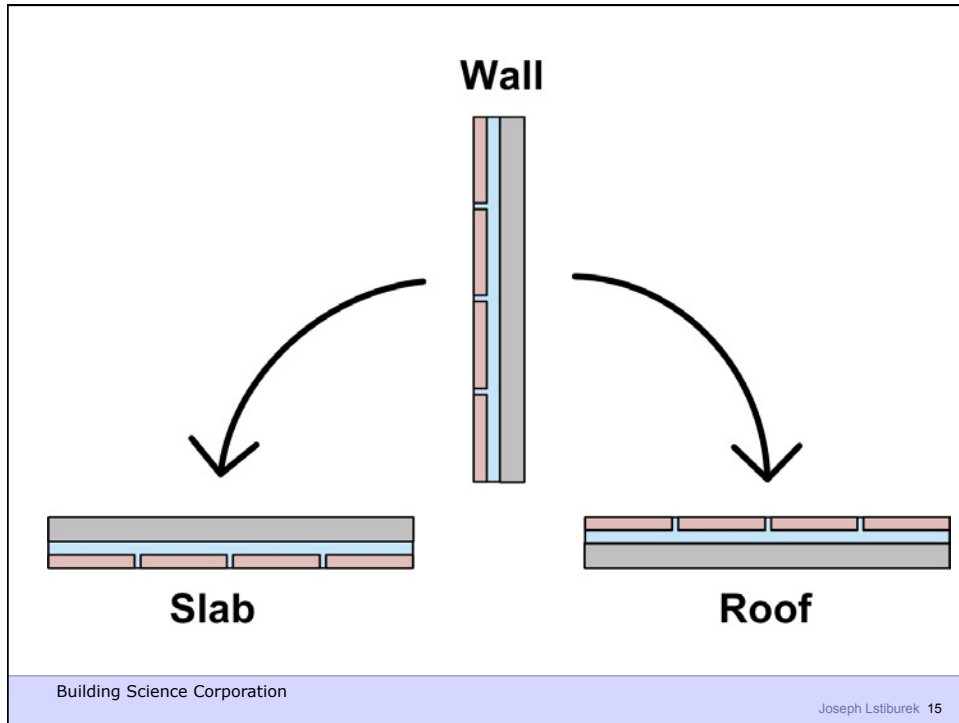
Joseph Lstiburek 10

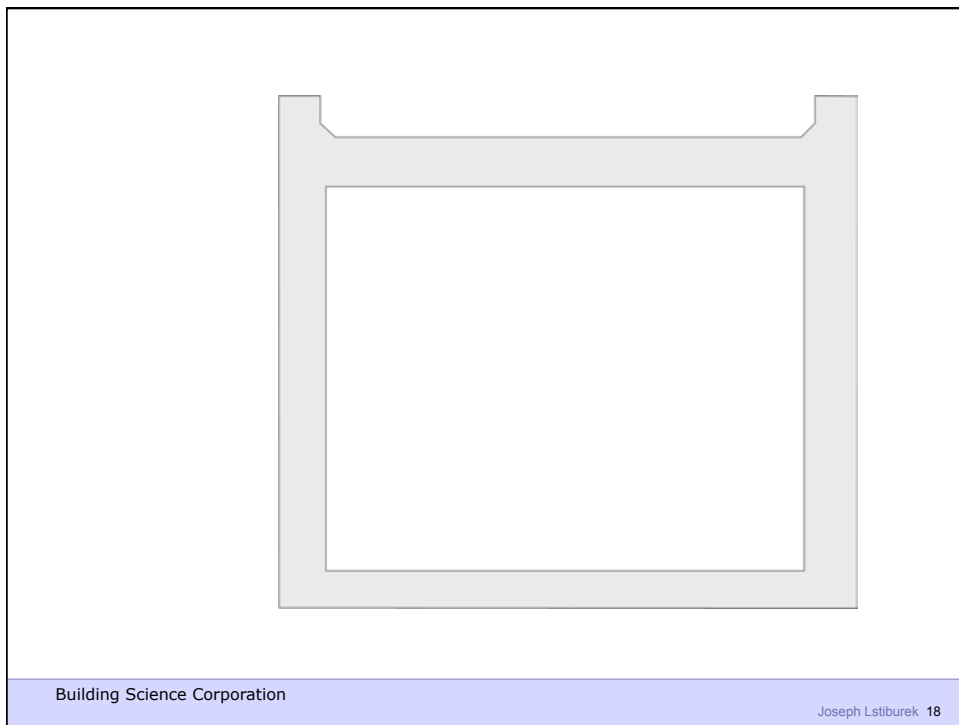
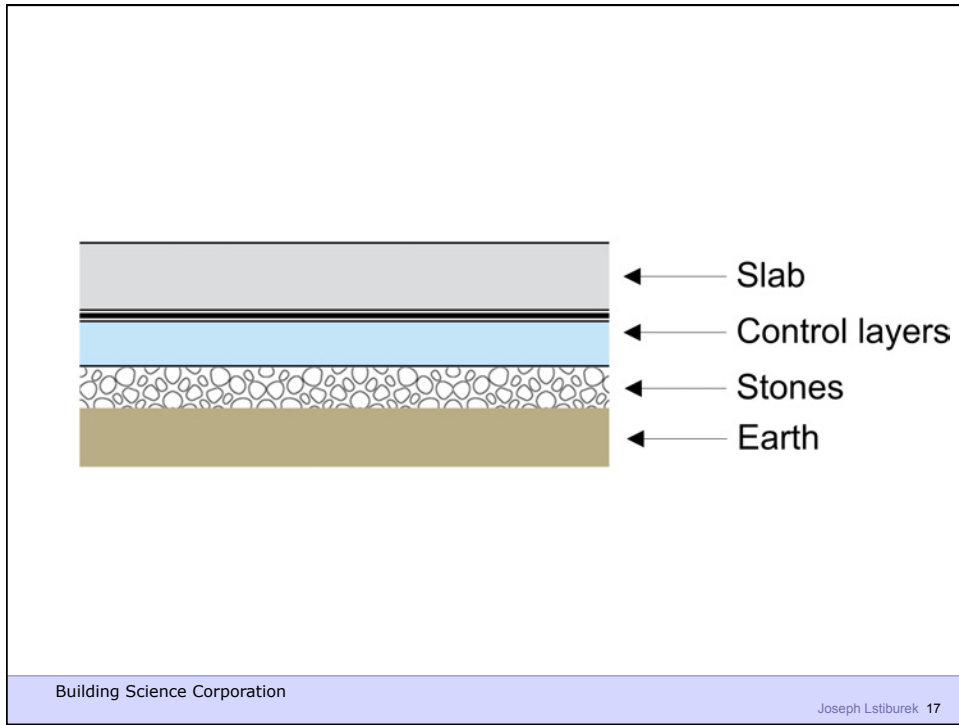
- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and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

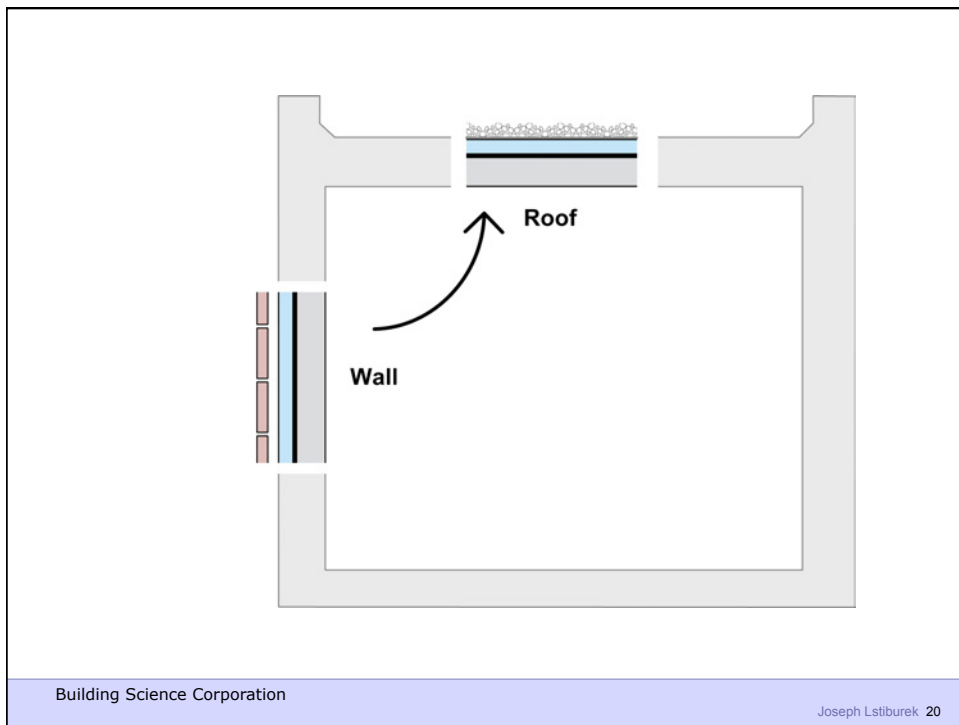
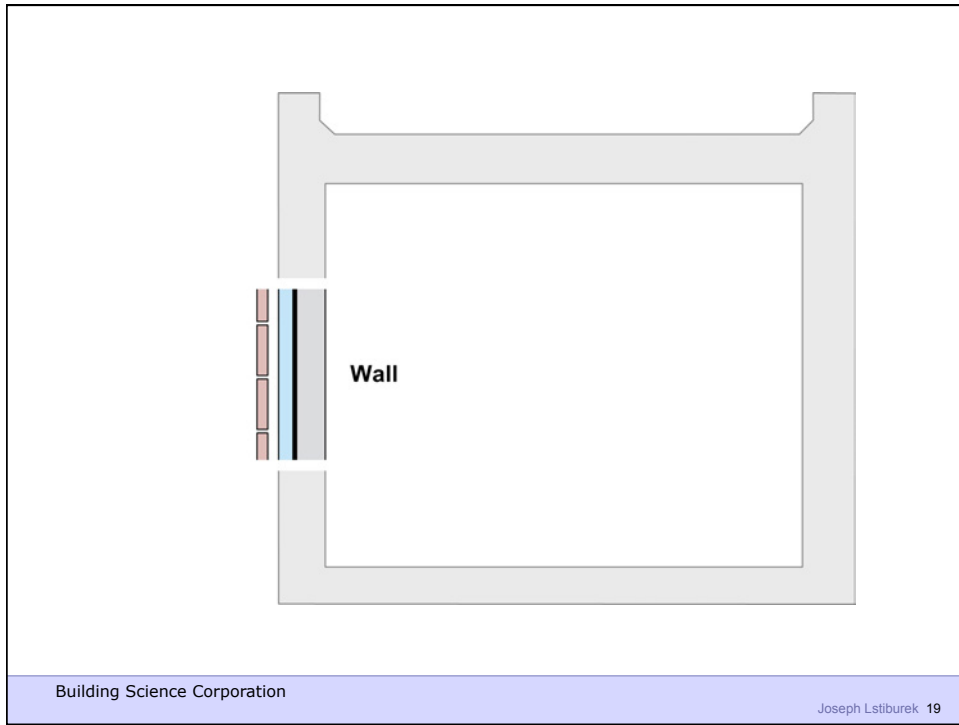


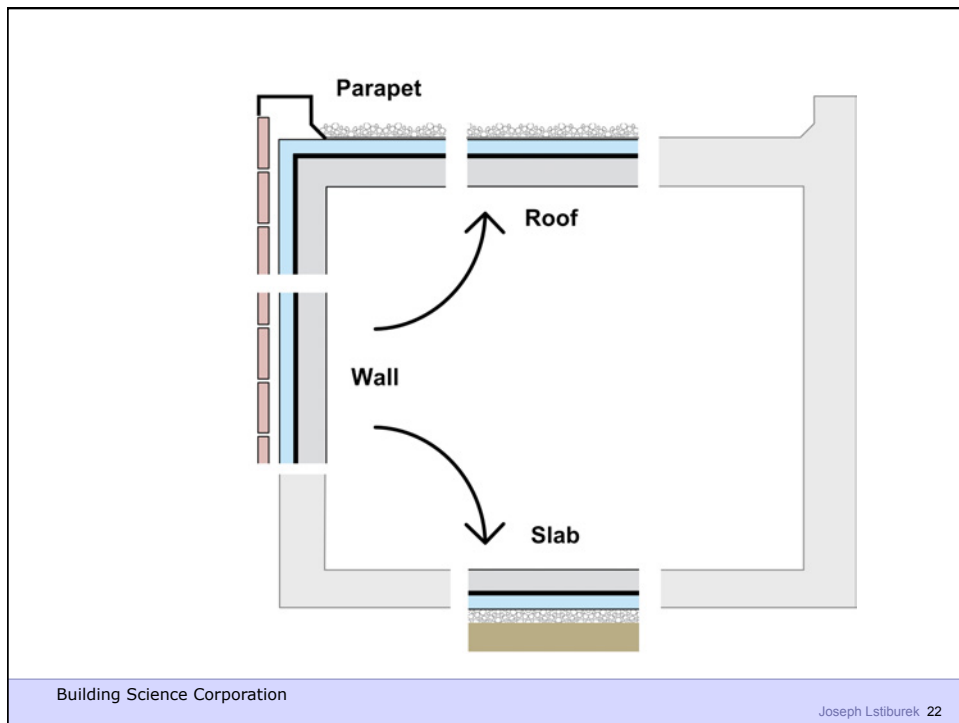
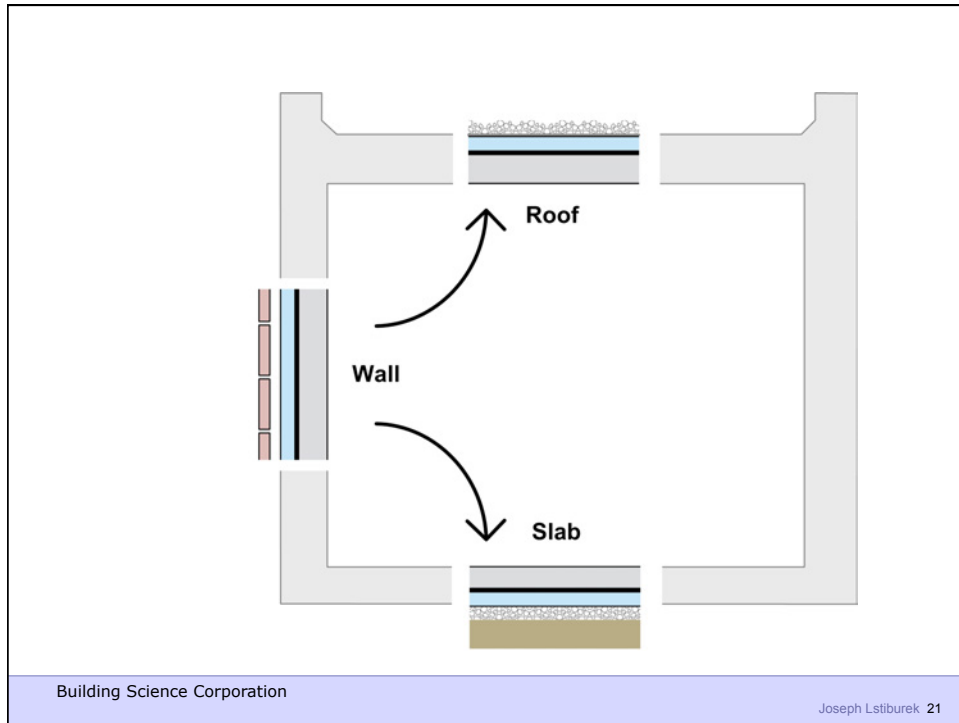
Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

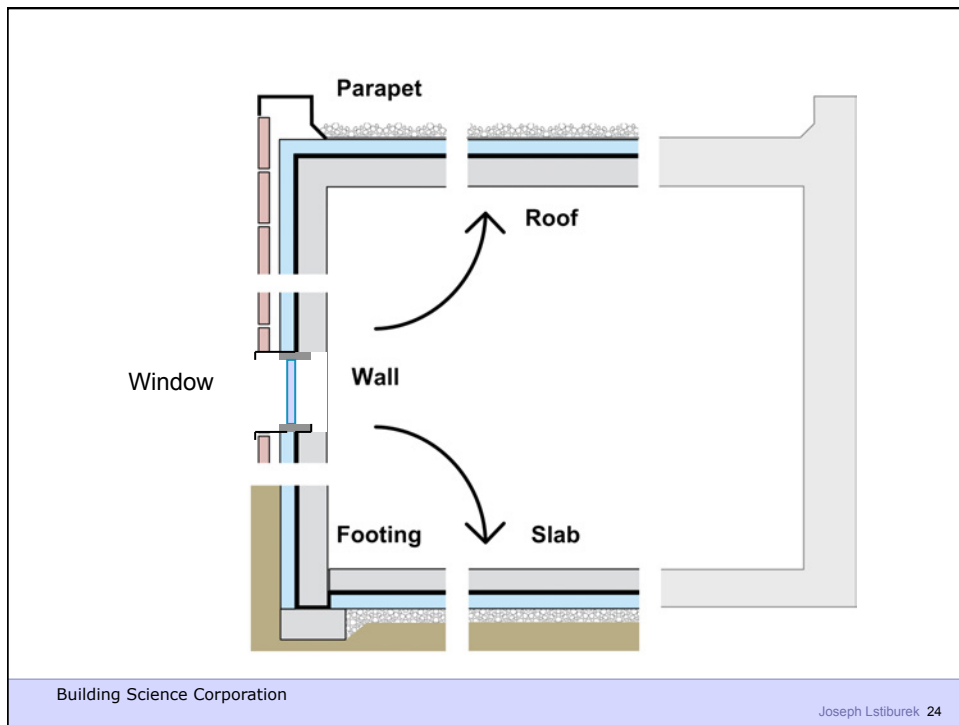
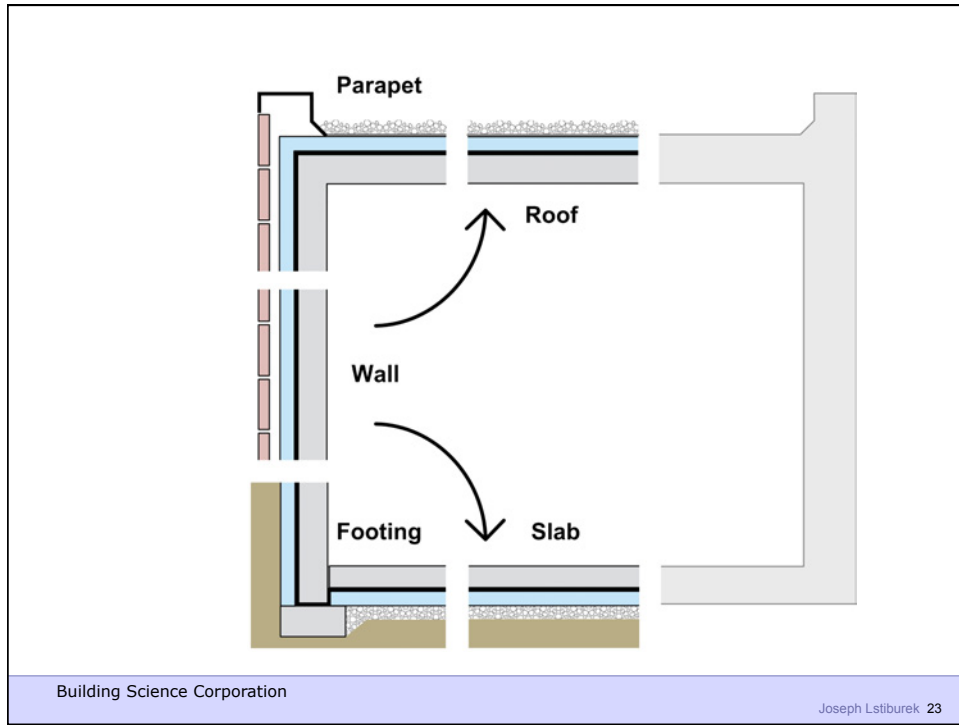


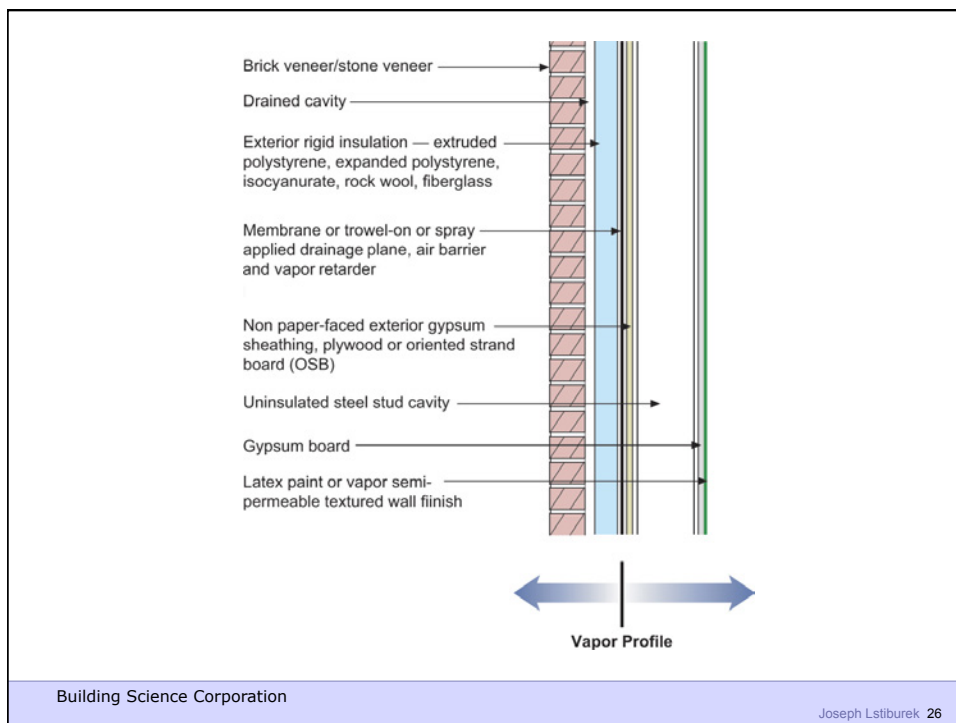
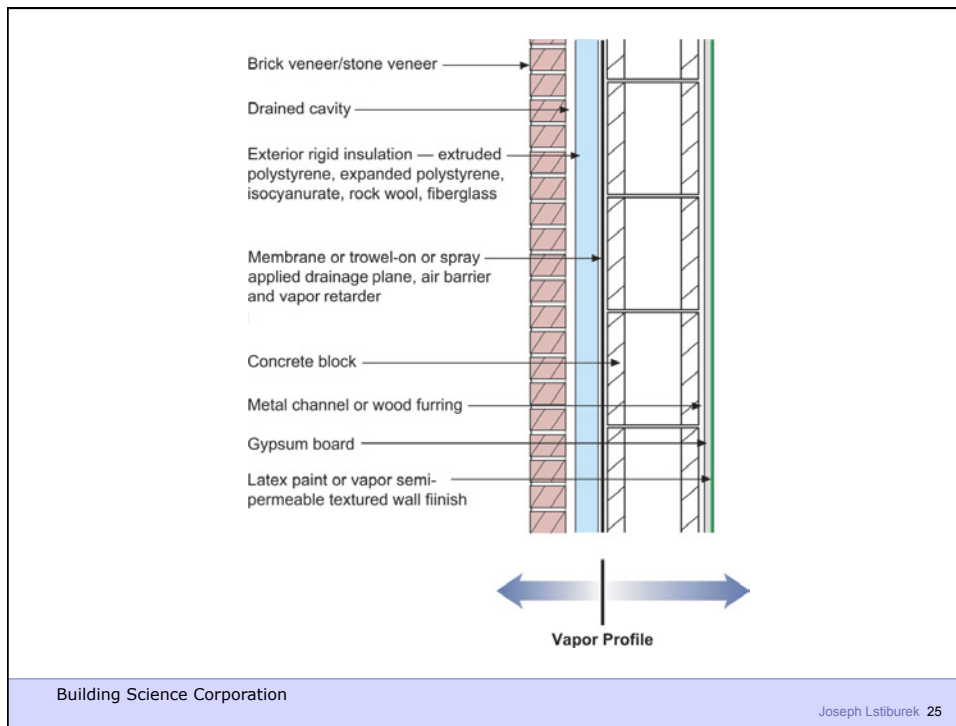


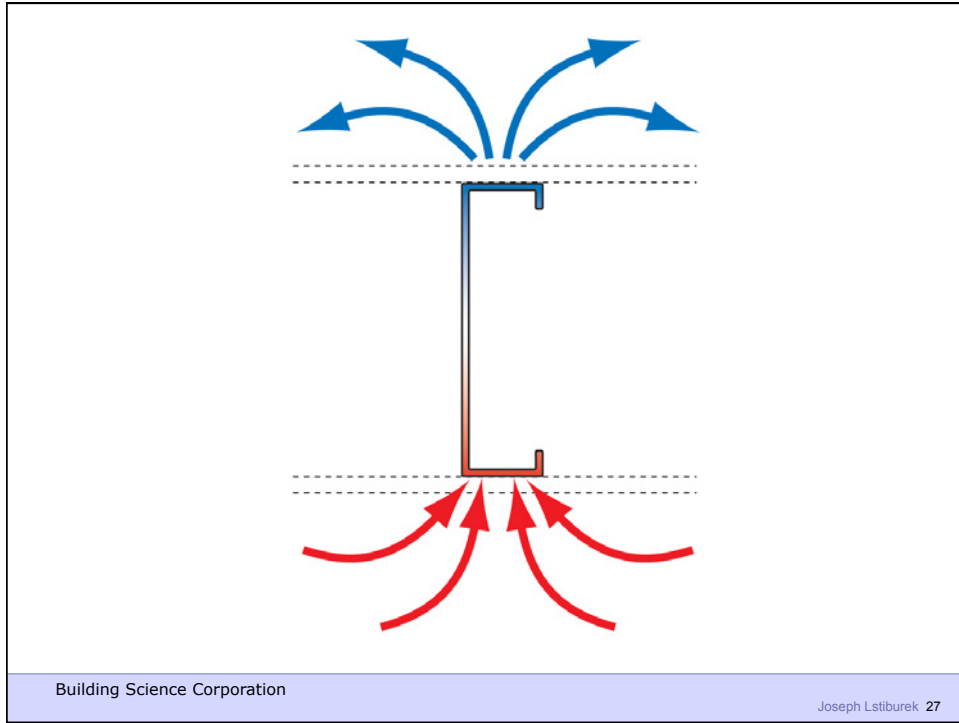


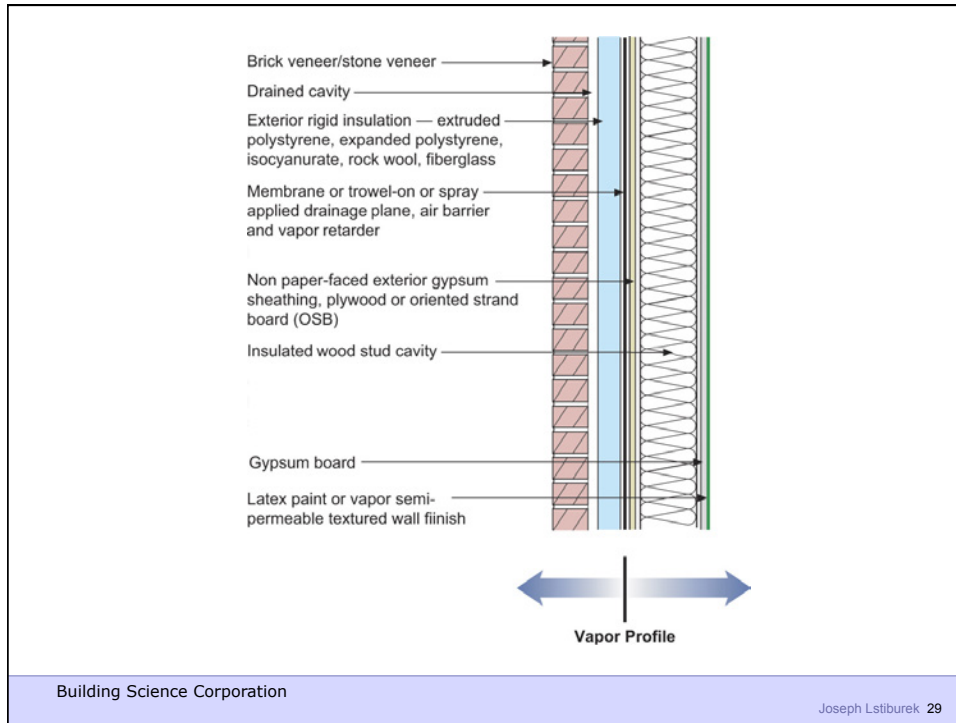




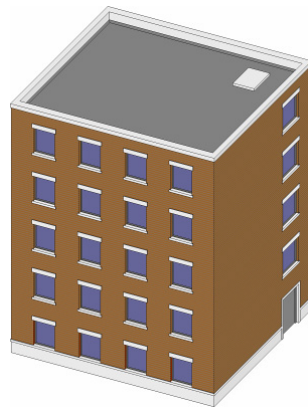




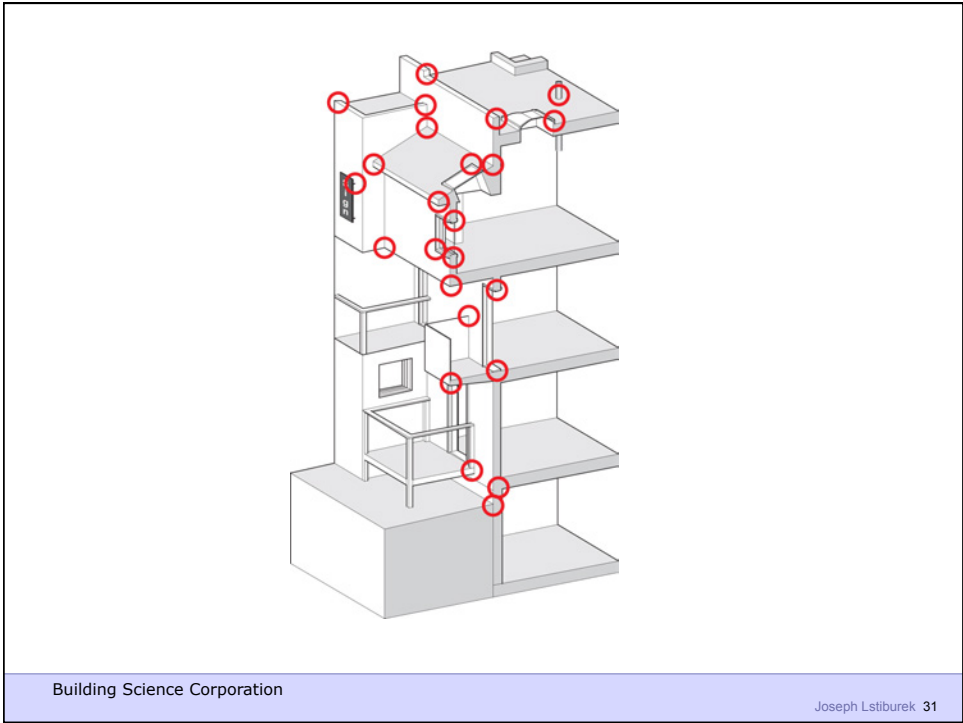




Commercial Enclosure: Simple Layers



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





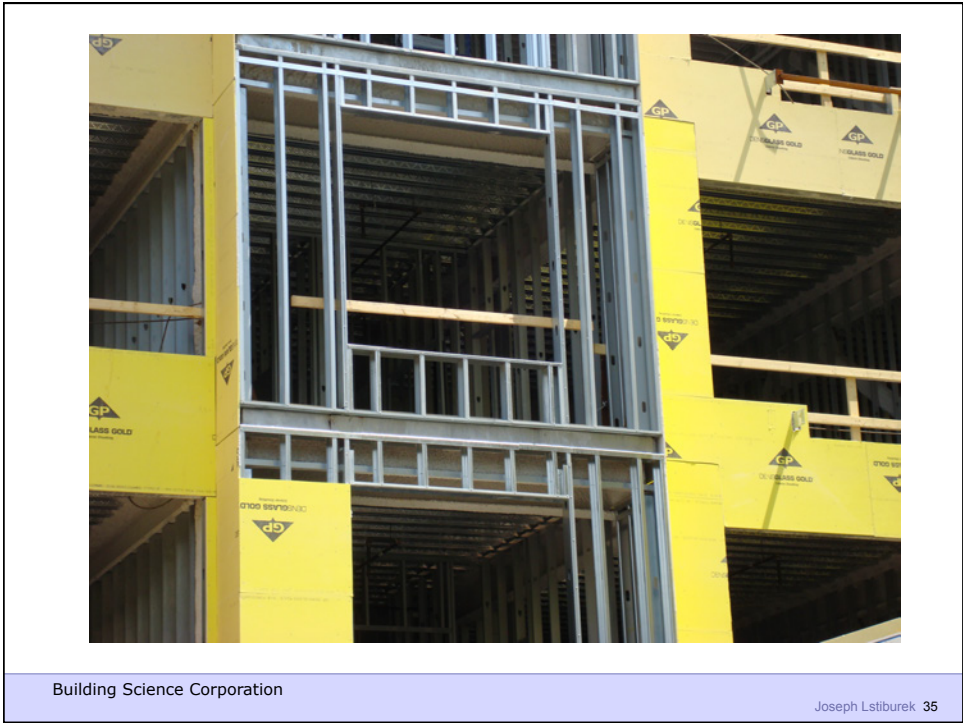
Building Science Corporation

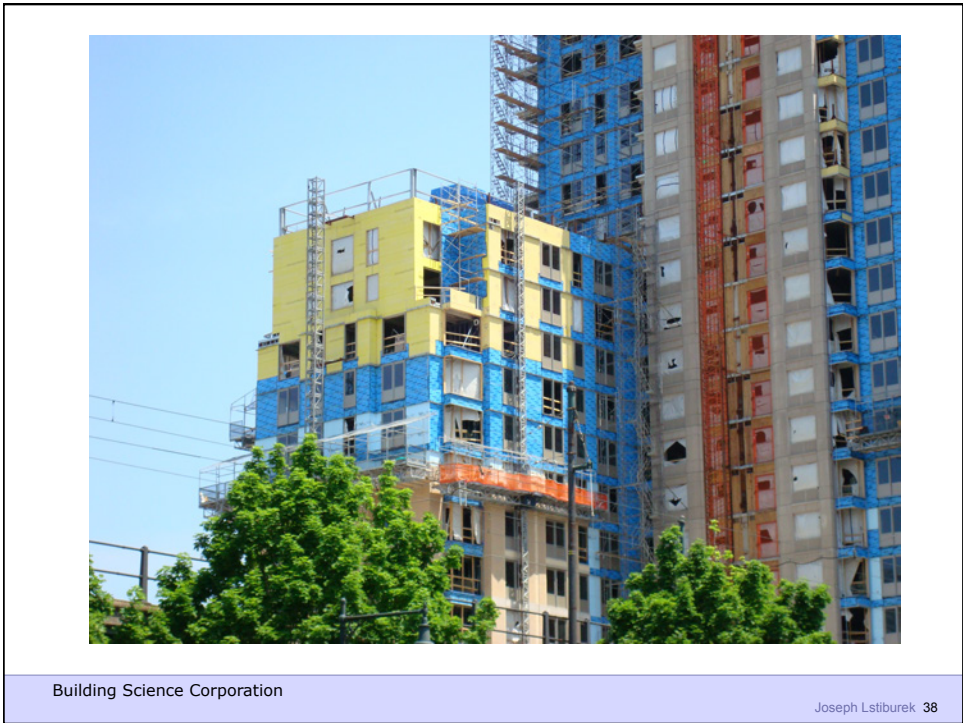
Joseph Lstiburek 33



Building Science Corporation

Joseph Lstiburek 34







Building Science Corporation

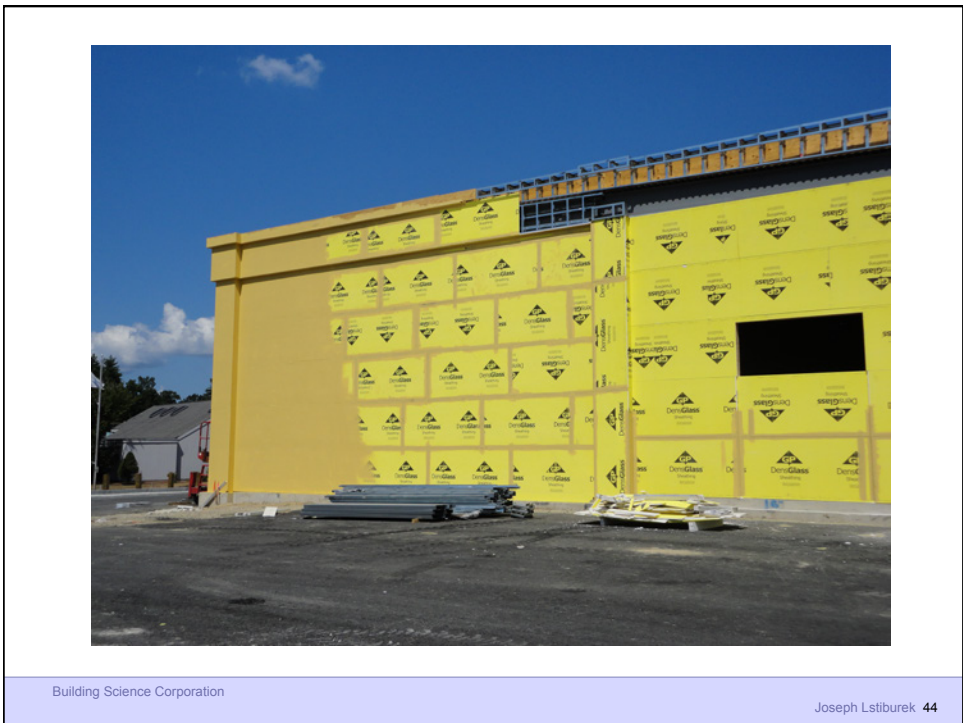
Joseph Lstiburek 39



Building Science

Joseph Lstiburek 40







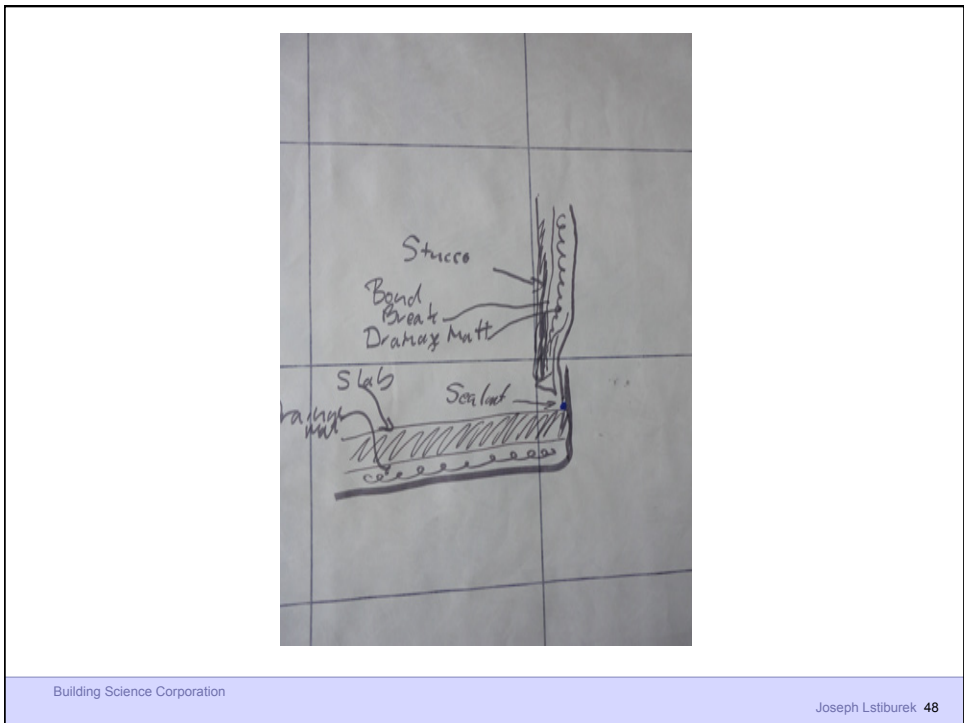
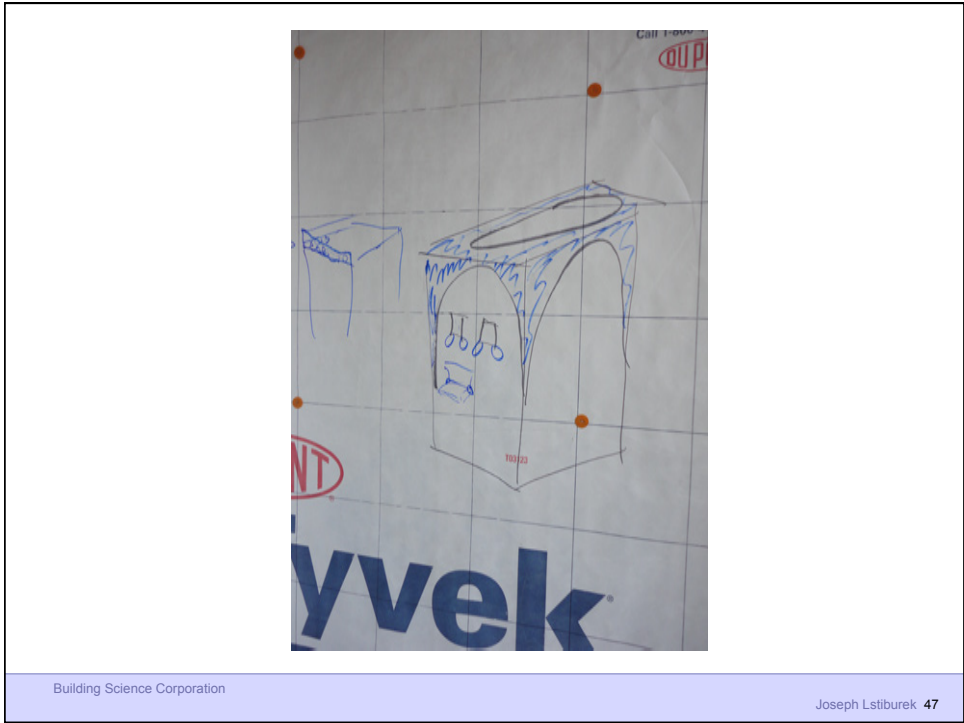
Building Science Corporation

Joseph Lstiburek 45



Building Science Corporation

Joseph Lstiburek 46







Building Science Corporation

Joseph Lstiburek 51



Building Science Corporation

Joseph Lstiburek 52







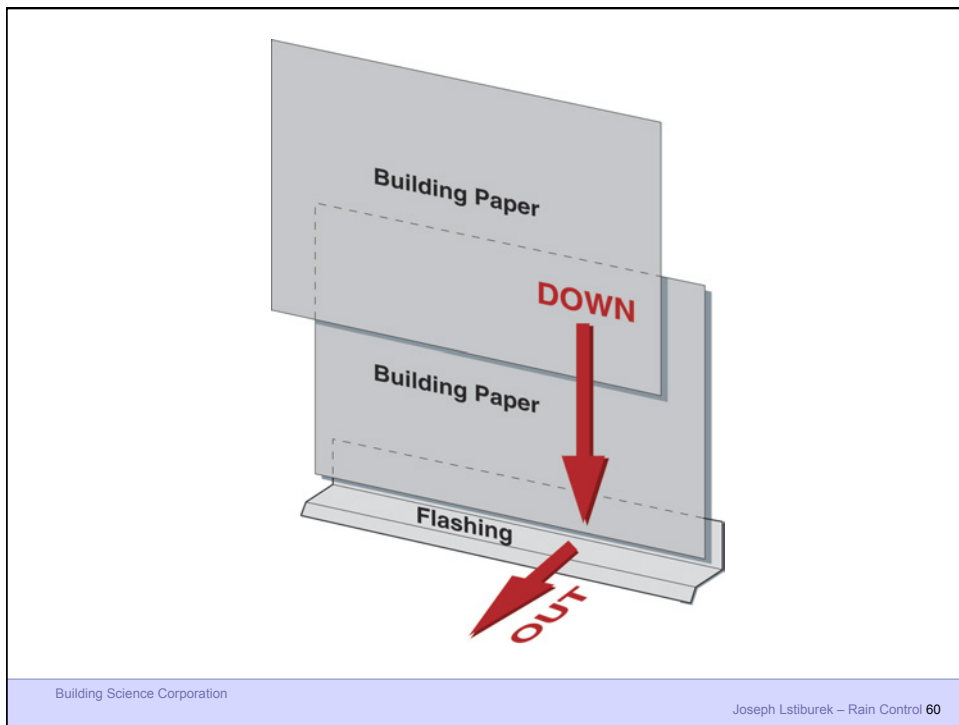
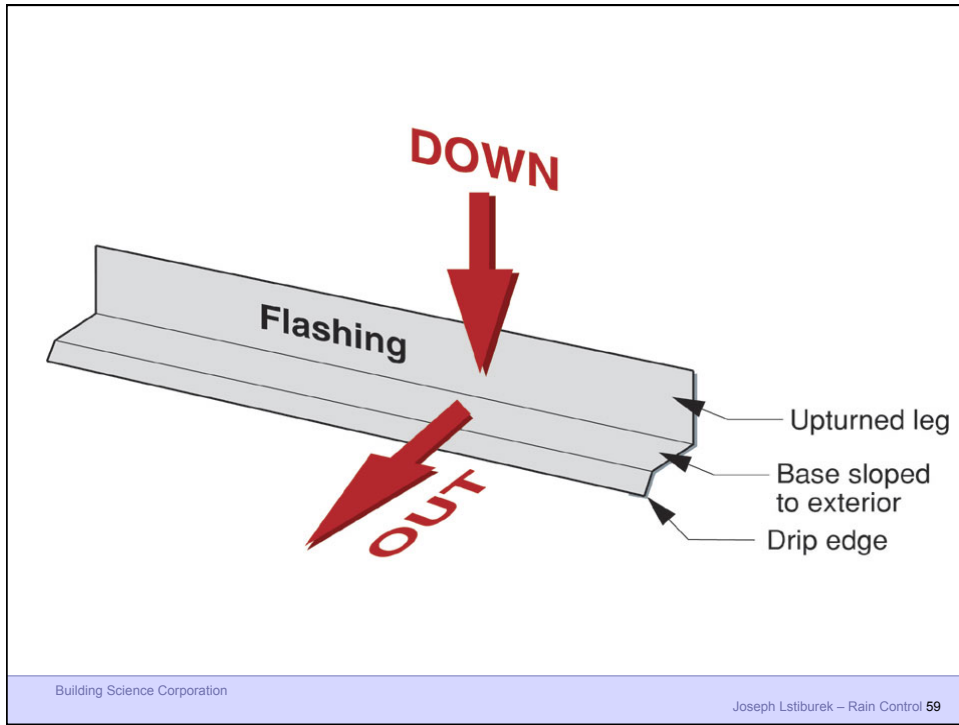
Building Science 2009

Joseph Lstiburek – HVAC 57

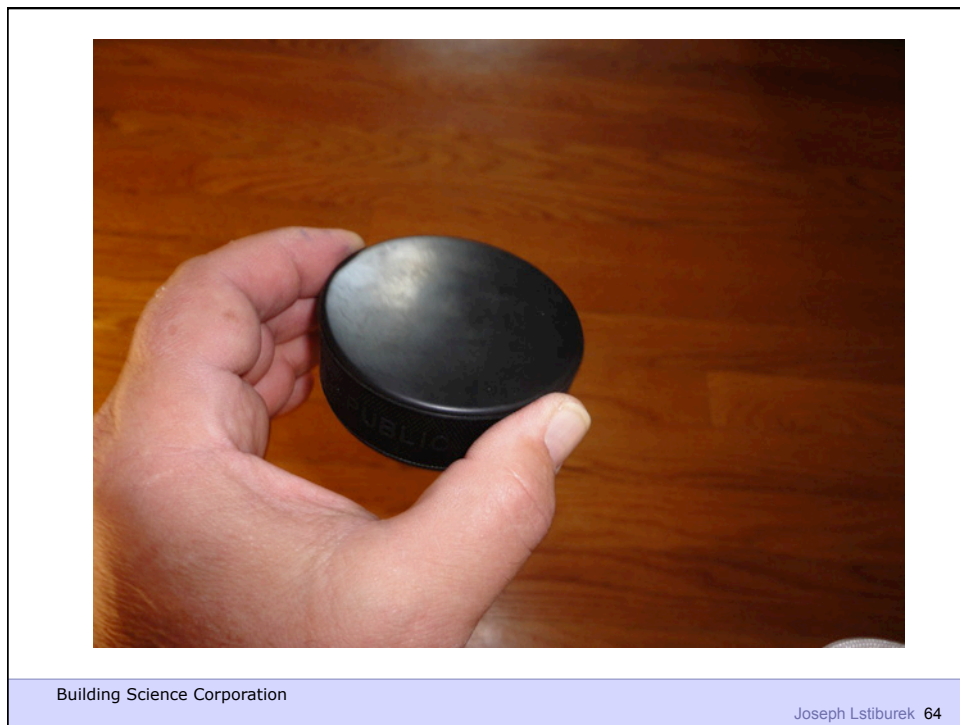
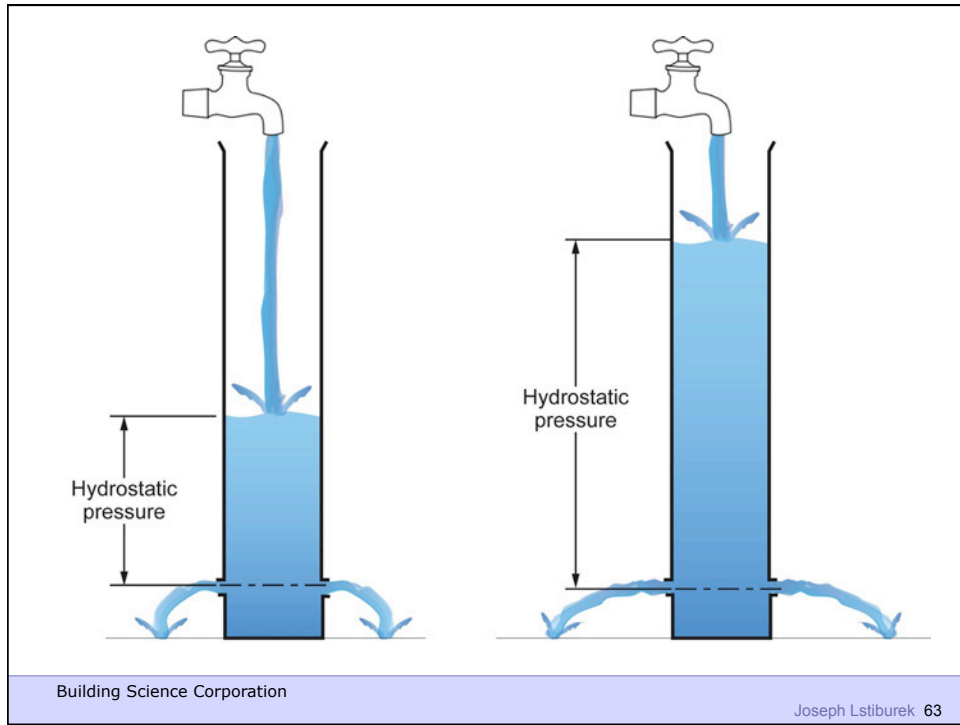


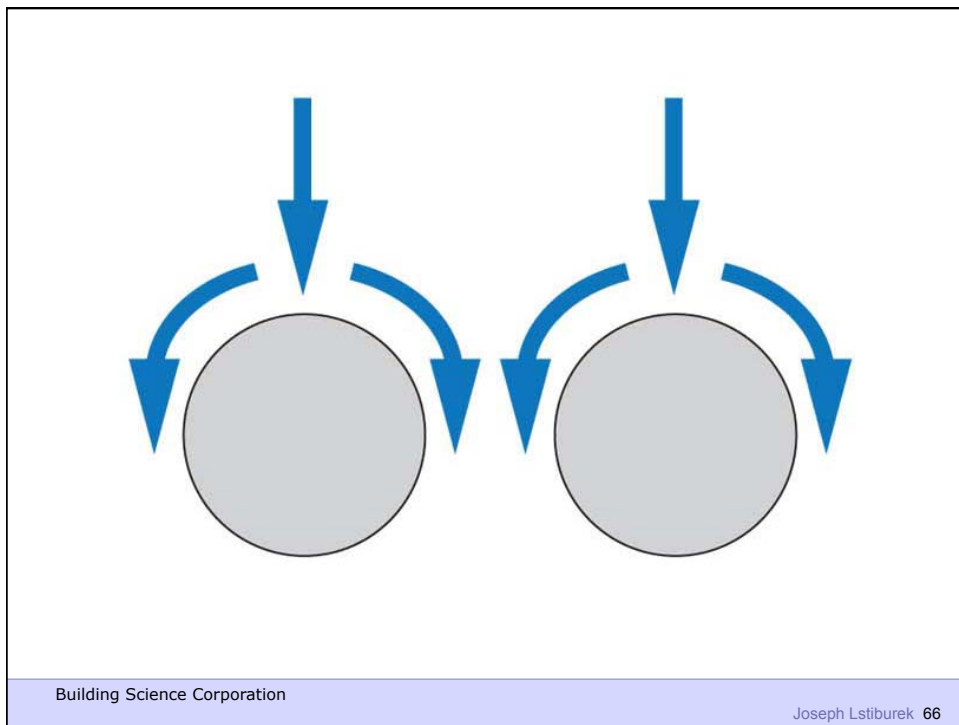
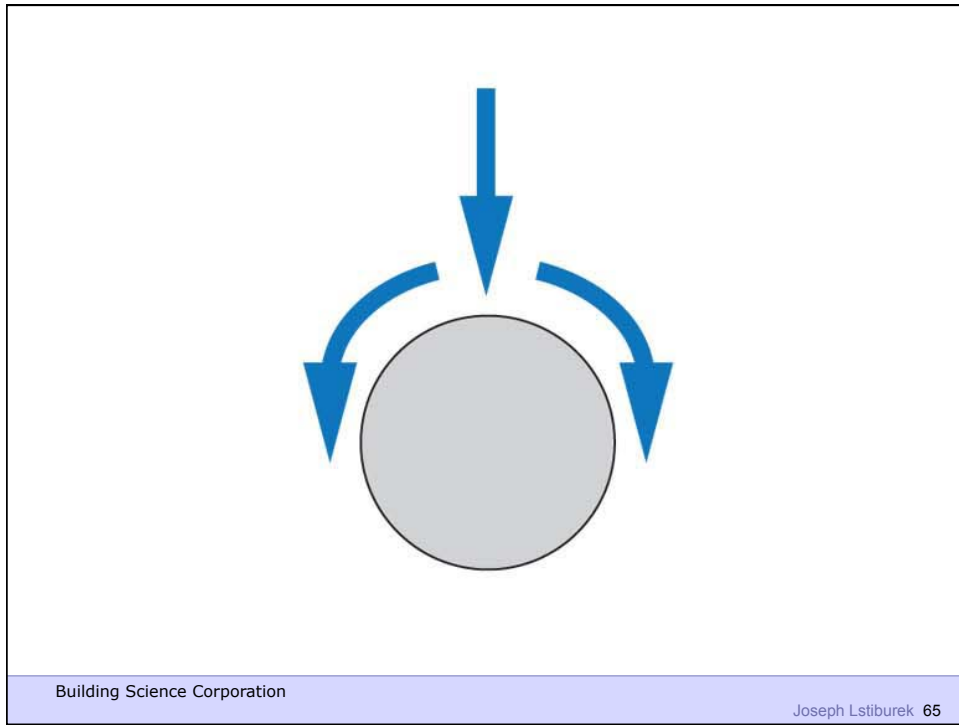
Building Science Corporation

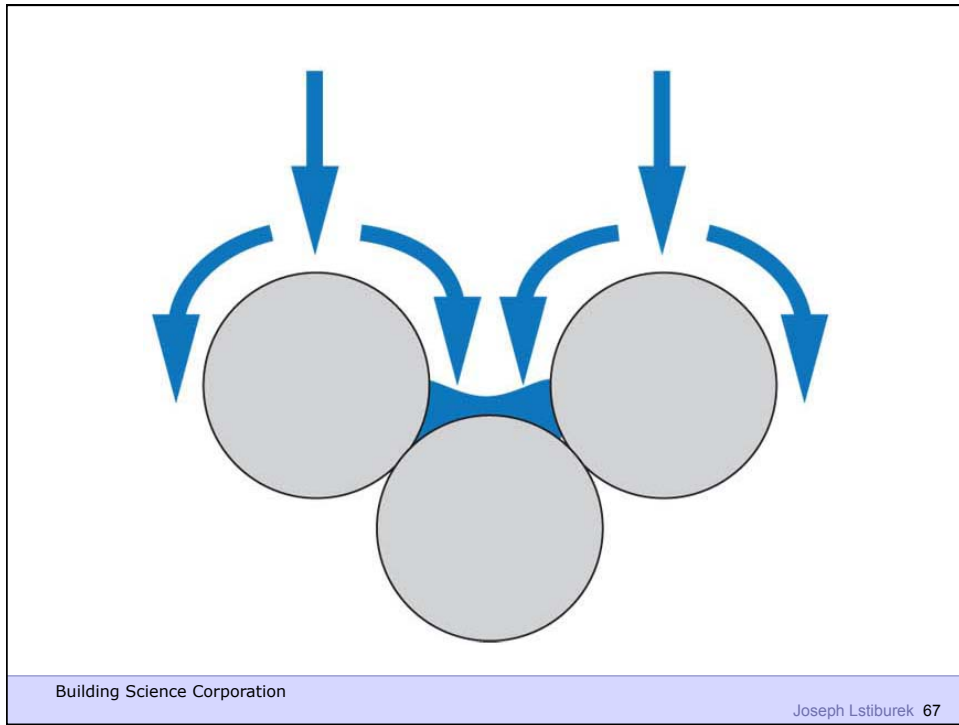
Joseph Lstiburek 58

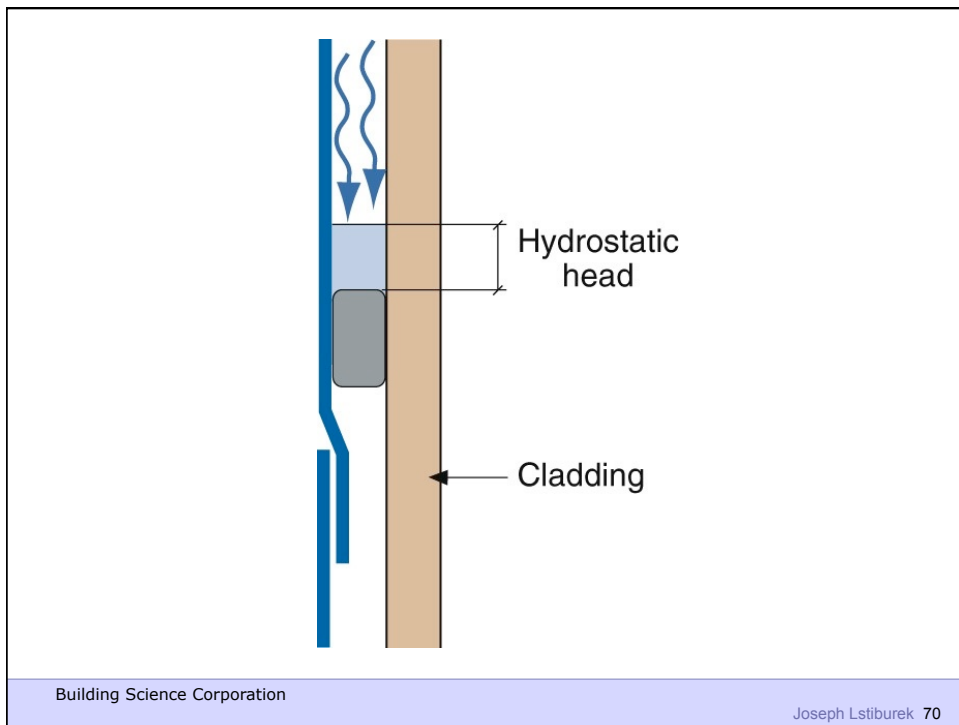
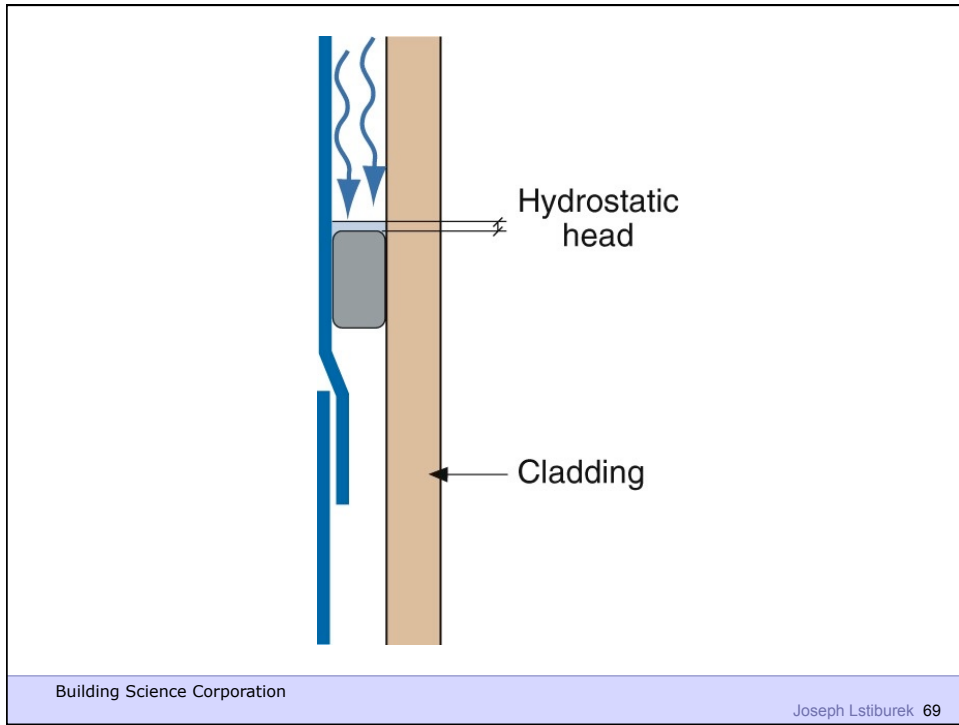


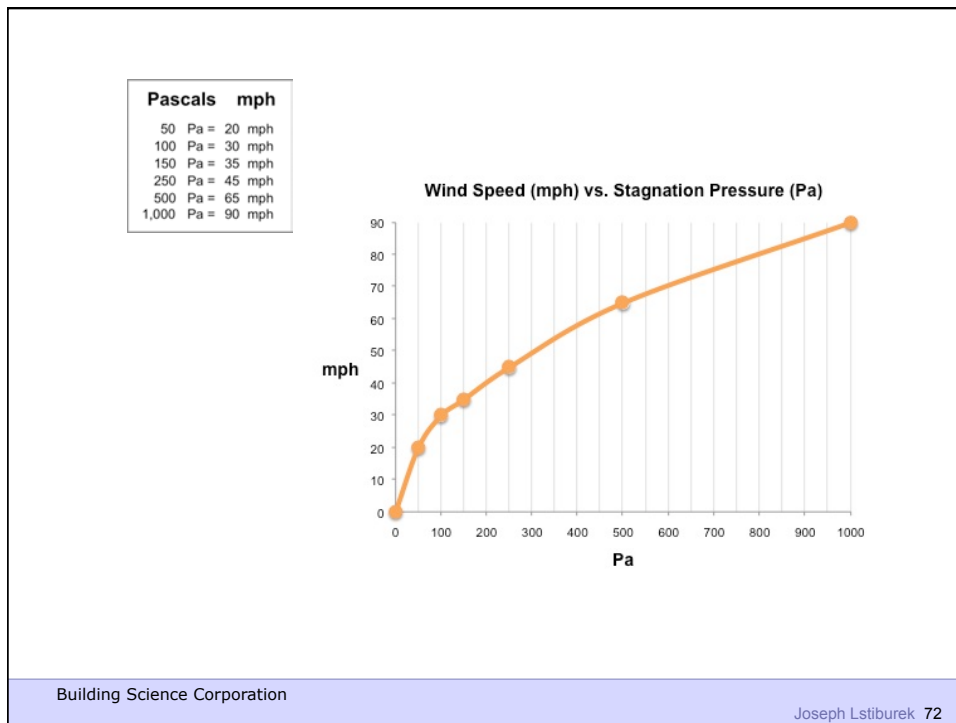
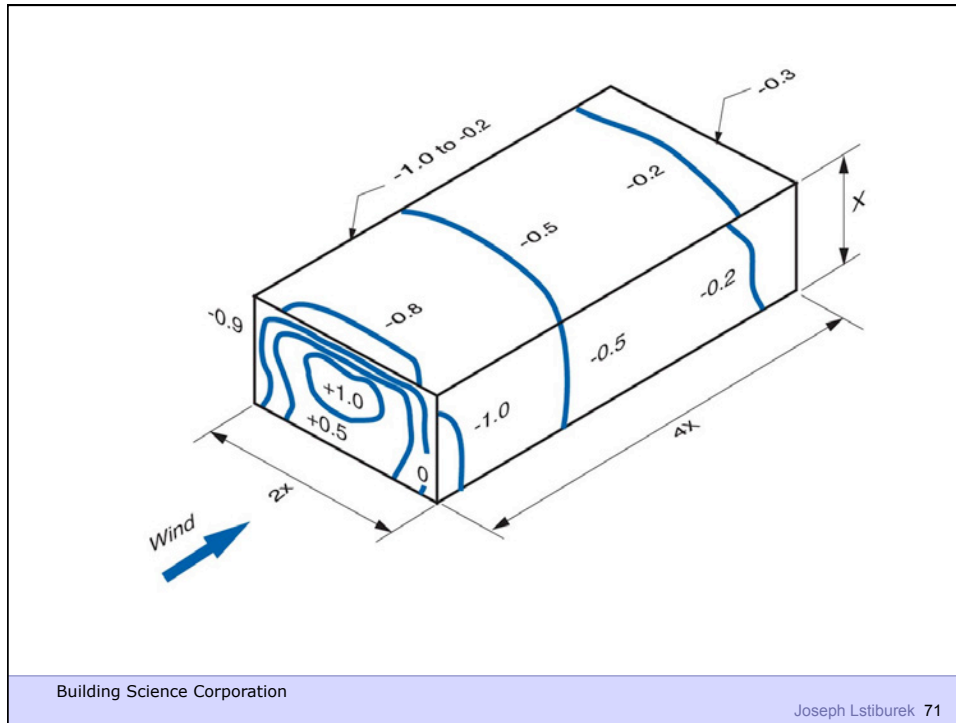














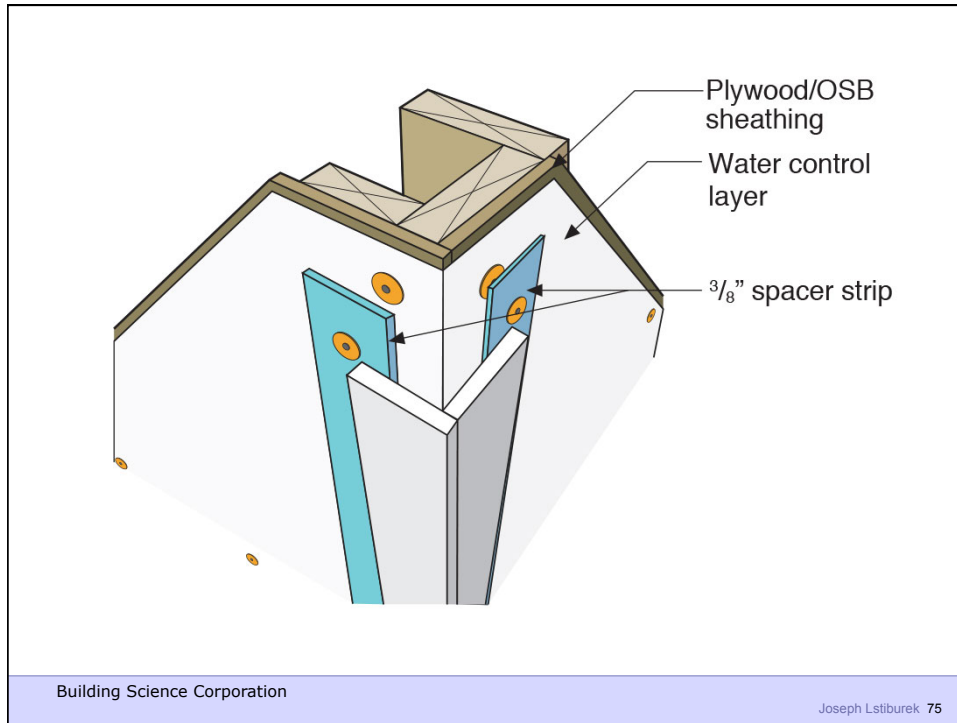
Building Science Corporation

Joseph Lstiburek 73



Building Science Corporation

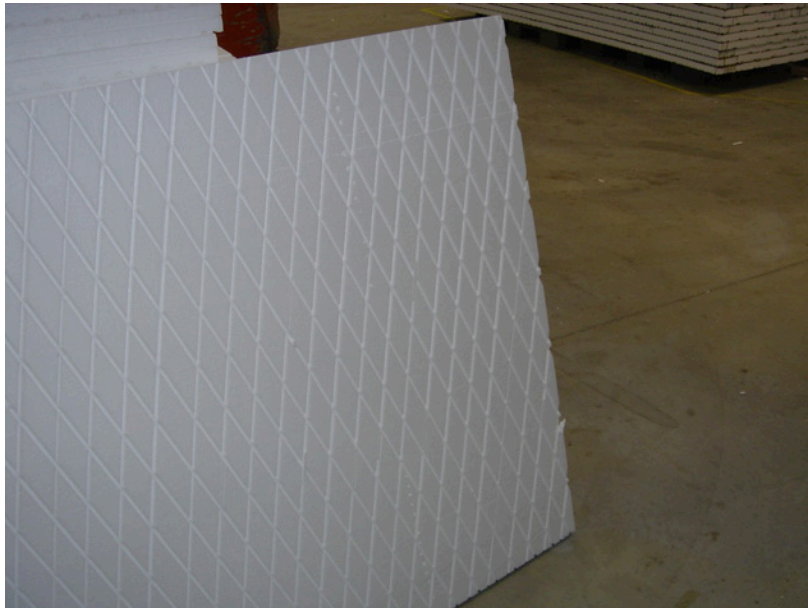
Joseph Lstiburek – Rain Control 74





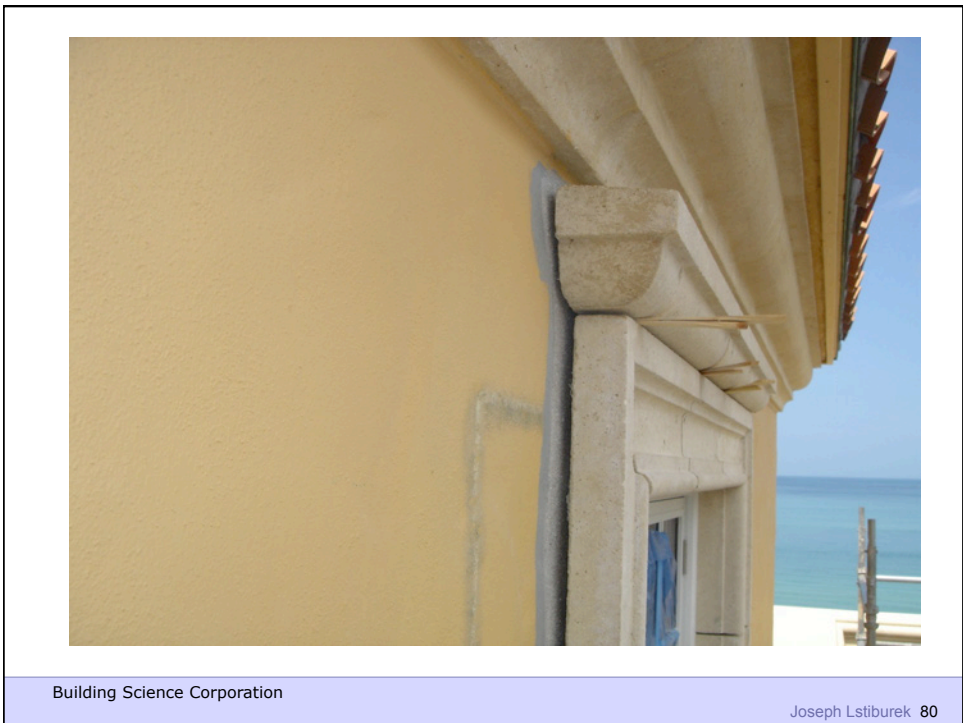
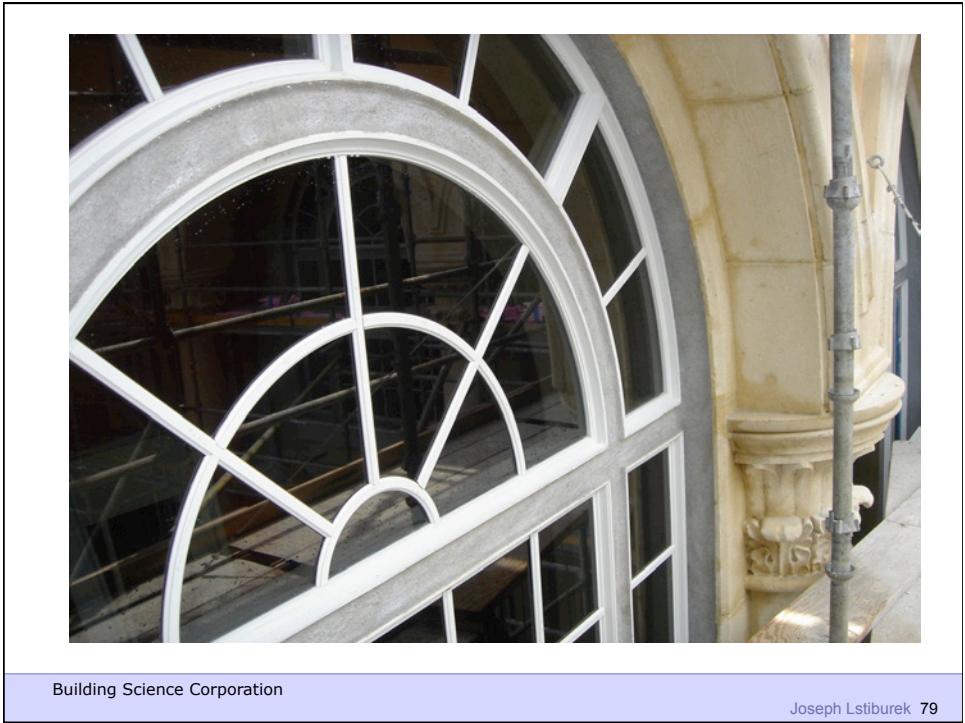
Building Science Corporation

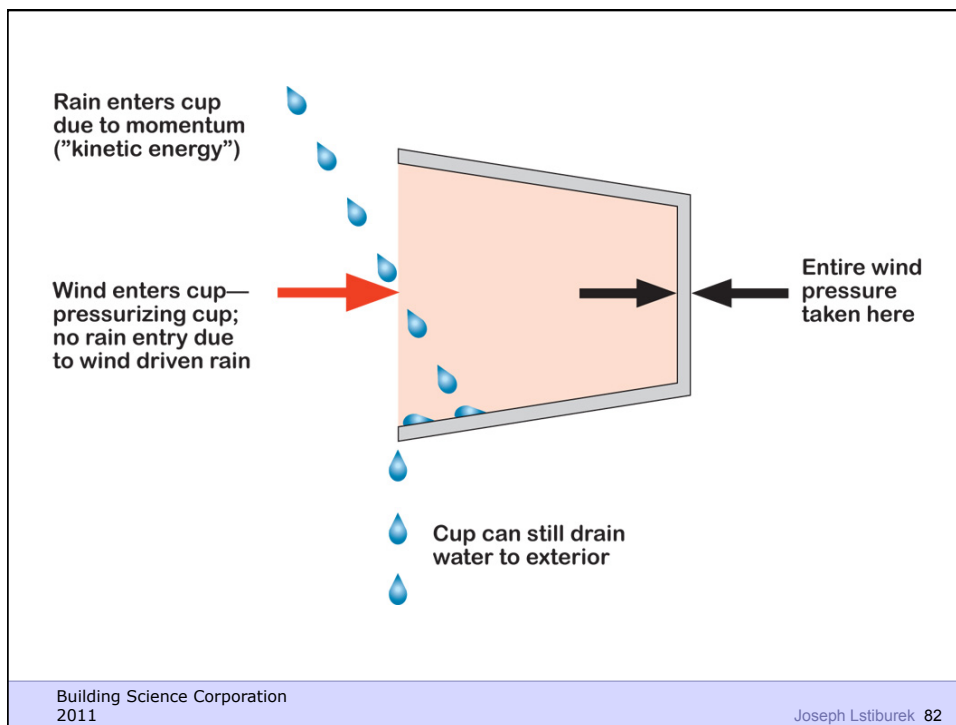
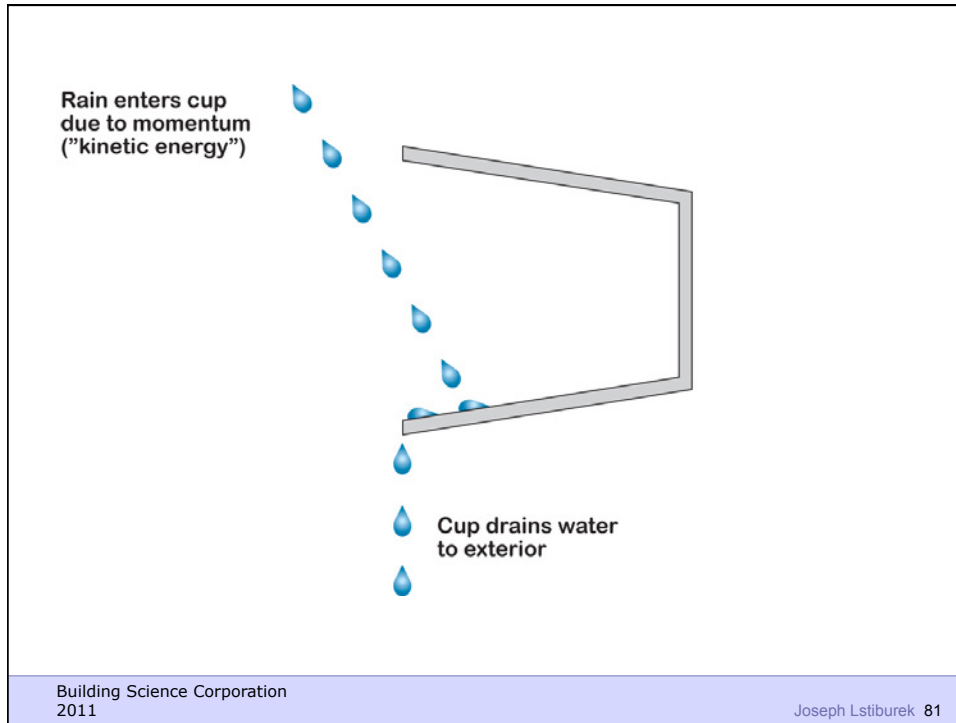
Joseph Lstiburek 77

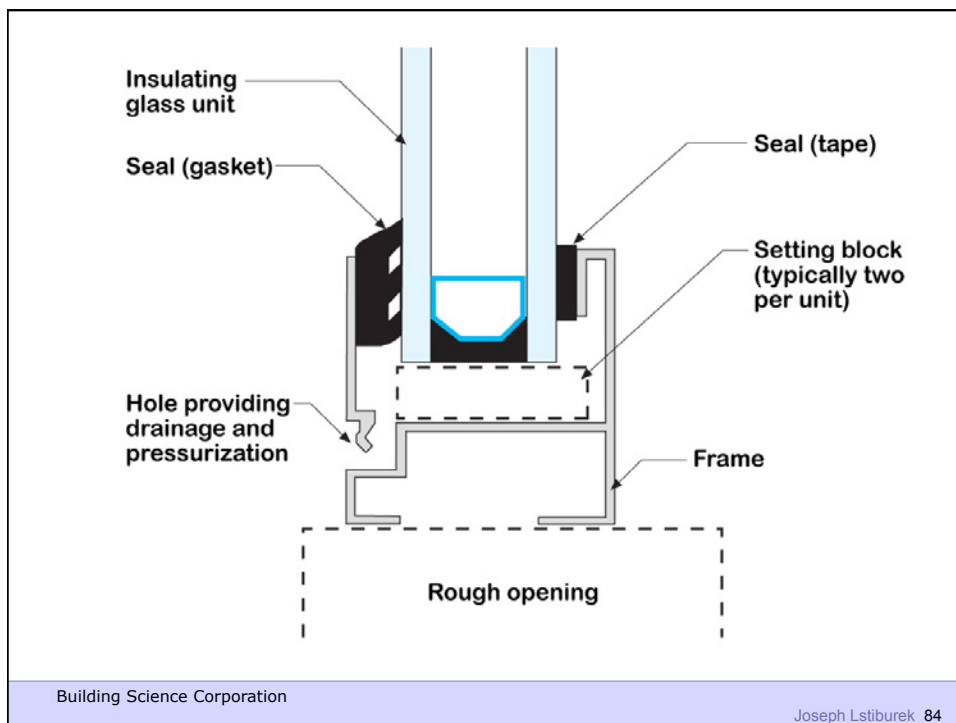
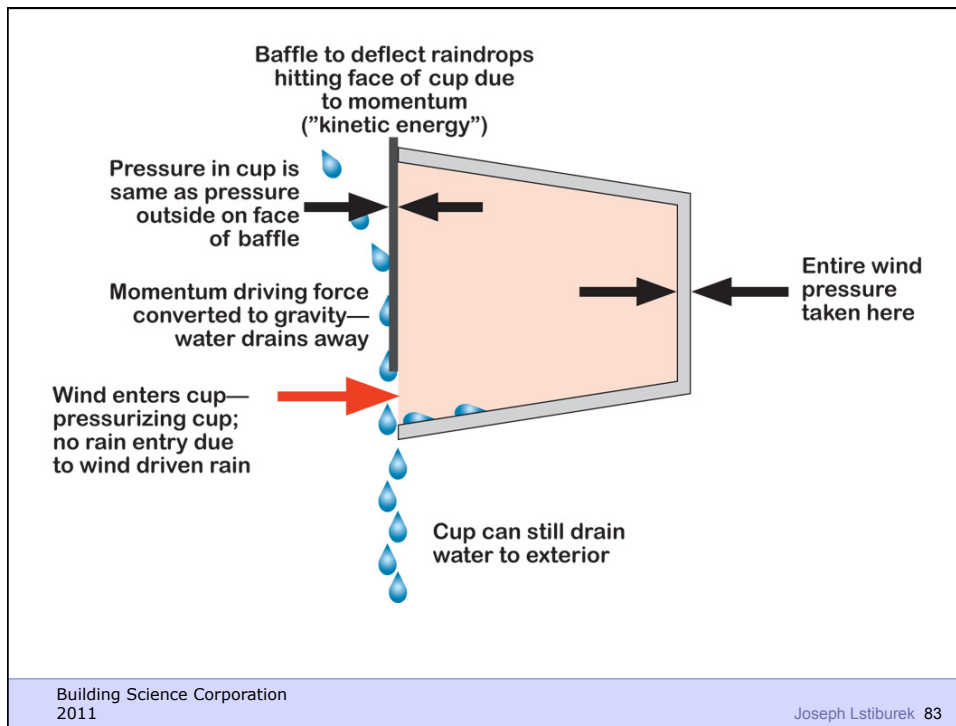


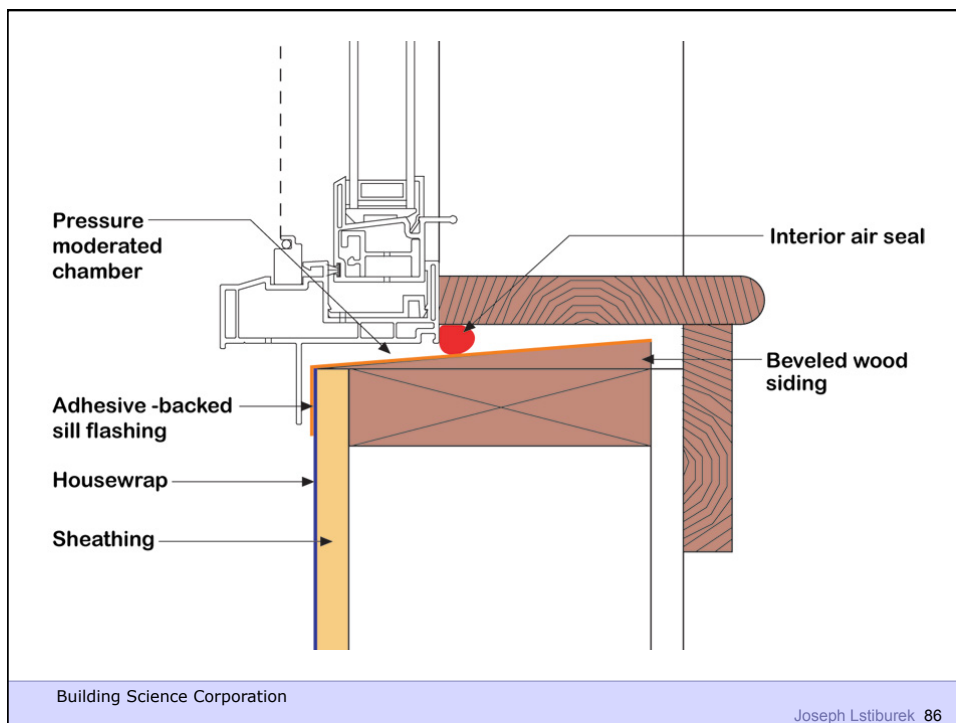
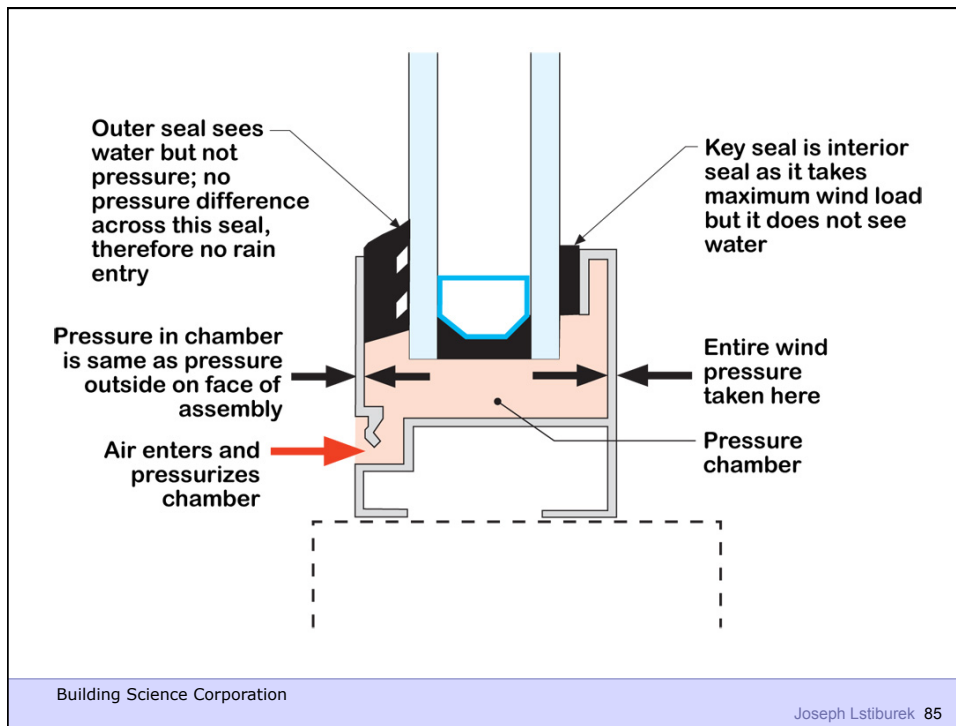
Building Science Corporation

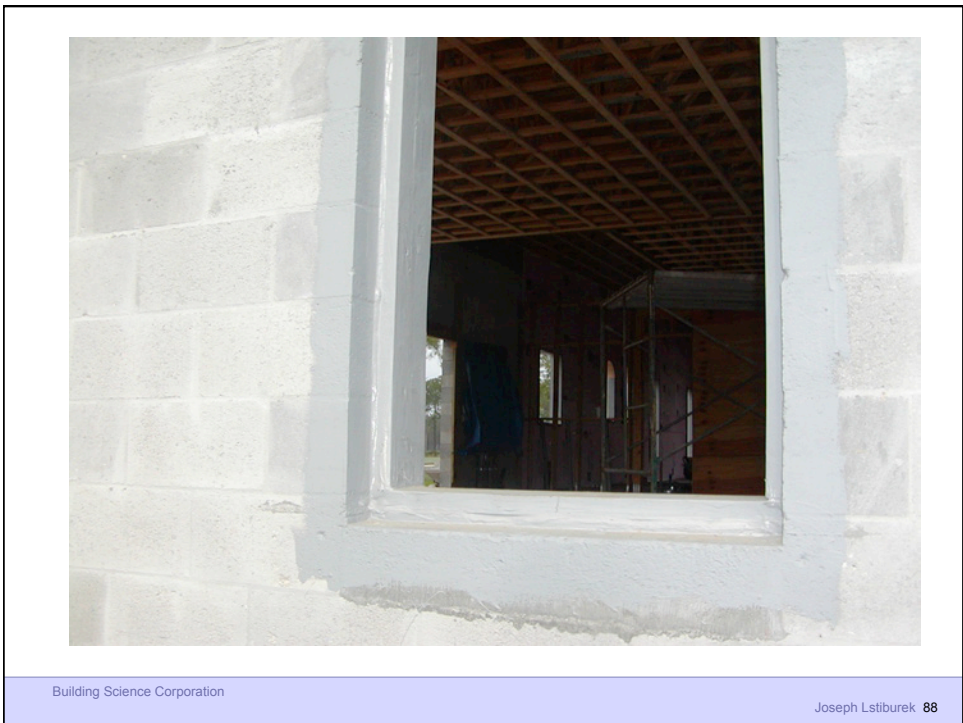
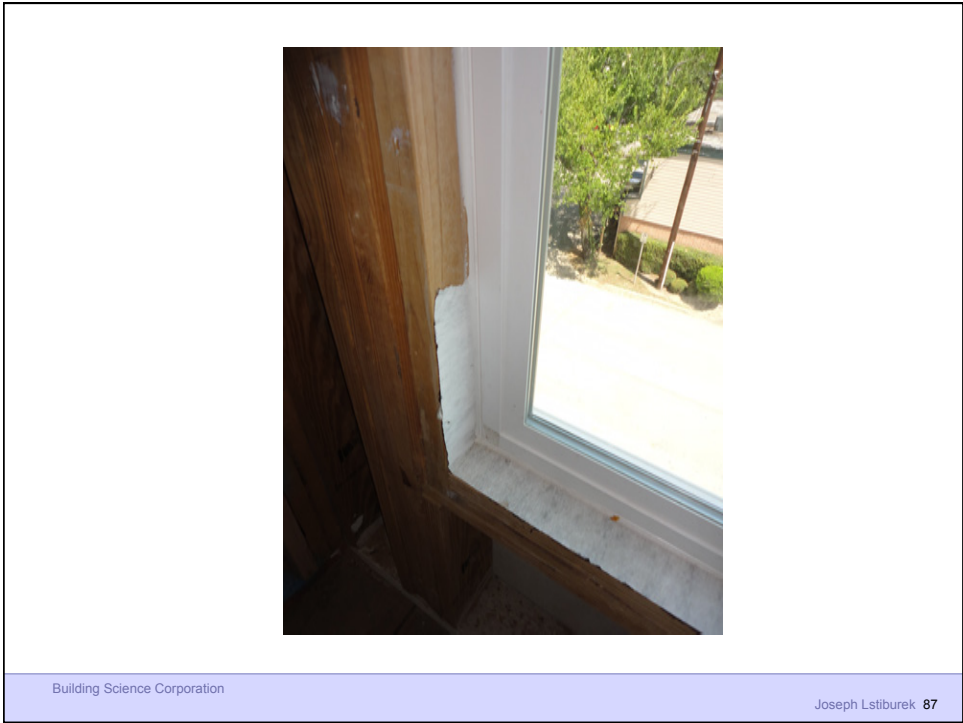
Joseph Lstiburek 78

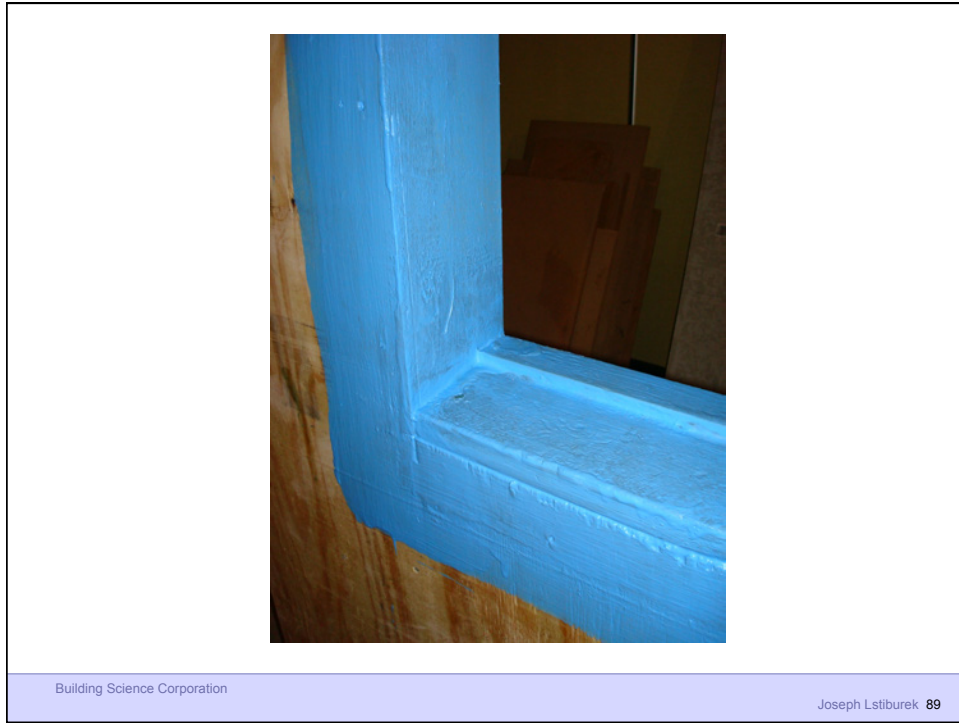


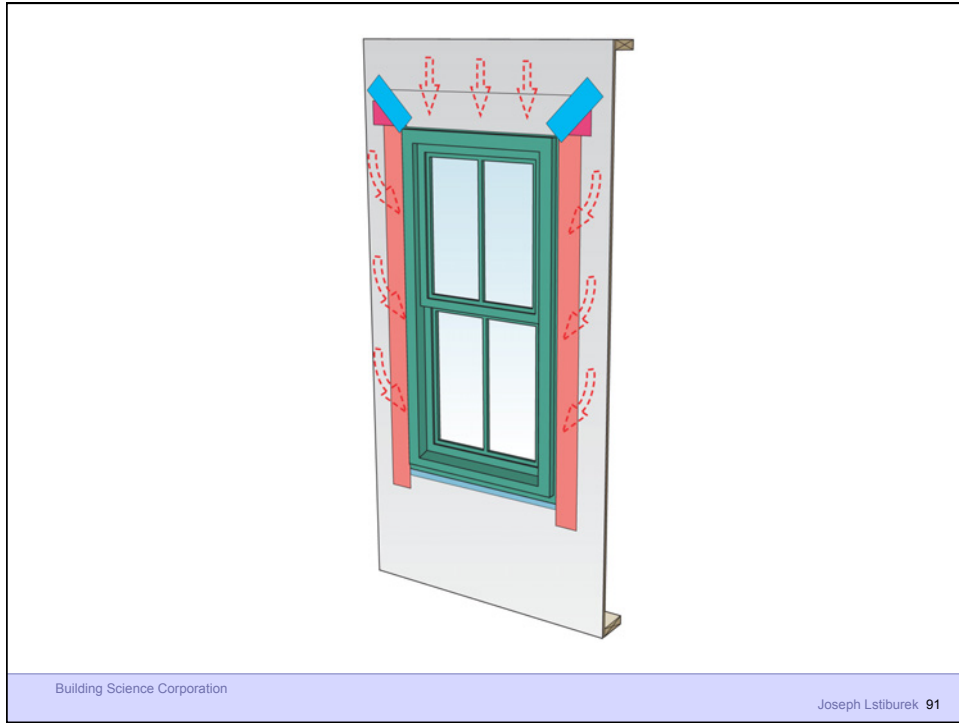


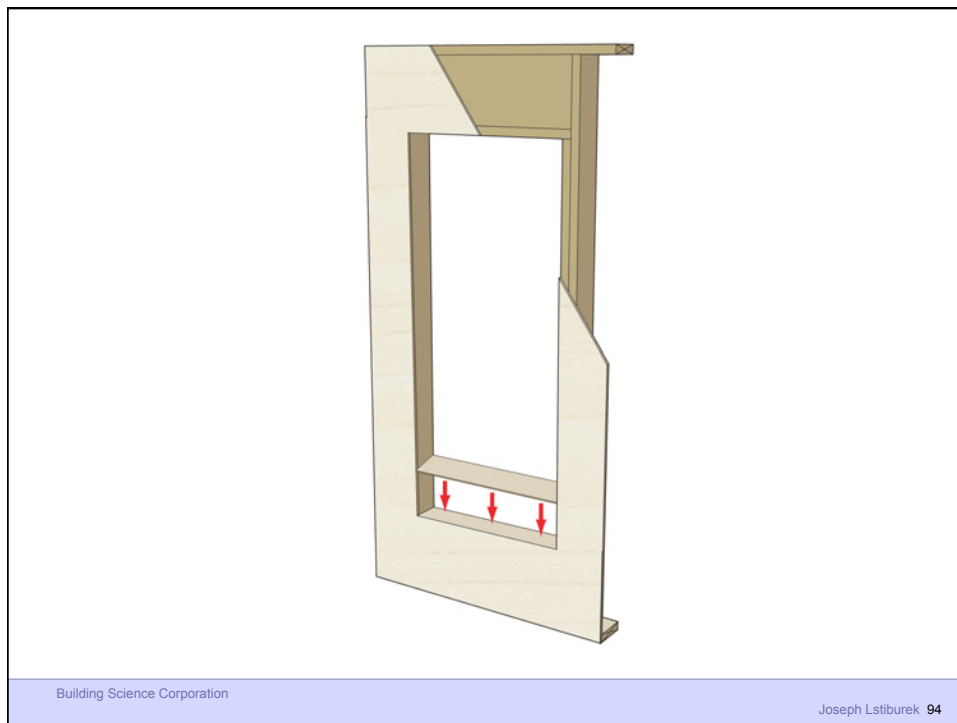
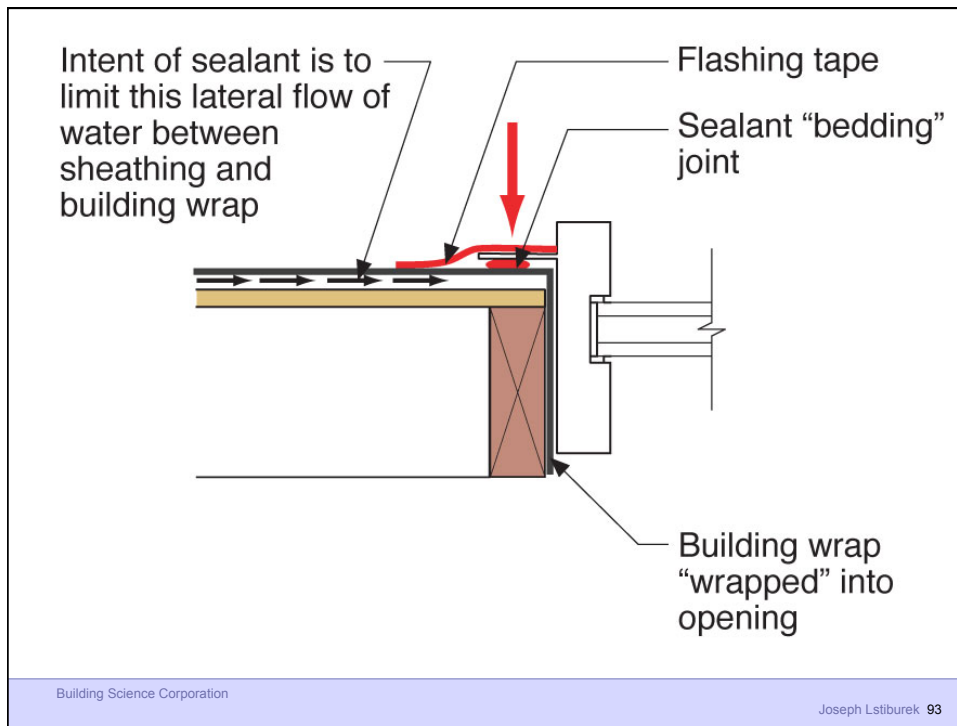


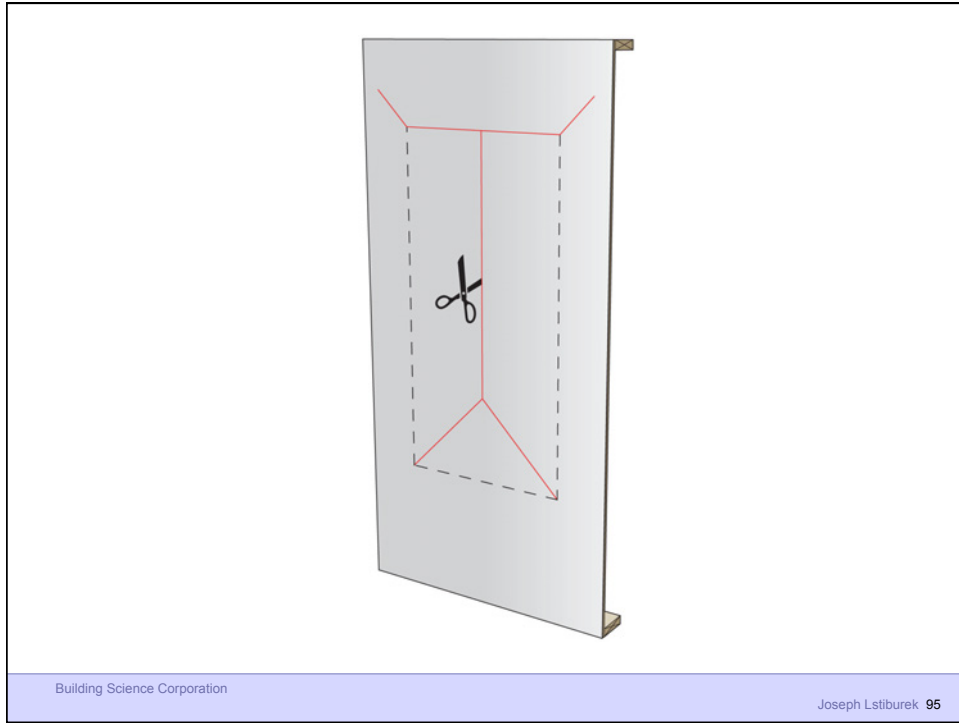


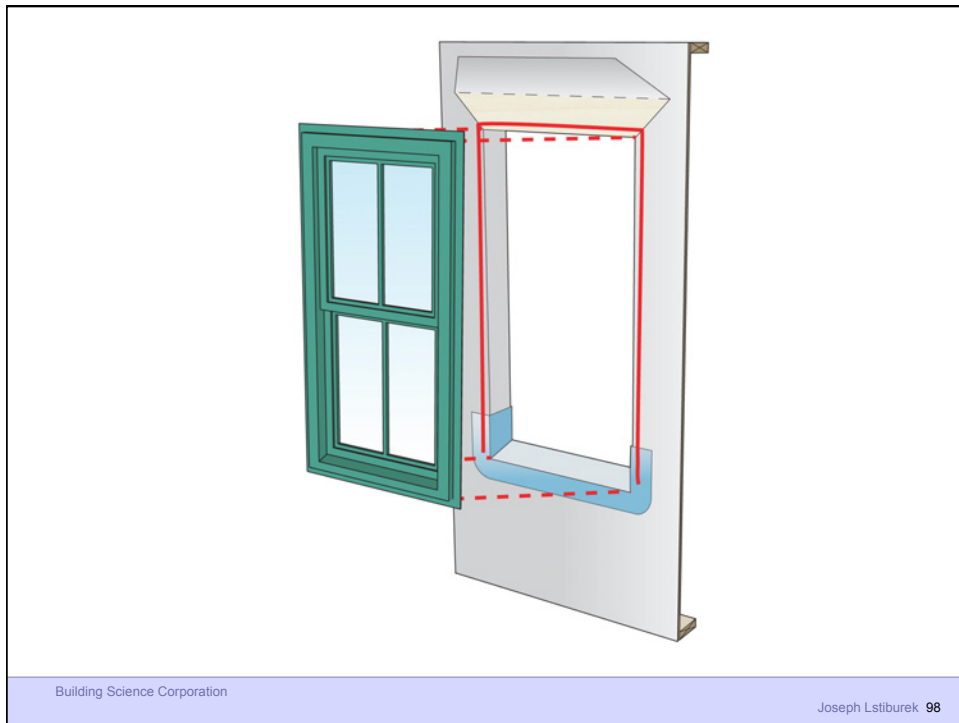
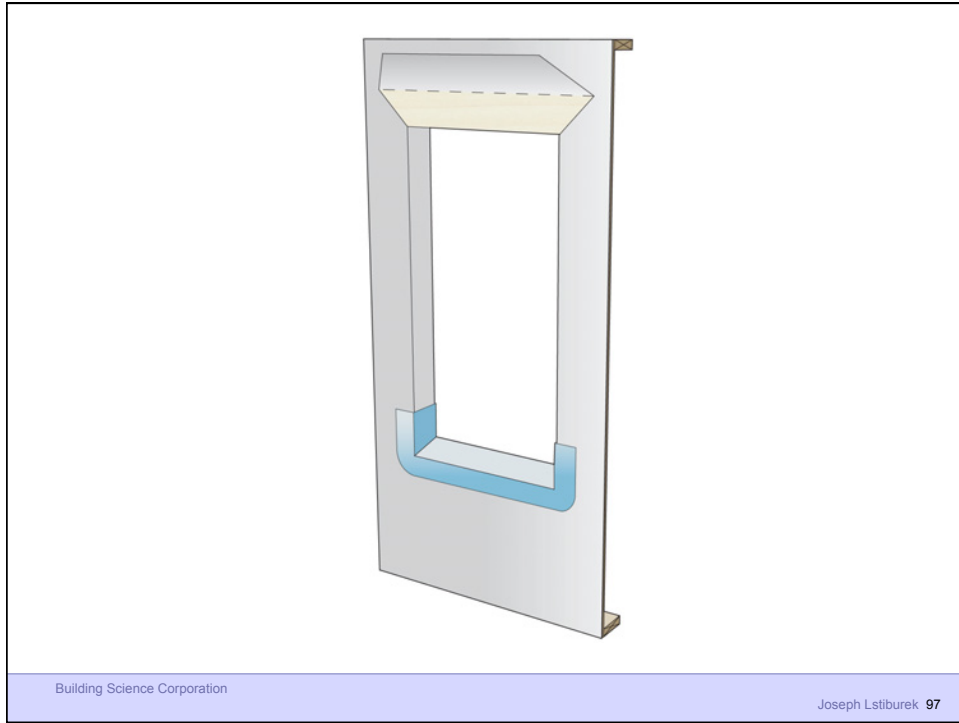


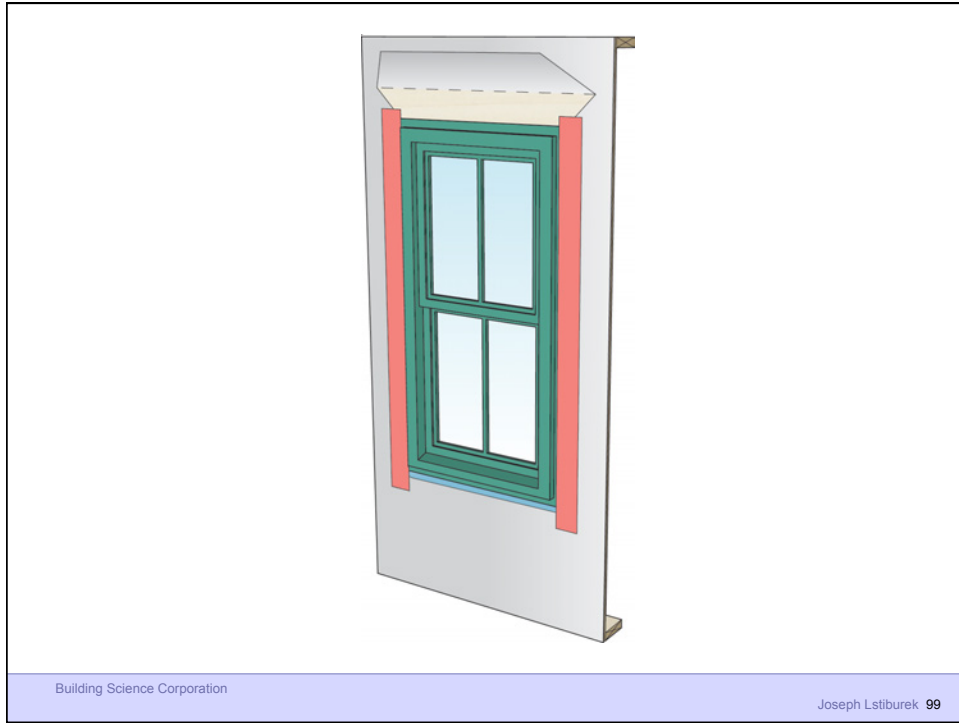


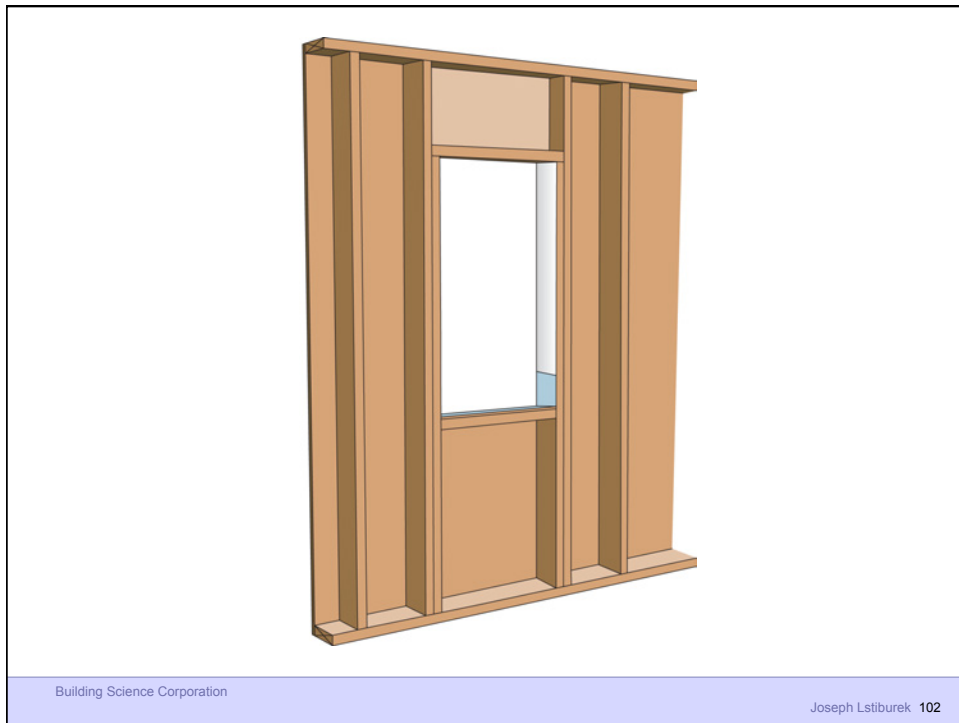
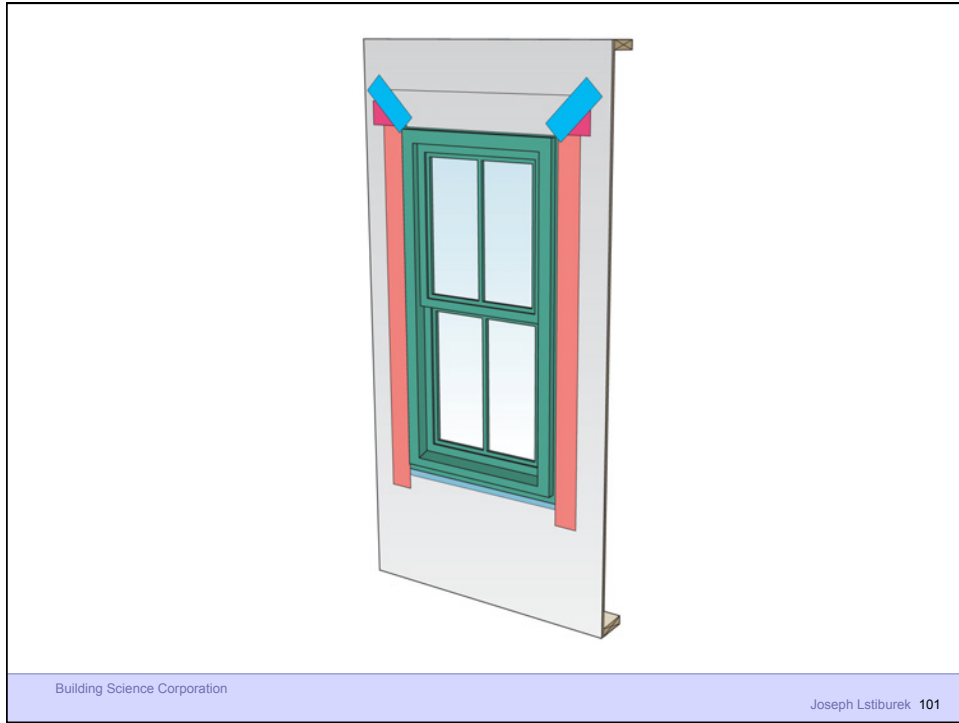


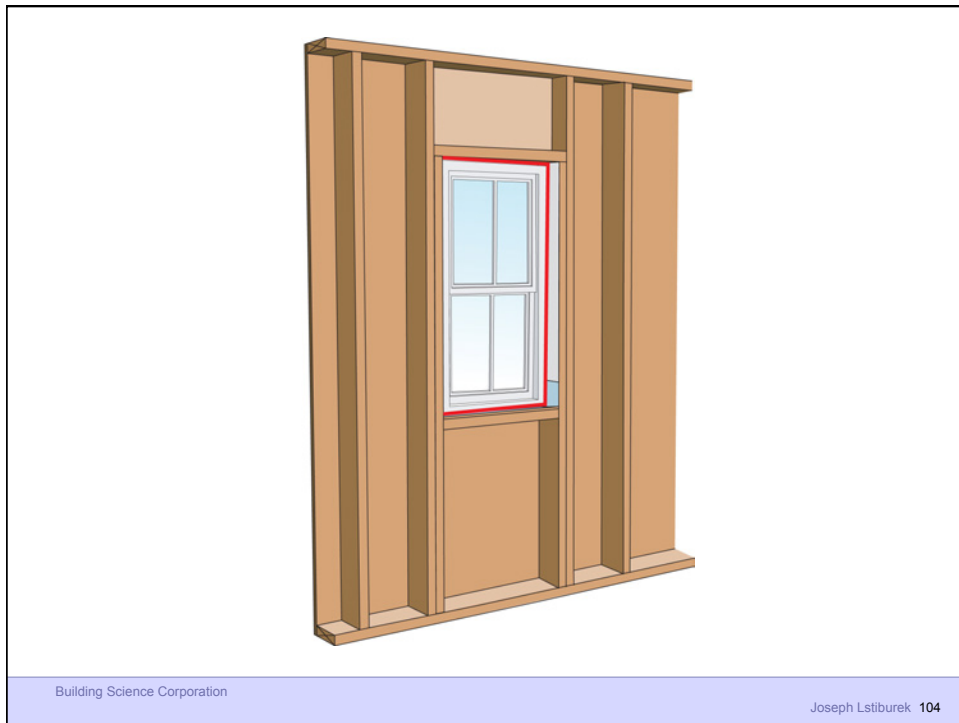
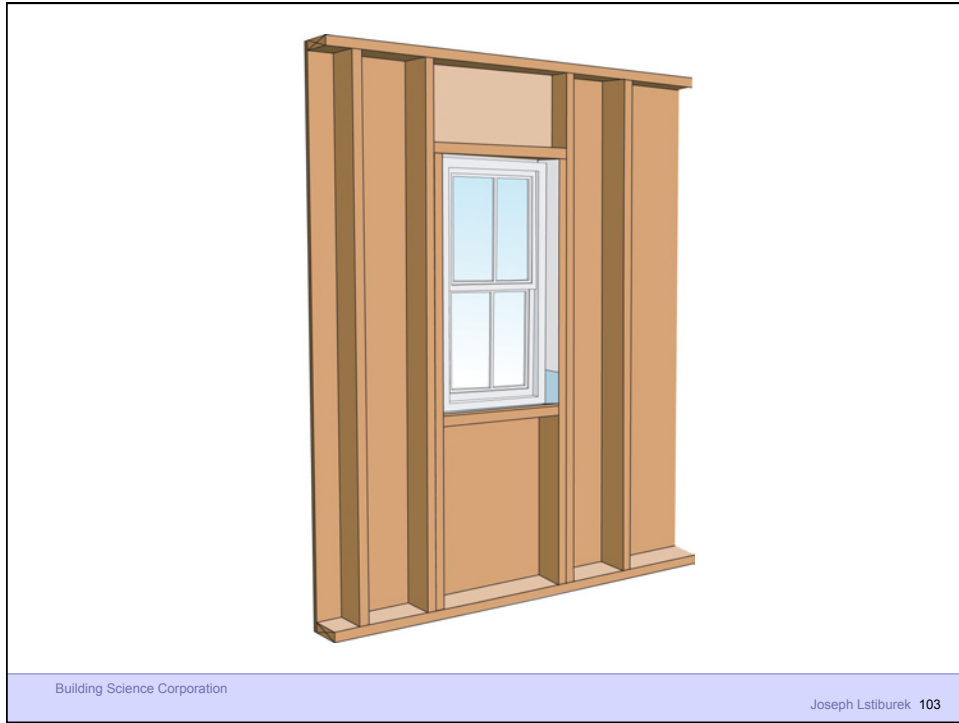


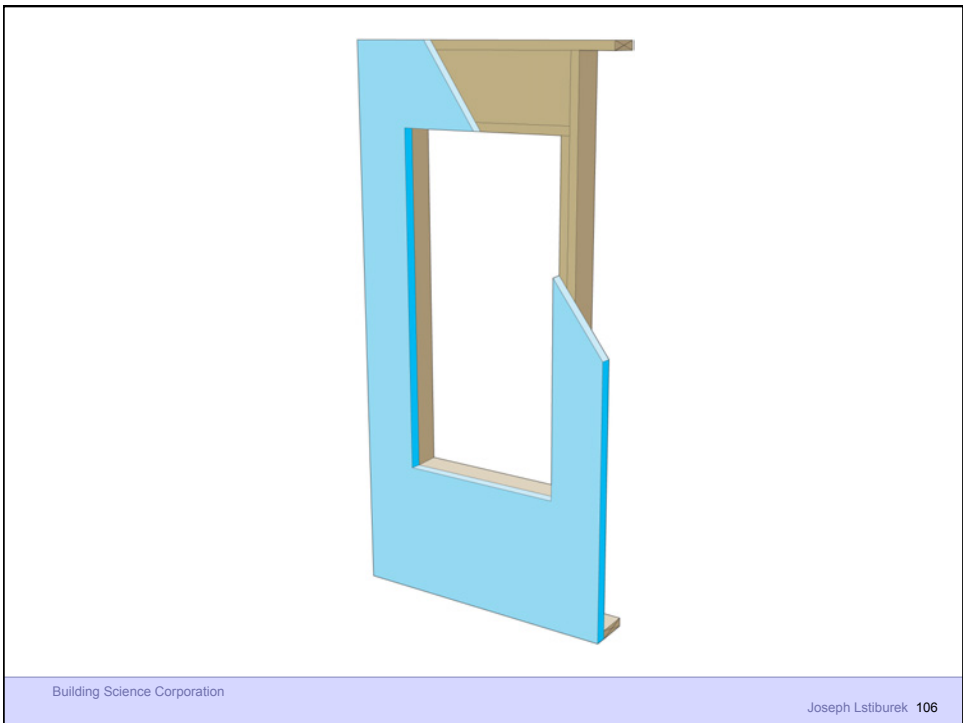


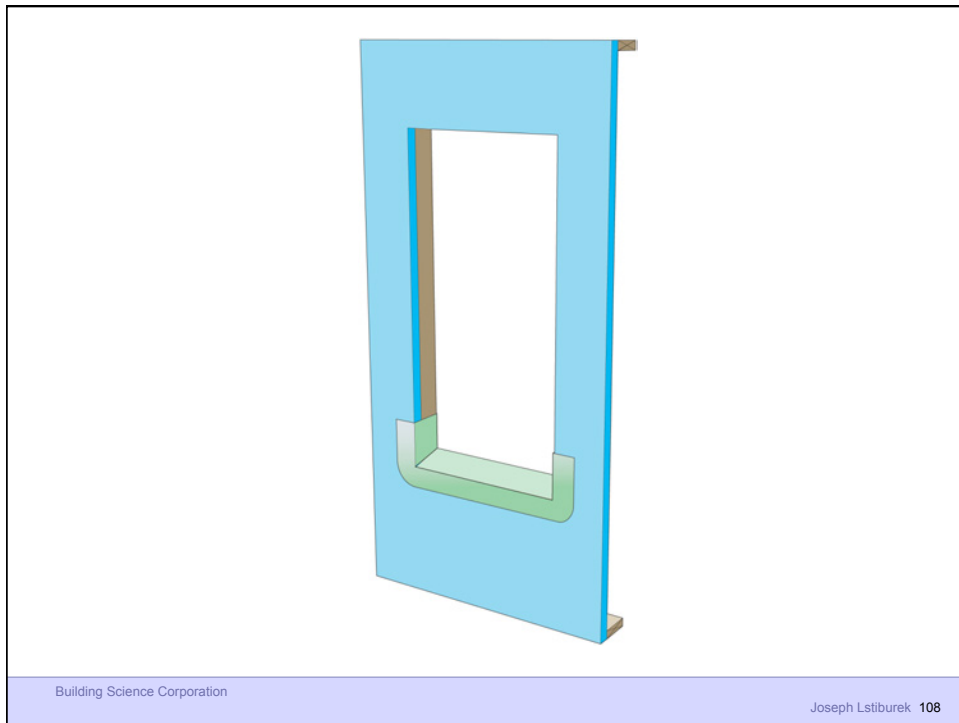
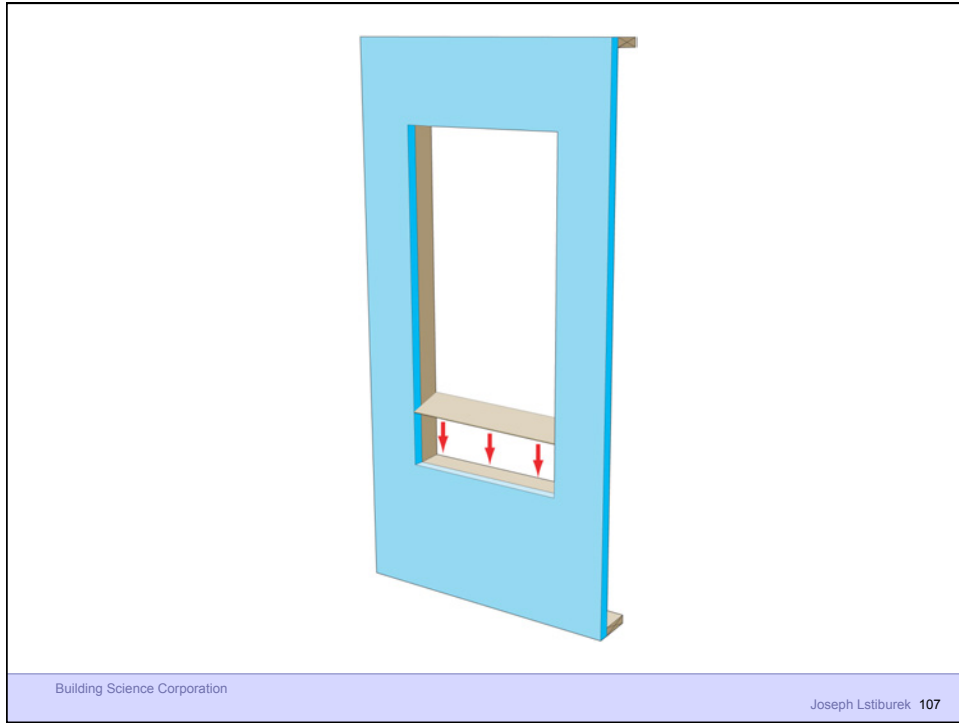


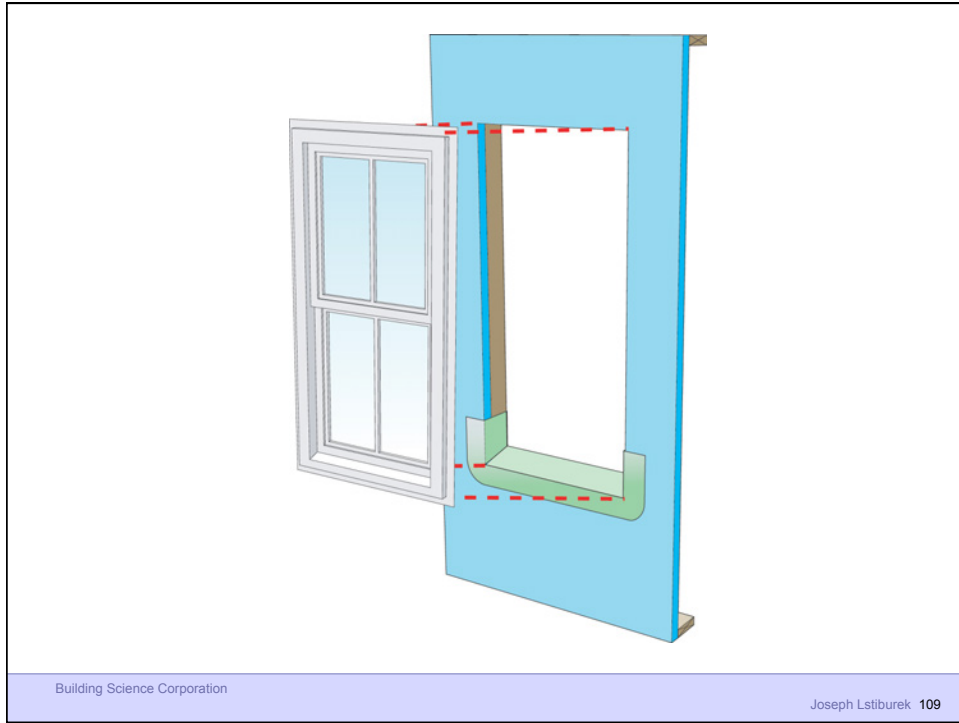


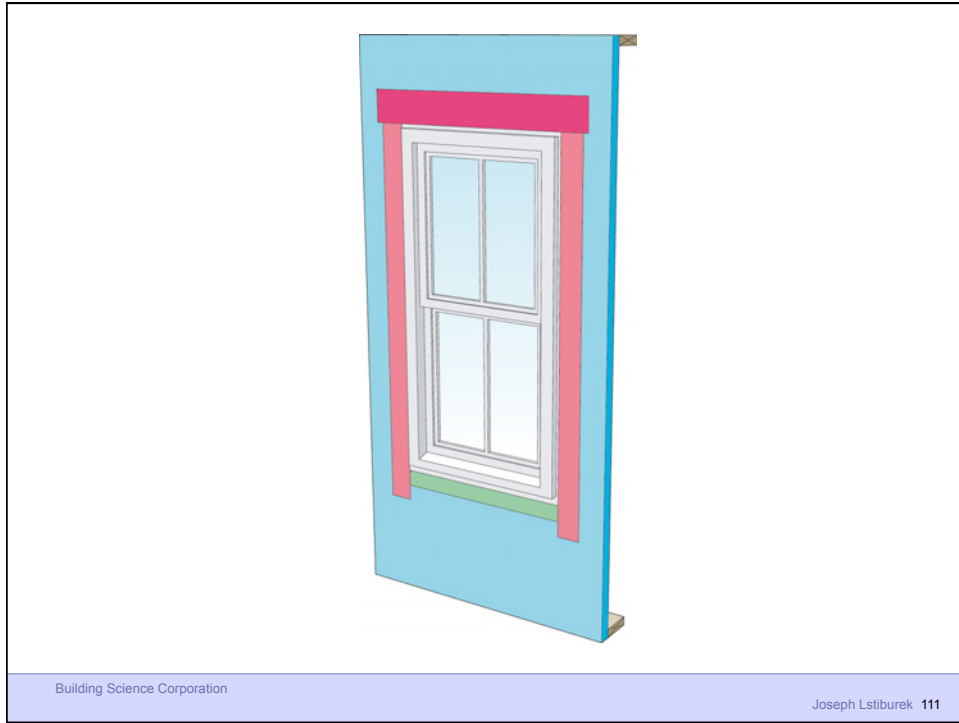


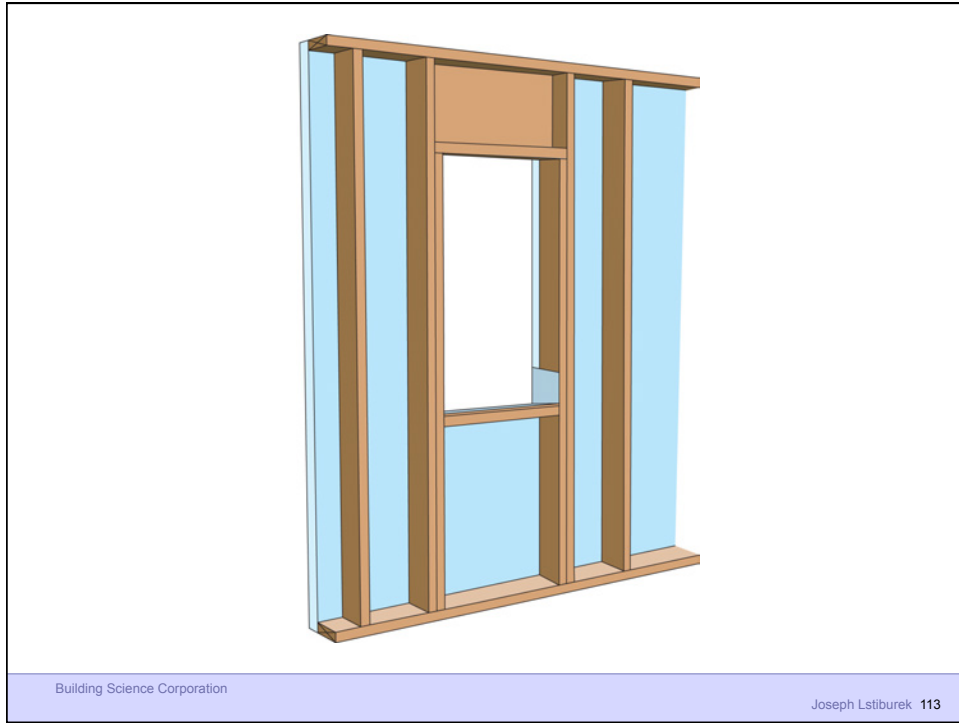


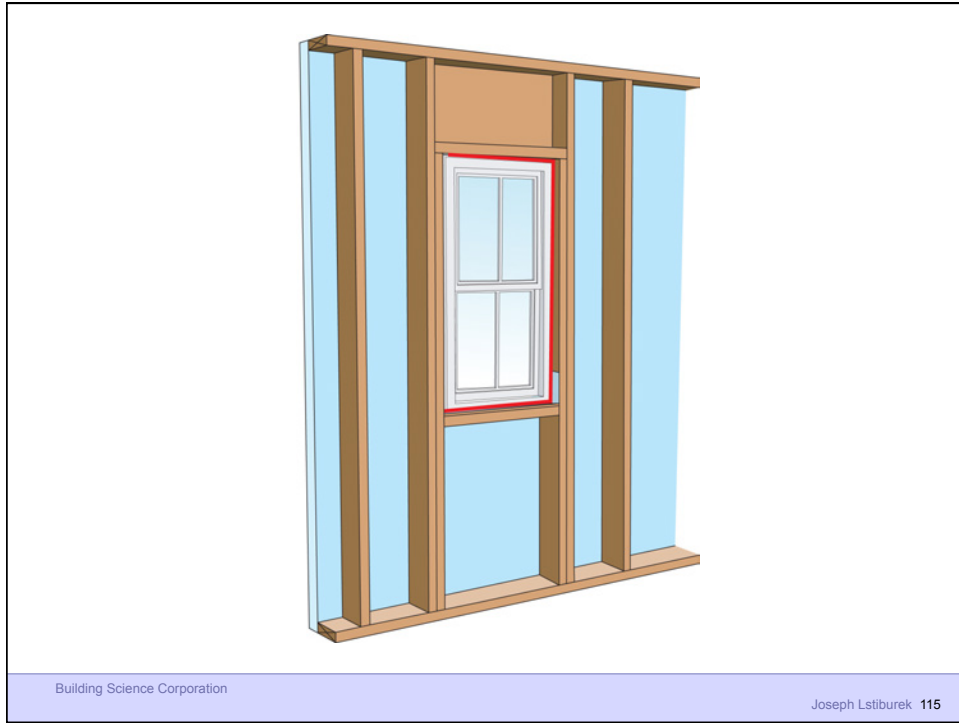


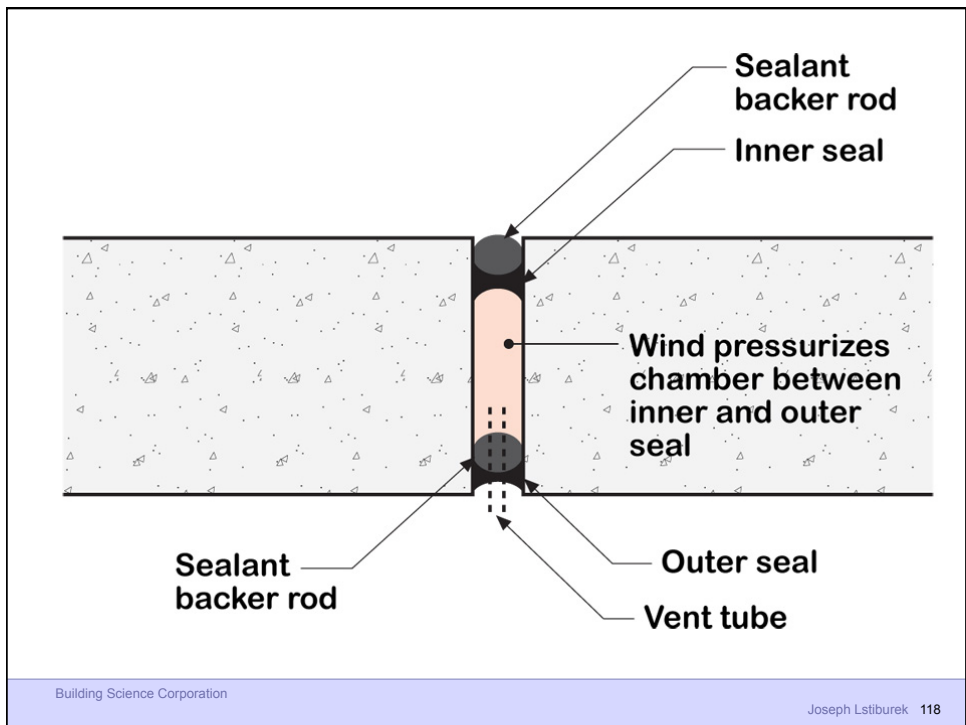
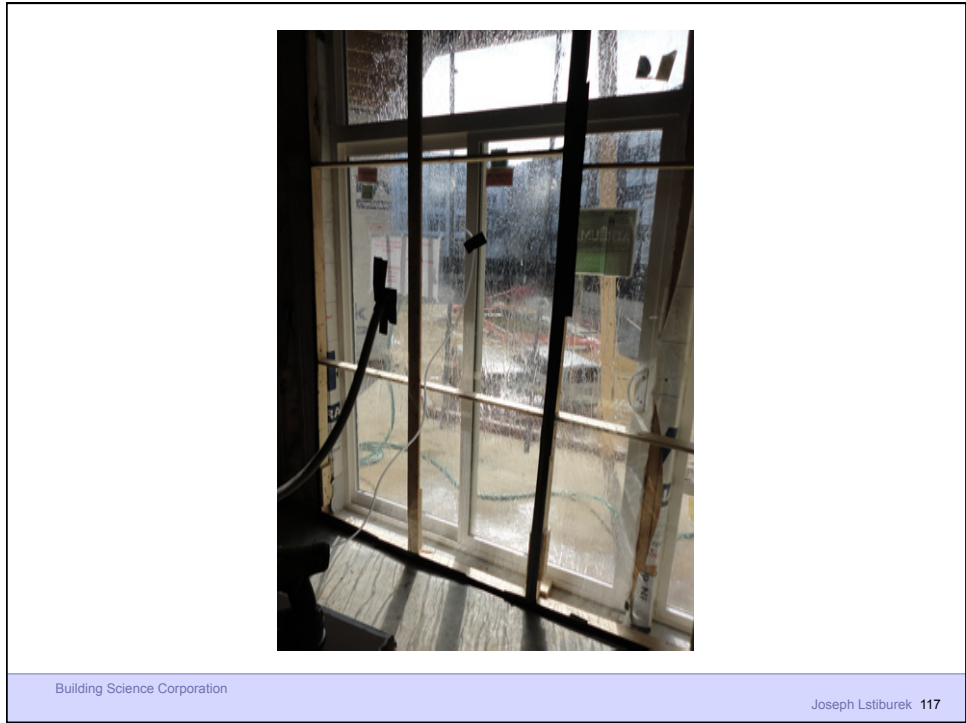


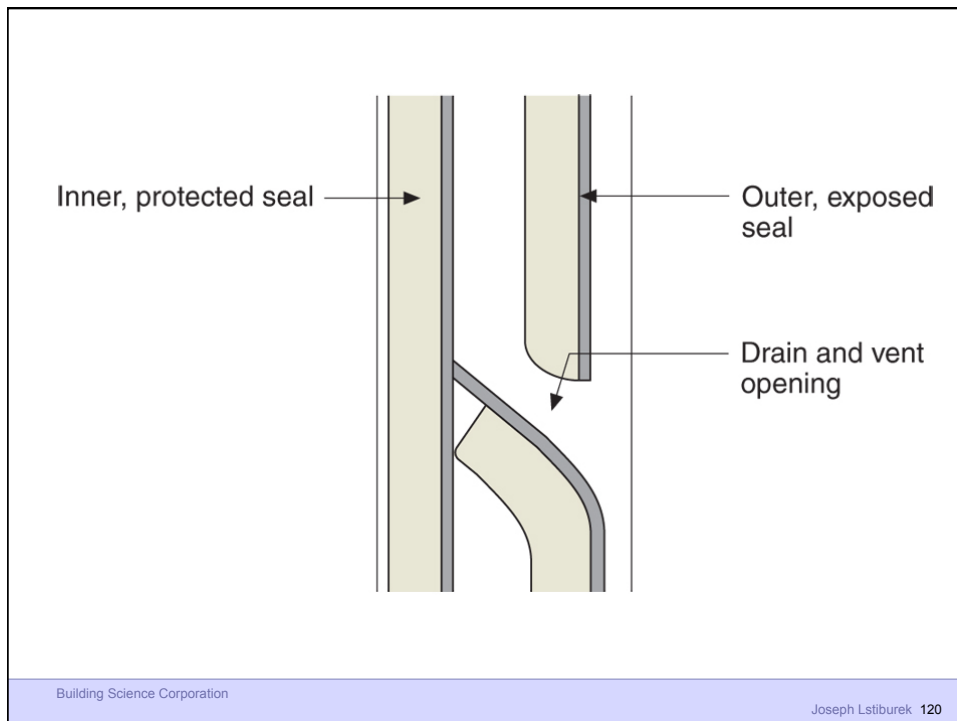
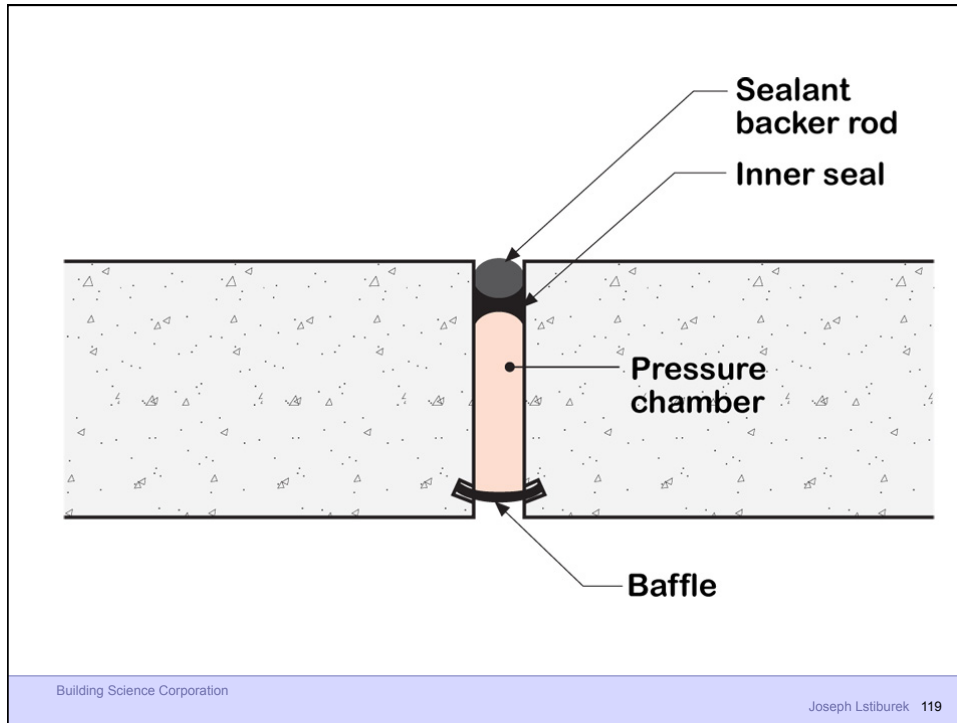


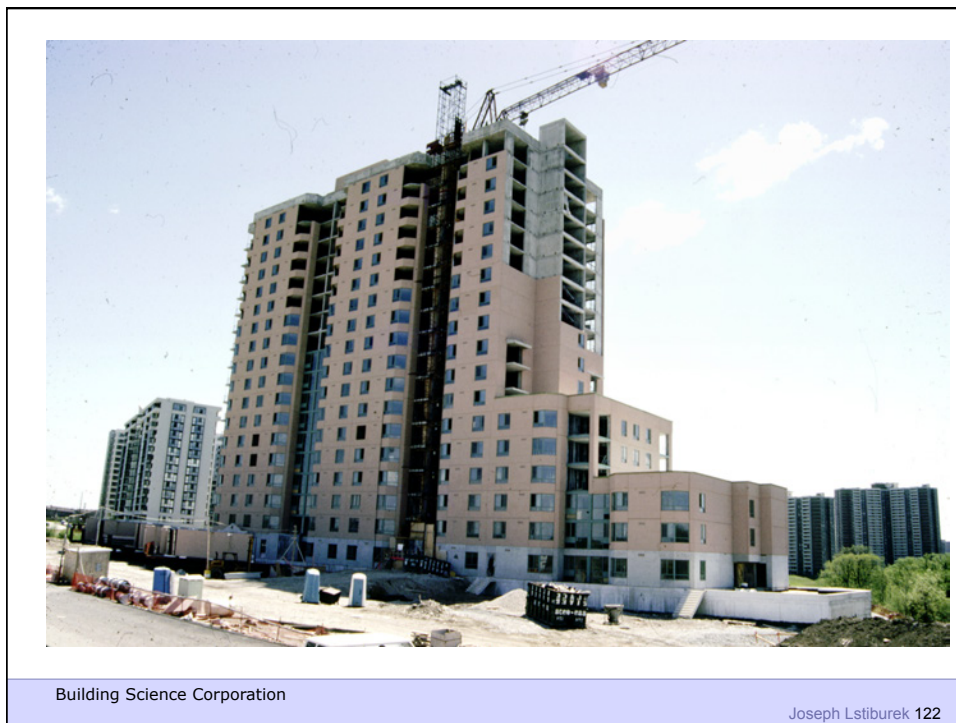
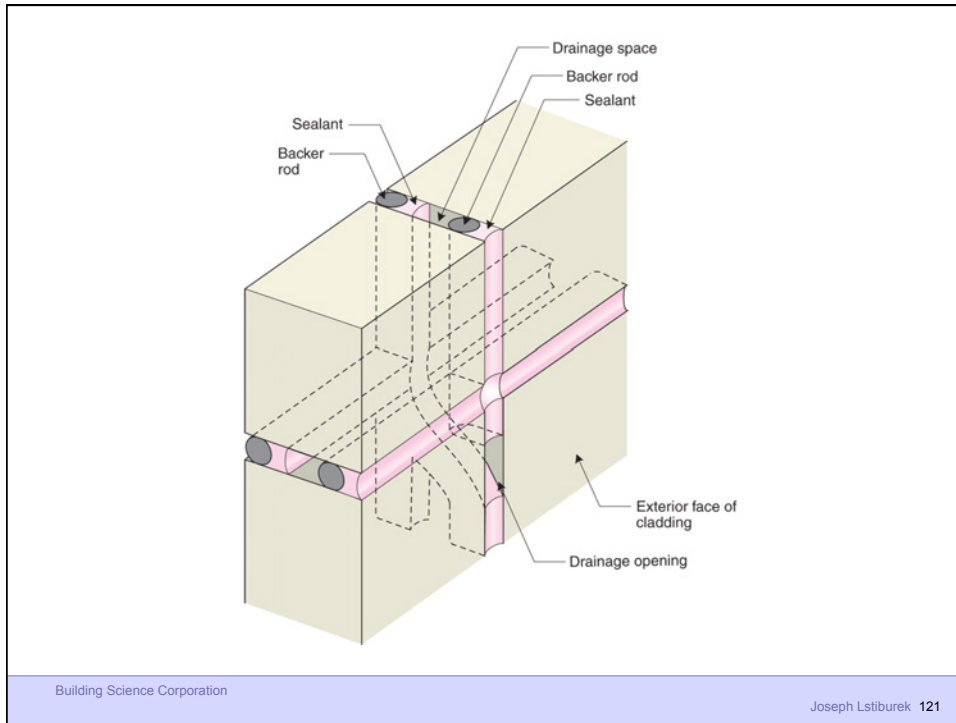


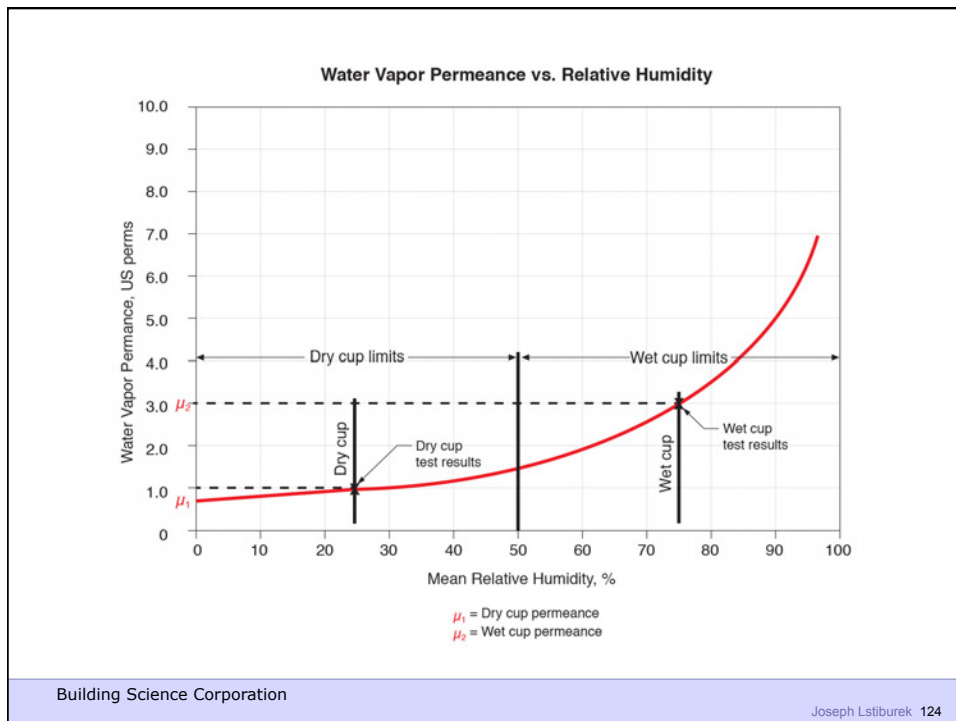
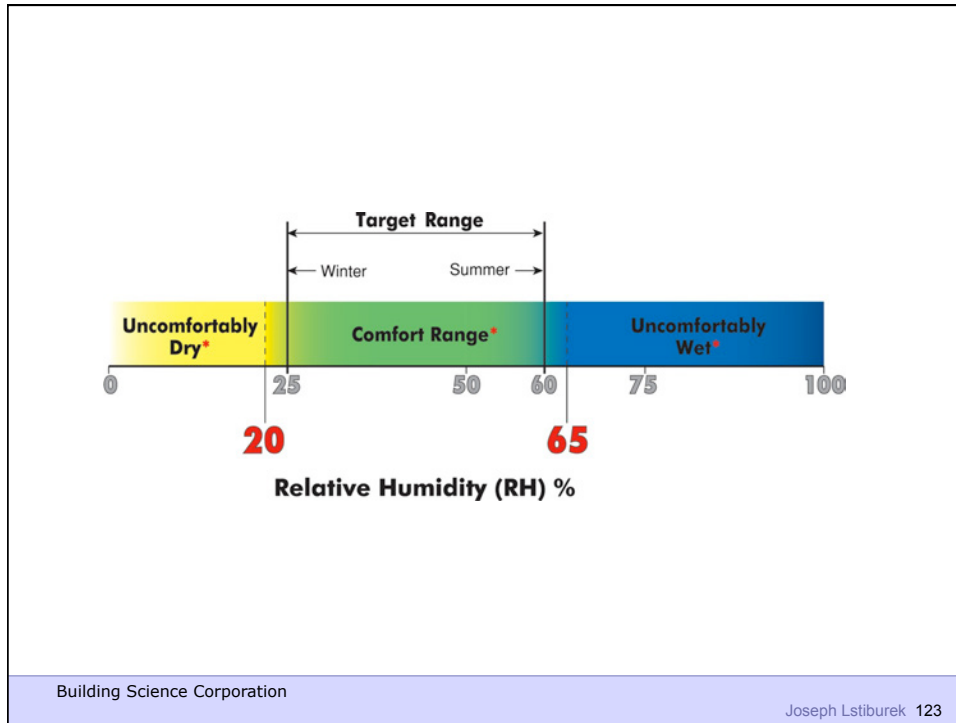


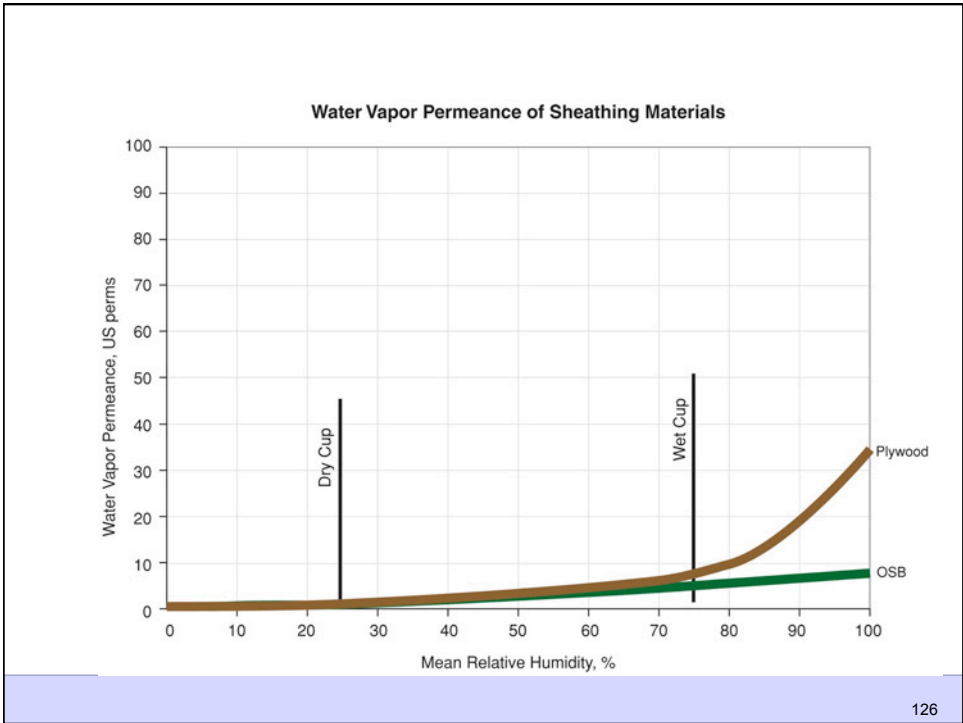


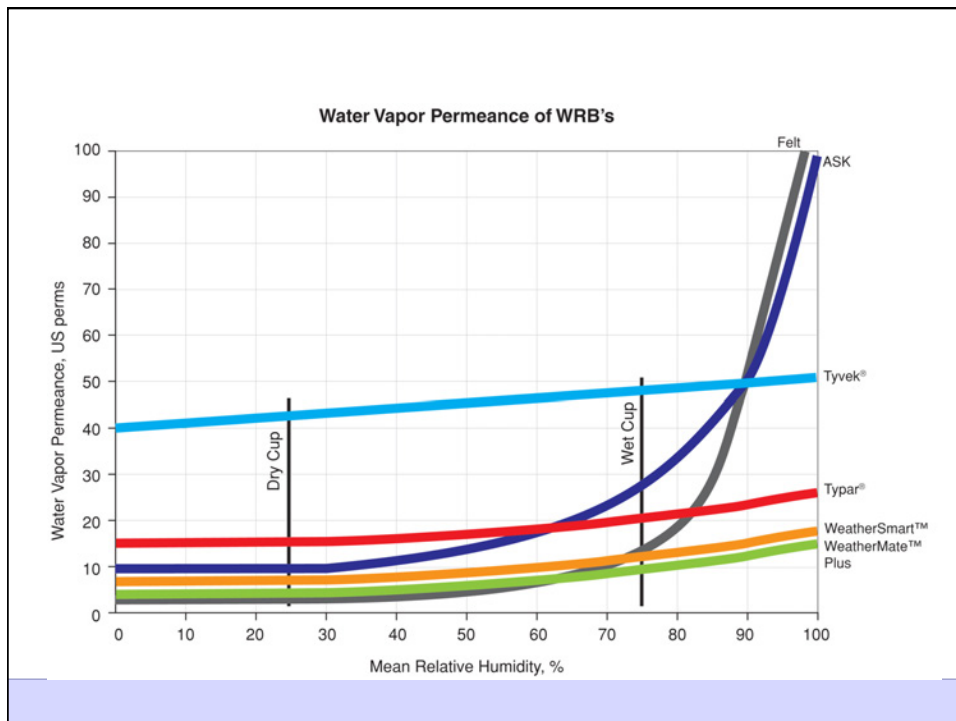
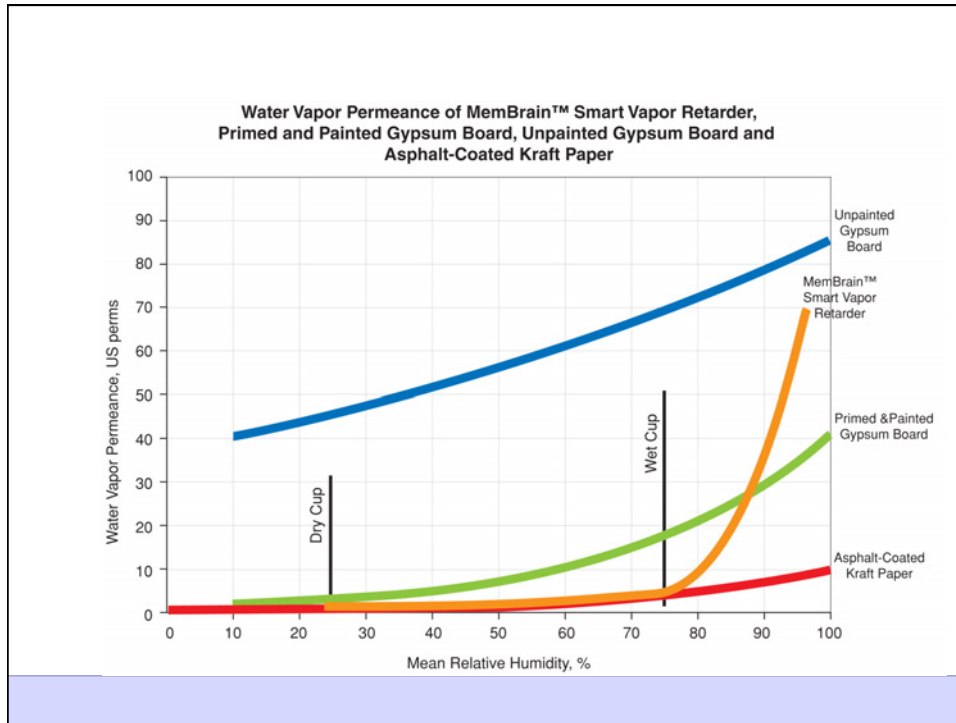


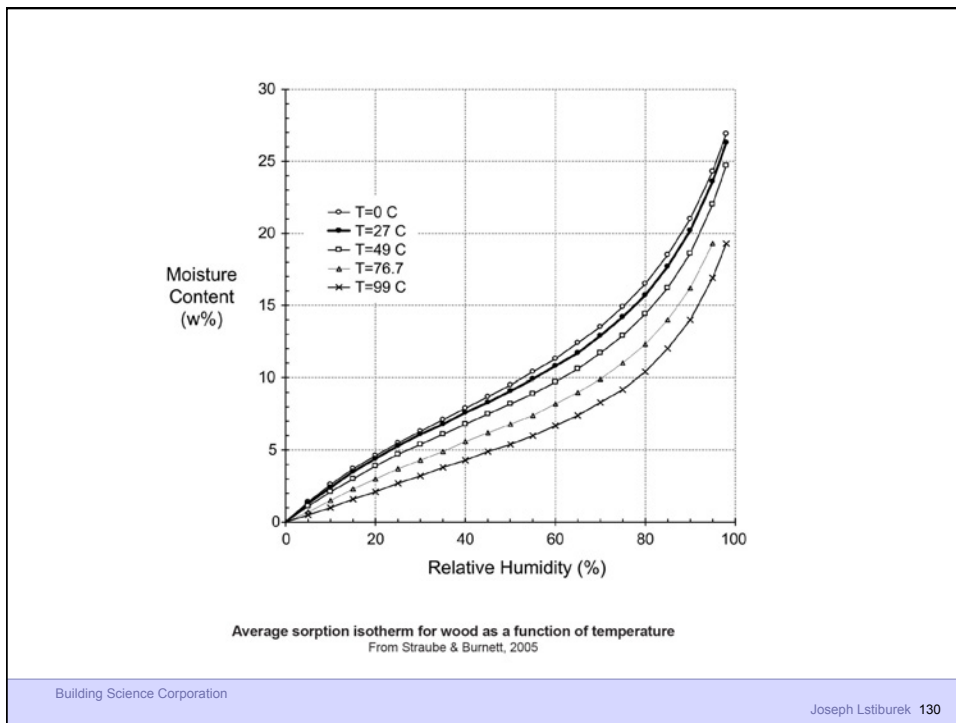
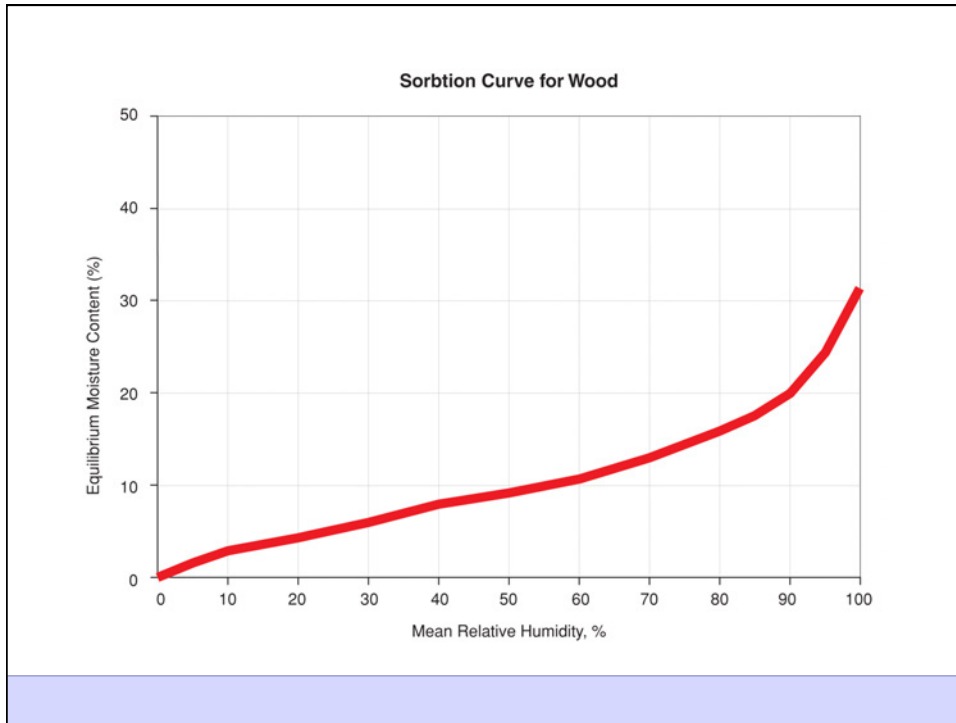


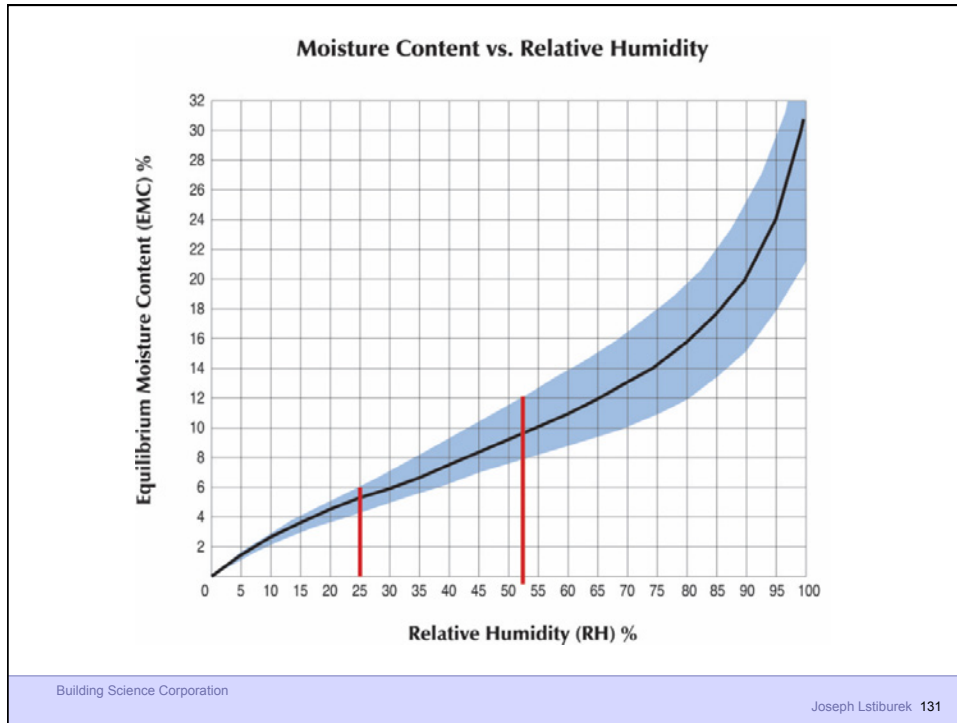


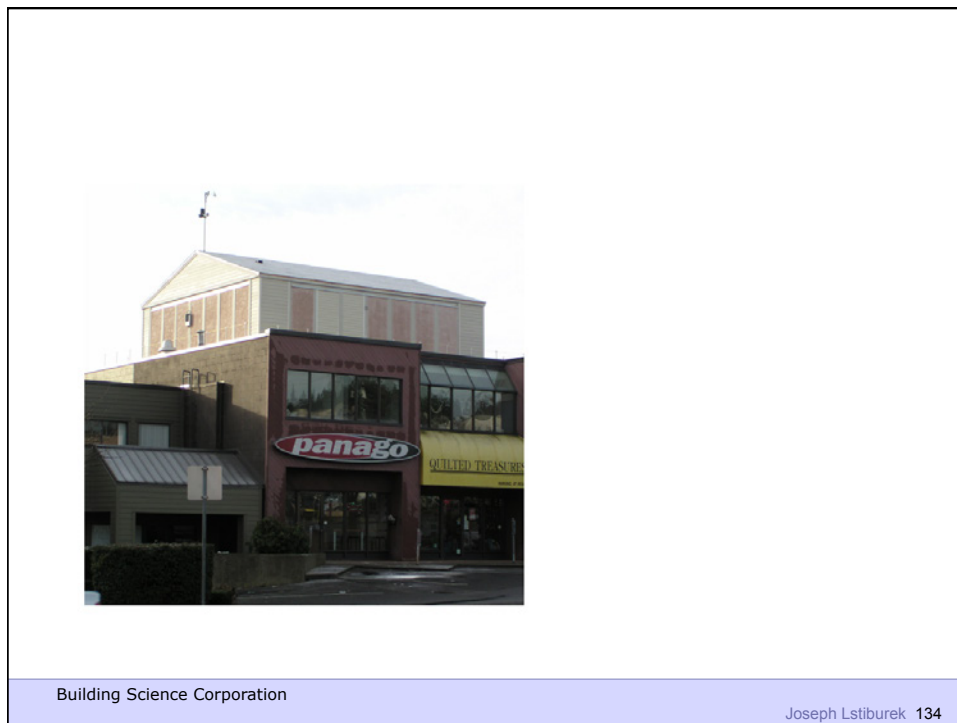
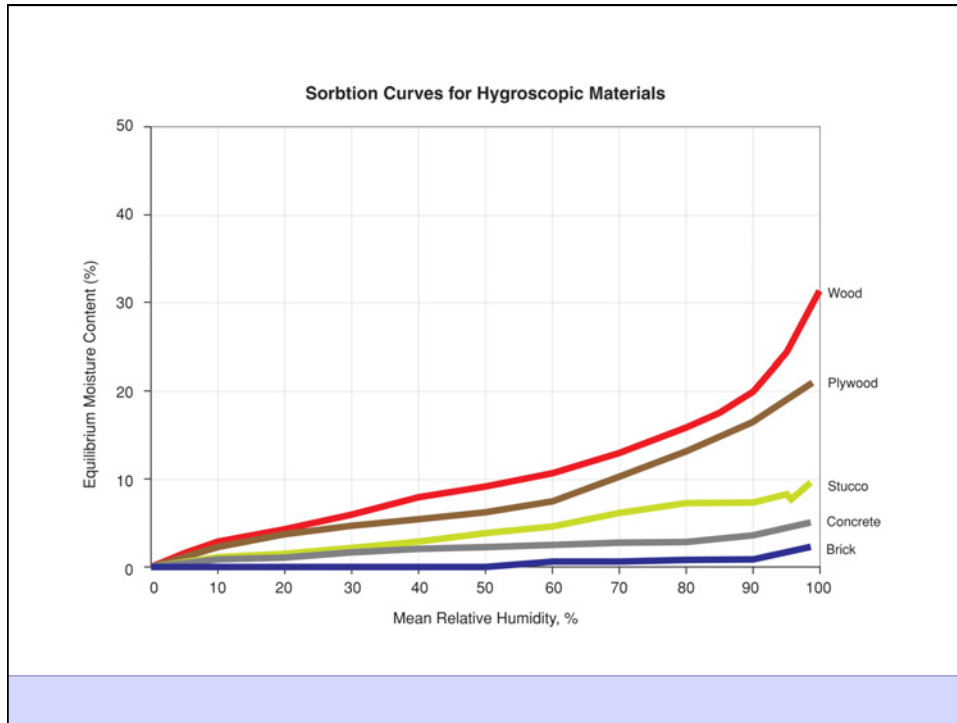


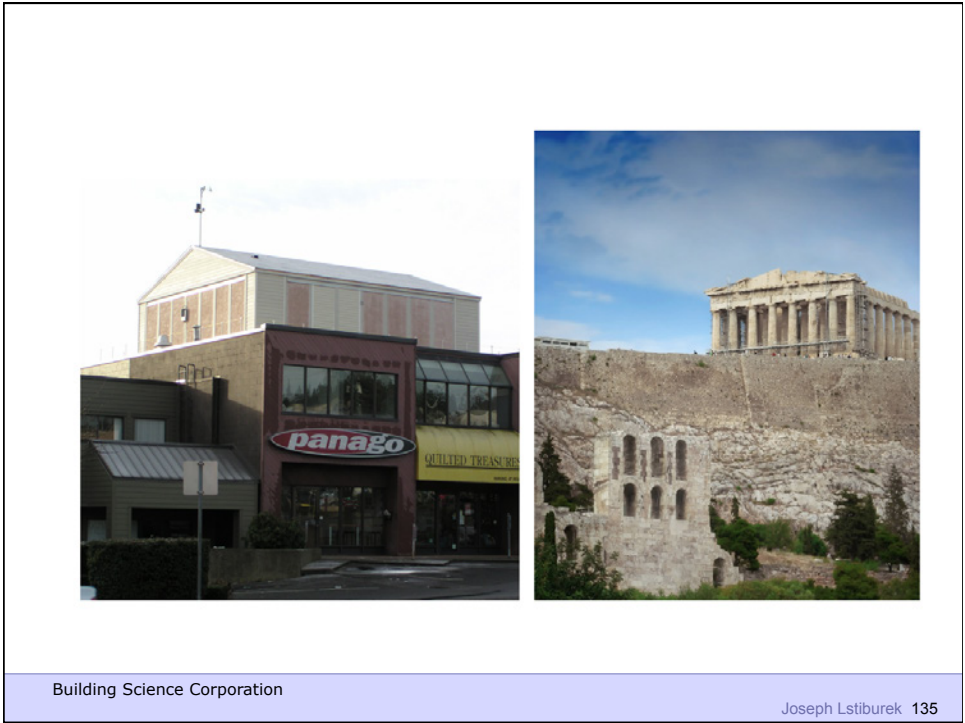














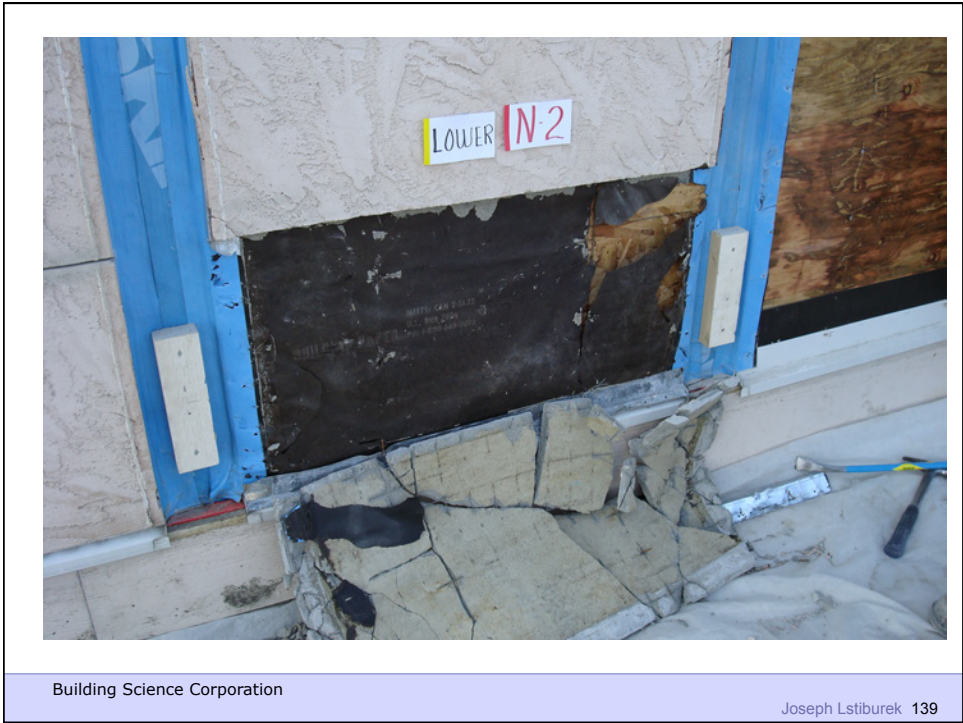
Building Science Corporation

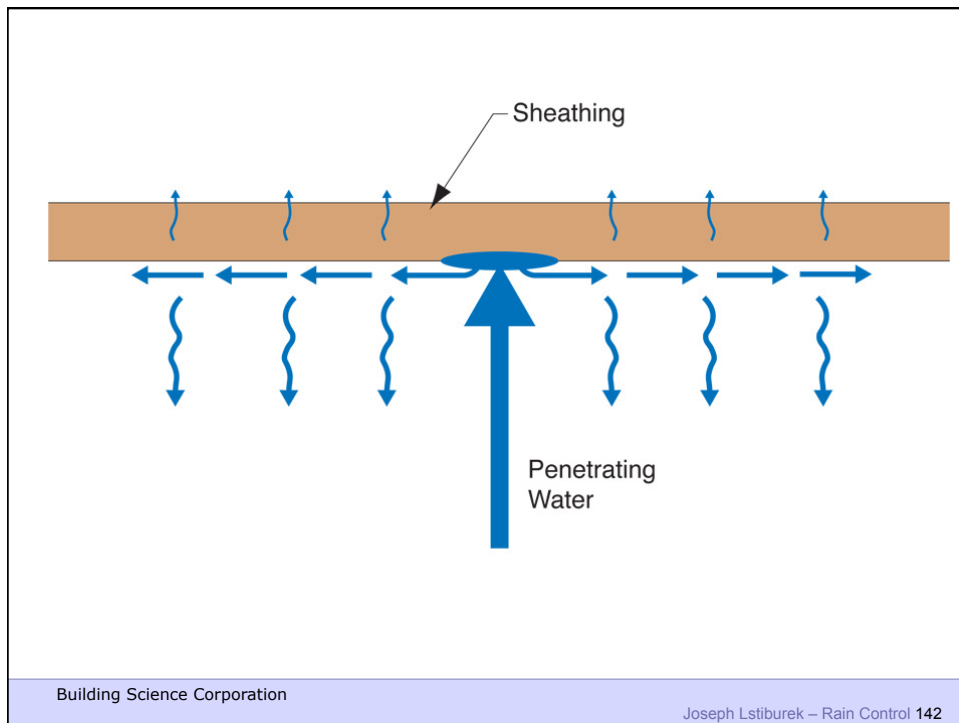
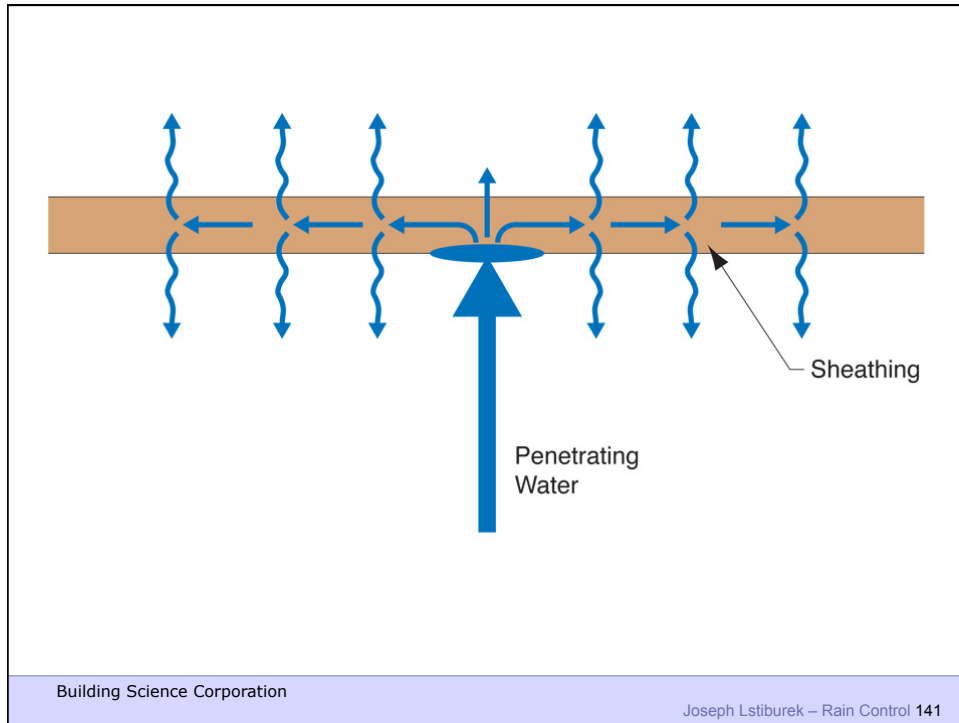
Joseph Lstiburek 137



Building Science Corporation

Joseph Lstiburek 138







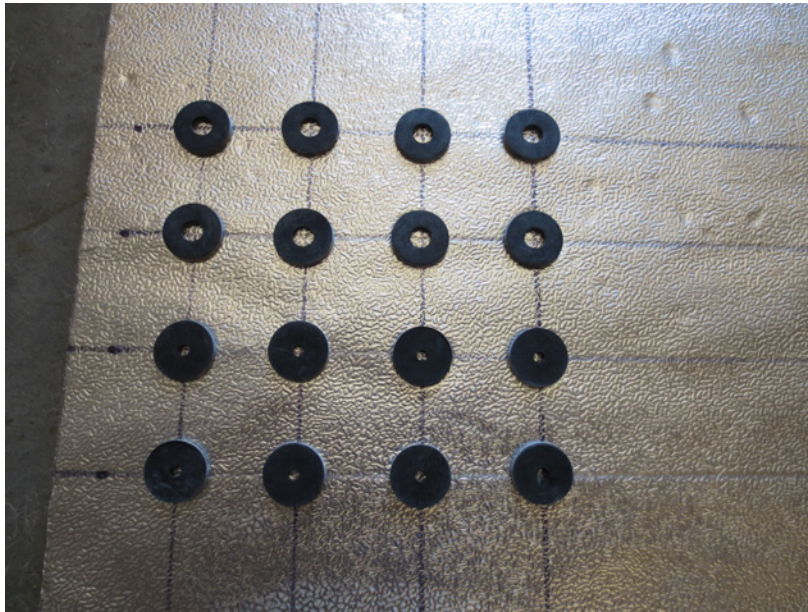
Building Science Corporation

Joseph Lstiburek – Rain Control 143

Rain Screen

Building Science Corporation

Joseph Lstiburek 144



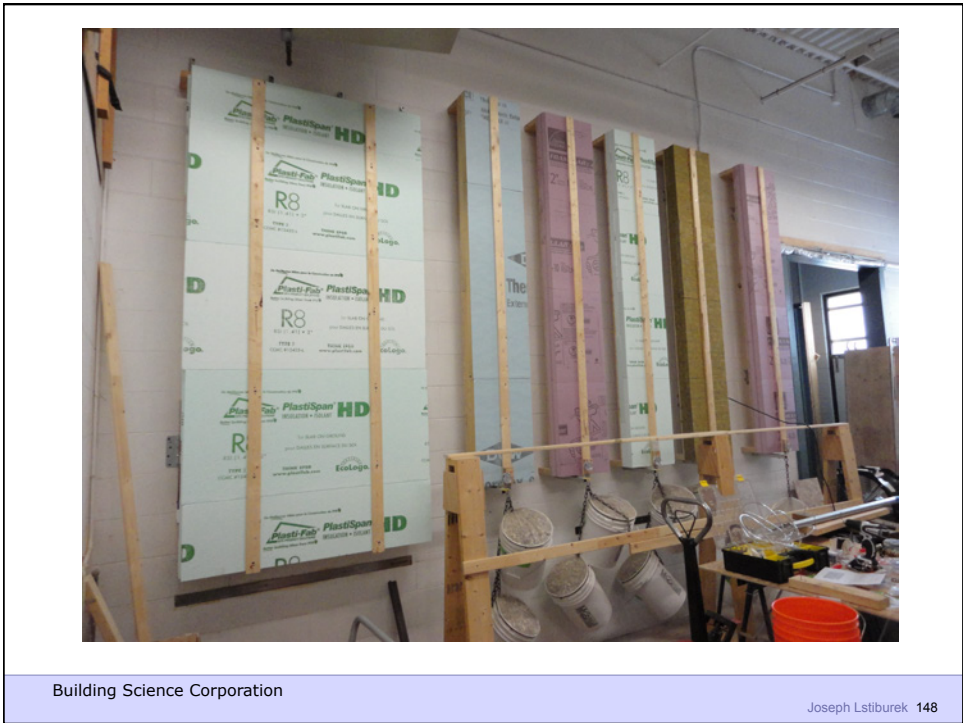
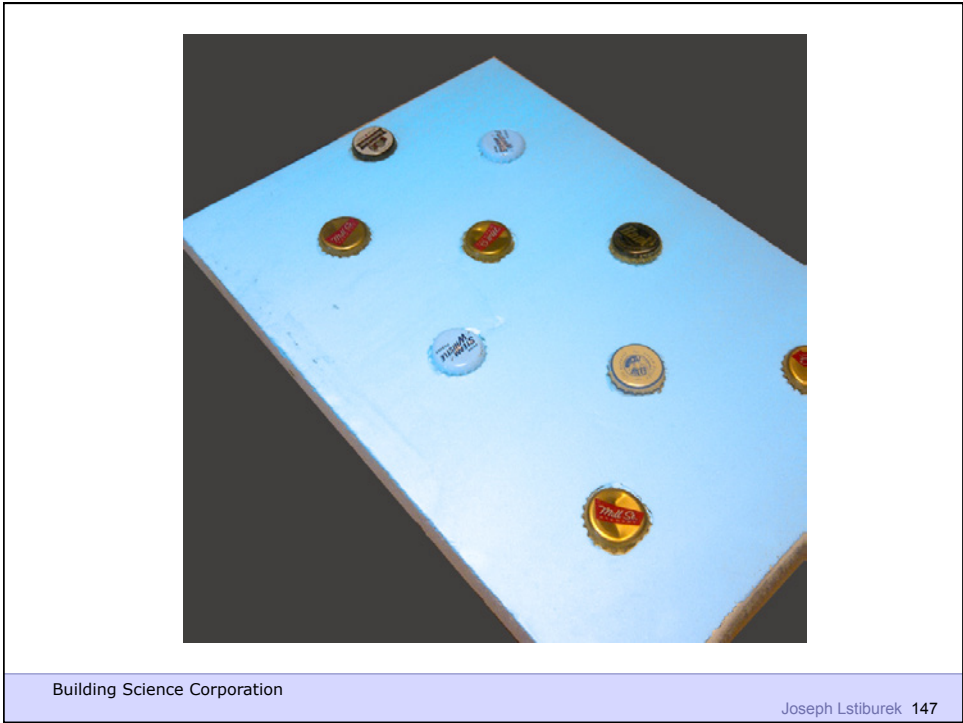
Building Science Corporation

Joseph Lstiburek 145

Beer Screen?

Building Science Corporation

Joseph Lstiburek 146

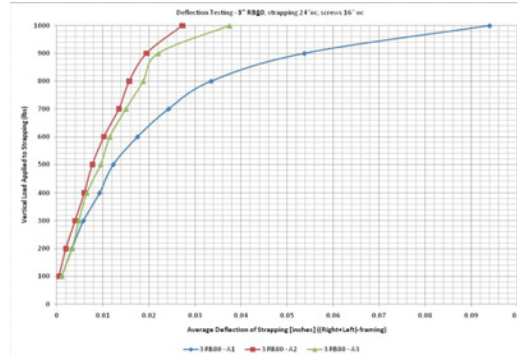






Rockwool

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

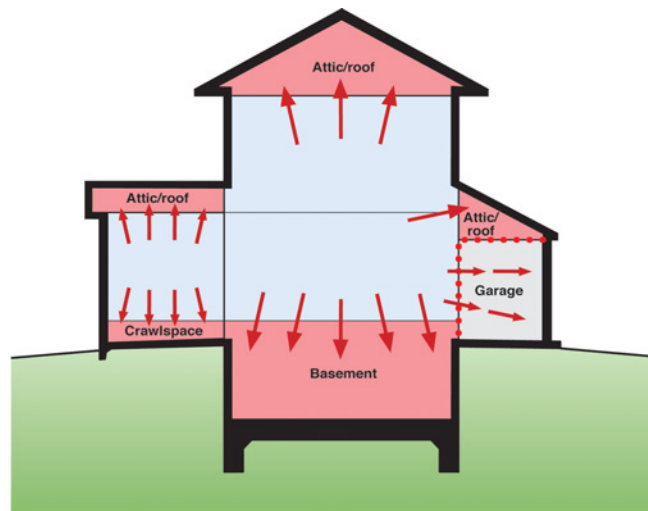


Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

Foundations

presented by www.buildingscience.com



Expansion of Conditioned Space

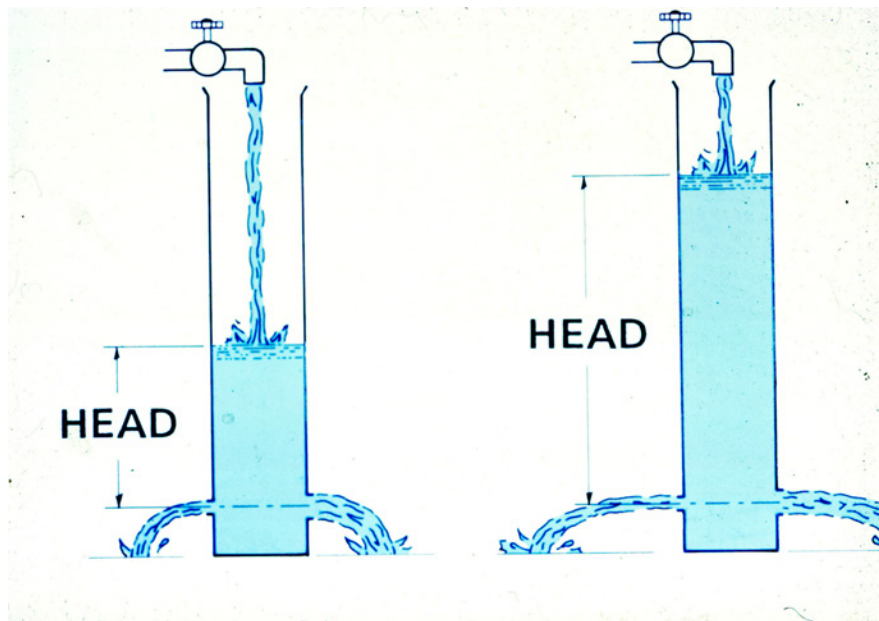
- Conditioned space boundaries moving towards exterior surfaces of building
- Garage isolated from house by air barrier/pressure boundary
- Garage ventilated and conditioned independently of rest of conditioned spaces

Mechanisms of Flow

- Liquid
 - Gravitational
 - Capillary
 - Osmosis
 - Hydrostatic Pressure
 - Suction Pressure
 - Solute Concentration
- Vapor
 - Diffusion
 - Convective
 - Vapor Pressure
 - Air Pressure

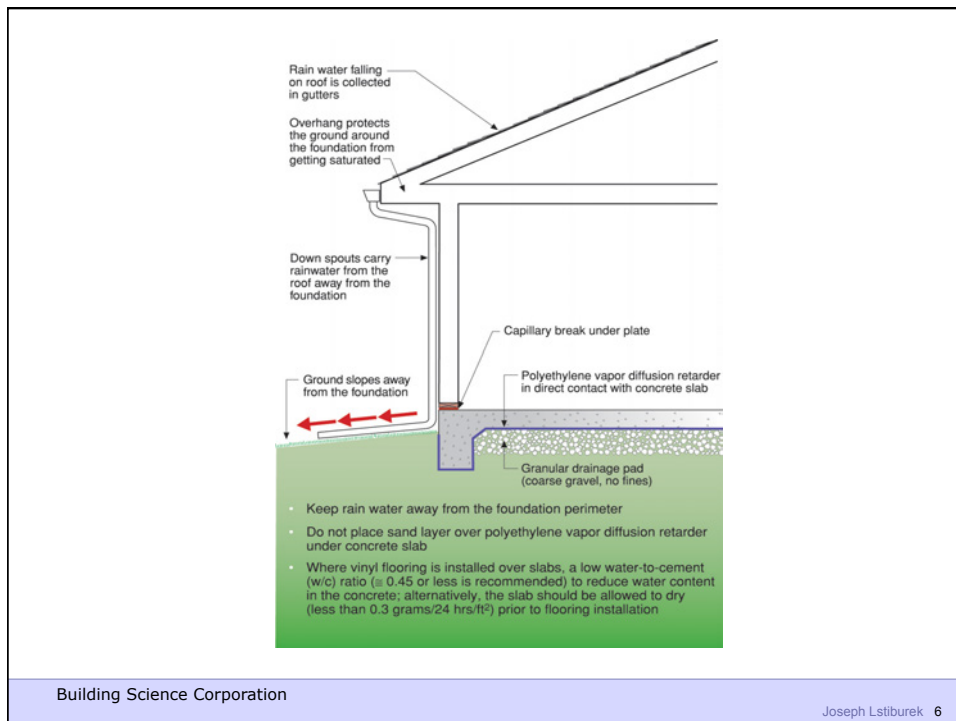
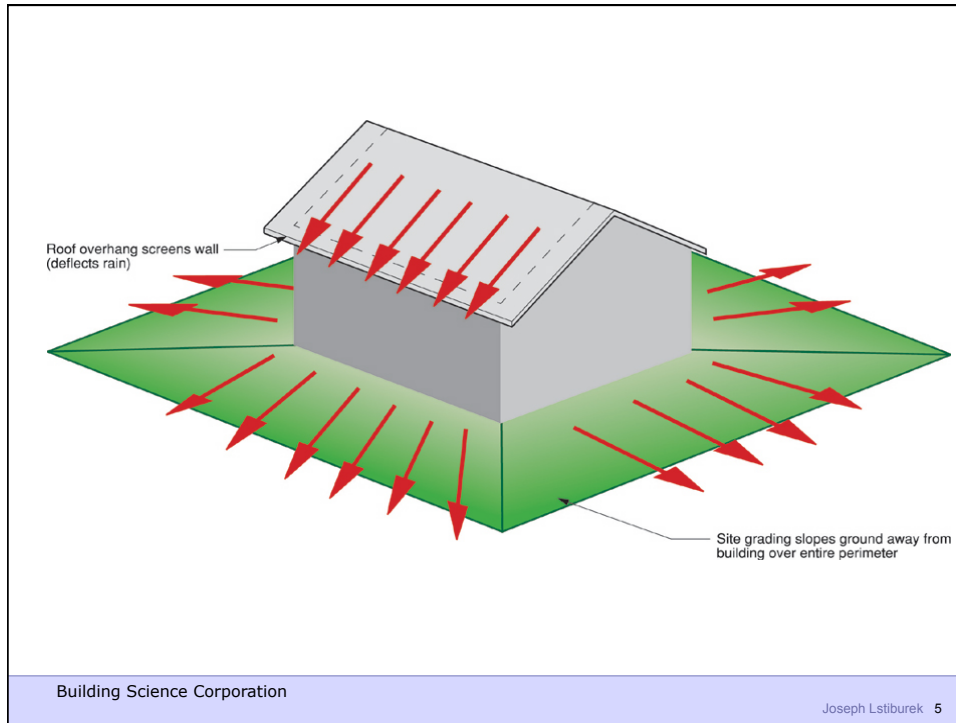
Building Science Corporation

Joseph Lstiburek 3



Building Science Corporation

Joseph Lstiburek 4



Rain water falling on roof is collected in gutters
 Overhang protects the ground around the foundation from getting saturated
 Flash roof into gutter
 Down spouts carry rainwater from the roof away from the foundation
 Capillary break under plate
 Ground slopes away from the foundation
 Conditioned space
 Polyethylene ground cover acting as both an air barrier and a vapor barrier
 Interior grade of crawspace higher than surrounding grade

- Keep rain water away from the foundation perimeter
- If the interior crawspace is lower than the exterior grade, a sub-grade perimeter footing drain is necessary as in a basement foundation
- The crawspace is conditioned space; it is part of the "interior" of the building and should be heated, cooled and ventilated as part of the building's heating, cooling and ventilating strategy

Building Science Corporation Joseph Lstiburek 7

Rain water falling on roof is collected in gutters
 Overhang protects the ground around the foundation from getting saturated
 Flash roof into gutter
 Down spouts carry rainwater from the roof away from the foundation
 Ground slopes away from the foundation
 Concrete foundation wall
 Impermeable top layer of backfill (clay caps) prevents ground adjacent to foundation from getting saturated
 Free-draining backfill (or drainage board)
 Filter fabric above and below drain pipe
 Coarse gravel (no fines)
 Perforated drain pipe located below floor slab level (piped to sump or daylight)
 Pipe connection through footing connects exterior perimeter drain to granular drainage pad under basement slab
 Capillary break over footing
 Slab isolation joint
 Polyethylene vapor diffusion retarder
 Granular drainage pad (coarse gravel, no fines)
 Groundwater flow is downward (not horizontal) under the influence of gravity to the perimeter drainage system

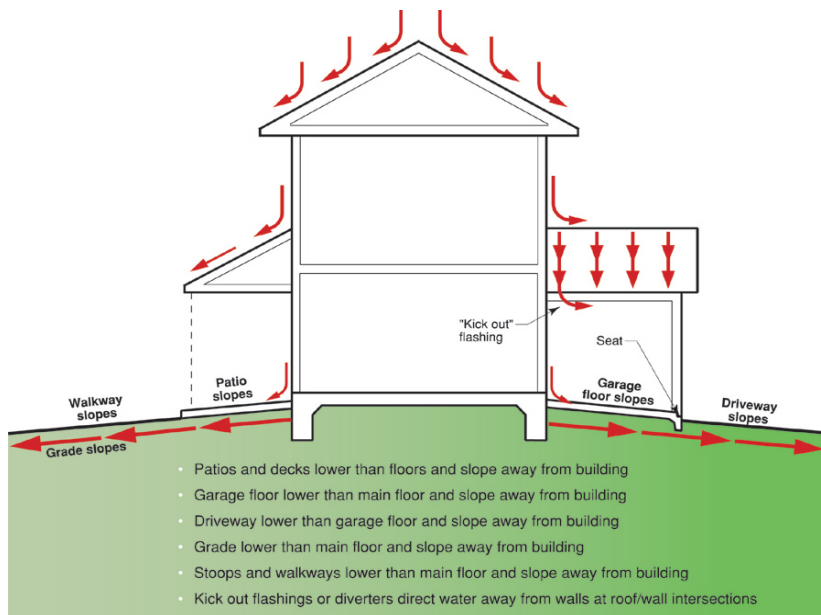
- Keep rain water away from the foundation perimeter
- Drain groundwater away in sub-grade perimeter footing drains before it gets to the foundation wall

Building Science Corporation Joseph Lstiburek 8



Building Science Corporation

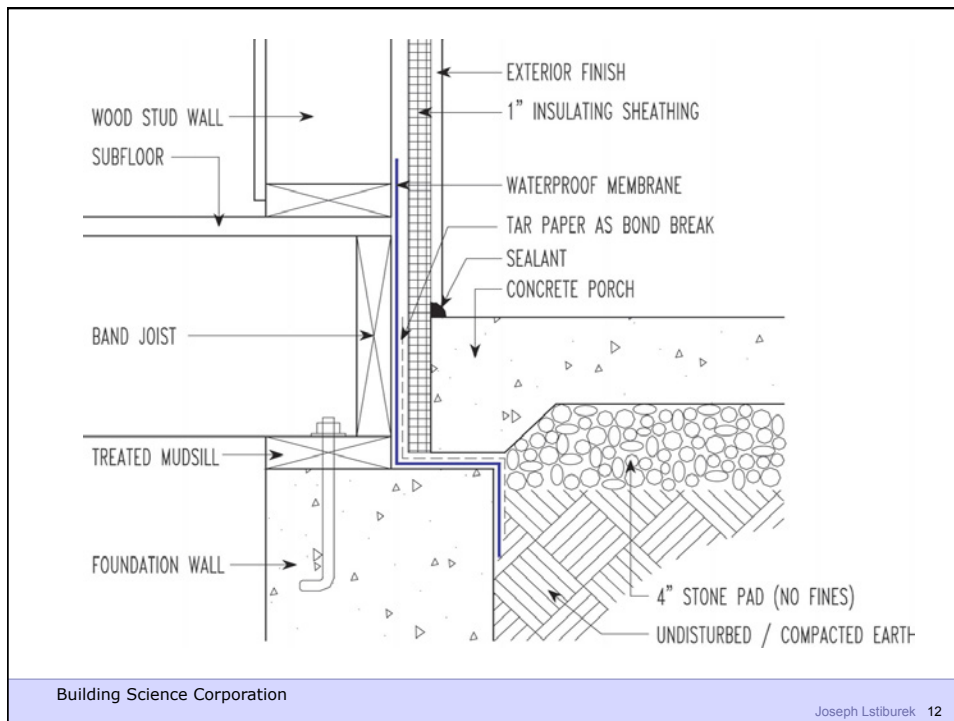
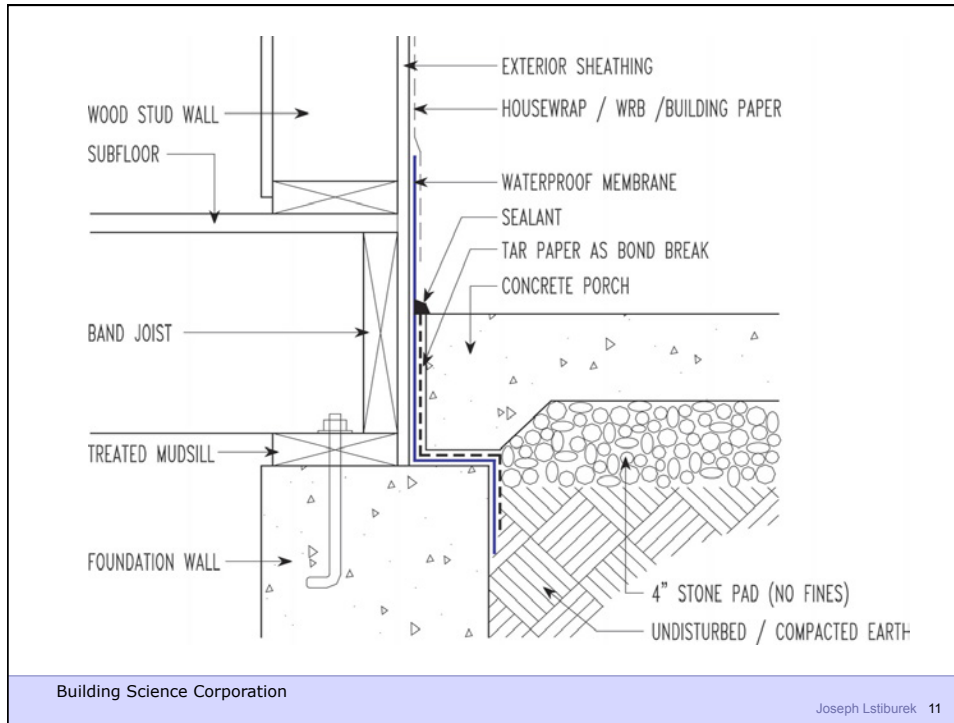
Joseph Lstiburek 9

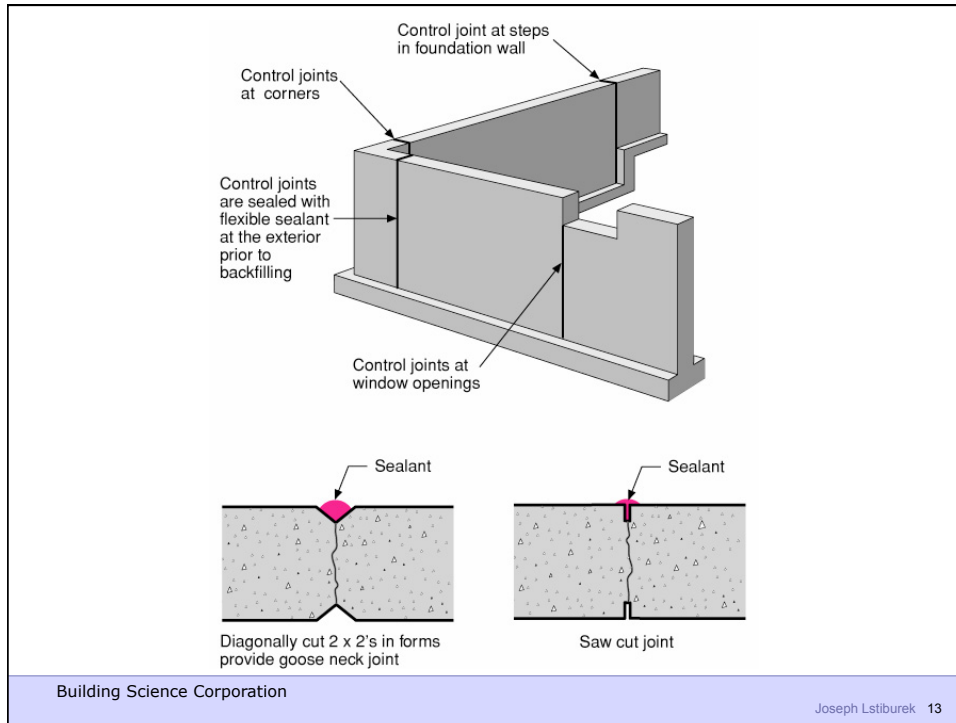


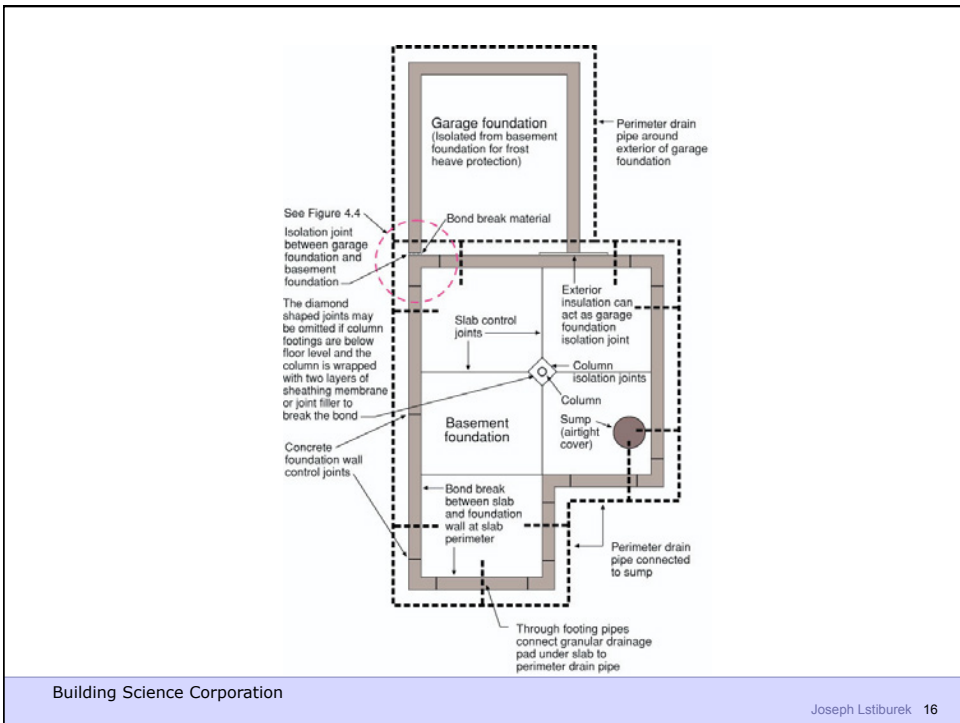
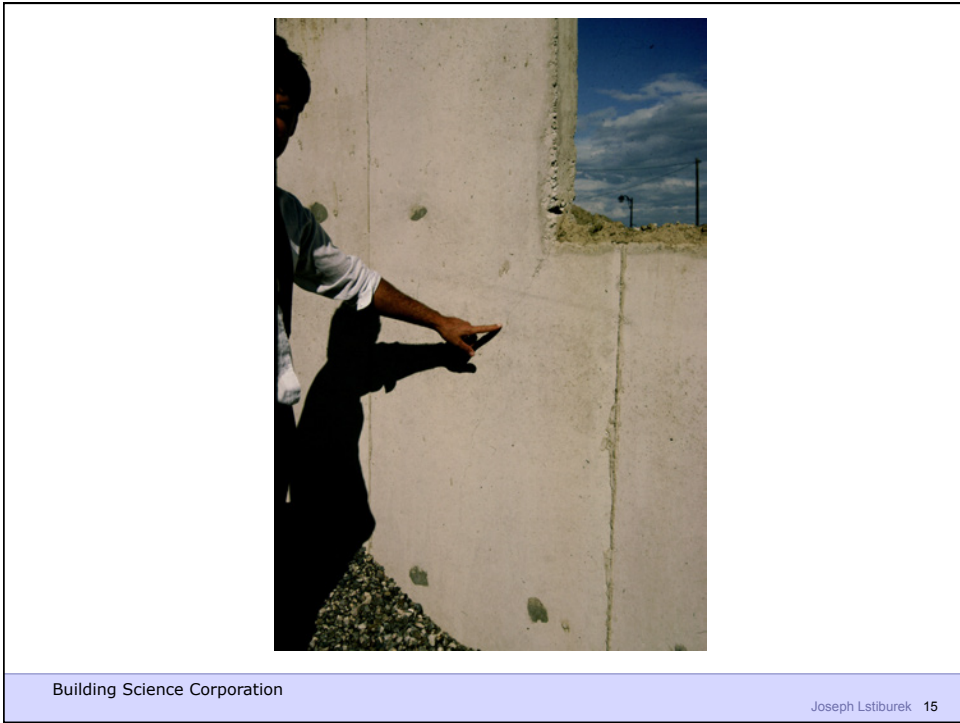
- Patios and decks lower than floors and slope away from building
- Garage floor lower than main floor and slope away from building
- Driveway lower than garage floor and slope away from building
- Grade lower than main floor and slope away from building
- Stoops and walkways lower than main floor and slope away from building
- Kick out flashings or diverters direct water away from walls at roof/wall intersections

Building Science Corporation

Joseph Lstiburek 10





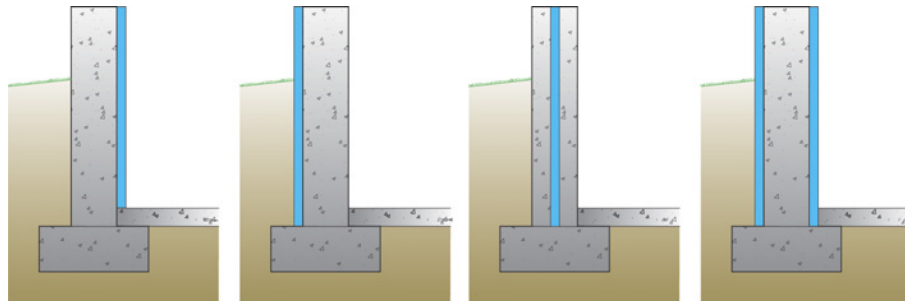






Building Science Corporation

Joseph Lstiburek 19



Internally Insulated Basement

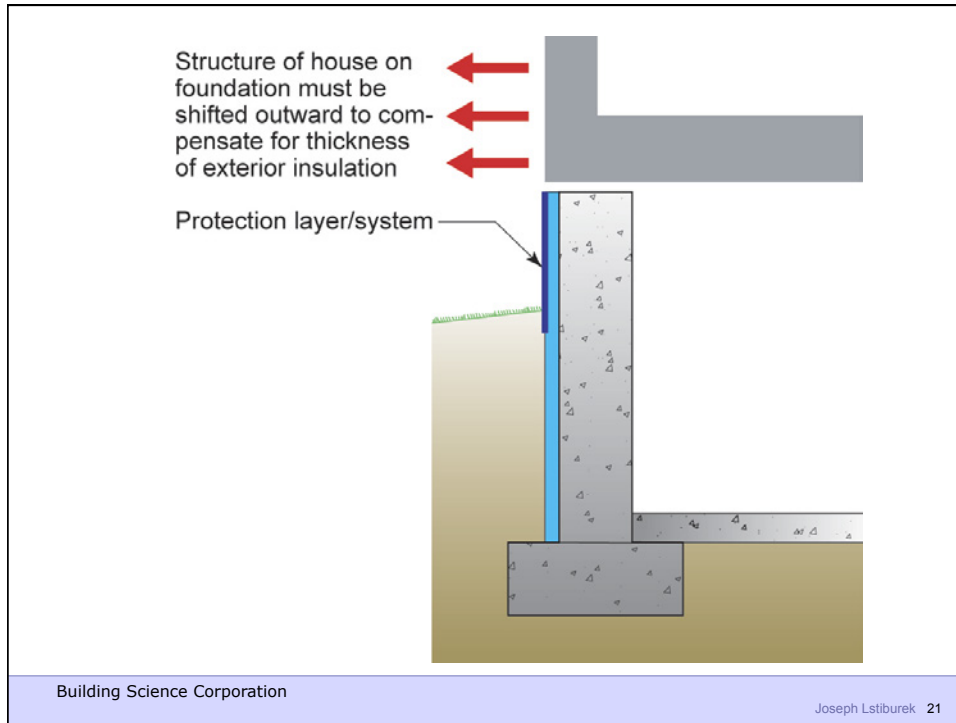
Externally Insulated Basement

Basement Insulated in the Middle

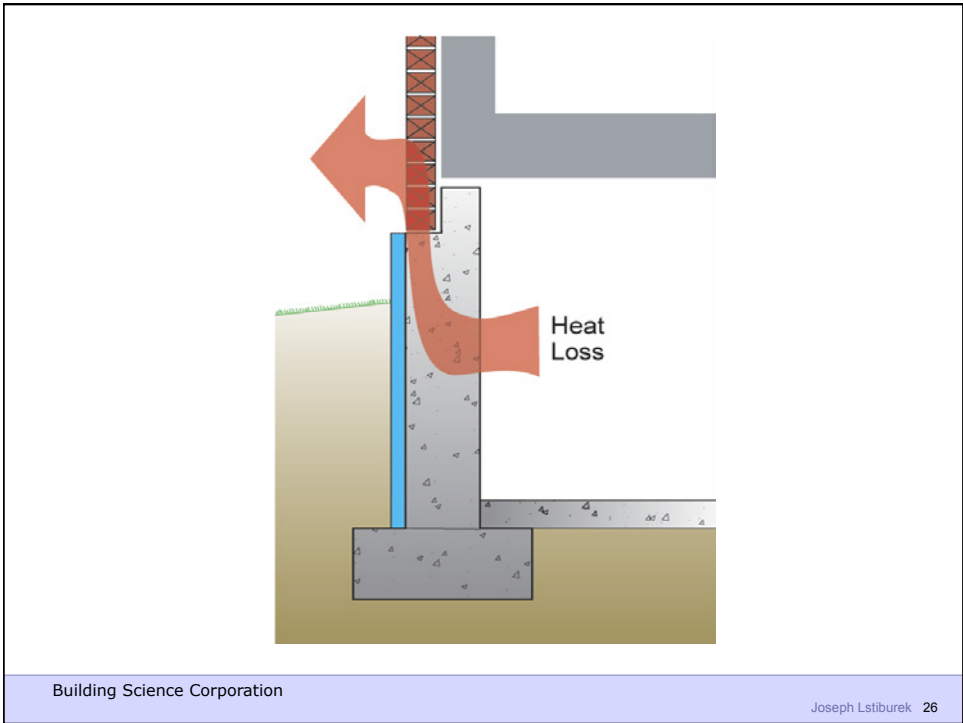
Basement Insulated Both Externally and Internally

Building Science Corporation

Joseph Lstiburek 20









Building Science Corporation

Joseph Lstiburek 27



Building Science Corporation

Joseph Lstiburek 28

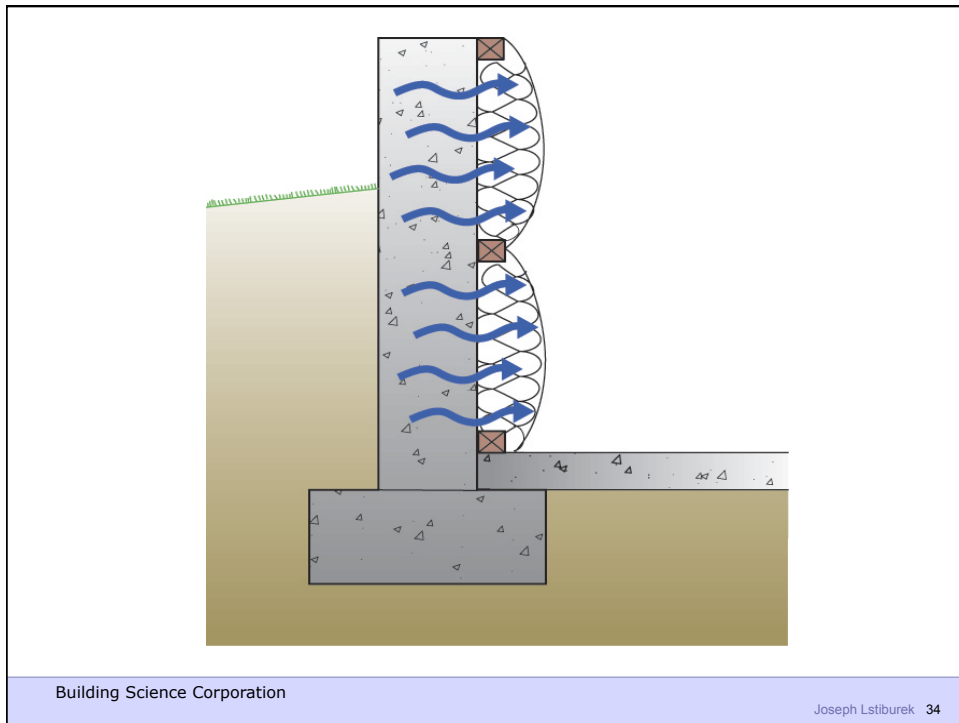
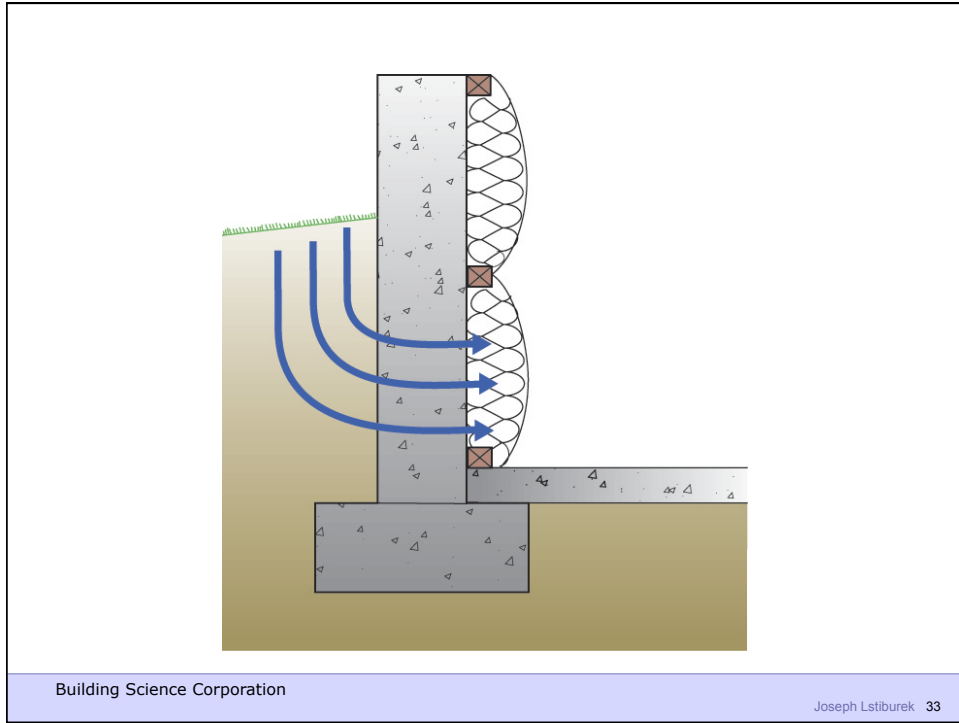


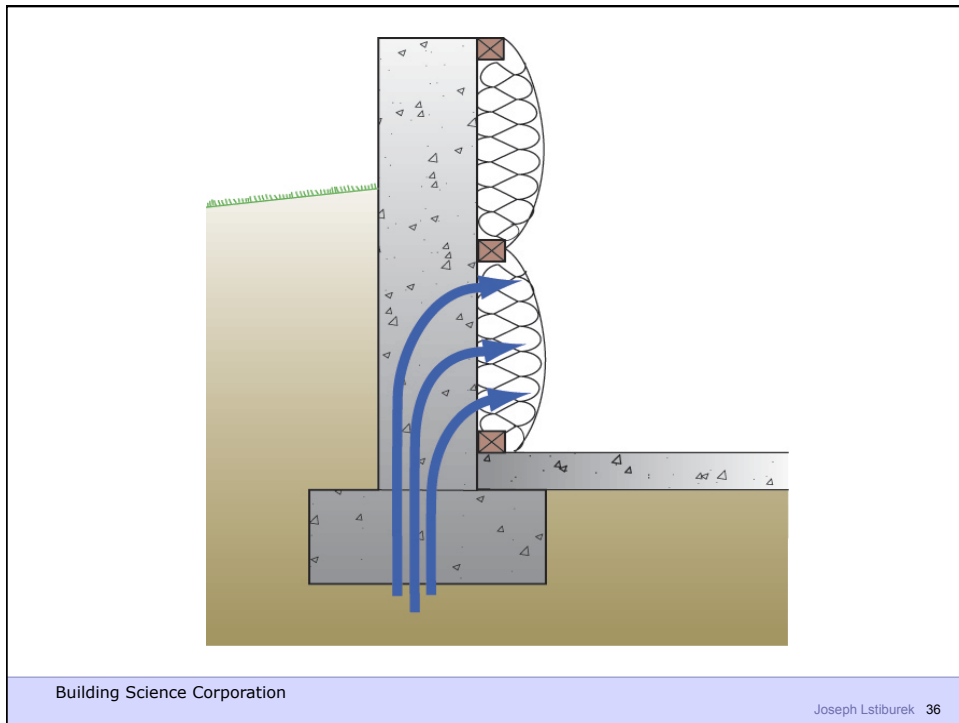
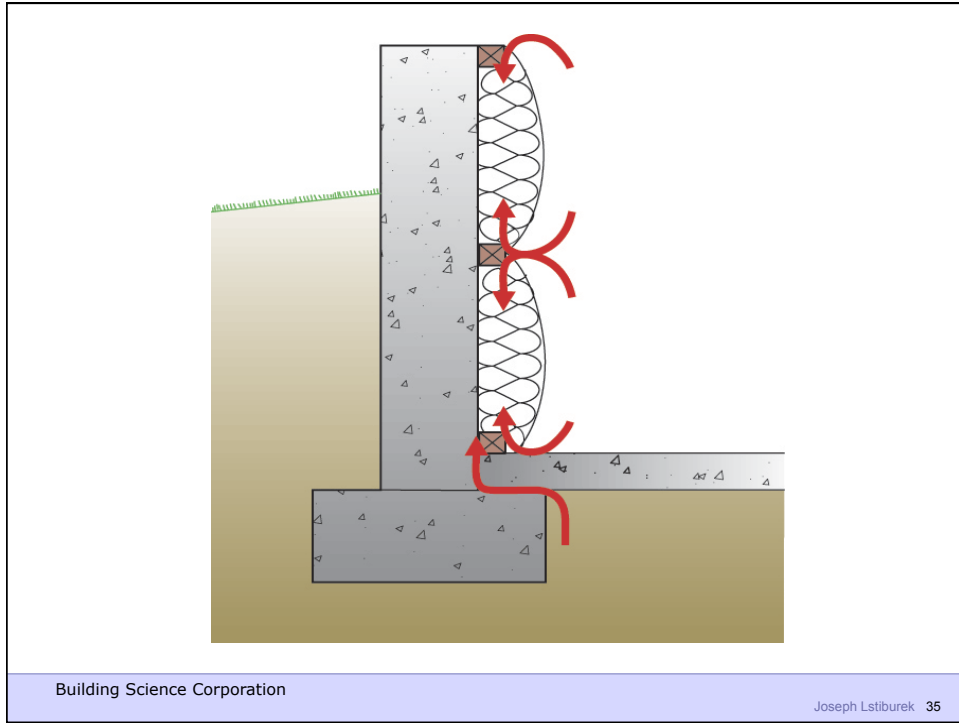
Building Science Corporation



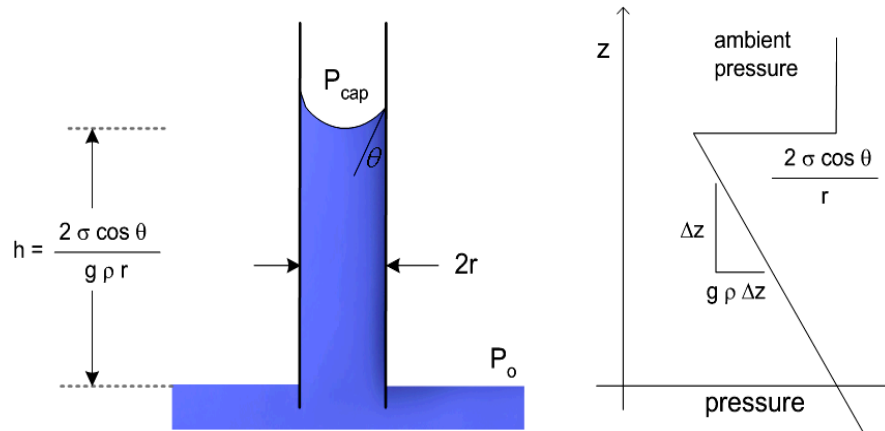
Building Science Corporation







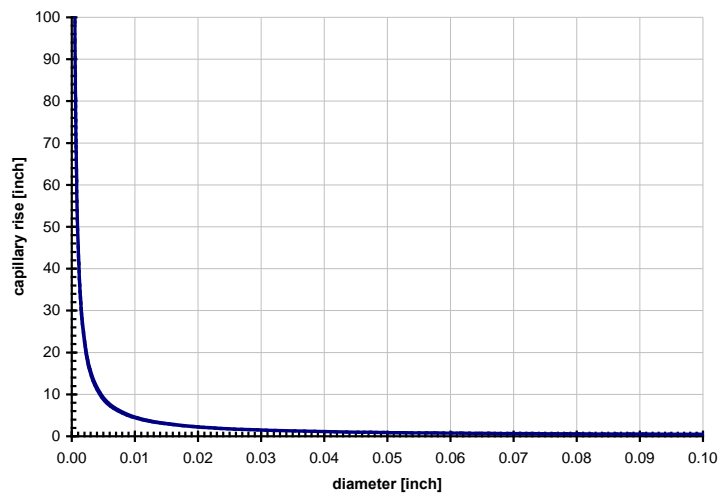
Calculating capillary rise



Building Science Corporation

Joseph Lstiburek 37

Capillary rise versus diameter



Building Science Corporation

Joseph Lstiburek 38

Capillary Flow

Siding laps



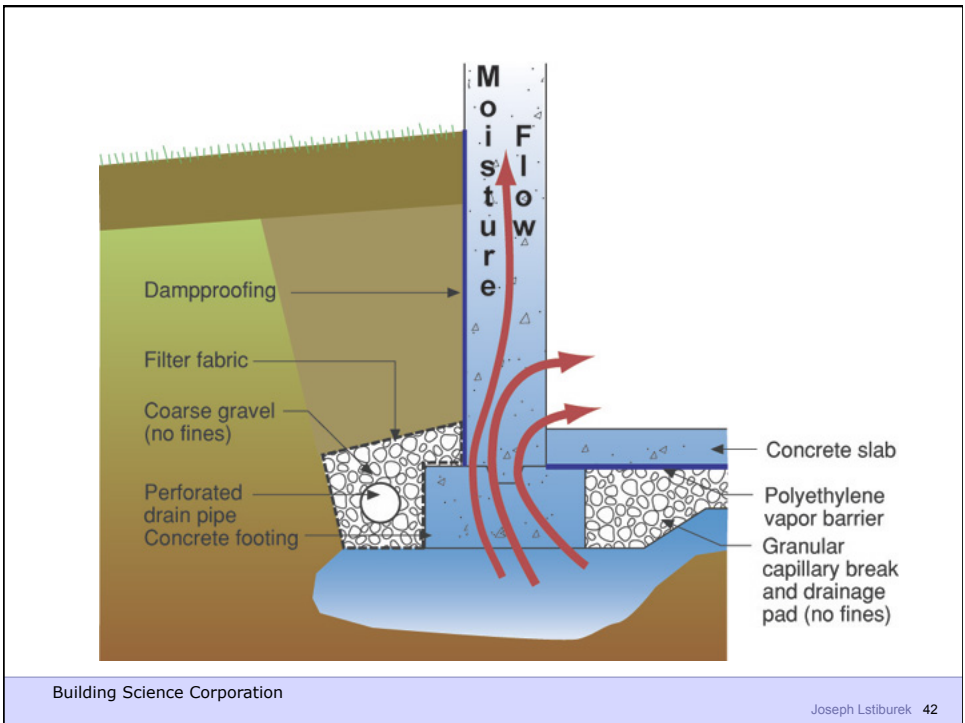
Building Science Corporation

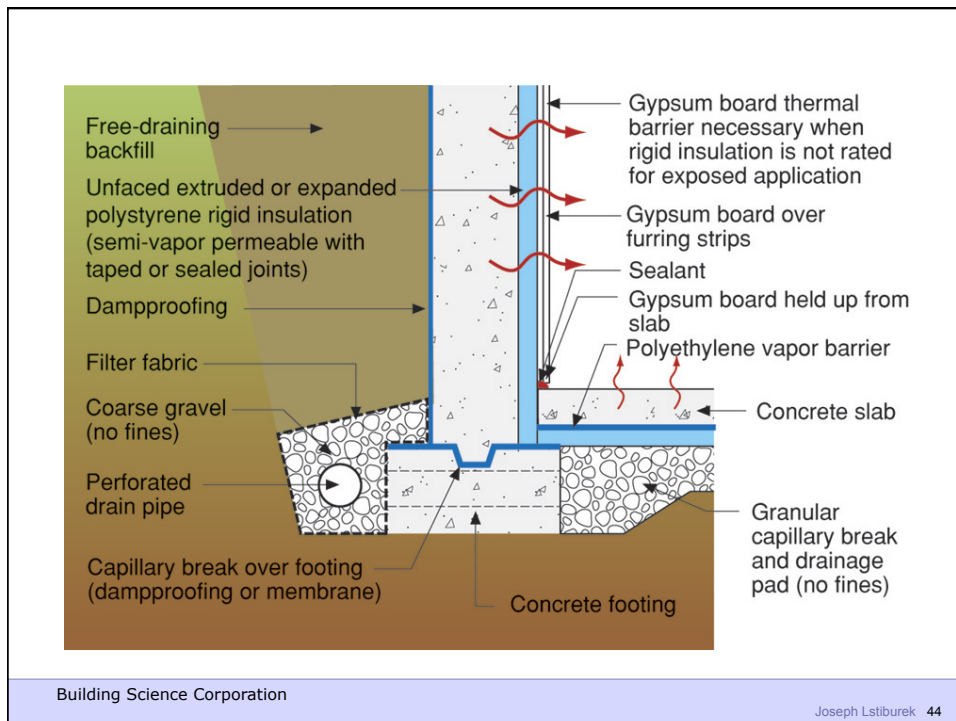
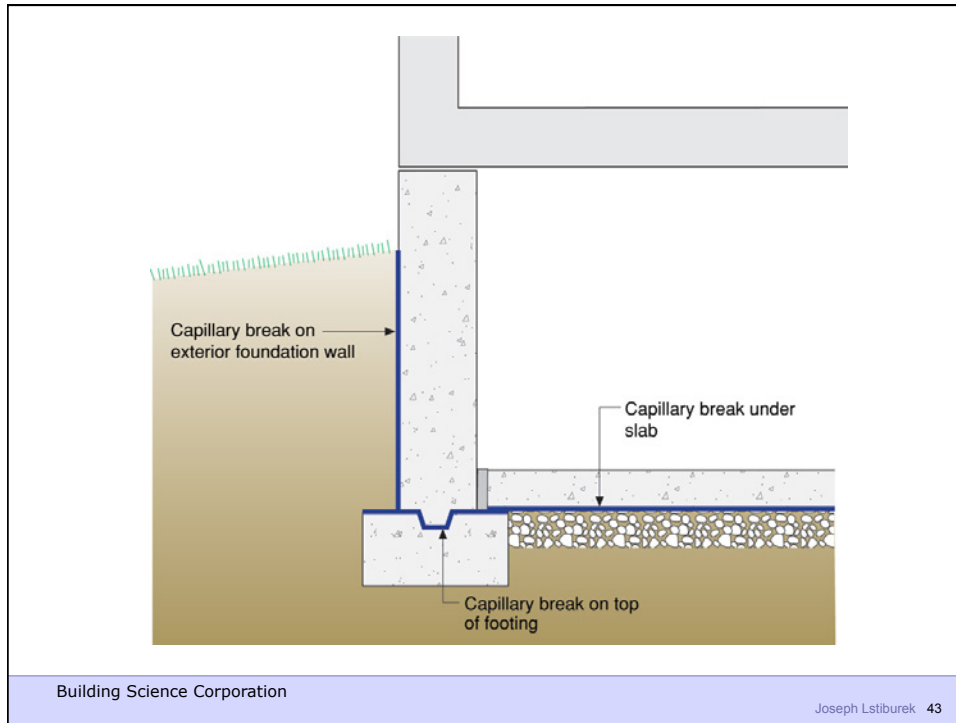
Joseph Lstiburek 39

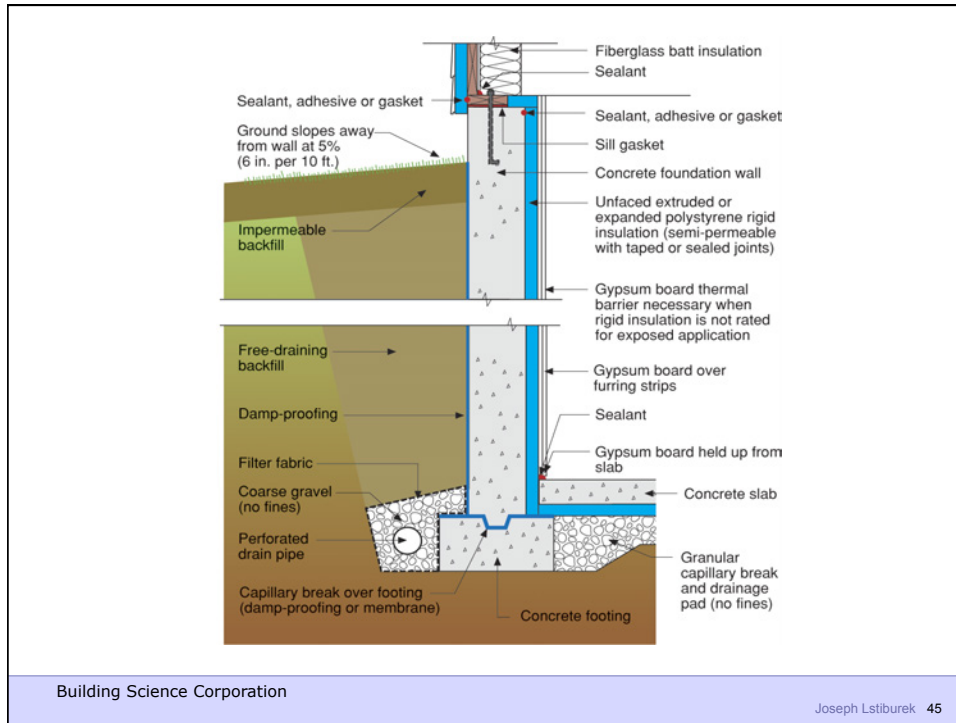


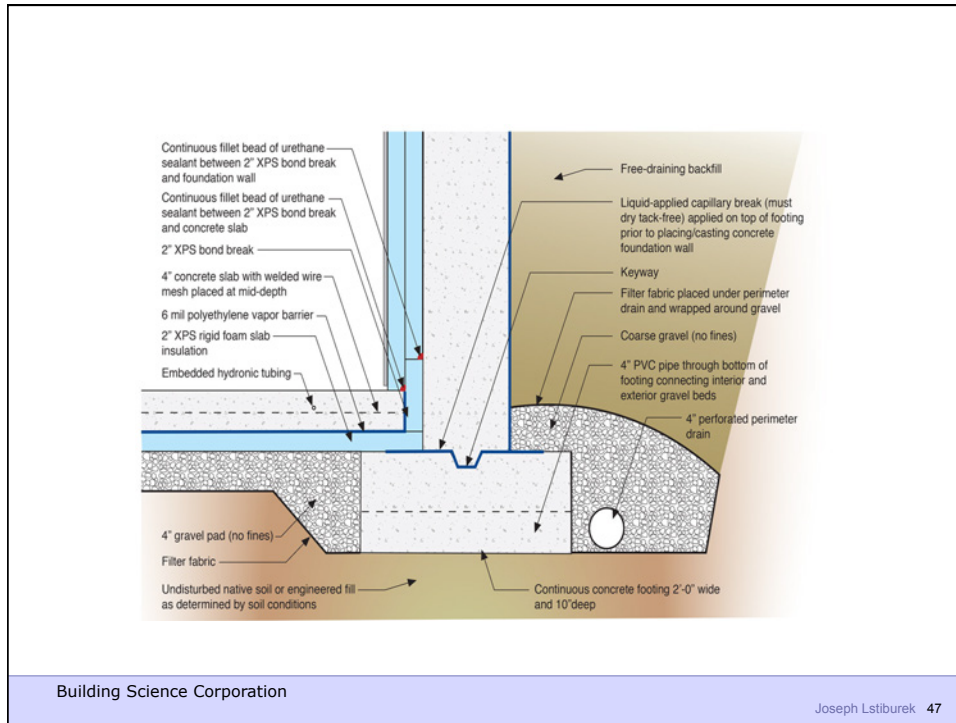
Building Science Corporation

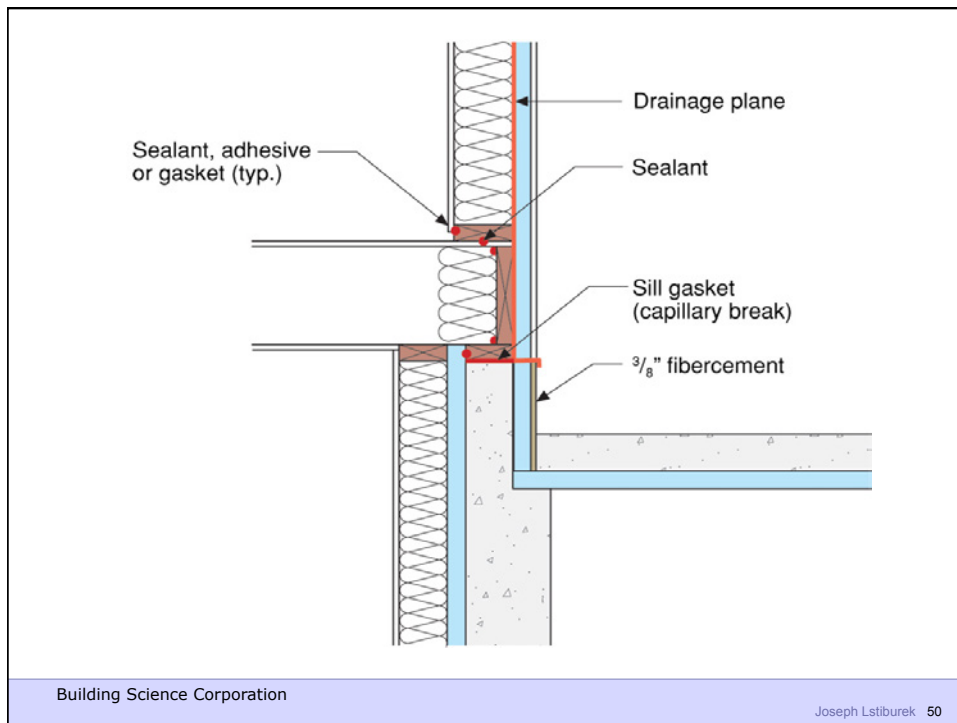
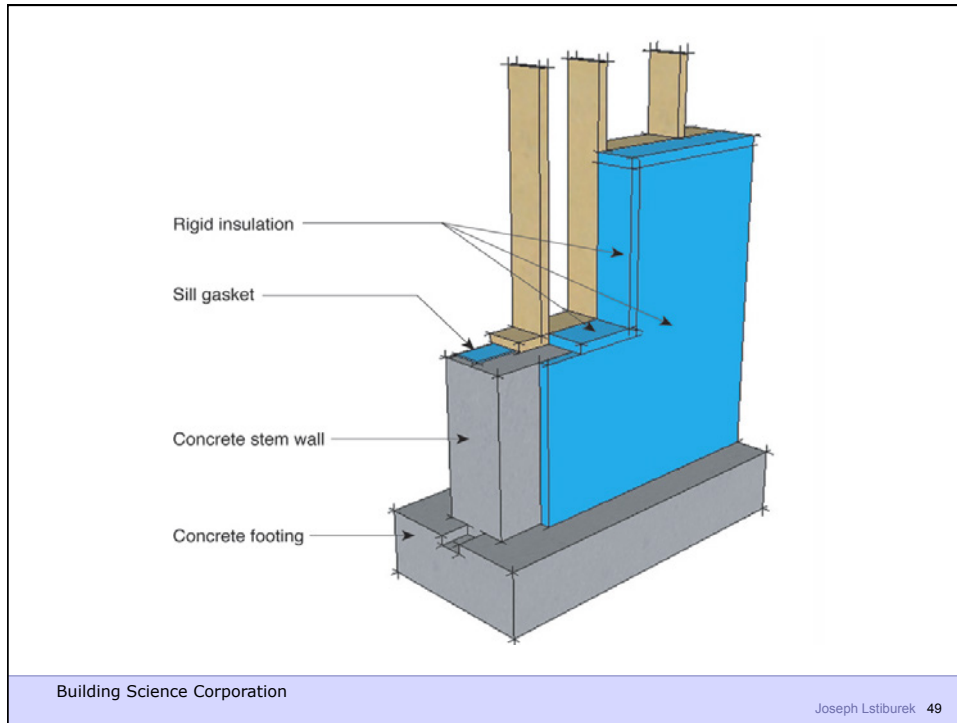
Joseph Lstiburek 40

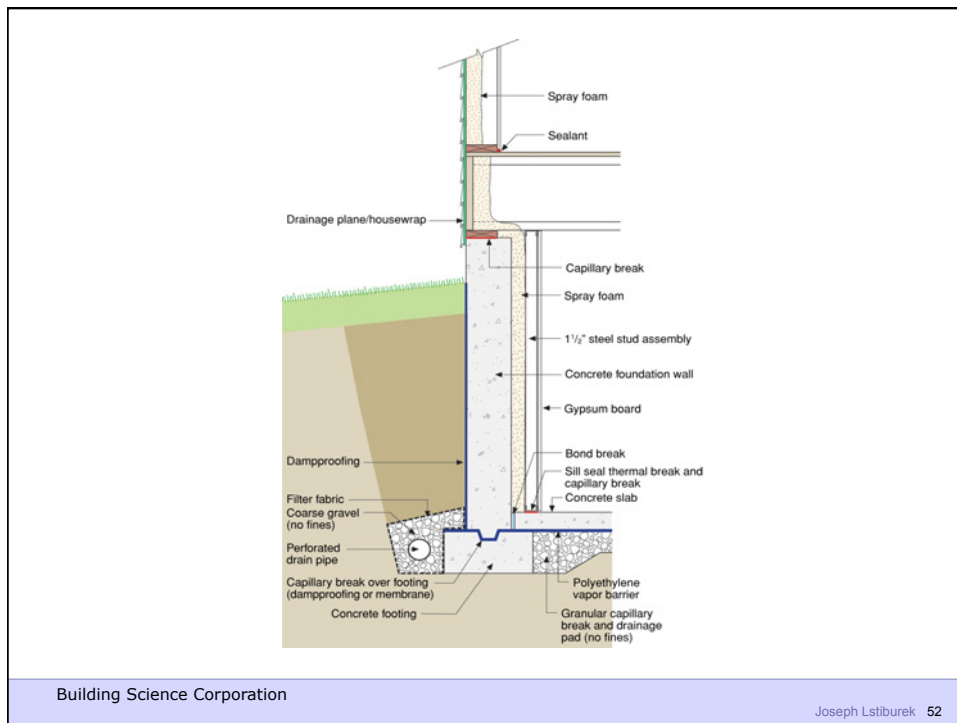
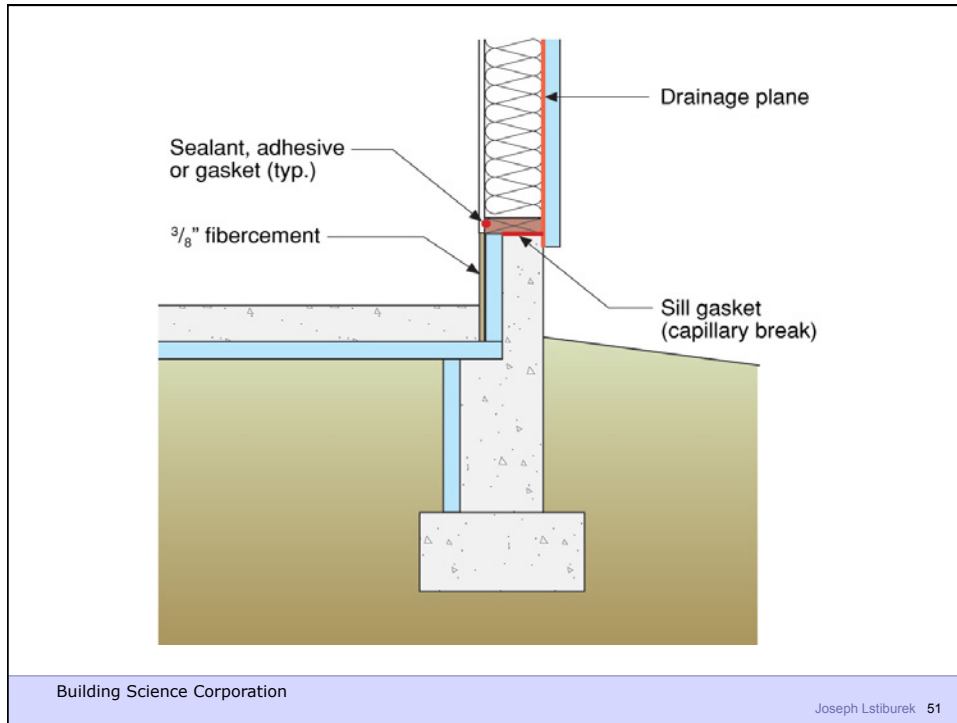
















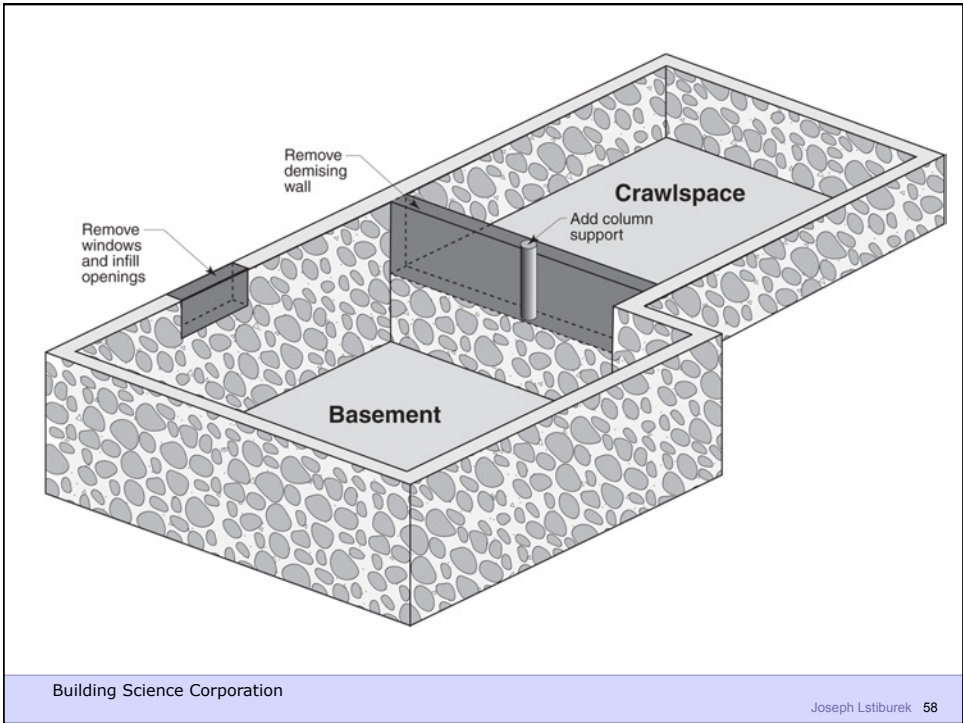
Building Science Corporation

Joseph Lstiburek 55



Building Science Corporation

Joseph Lstiburek 56

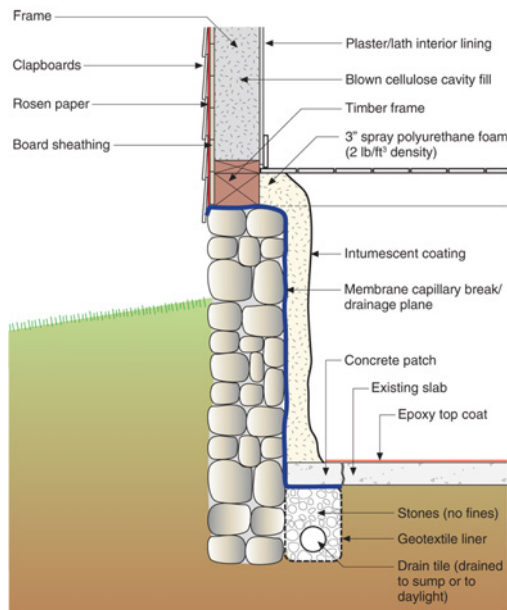






Building Science Corporation

Joseph Lstiburek 61



Building Science Corporation

Joseph Lstiburek 62



Building Science Corporation

Joseph Lstiburek 63



Building Science Corporation

Joseph Lstiburek 64



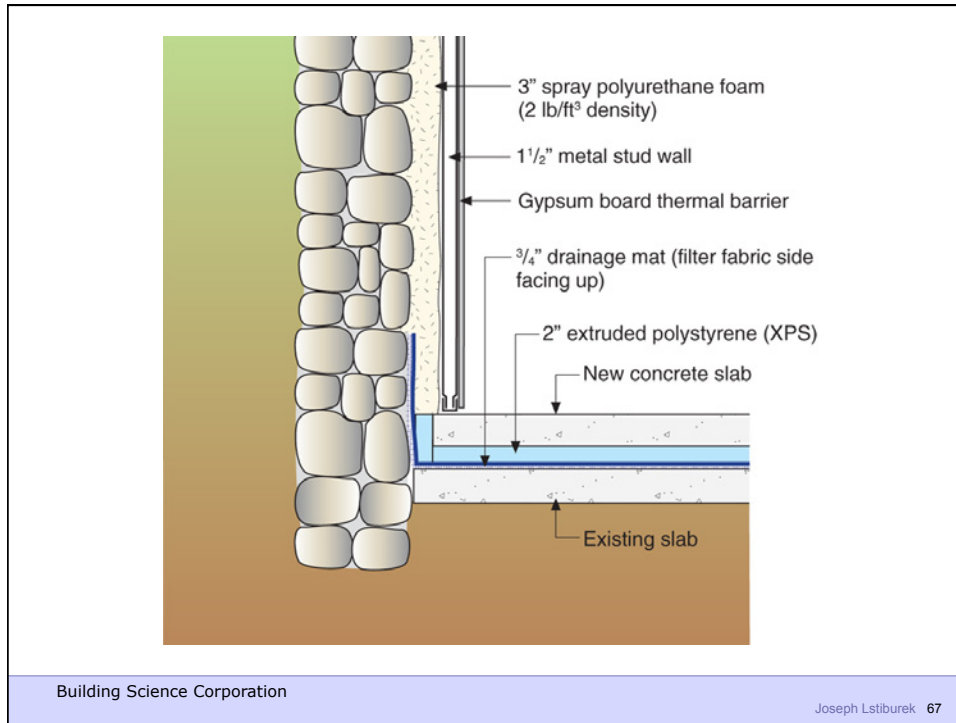
Building Science Corporation

Joseph Lstiburek 65



Building Science Corporation

Joseph Lstiburek 66





Building Science Corporation

Joseph Lstiburek 69



Building Science Corporation

Joseph Lstiburek 70



Building Science Corporation

Joseph Lstiburek 71



Building Science Corporation

Joseph Lstiburek 72



Building Science Corporation

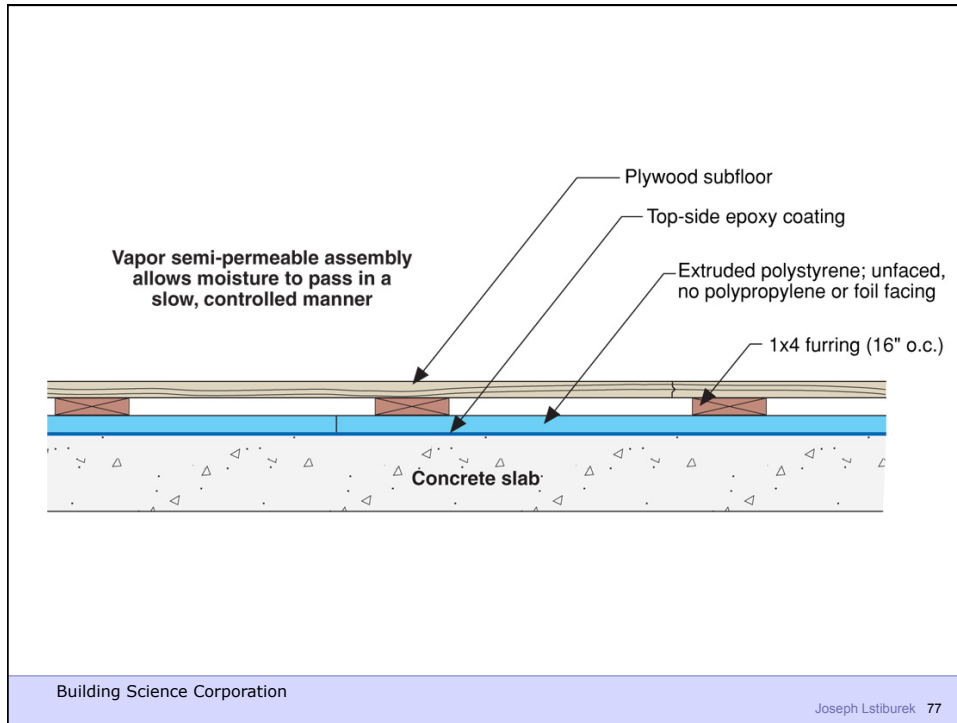
Joseph Lstiburek 73

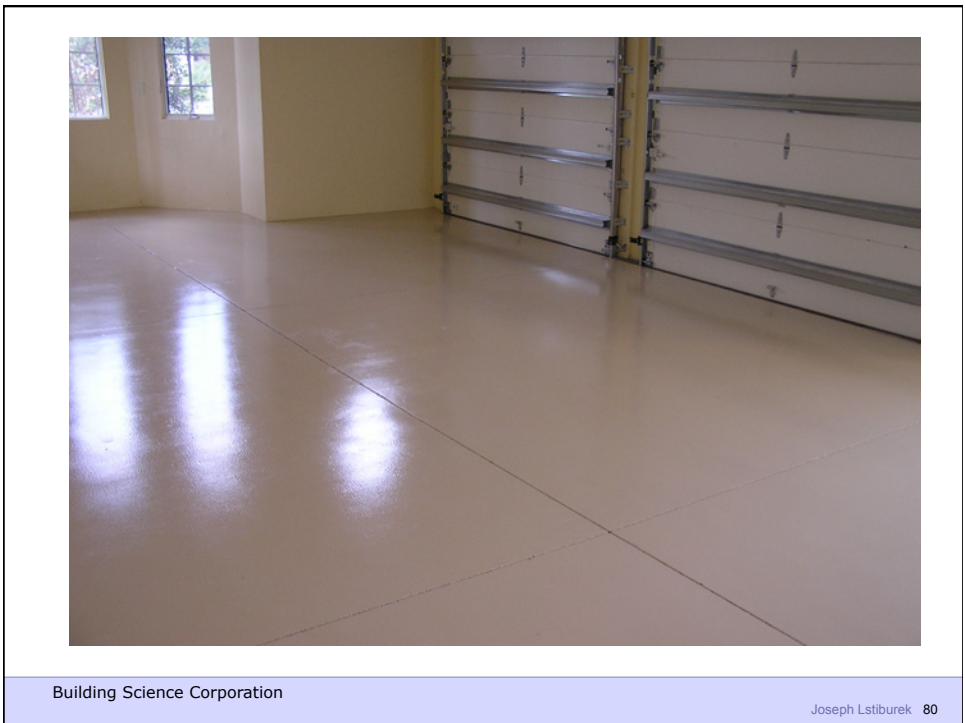
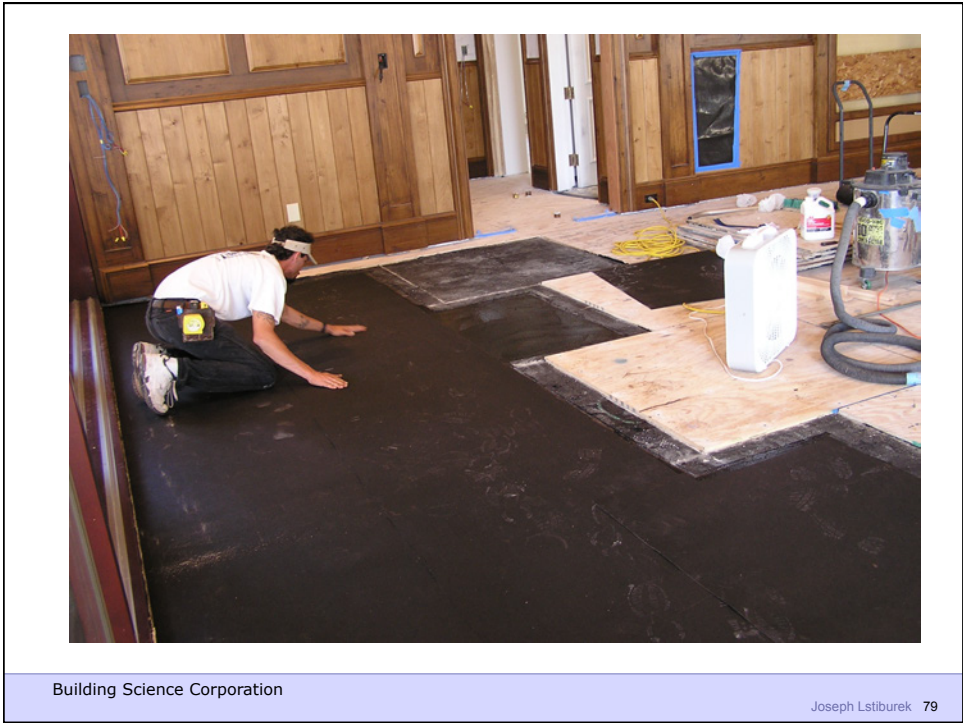


Building Science Corporation

Joseph Lstiburek 74







Carpet or wood floor (avoid vinyl flooring as vinyl flooring does not breathe)

$\frac{3}{4}$ " plywood (T&G — narrow edges "biscuit" joined)

Rigid insulation (extruded polystyrene — unfaced, no polypropylene or foil facers)

Airspace

Dimpled plastic sheet membrane (air tight and gas tight)

Existing slab

Damp ground (no capillary break, no polyethylene ground cover)

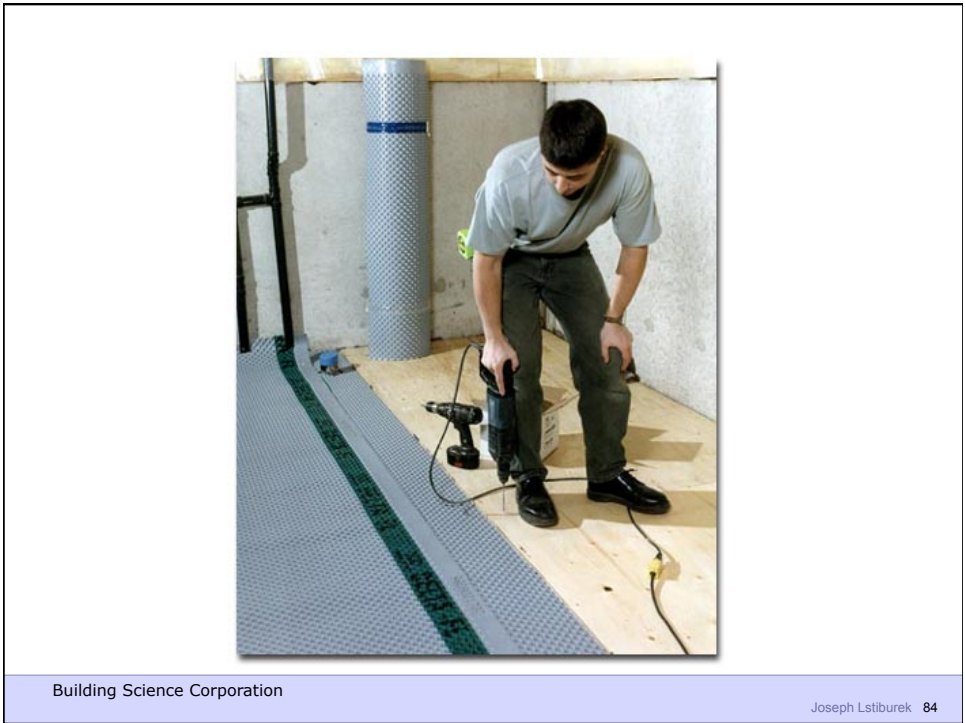
Vapor pressure on top of slab and under slab equalizes, thereby stopping capillary transfer of water and soluble mineral salts (moisture content in air space and under slab remains the same; i.e. "wet")

Building Science Corporation

Joseph Lstiburek 81

Building Science Corporation

Joseph Lstiburek 82





Building Science Corporation

Joseph Lstiburek 85

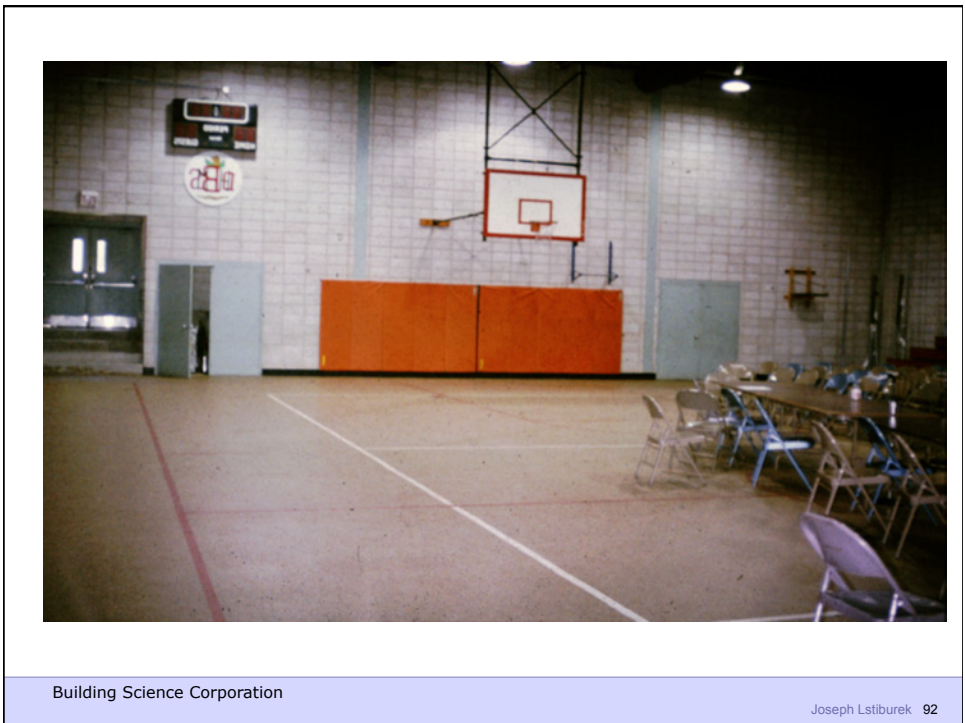


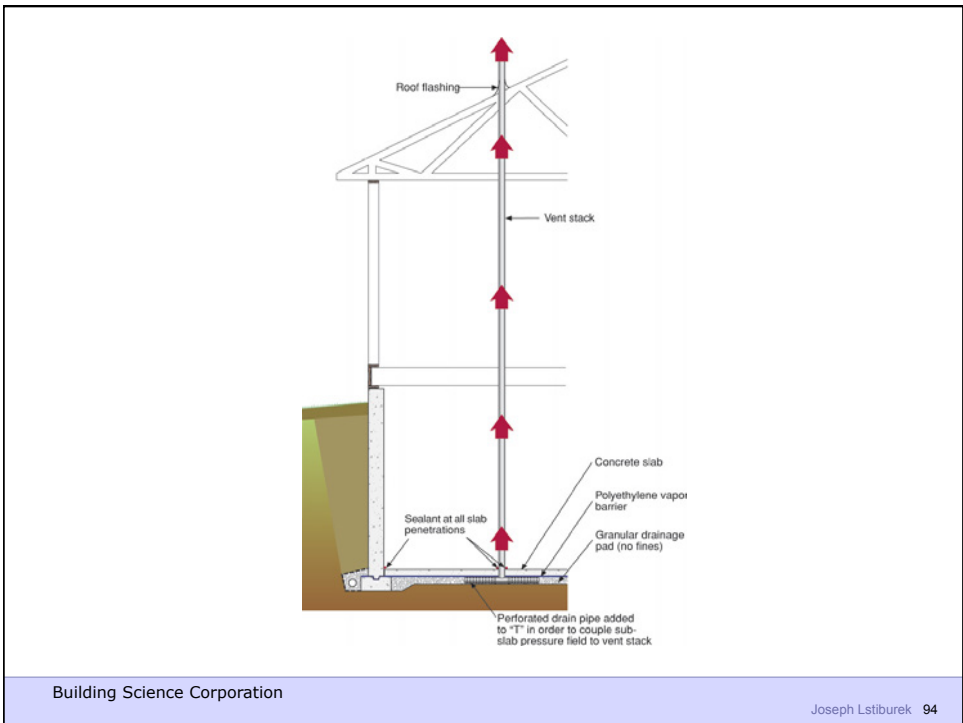
Building Science Corporation

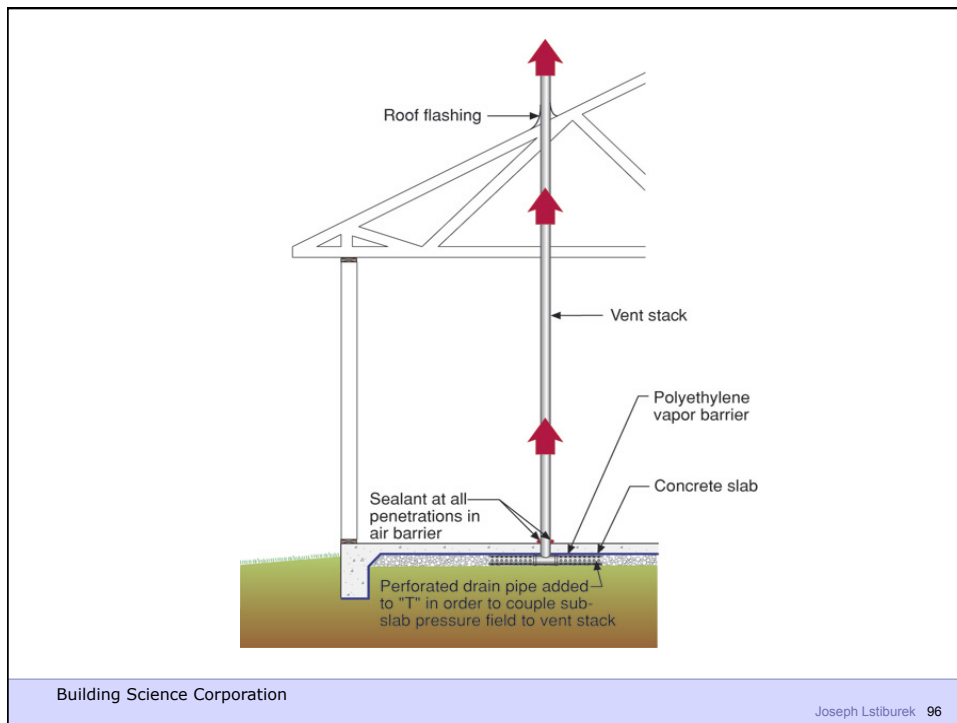
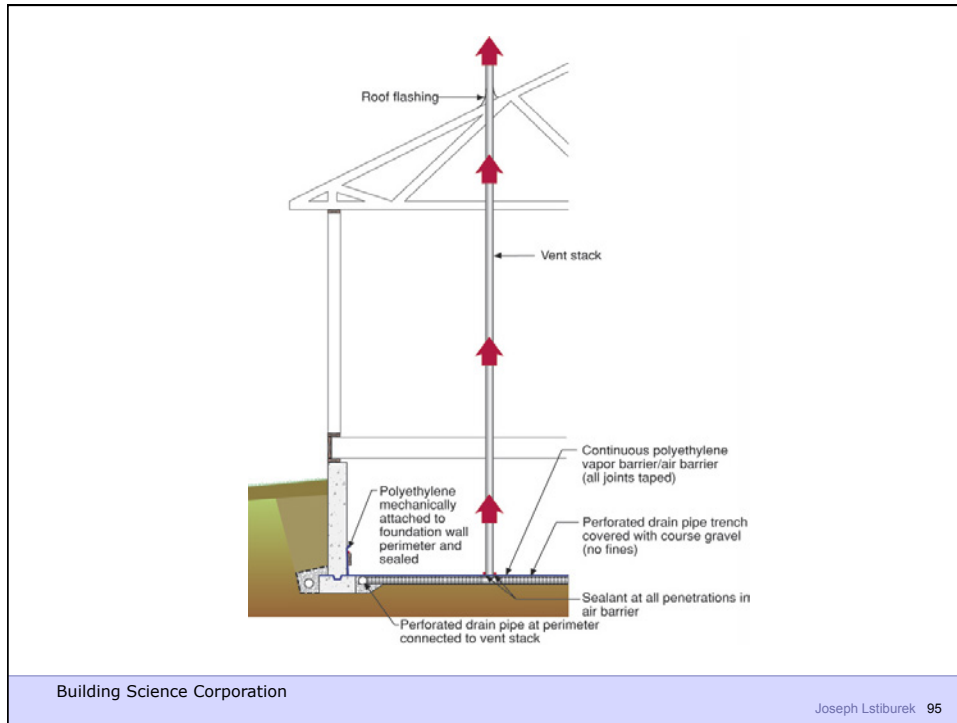
Joseph Lstiburek 86

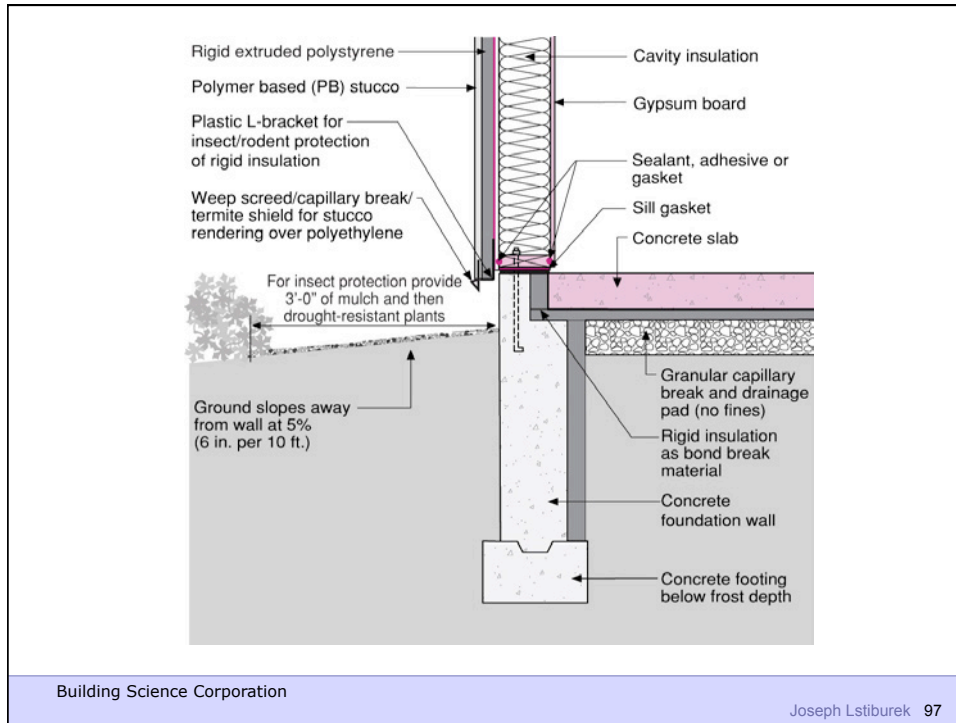














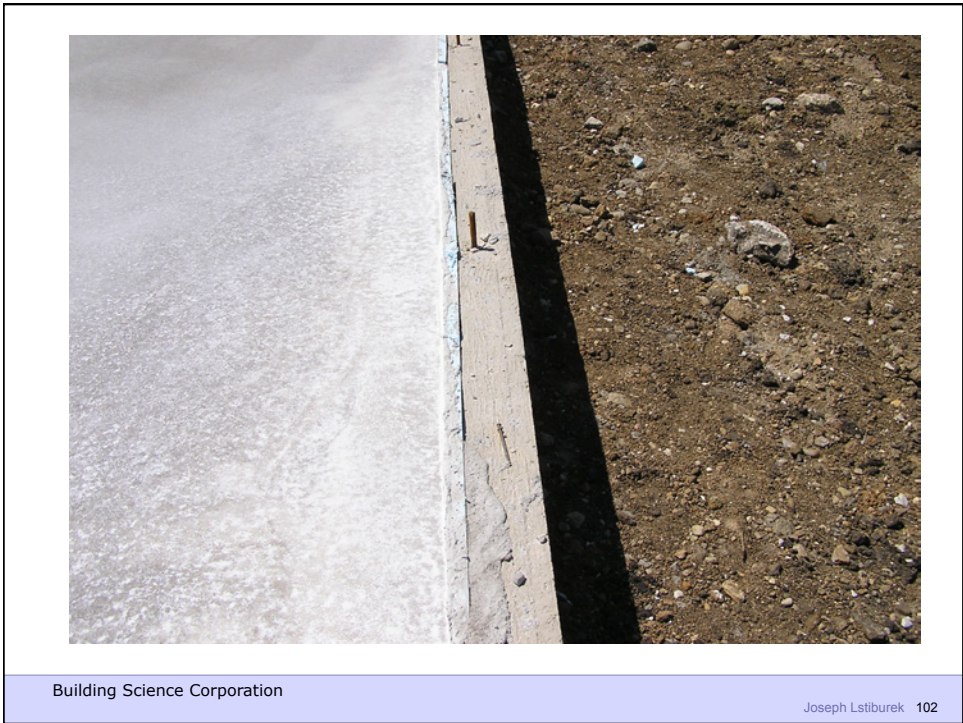
Building Science Corporation

Joseph Lstiburek 99



Building Science Corporation

Joseph Lstiburek 100

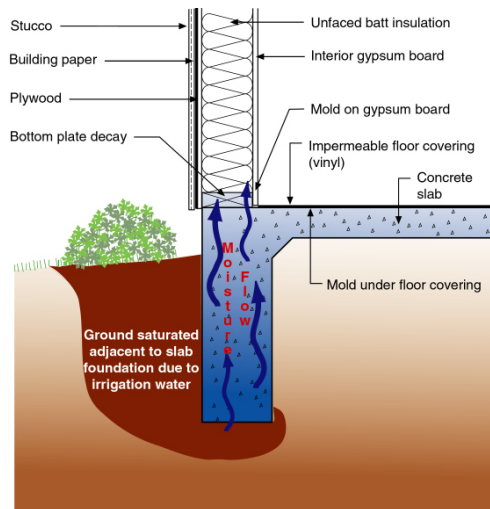




Building Science Corporation

Joseph Lstiburek 103

Capillary Moisture Flow



Building Science Corporation

Joseph Lstiburek 104

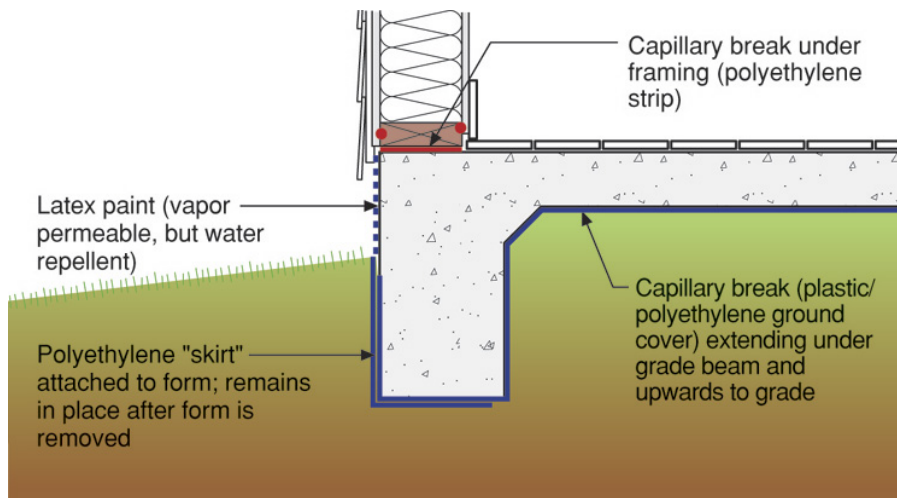






Building Science Corporation

Joseph Lstiburek 109



Building Science Corporation

Joseph Lstiburek 110



Building Science Corporation

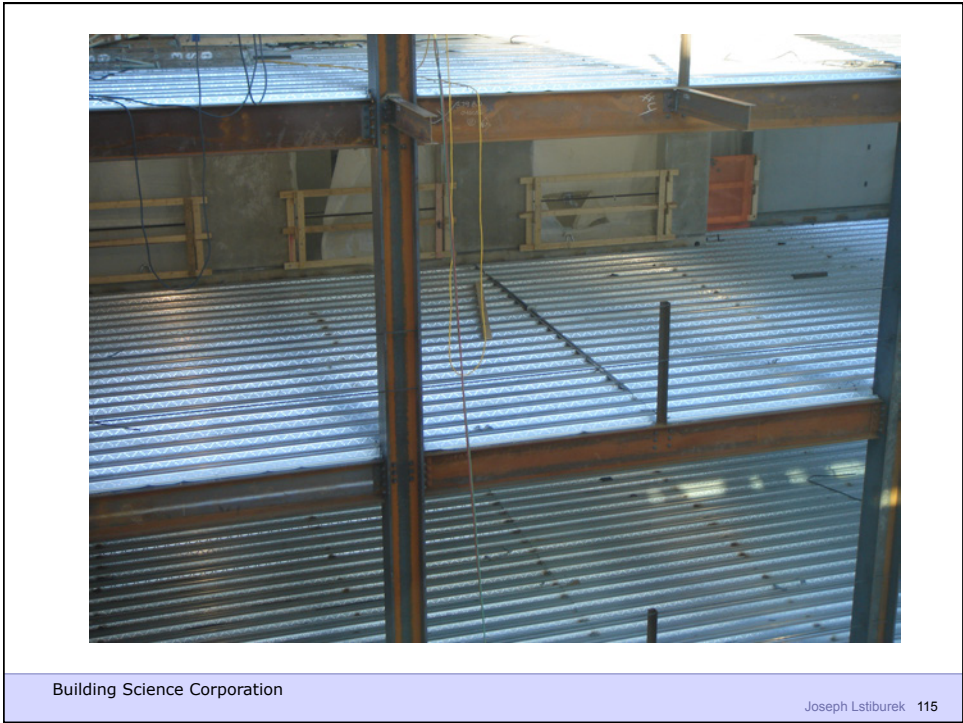
Joseph Lstiburek 111



Building Science Corporation

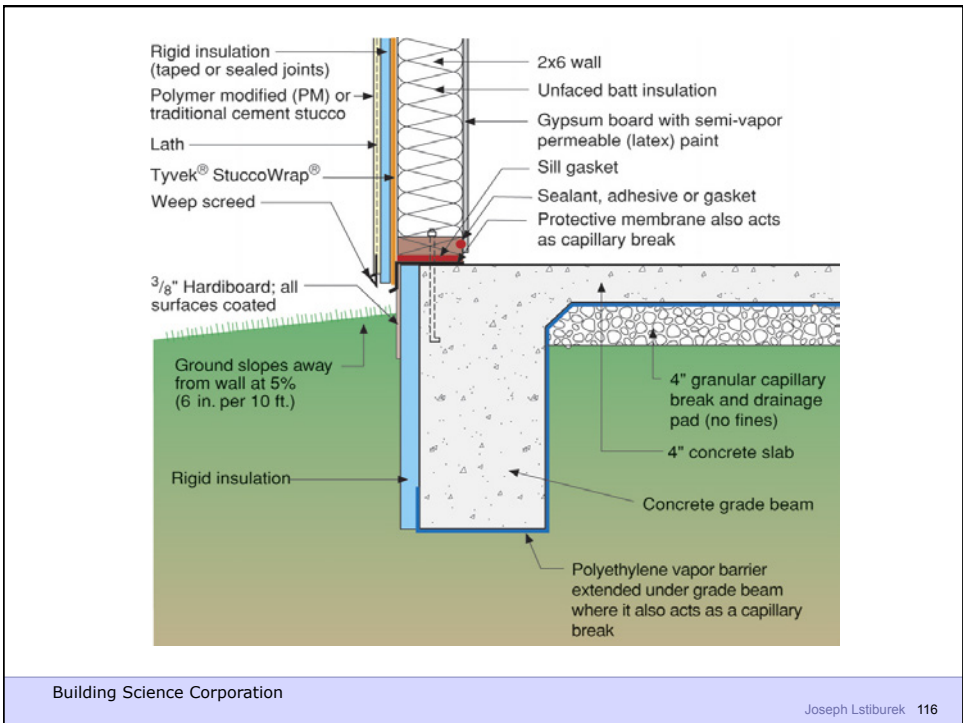
Joseph Lstiburek 112





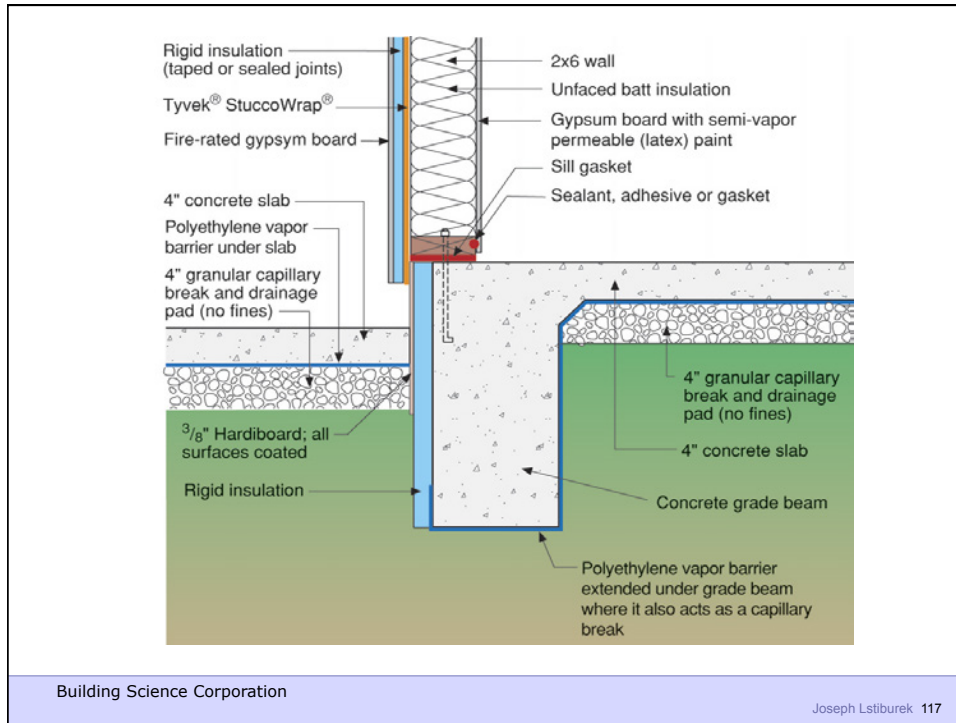
Building Science Corporation

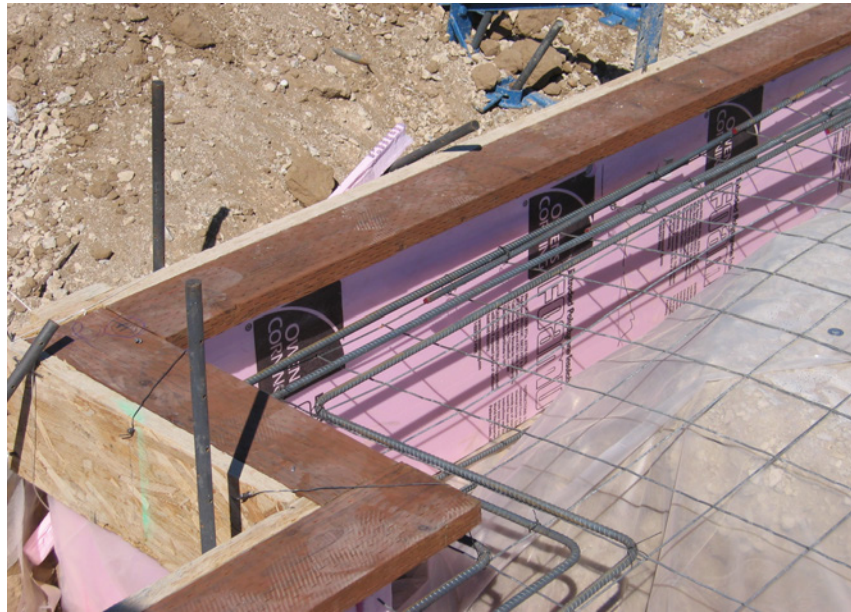
Joseph Lstiburek 115



Building Science Corporation

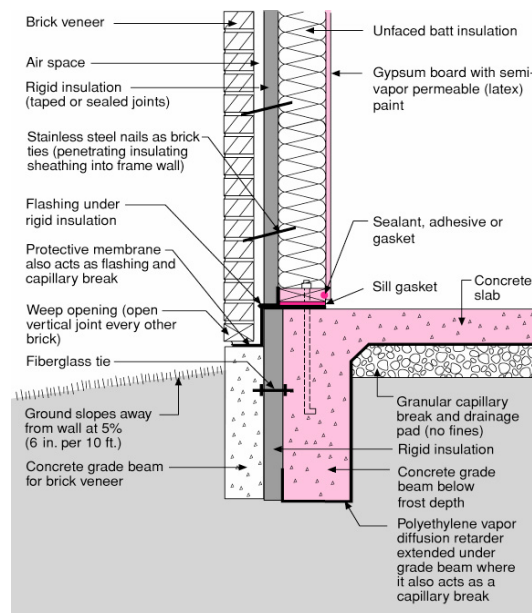
Joseph Lstiburek 116





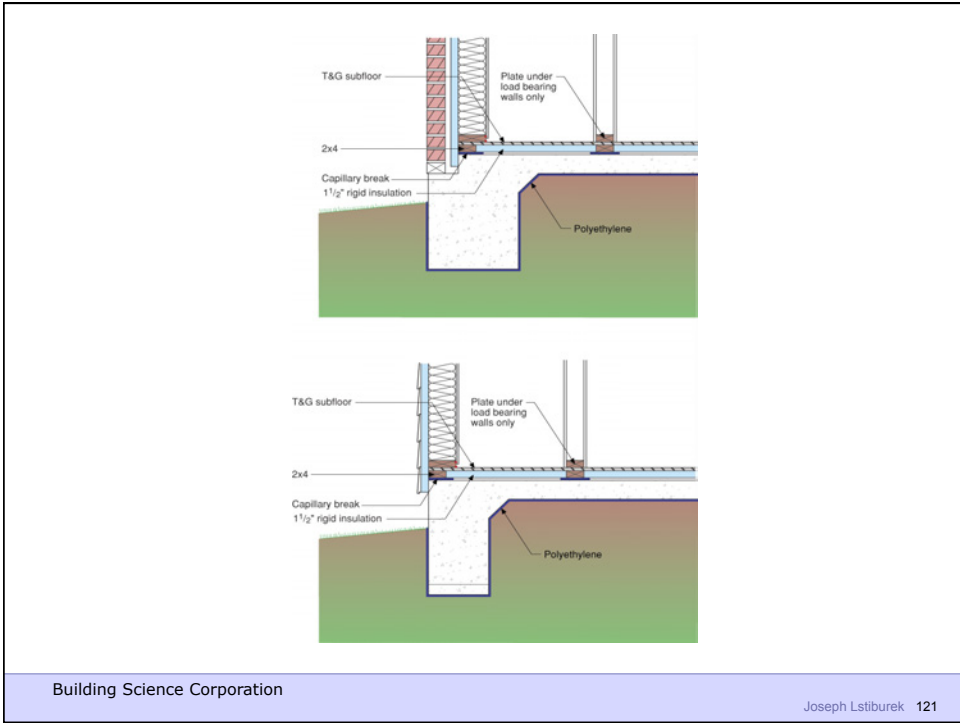
Building Science Corporation

Joseph Lstiburek 119



Building Science Corporation

Joseph Lstiburek 120

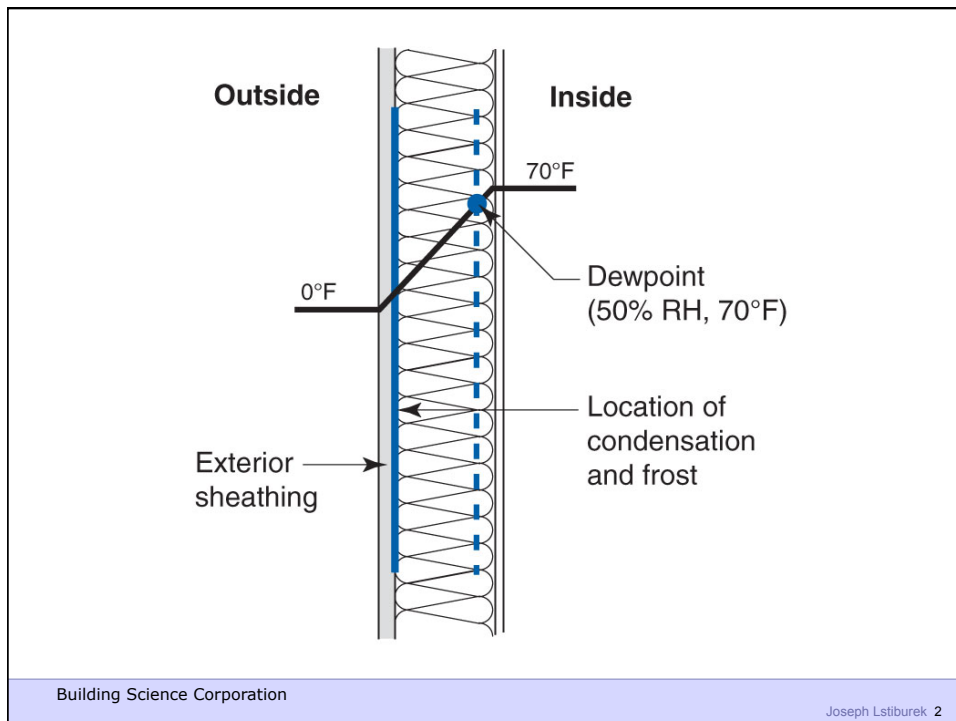


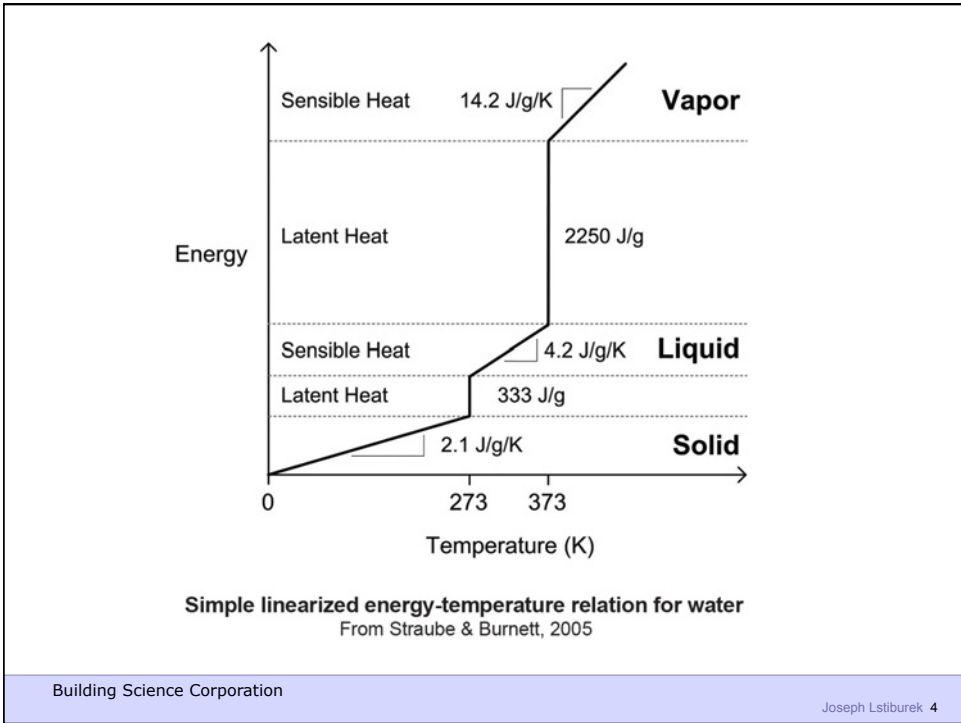
Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

Adventures In Building Science

www.buildingscience.com

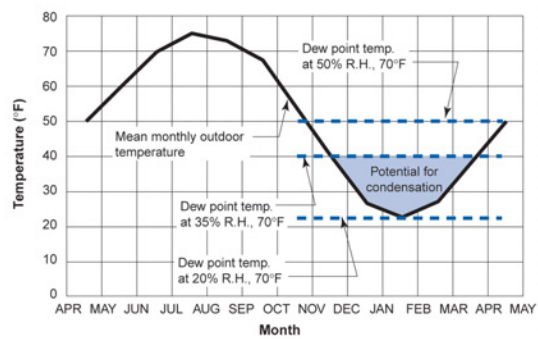
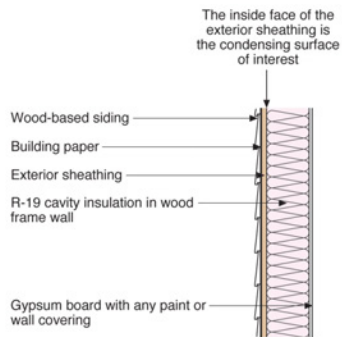






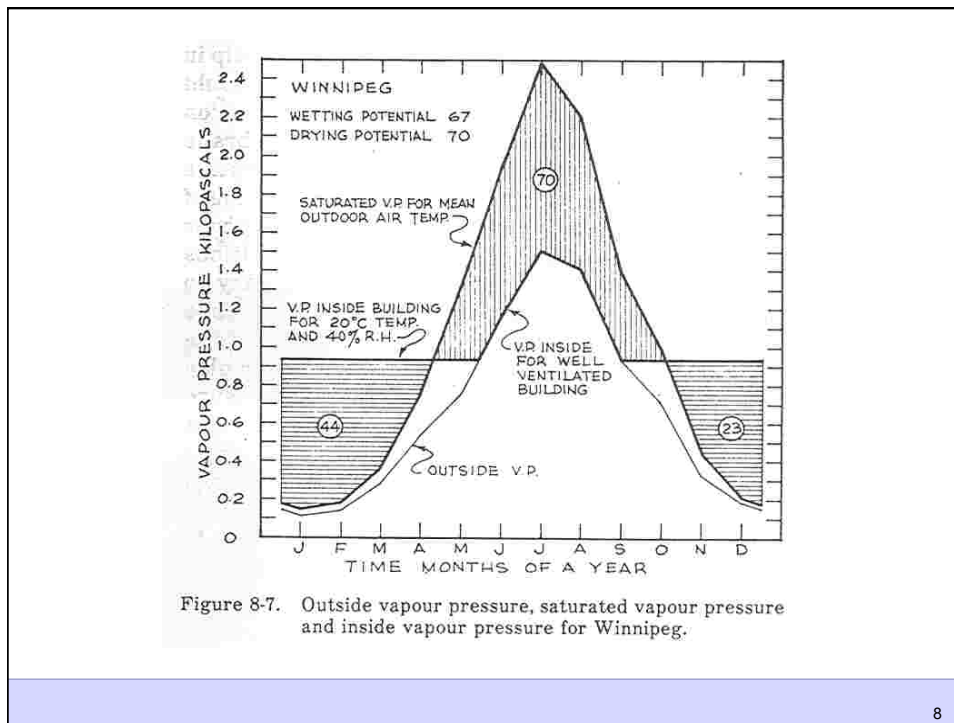
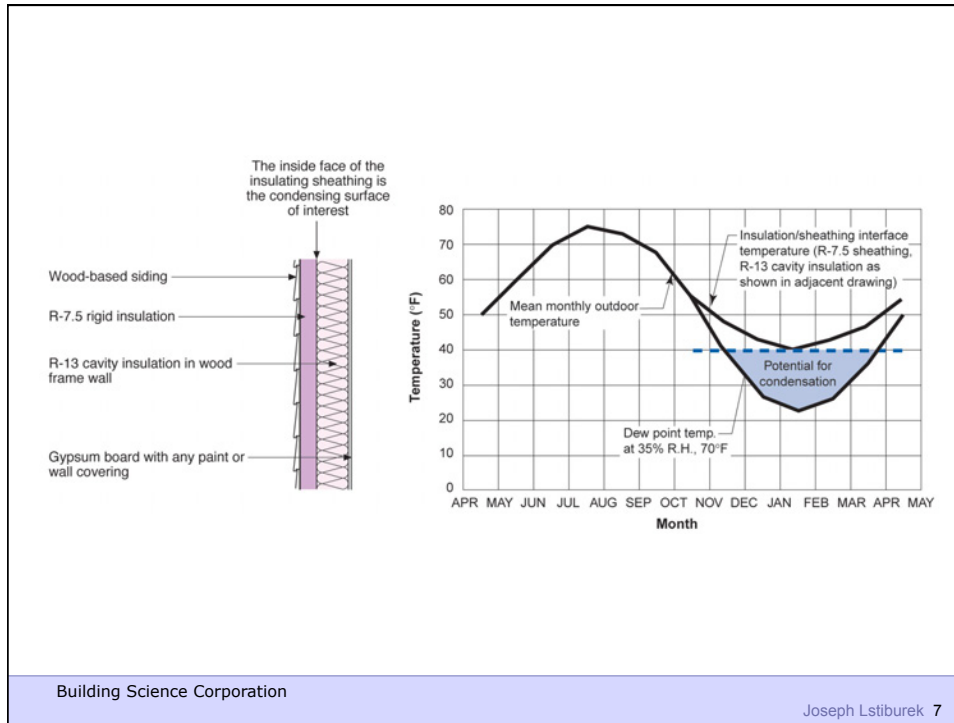
Building Science Corporation

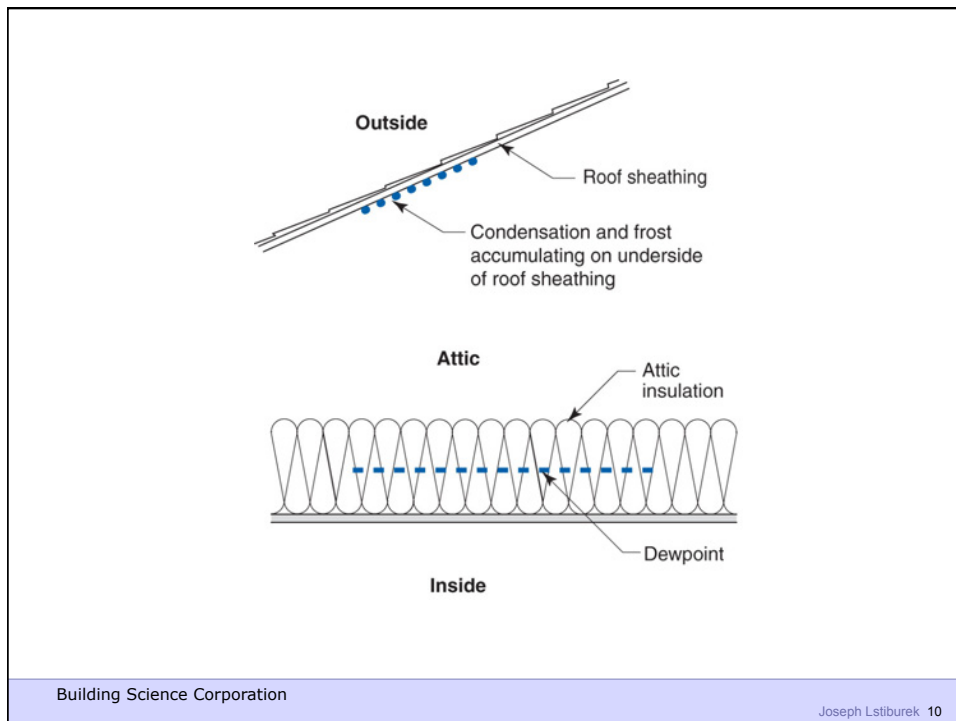
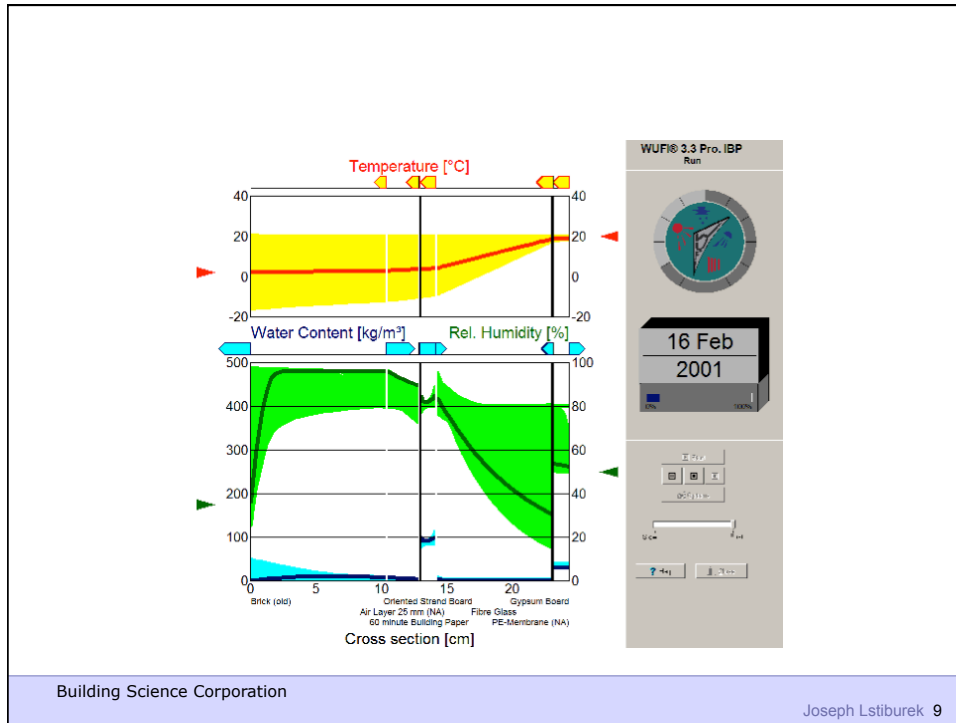
Joseph Lstiburek 5

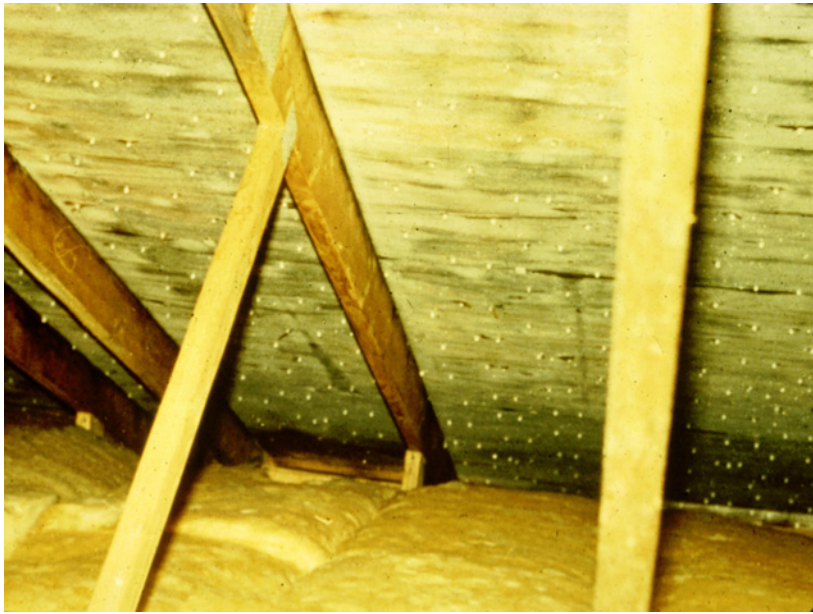


Building Science Corporation

Joseph Lstiburek 6

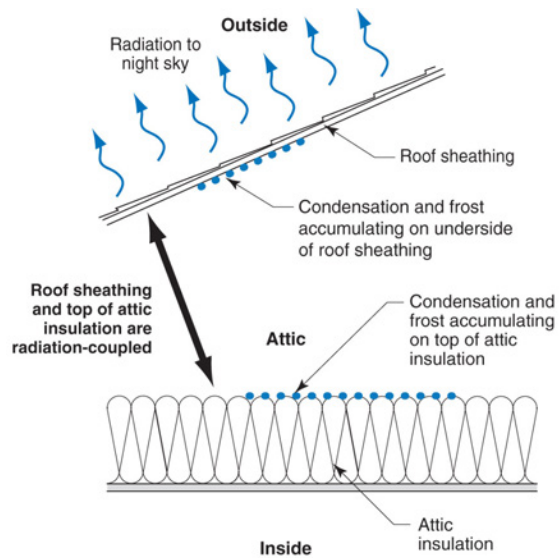






Building Science Corporation

Joseph Lstiburek 11



Building Science Corporation

Joseph Lstiburek 12



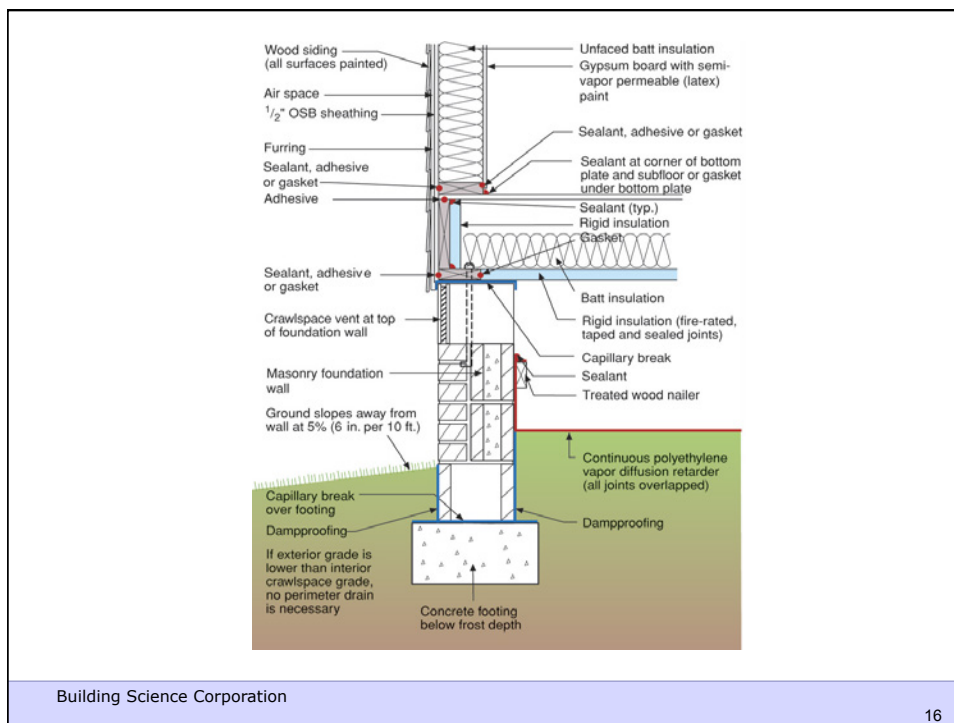
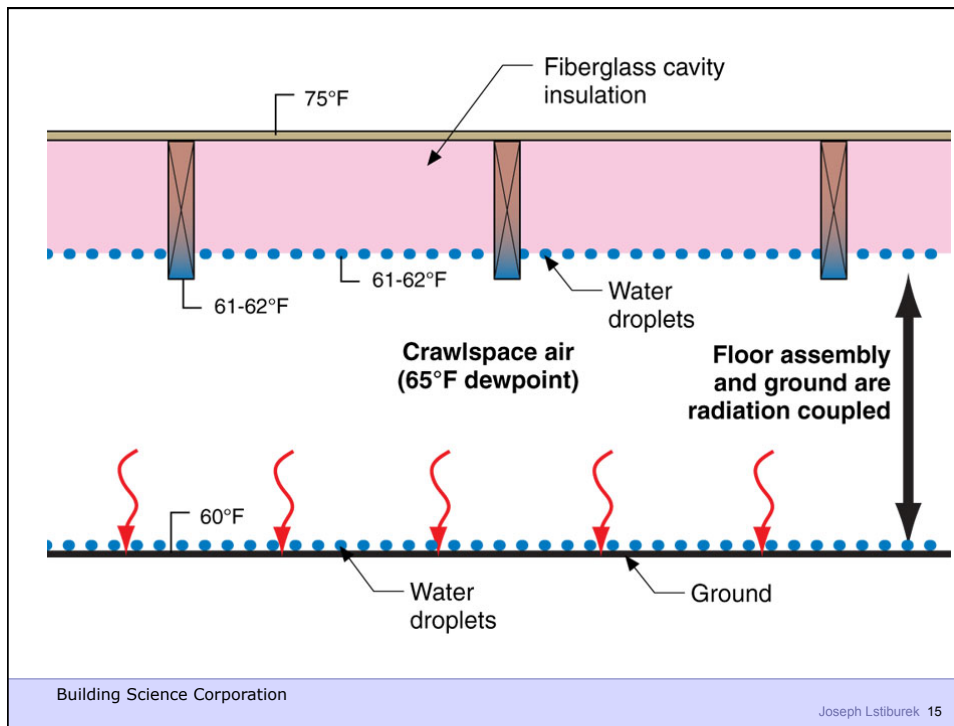
Building Science Corporation

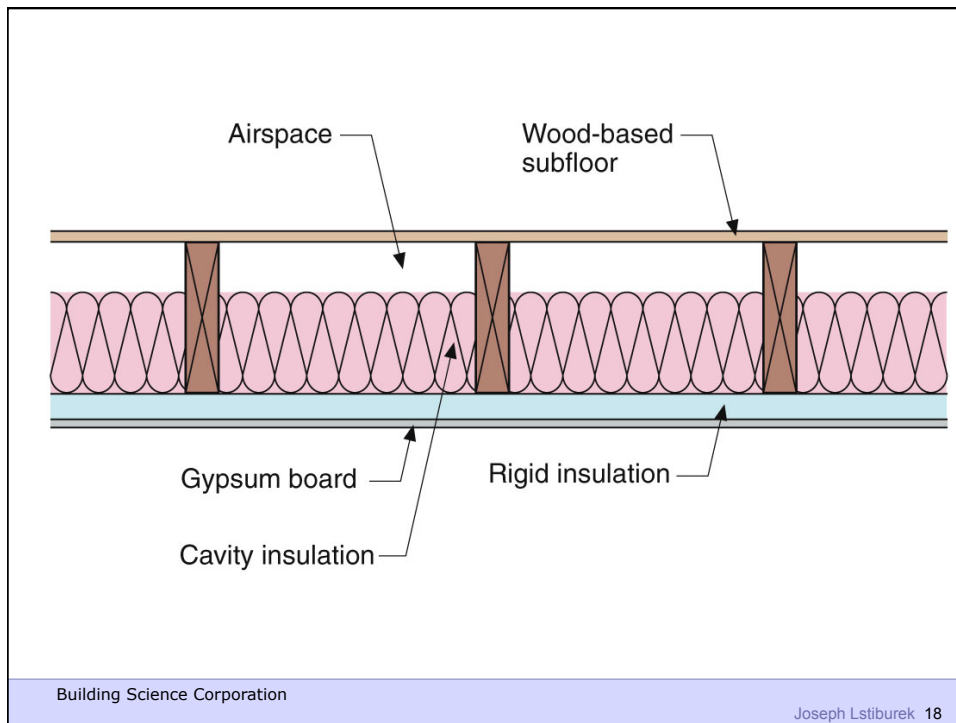
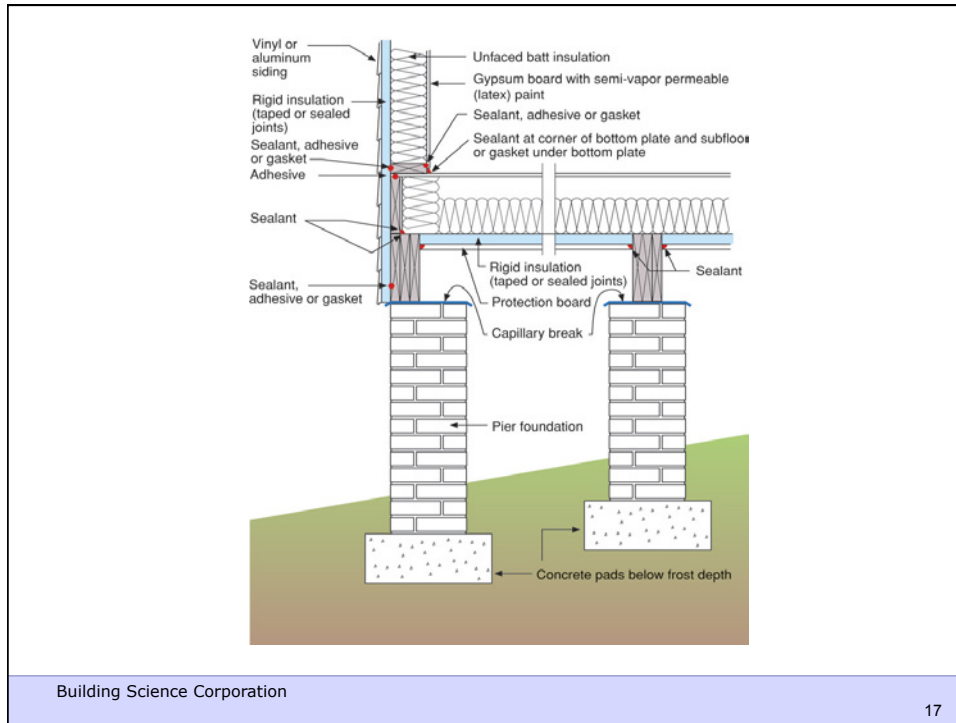
Joseph Lstiburek 13

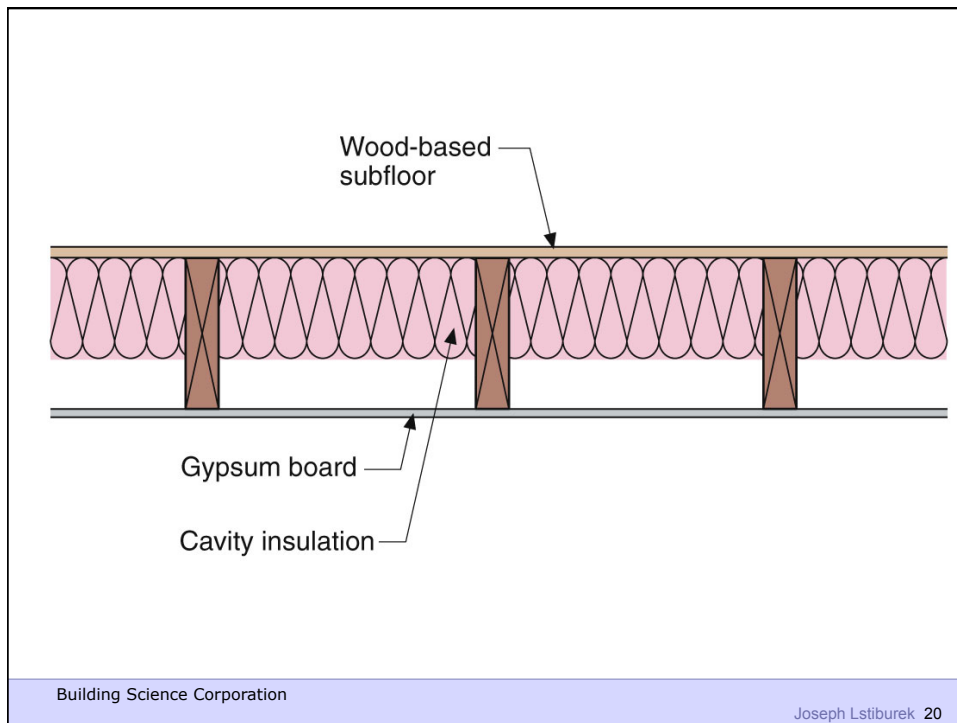
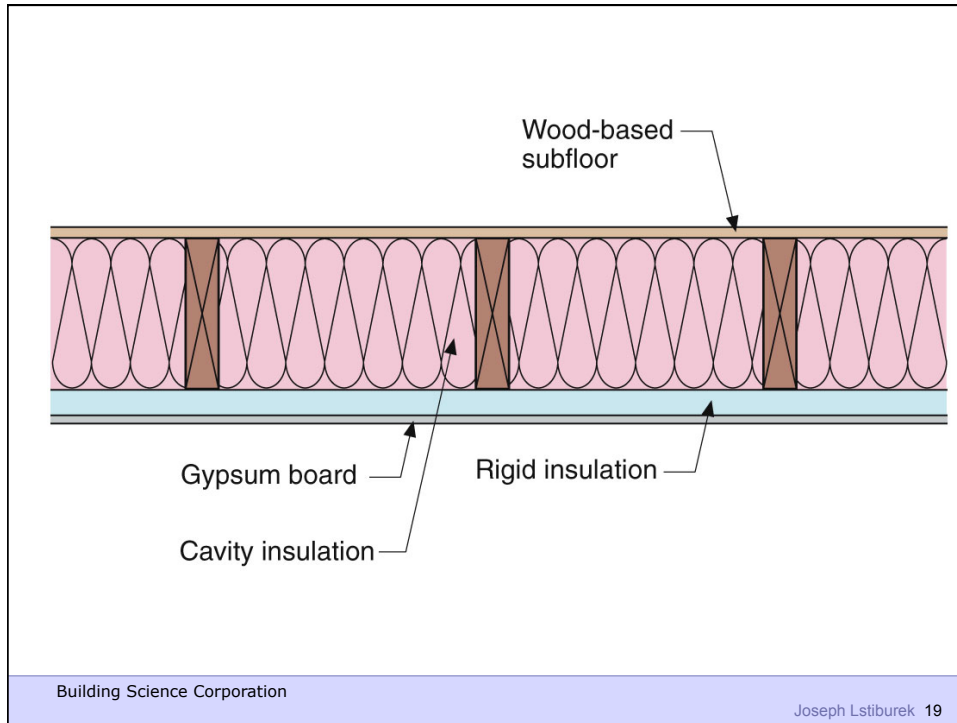


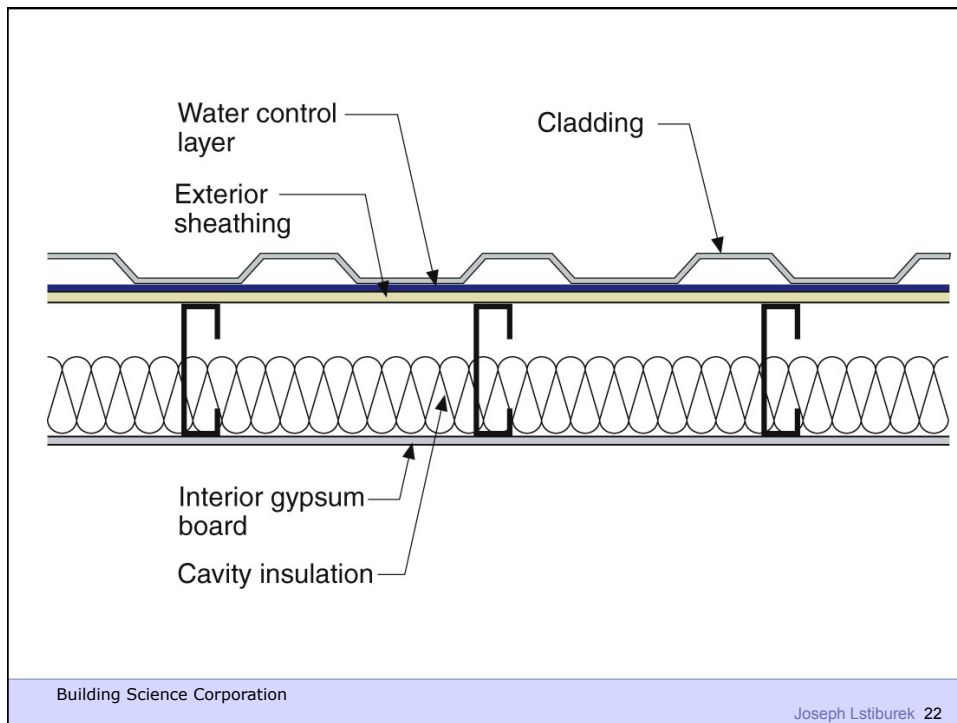
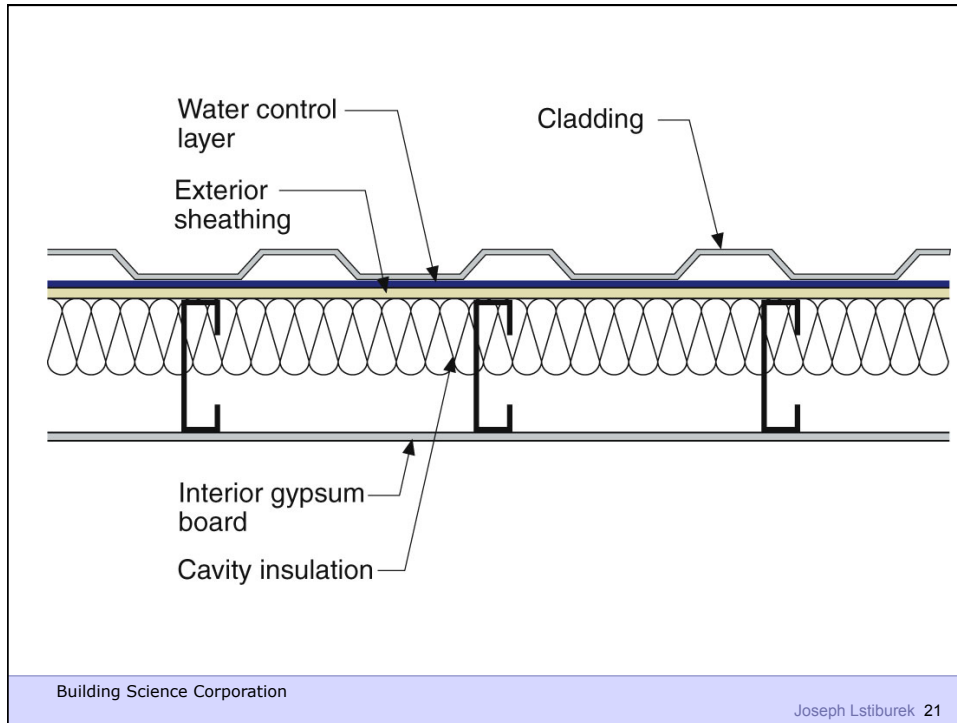
Building Science Corporation

Joseph Lstiburek 14









Don't Do Stupid Things

Building Science Corporation

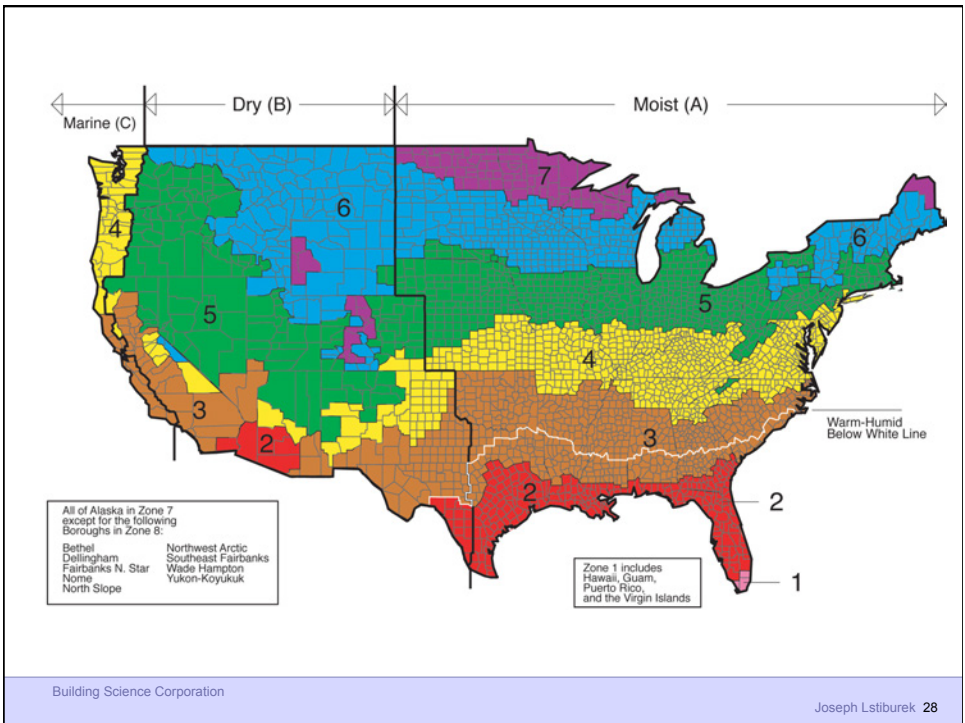
Joseph Lstiburek 23



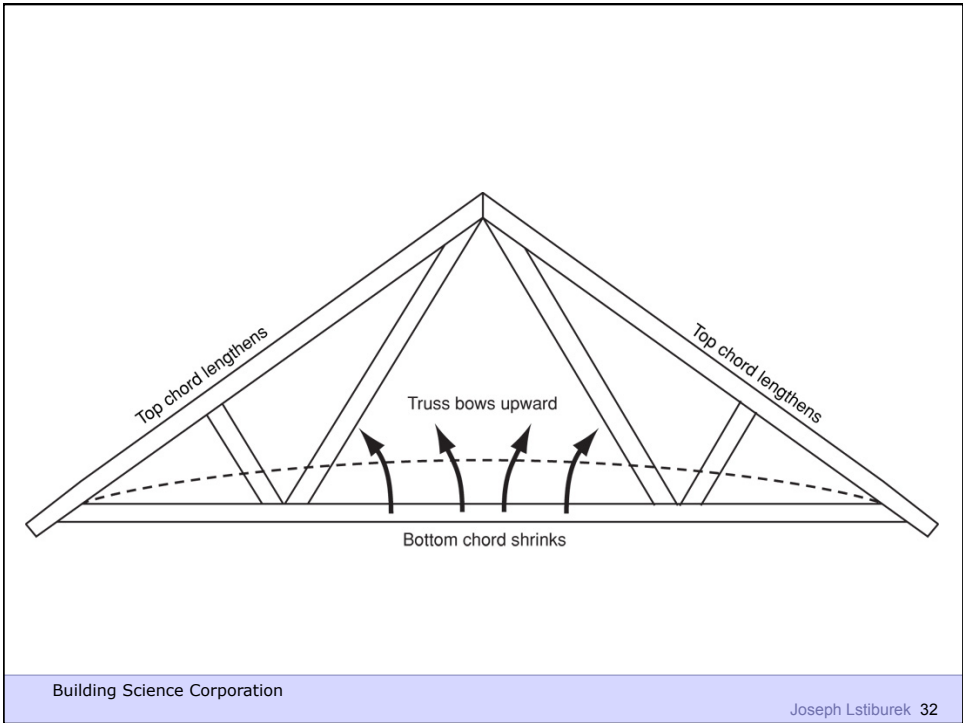
Building Science Corporation

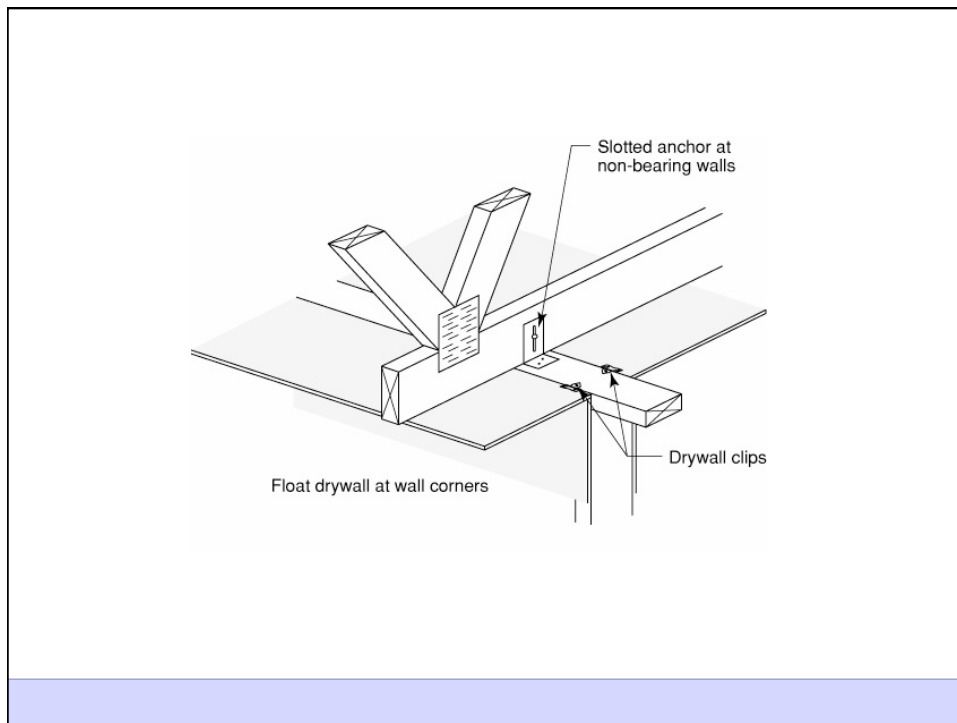
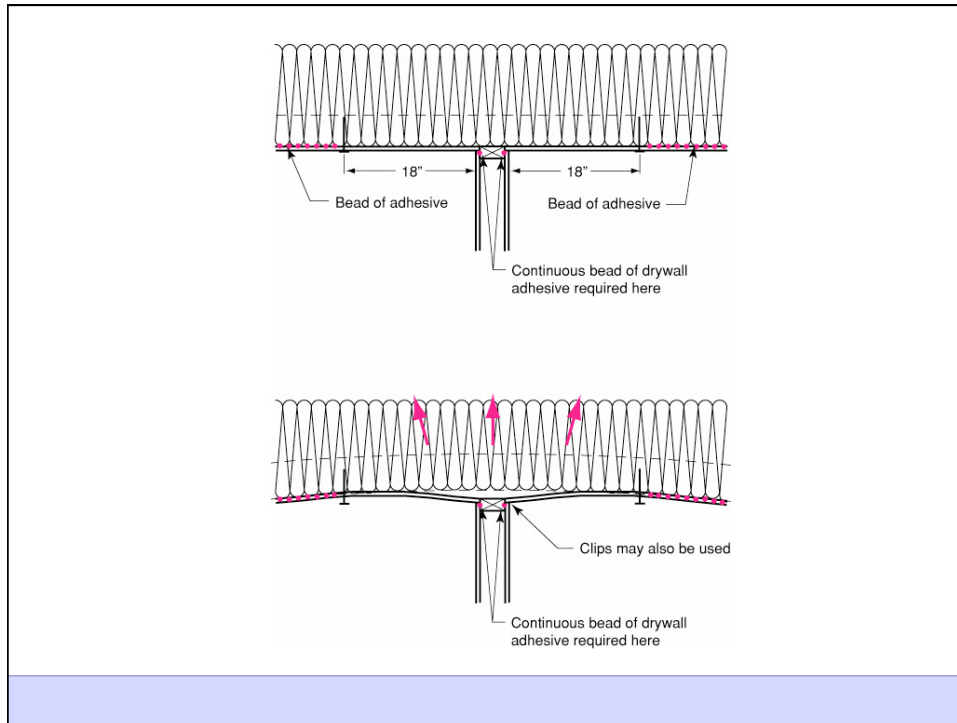
Joseph Lstiburek 24













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

Building Science

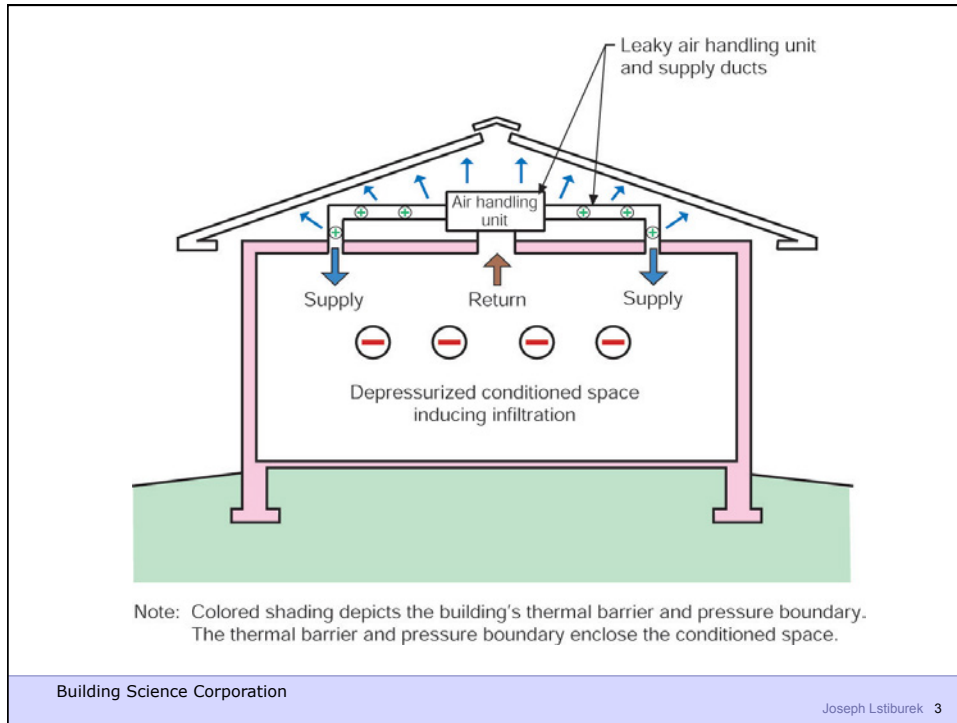
HVAC Systems

presented by www.buildingscience.com

Don't Do Stupid Things

Building Science Corporation

Joseph Lstiburek 2





Building Science Corporation

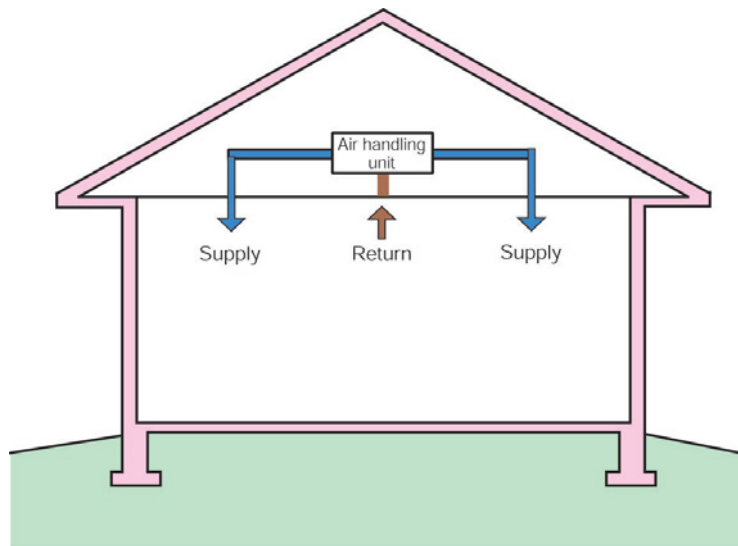
Joseph Lstiburek 5



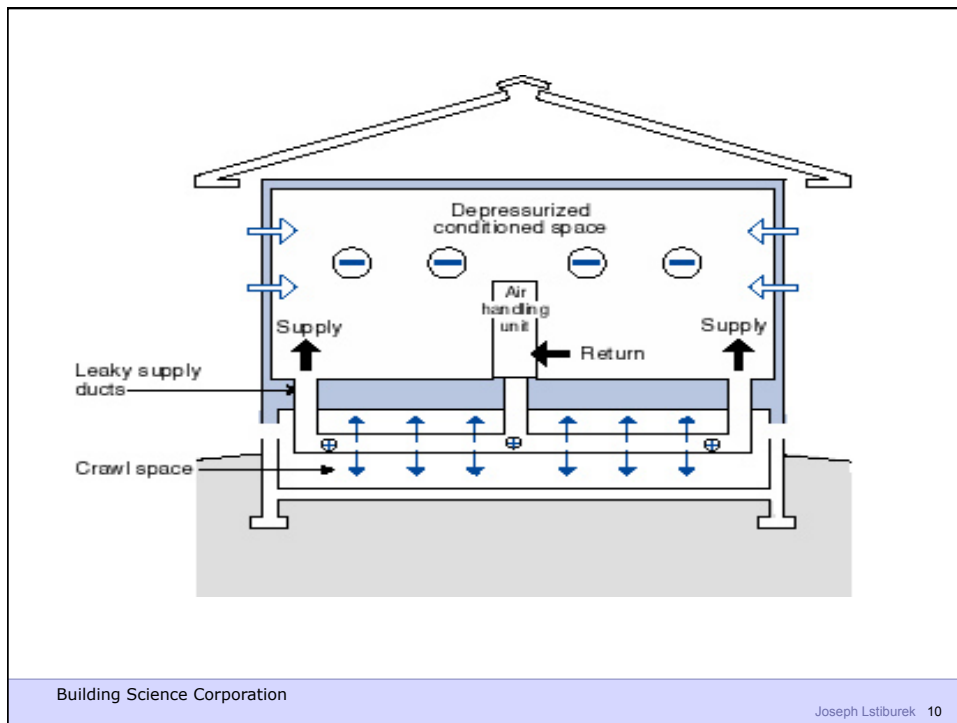
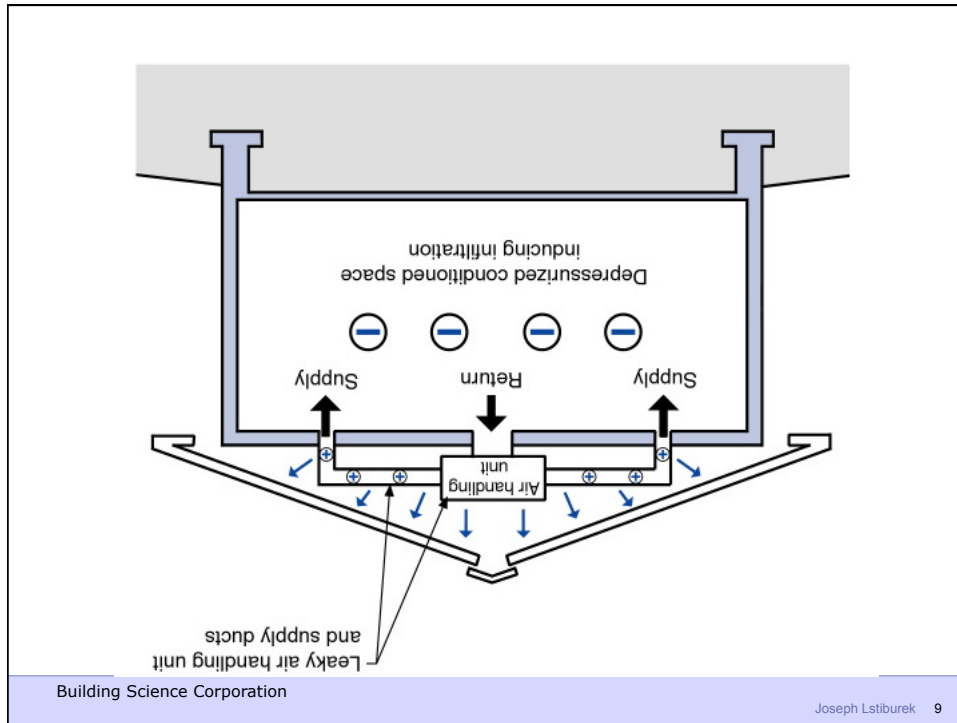
Building Science Corporation

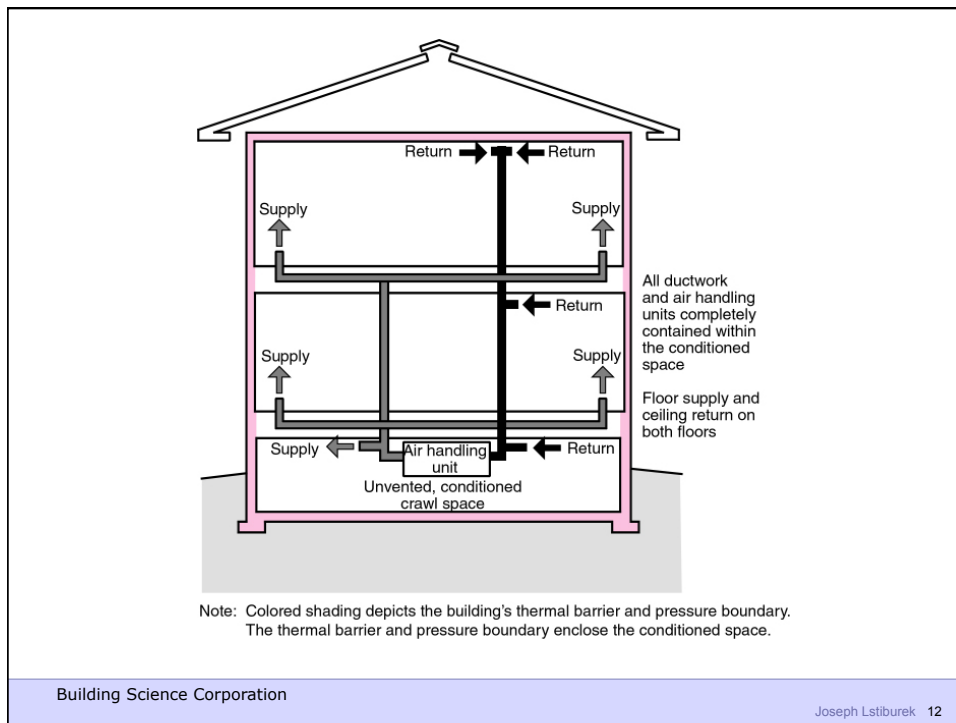
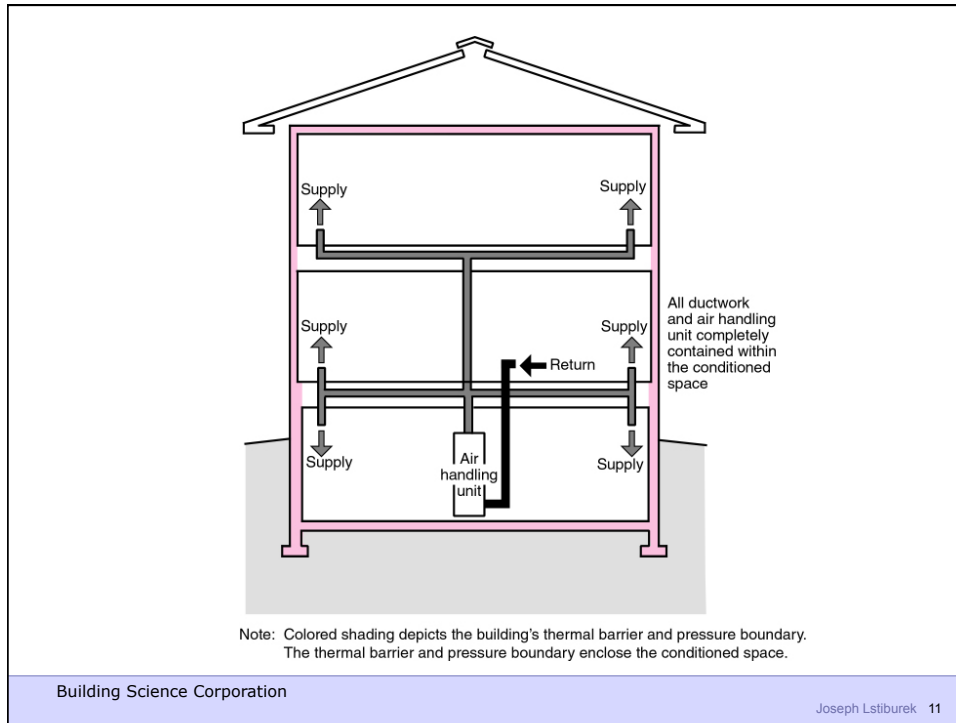
Joseph Lstiburek 6

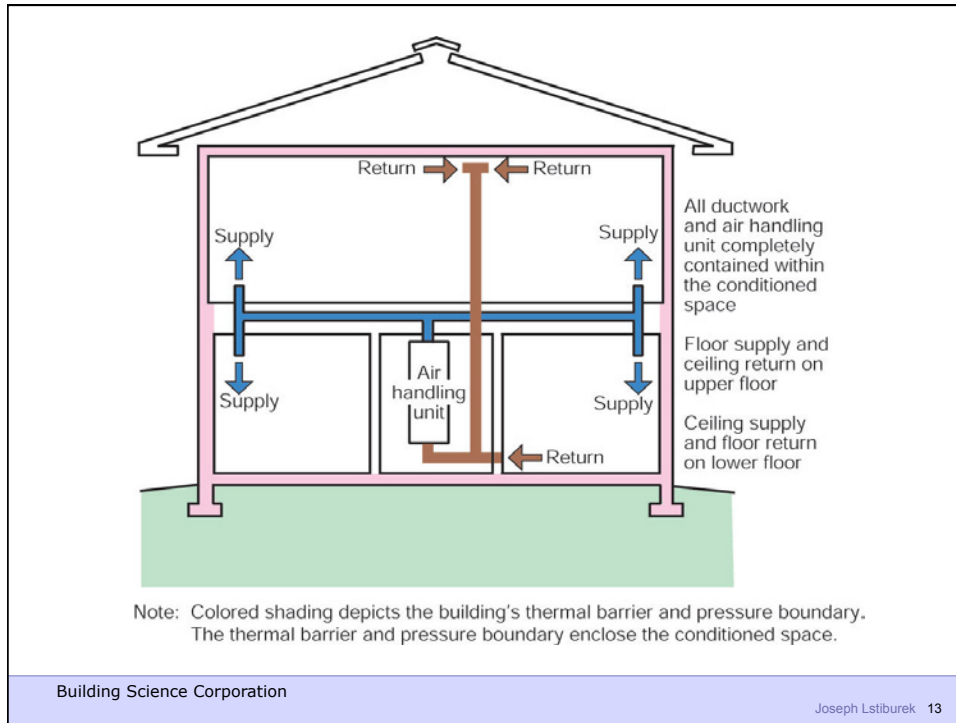
Duct Leakage Should Be Less Than 5% of Rated Flow As Tested By Pressurization To 25 Pascals

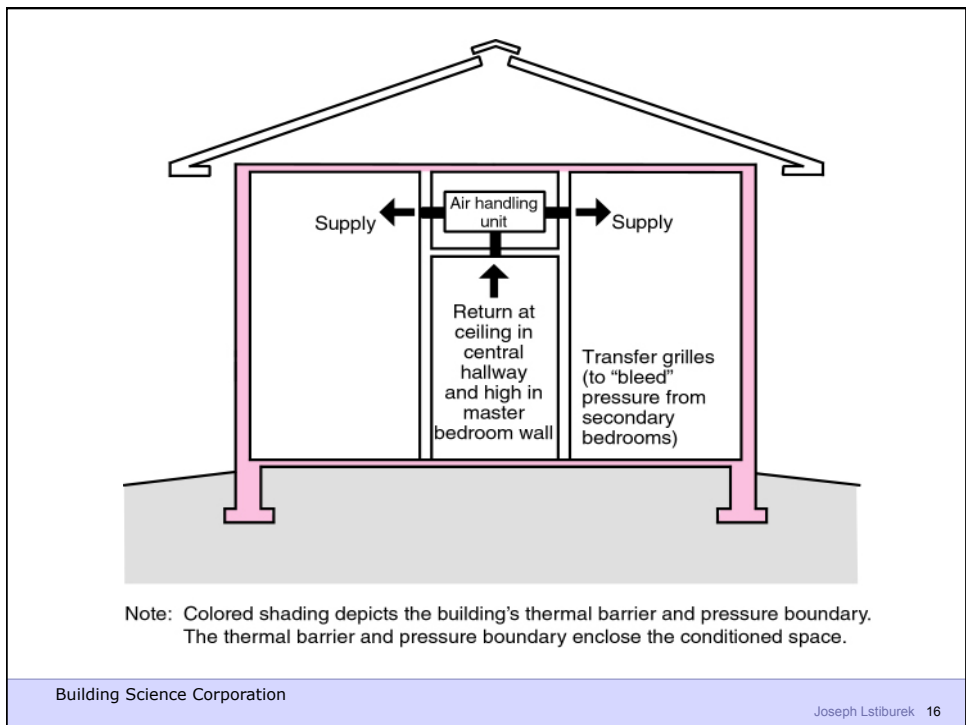
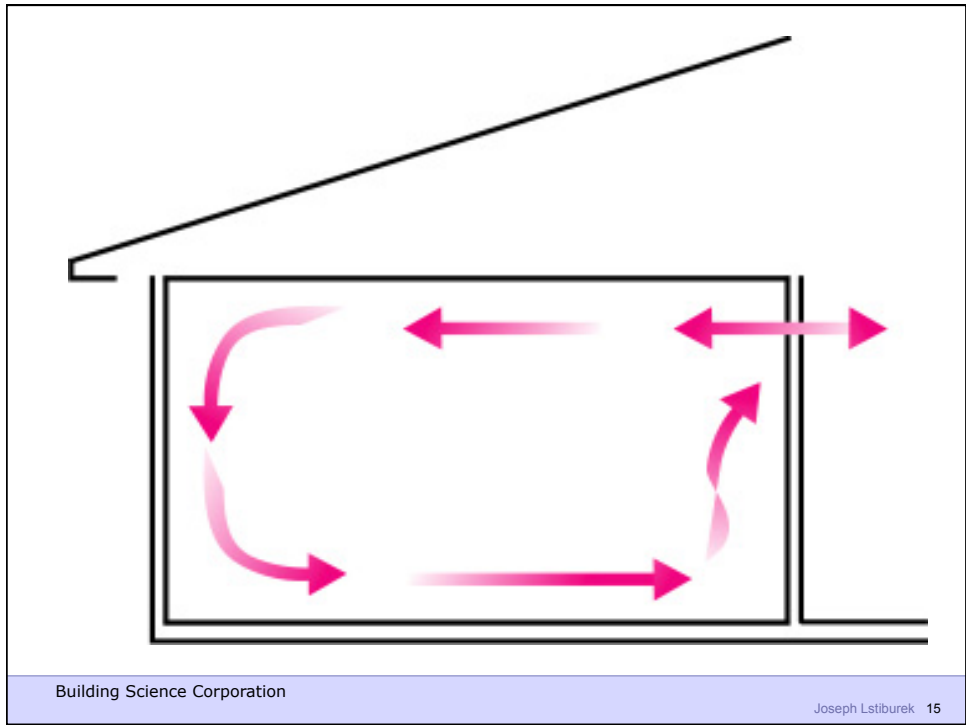


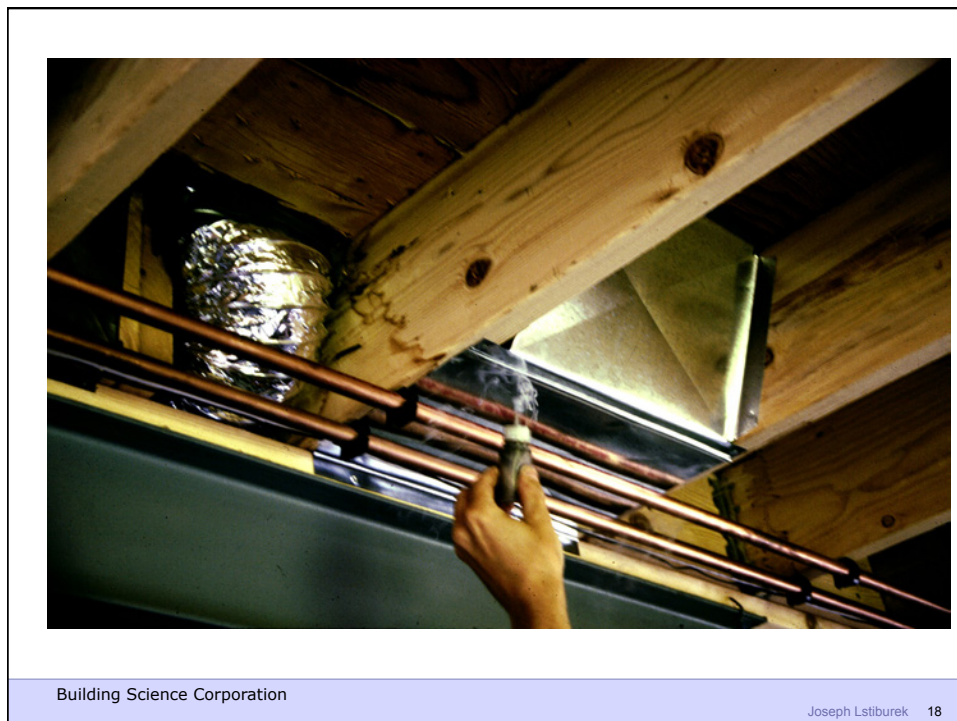
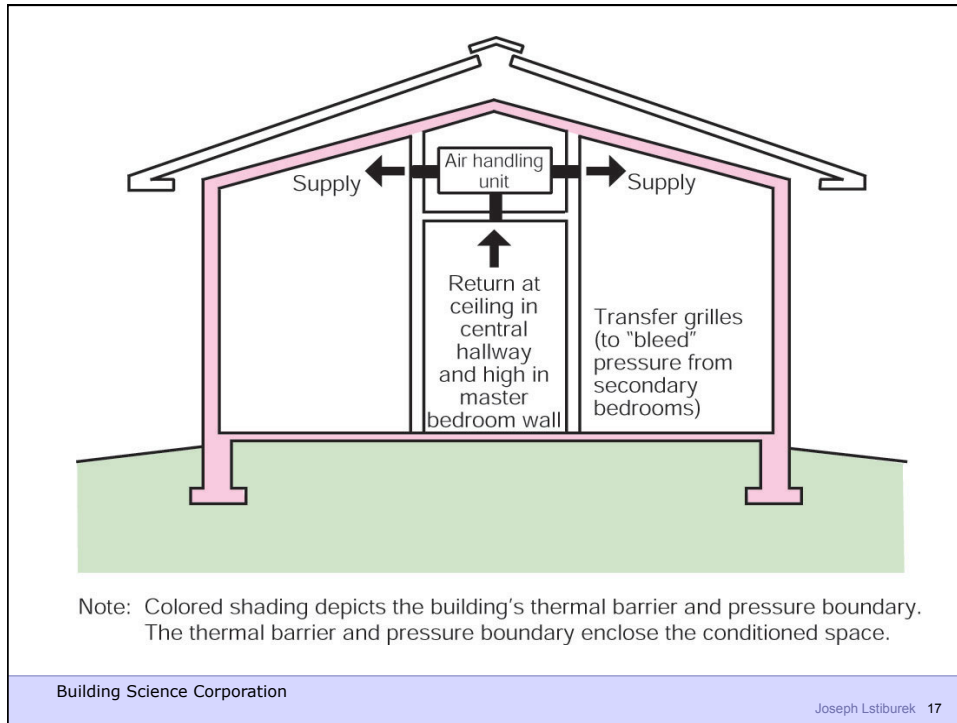
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.













Building Science Corporation

Joseph Lstiburek 19



Building Science Corporation

Joseph Lstiburek 20

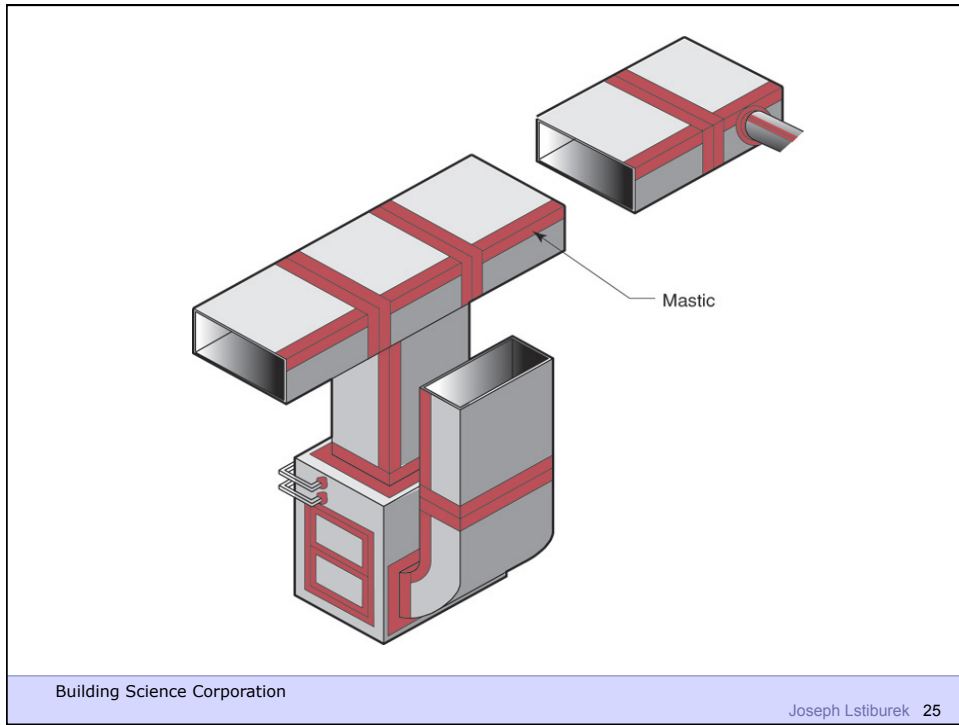


Building Science Corporation



Building Science Corporation

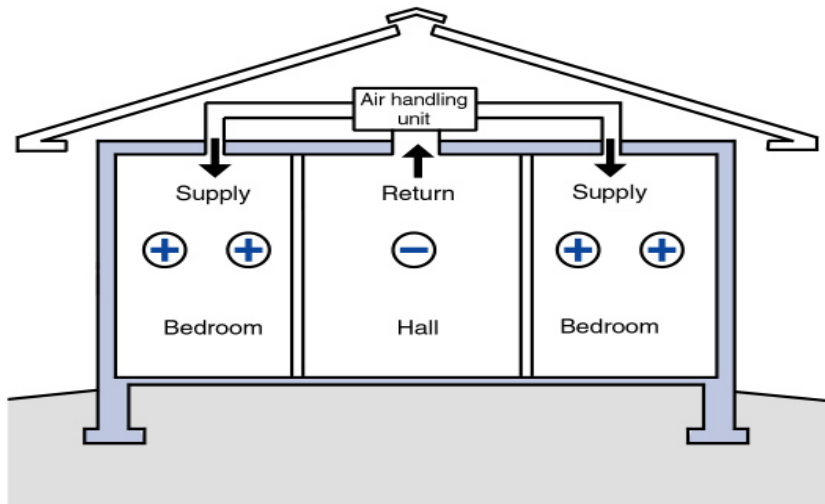






Building Science Corporation

Joseph Lstiburek 27



Building Science Corporation

Joseph Lstiburek 28



Building Science Corporation

Joseph Lstiburek 29



Building Science Corporation

Joseph Lstiburek 30



Building Science Corporation

Joseph Lstiburek 31



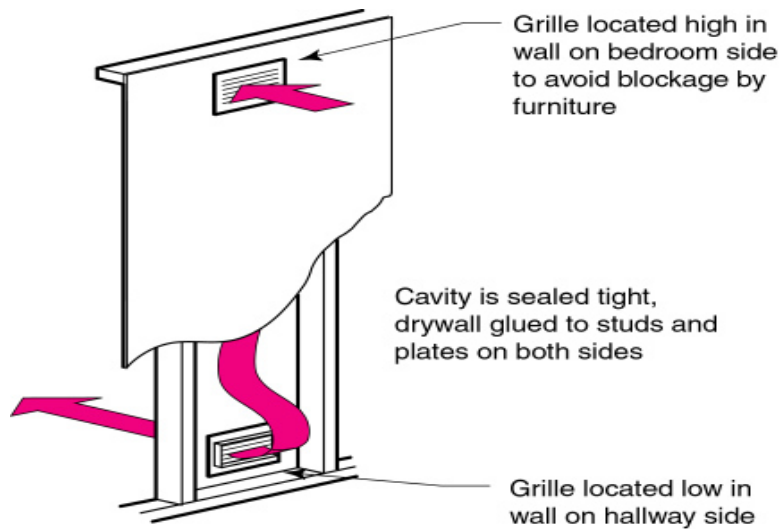
Building Science Corporation

Joseph Lstiburek 32



Building Science Corporation

Joseph Lstiburek 33



Building Science Corporation

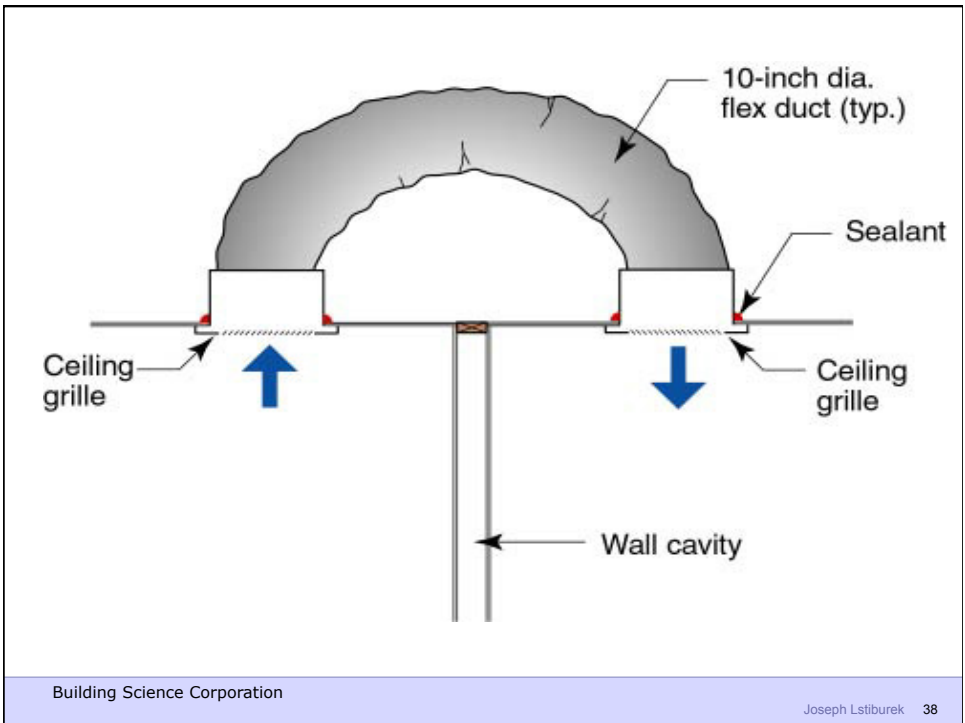
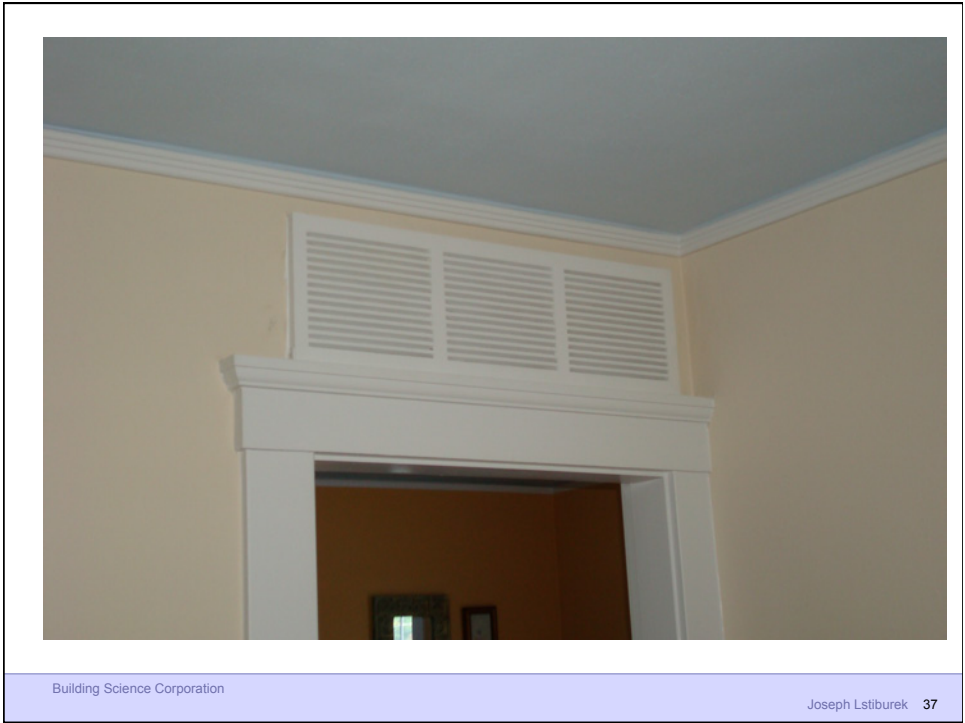
Joseph Lstiburek 34

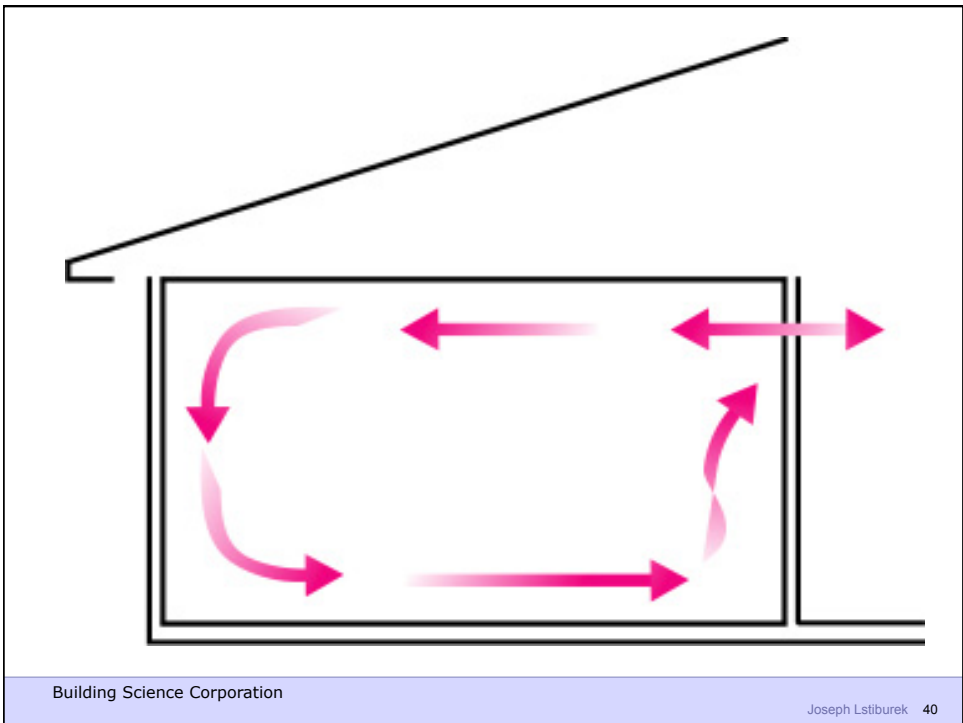


Building Science Corporation



Building Science Corporation







ENERGY STAR® Qualified
in All 50 States

ENERGY STAR
10% ENERGY SAVINGS

ALL ZONES

MW PATRIOT
MC 2800 DOUBLE HUNG WINDOW
100% VINYL FRAME GLAZED
UPA (U.S.A.) CONTOUR GLAZING
Product Code: MWPC01, 9/10/09 8007

ENERGY PERFORMANCE RATINGS
U-Factor (U.S.A.F.) Solar Heat Gain Coefficient
0.34 **0.31**

ADDITIONAL PERFORMANCE RATINGS
Visible Transmittance
0.42

DP035 RATING
Product Code: DP035, 9/10/09 8007

28R50916U6-AI03

Building Science Corporation

Joseph Lstiburek 41

Build Tight - Ventilate Right

Building Science Corporation

Joseph Lstiburek 42

Build Tight - Ventilate Right

How Tight?

What's Right?

Building Science Corporation

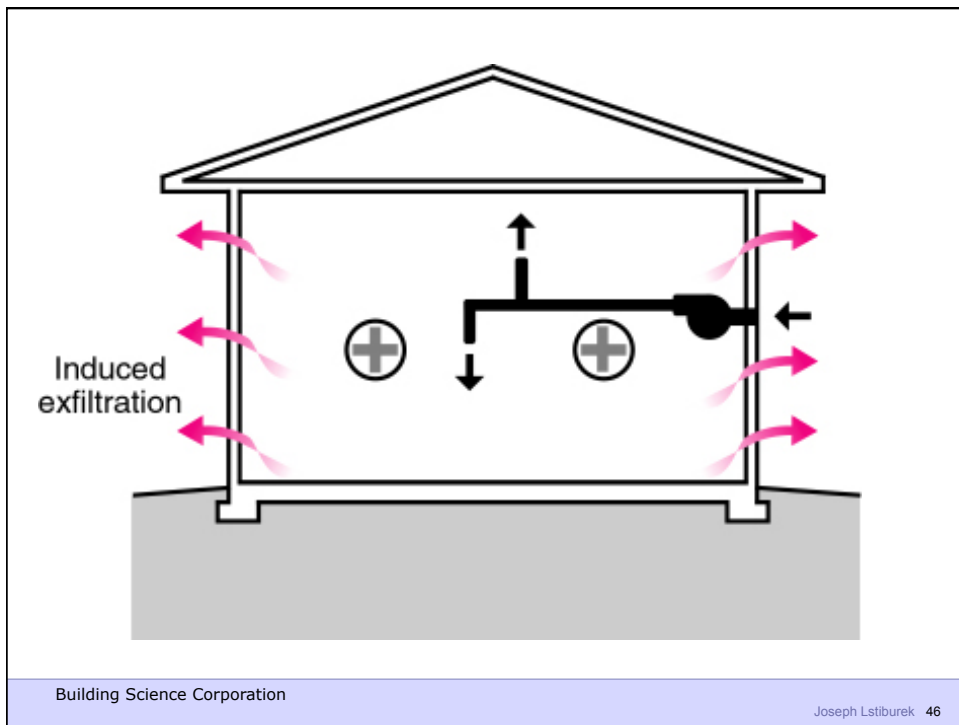
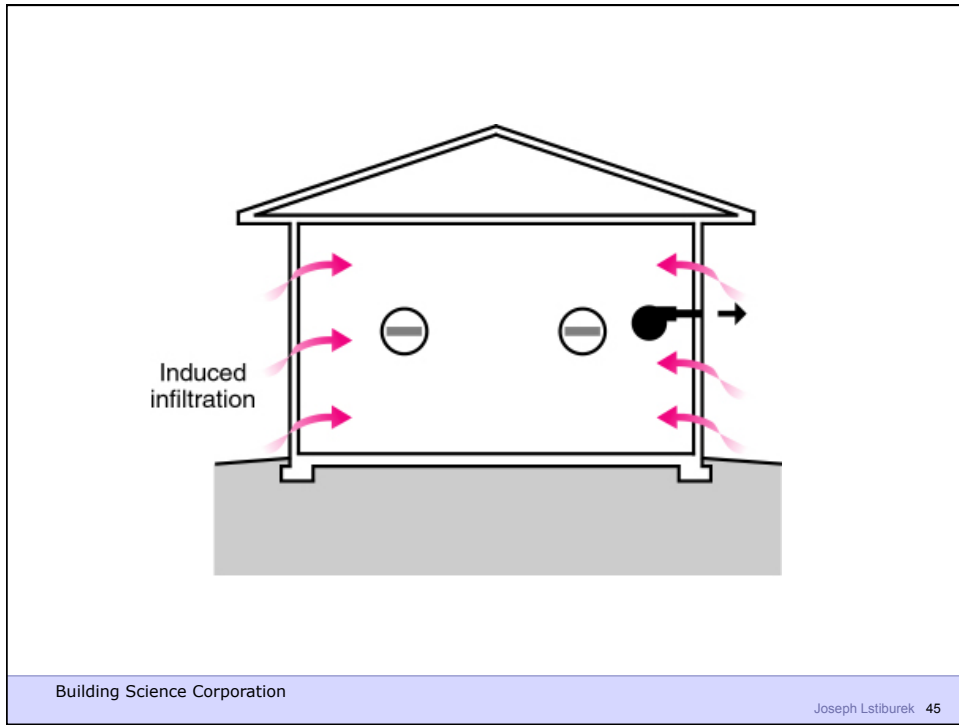
Joseph Lstiburek 43

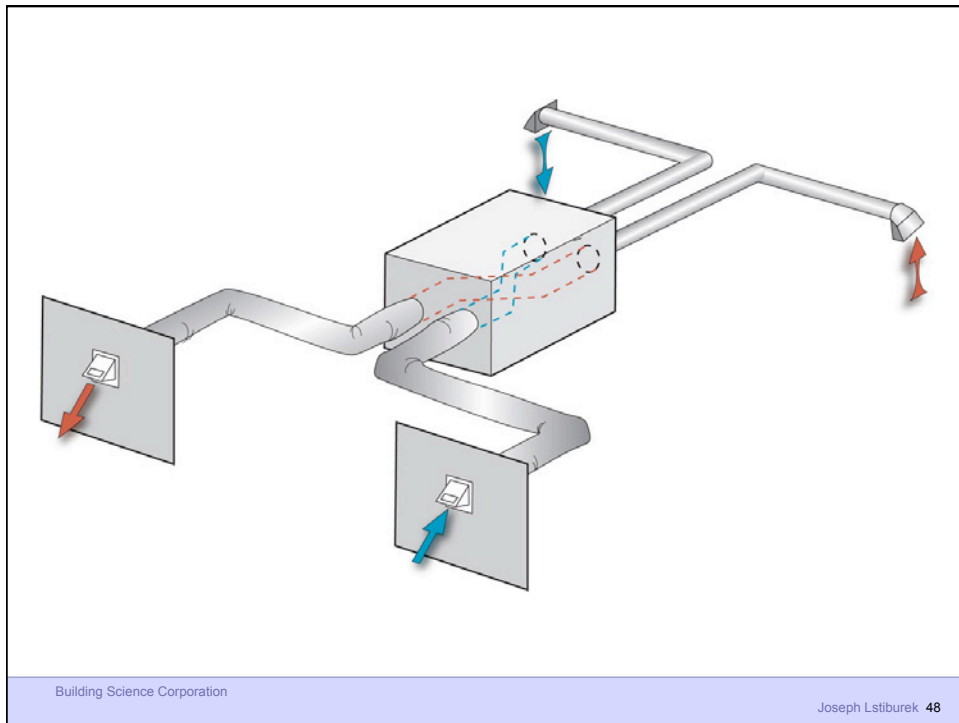
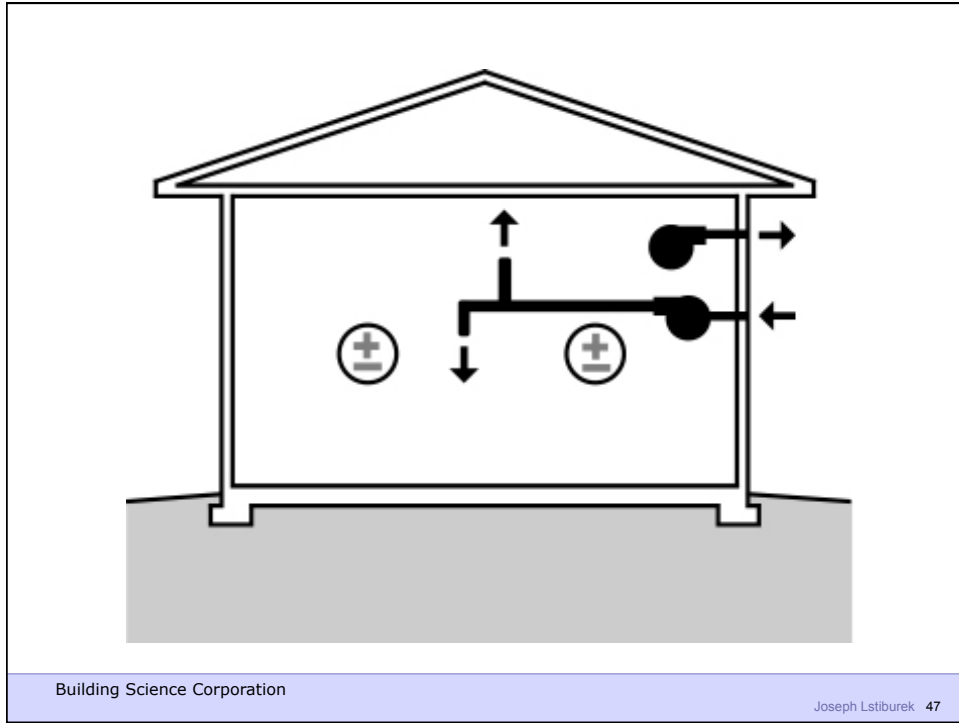
Three Types of Controlled Ventilation Systems

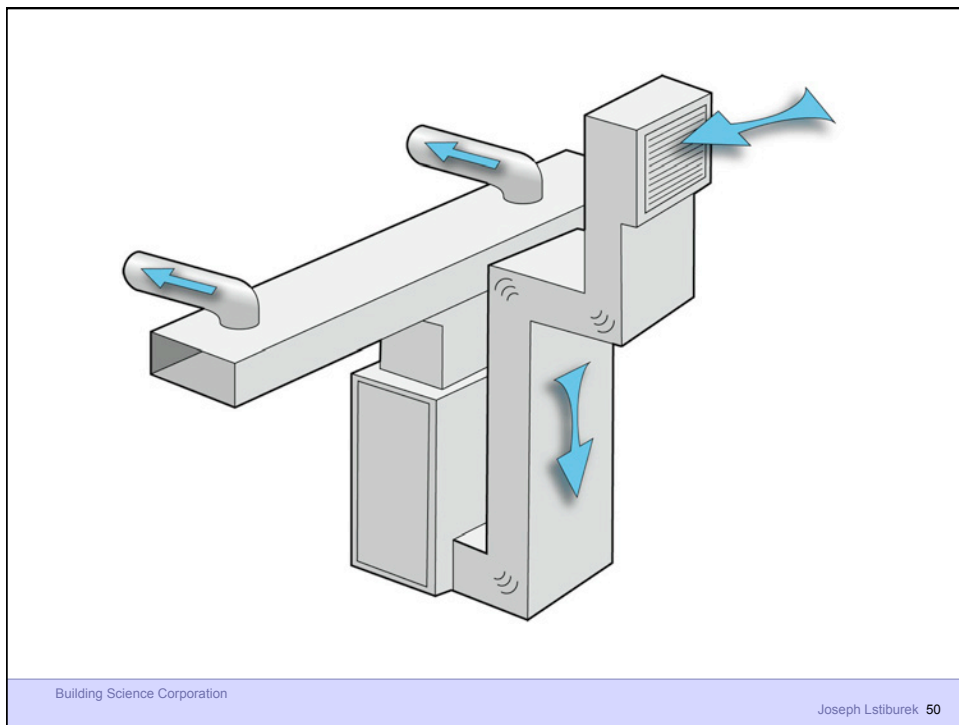
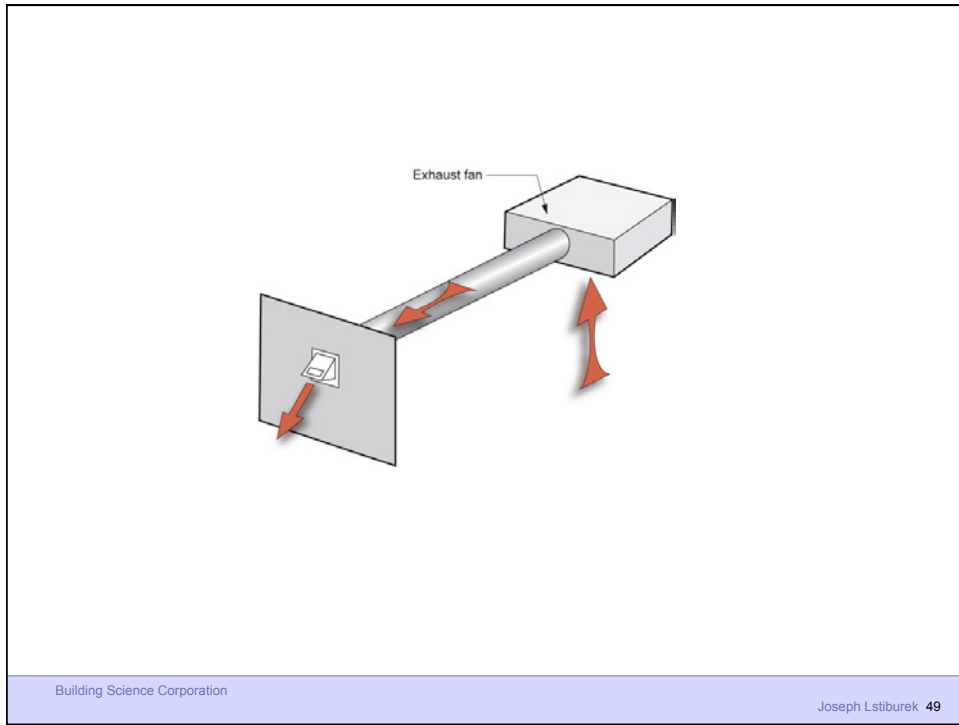
Exhaust Ventilation
Supply Ventilation
Balanced Ventilation

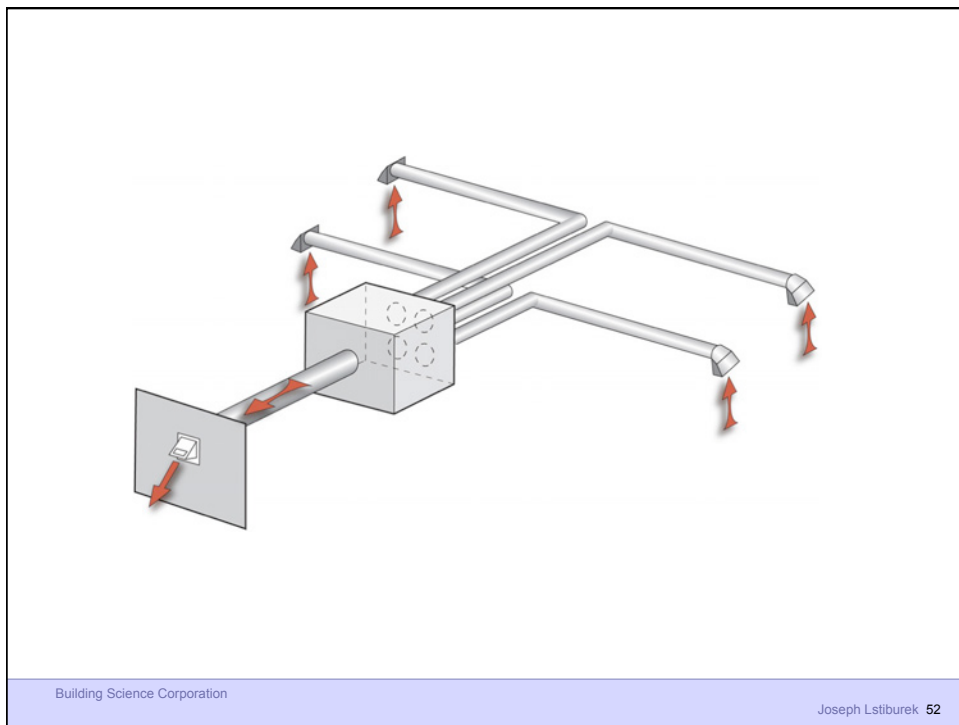
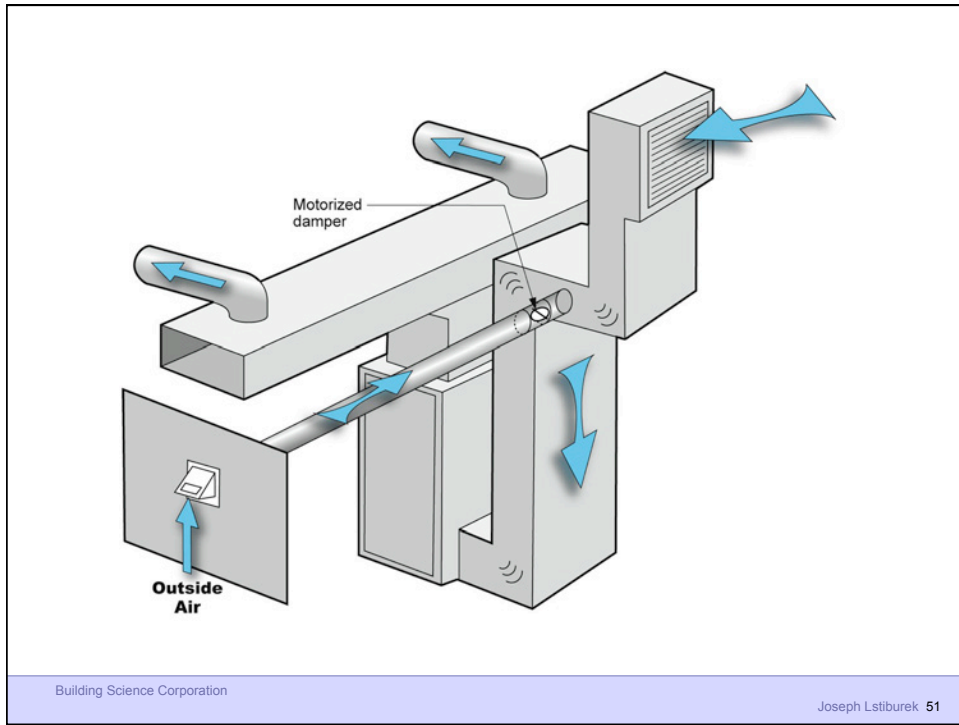
Building Science Corporation

Joseph Lstiburek 44









ASHRAE Standard 62.2 calls for 7.5 cfm per person plus 0.03 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one

ASHRAE Standard 62.2 calls for 7.5 cfm per person plus 0.03 cfm per square foot of conditioned area

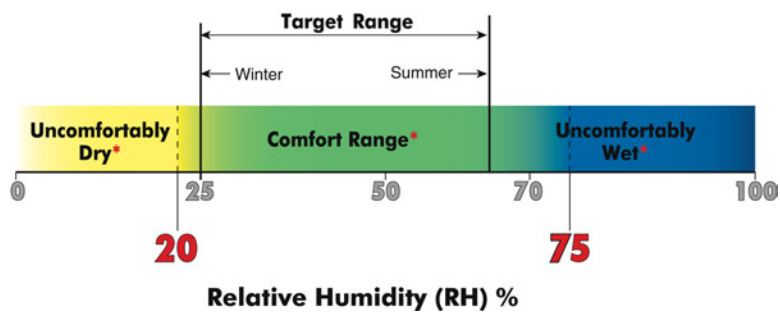
Occupancy is deemed to be the number of bedrooms plus one

Outcome is often bad – part load humidity problems, dryness problems, energy problems

Don't Do Stupid Things Humidifiers

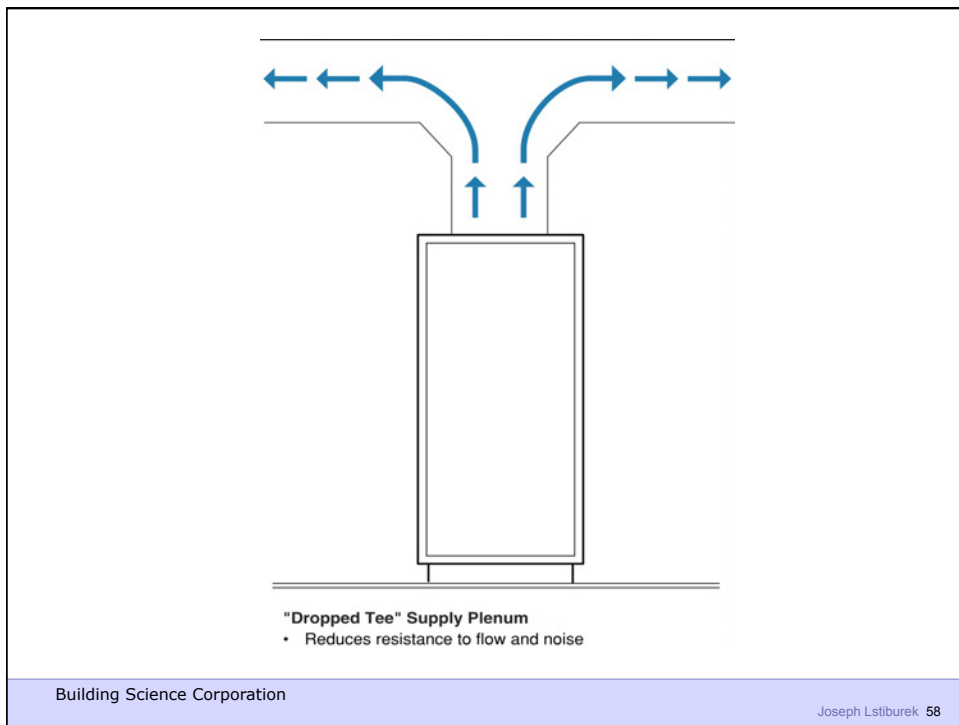
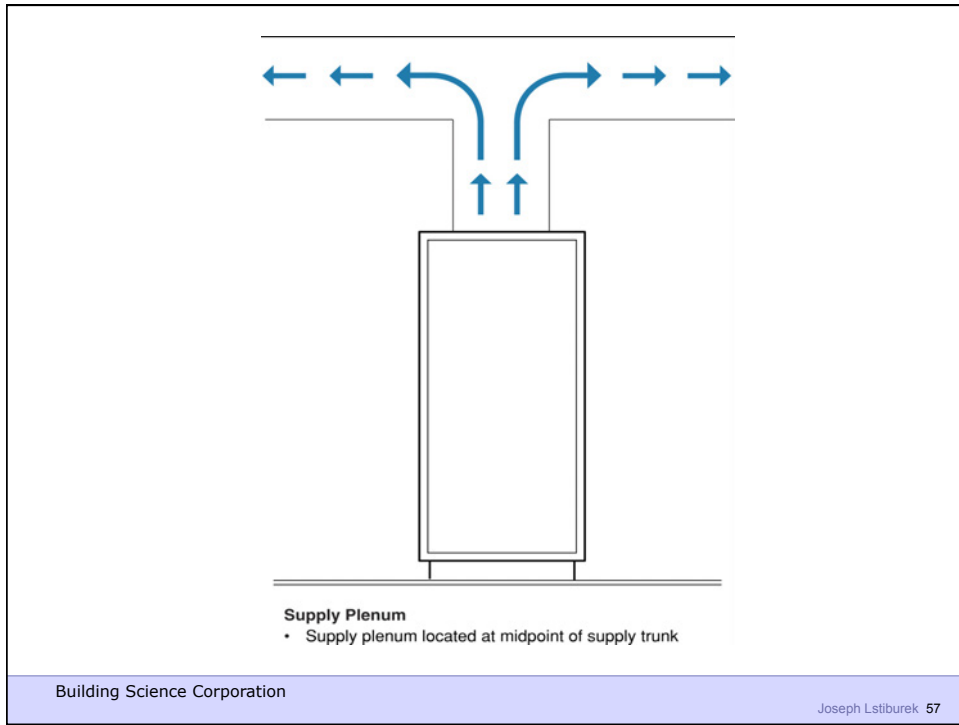
Building Science Corporation

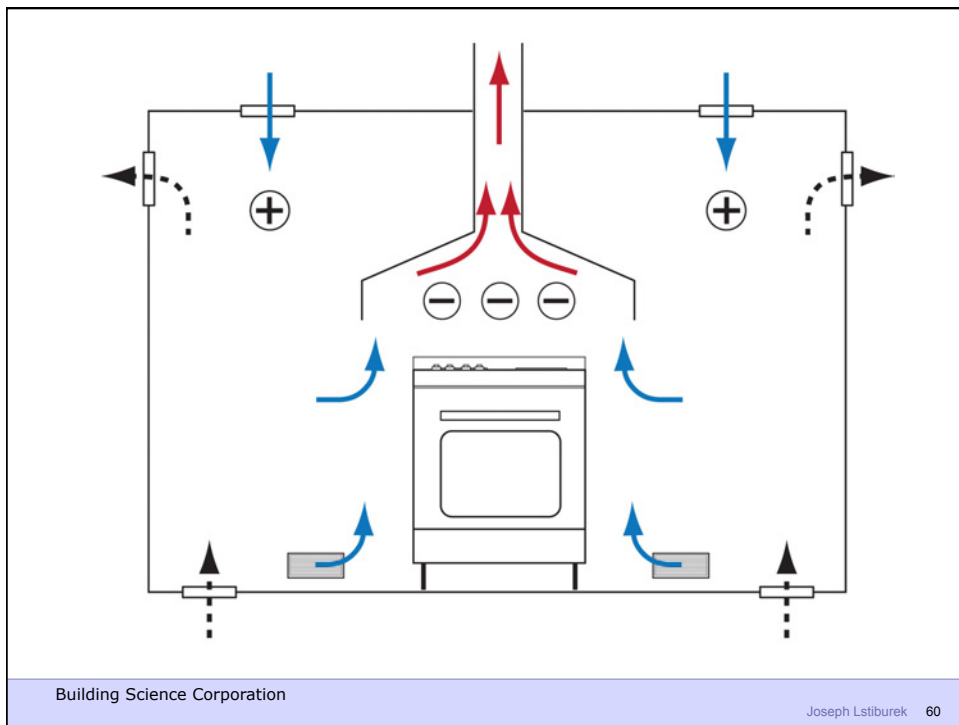
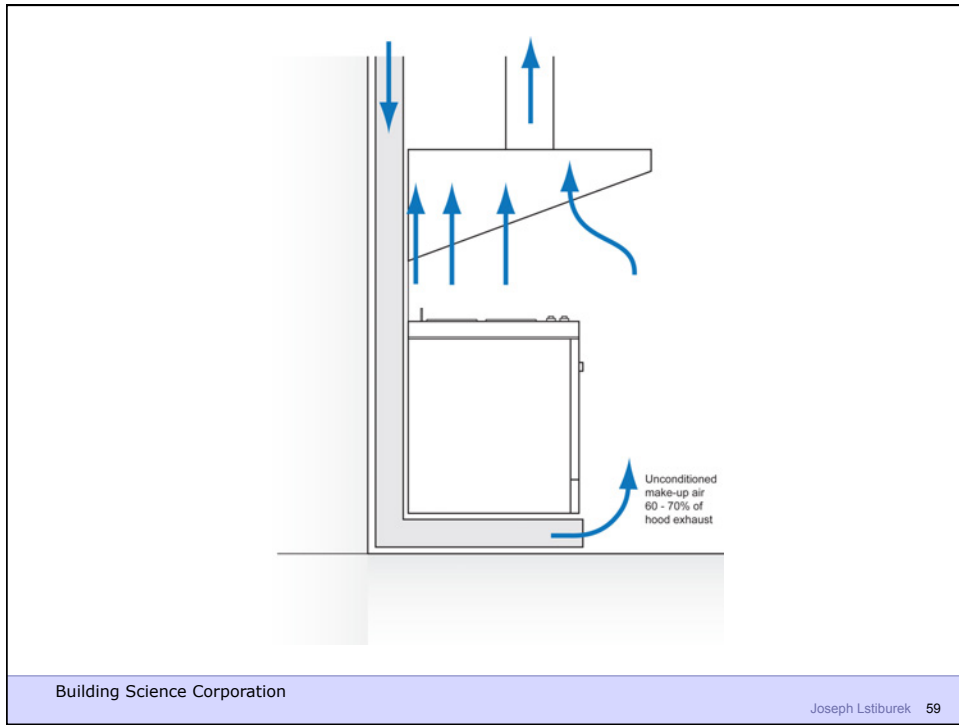
Joseph Lstiburek 55

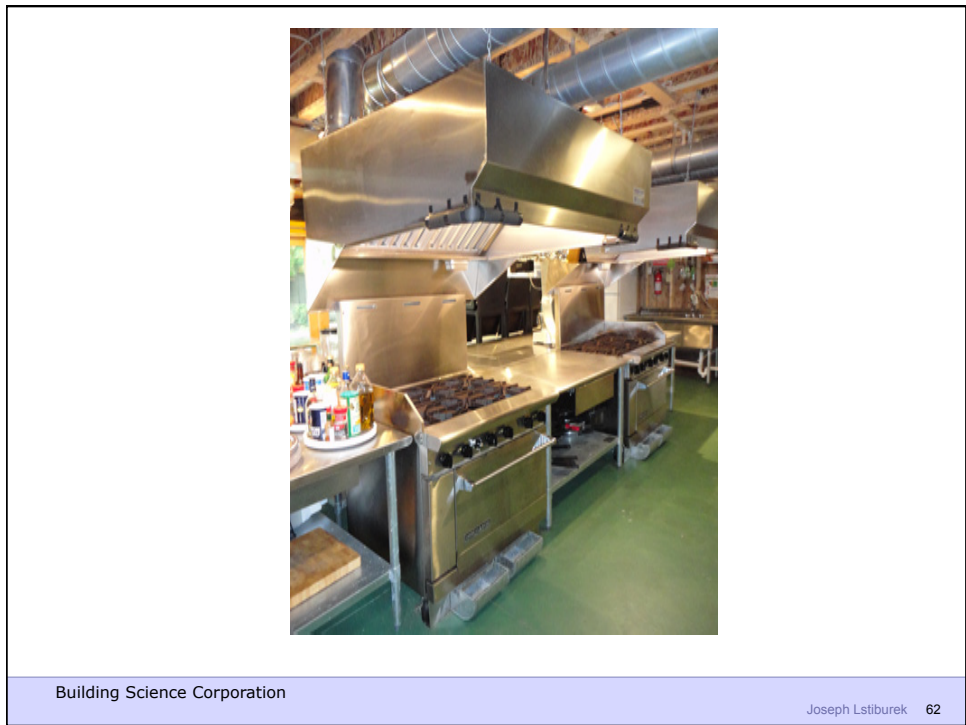
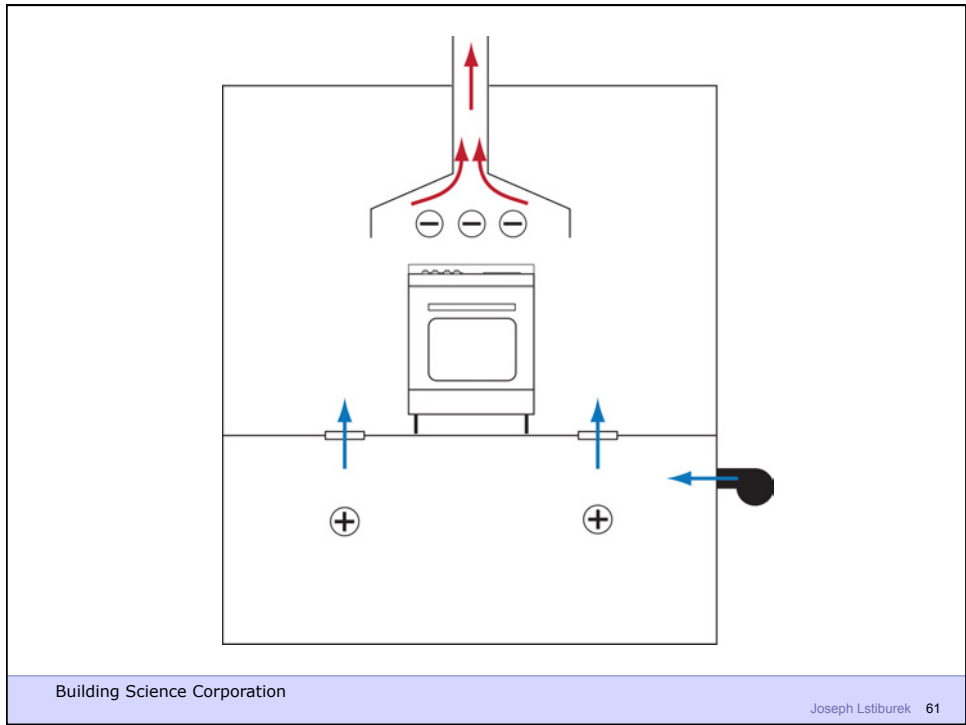


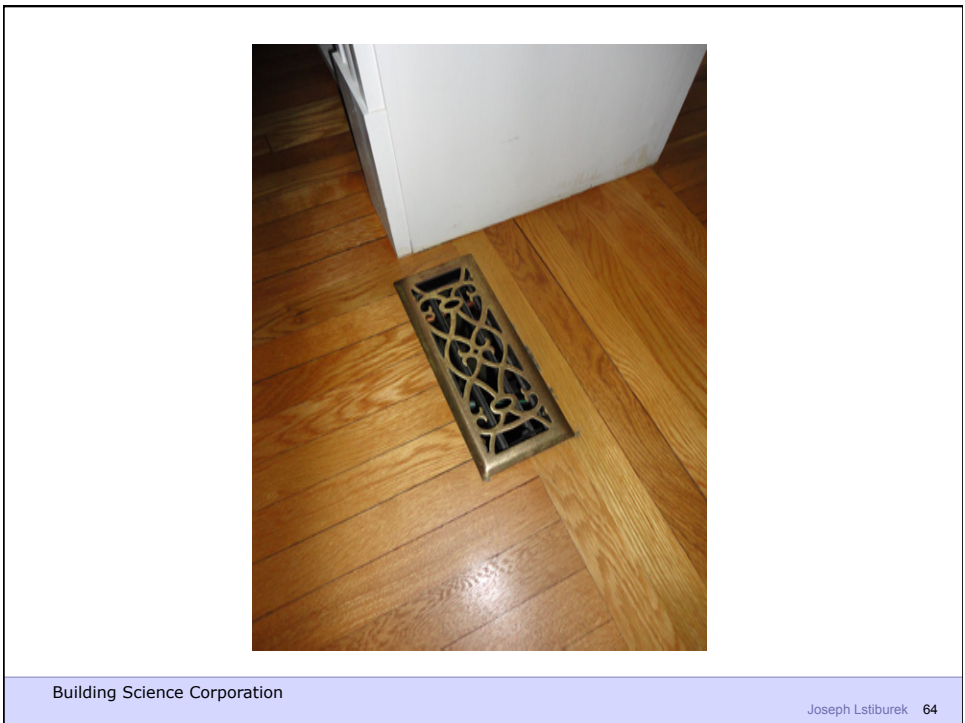
Building Science Corporation

Joseph Lstiburek 56











Building Science Corporation

Joseph Lstiburek 65



Building Science Corporation

Joseph Lstiburek 66

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

Building Science

Rain Control

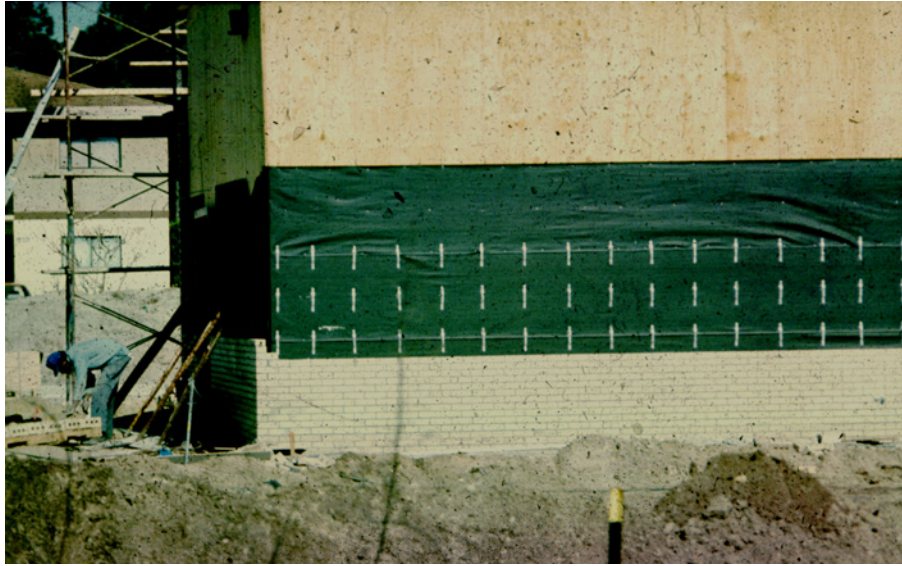
www.buildingscience.com



Building Science Corporation

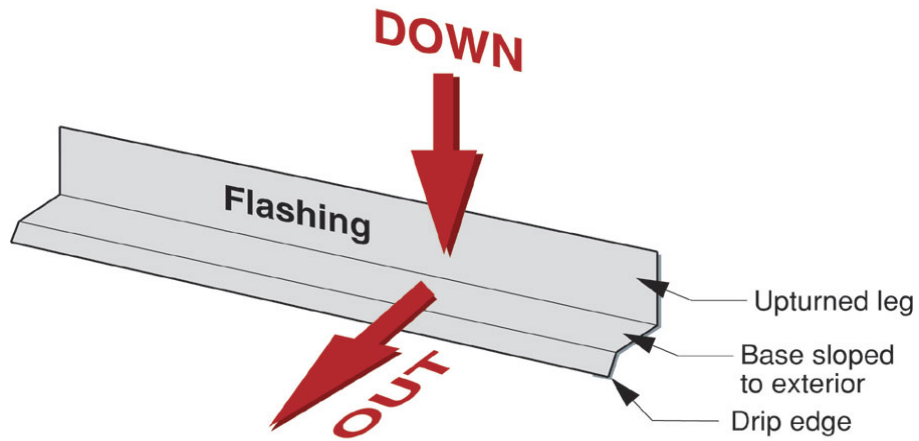
Joseph Lstiburek – Rain Control 2





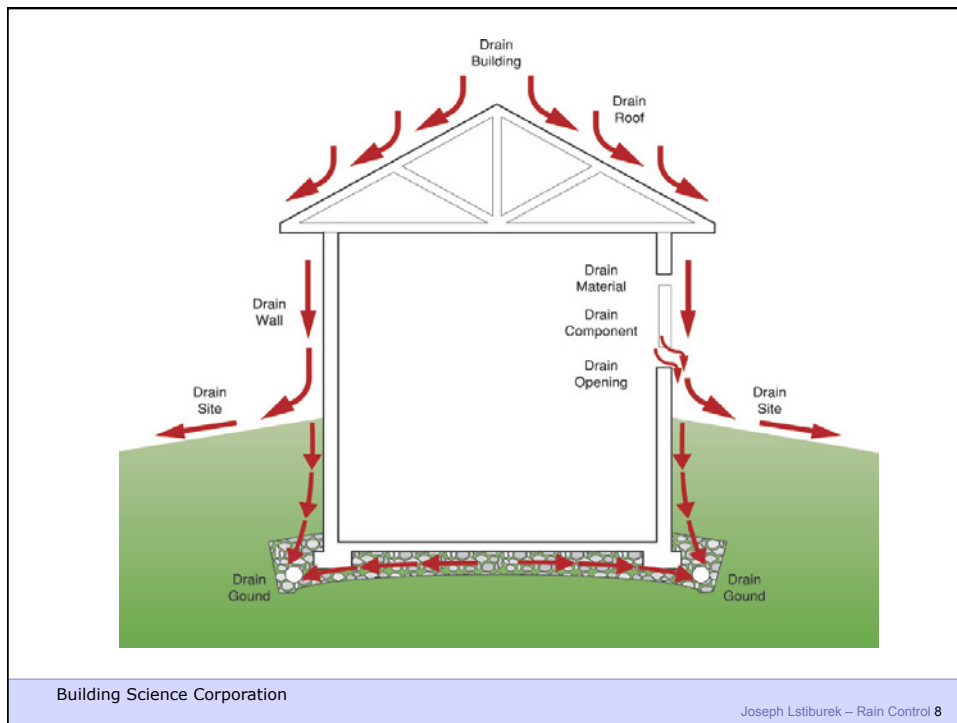
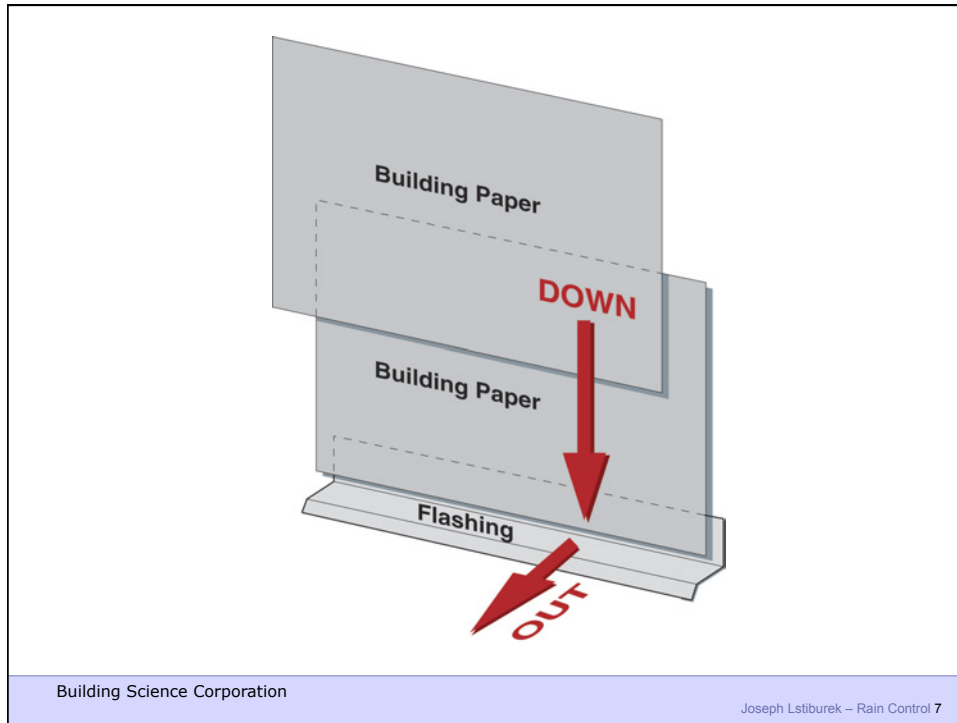
Building Science Corporation

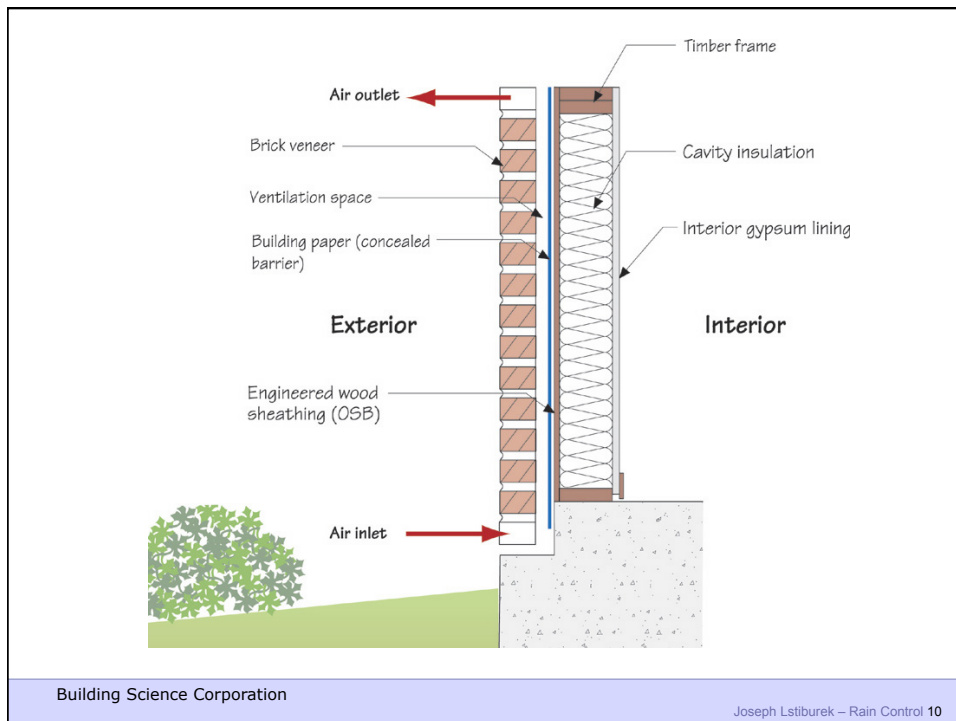
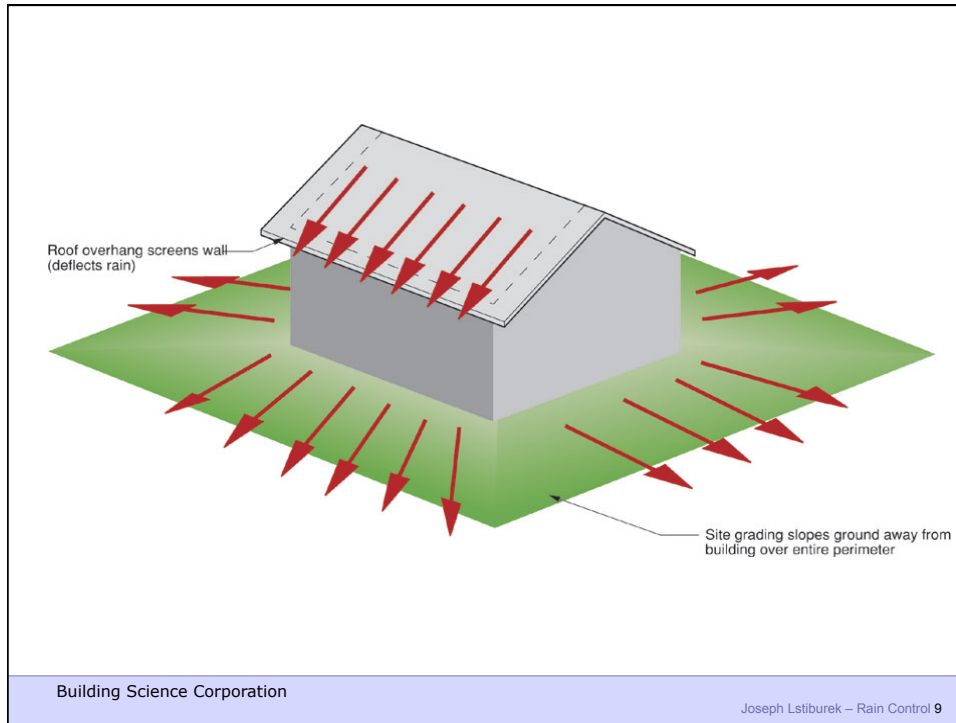
Joseph Lstiburek – Rain Control 5



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



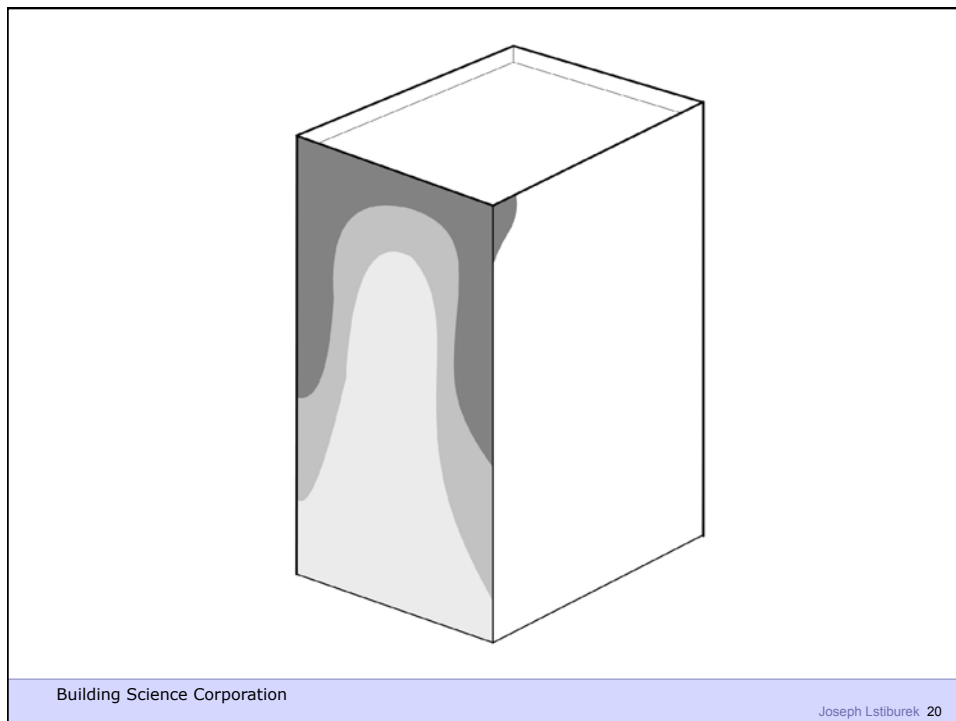
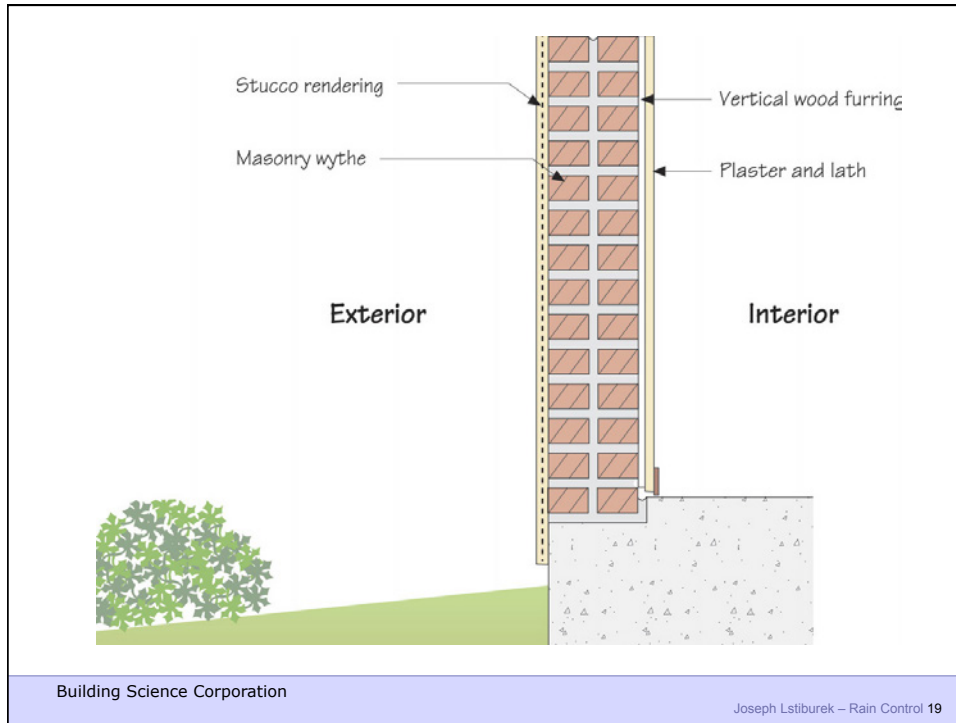
Building Science Corporation

Joseph Lstiburek – Rain Control 17



Building Science Corporation

Joseph Lstiburek 18





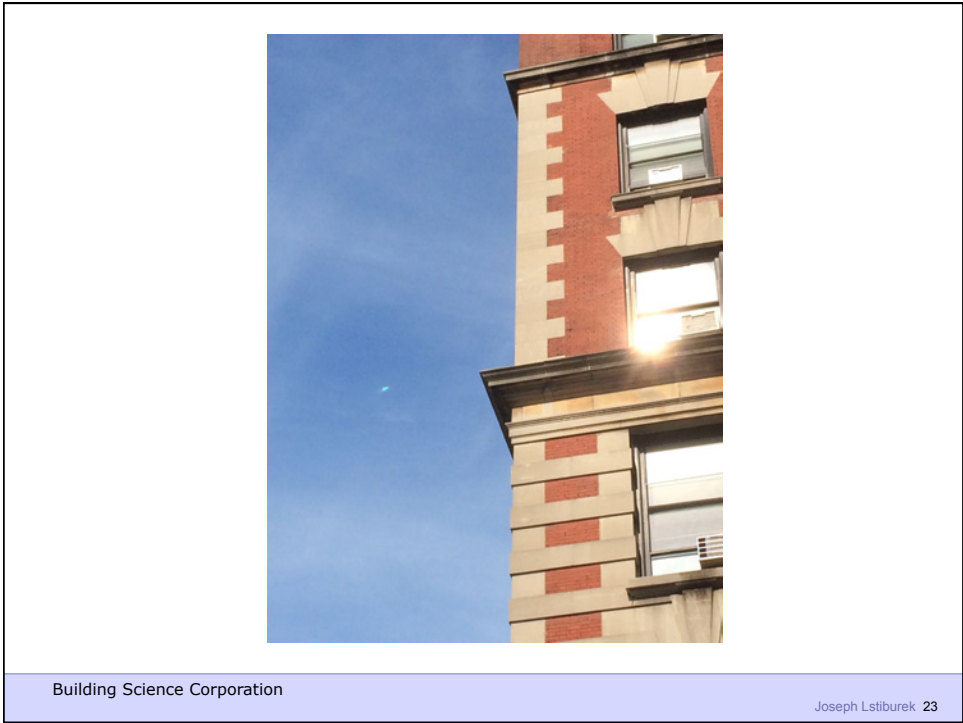
Building Science Corporation

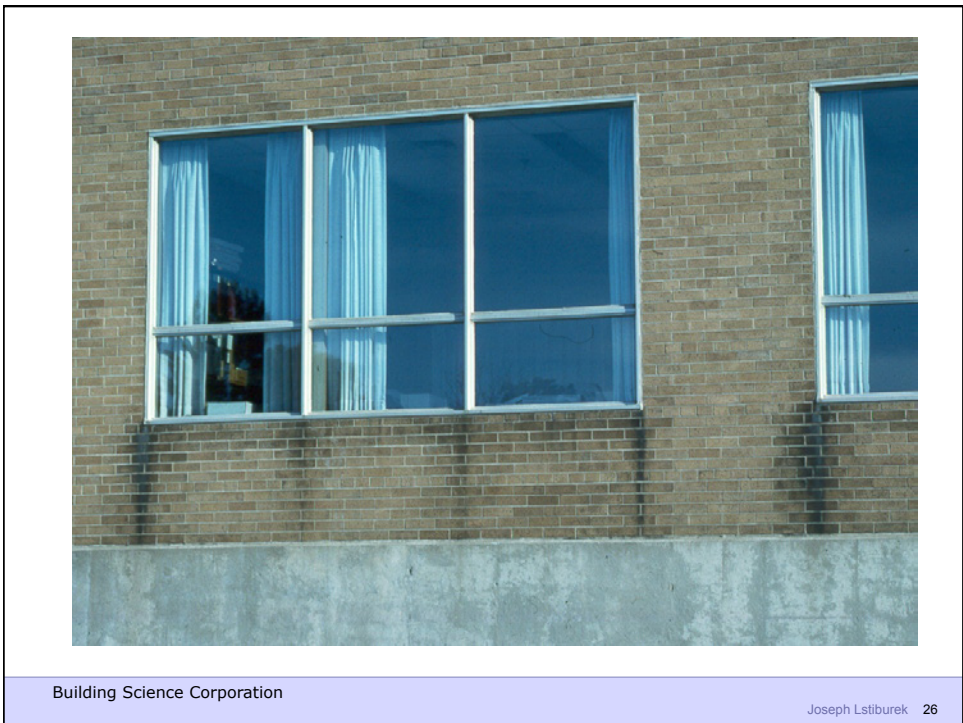
Joseph Lstiburek 21

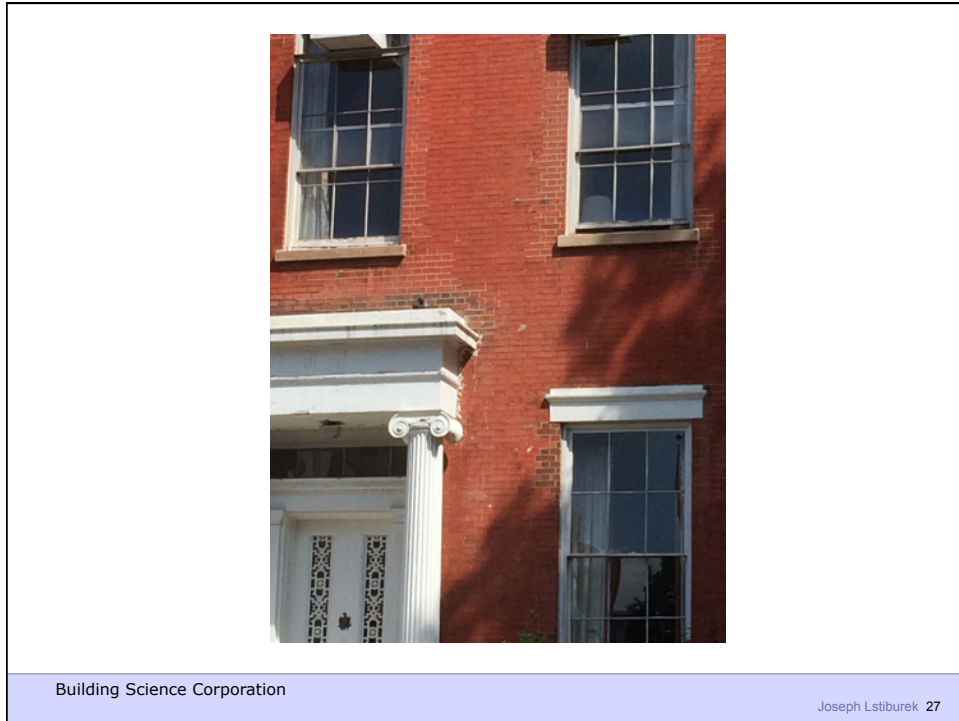


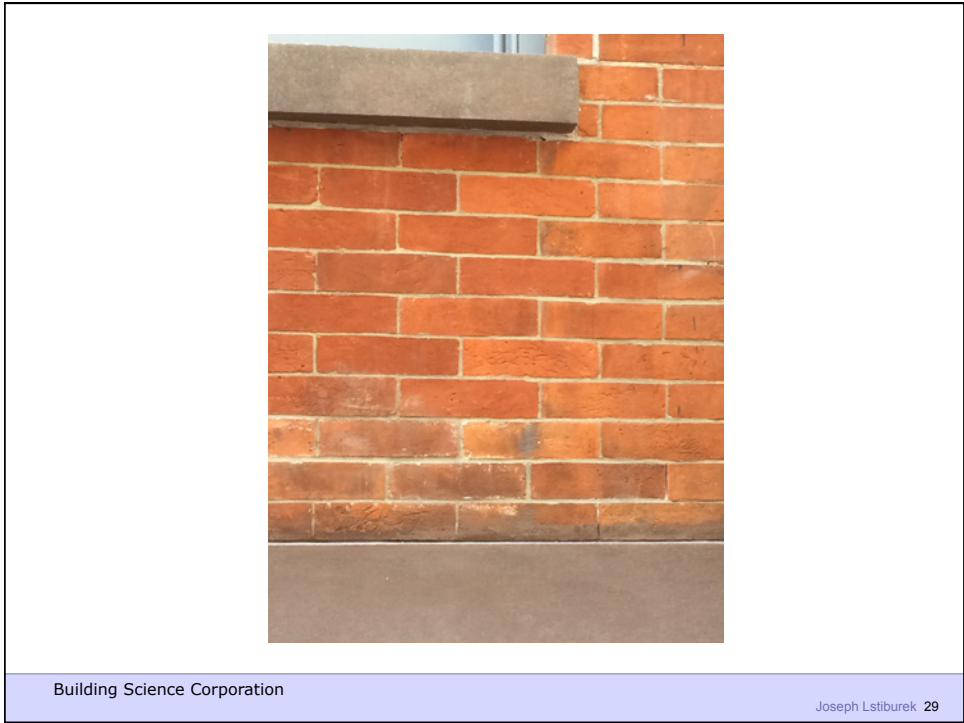
Building Science Corporation

Joseph Lstiburek 22



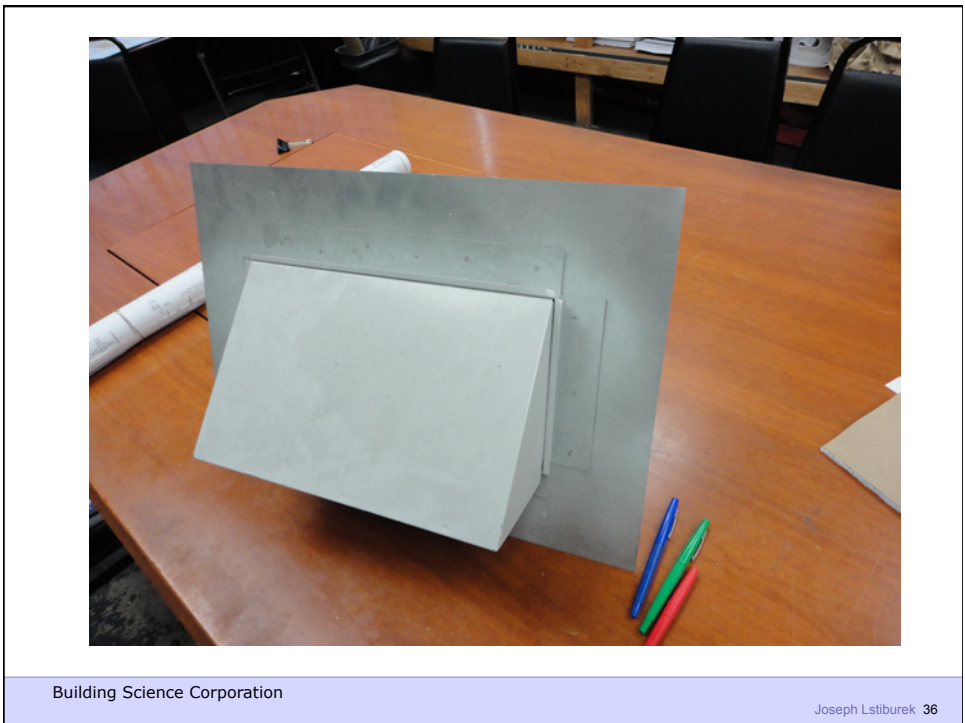




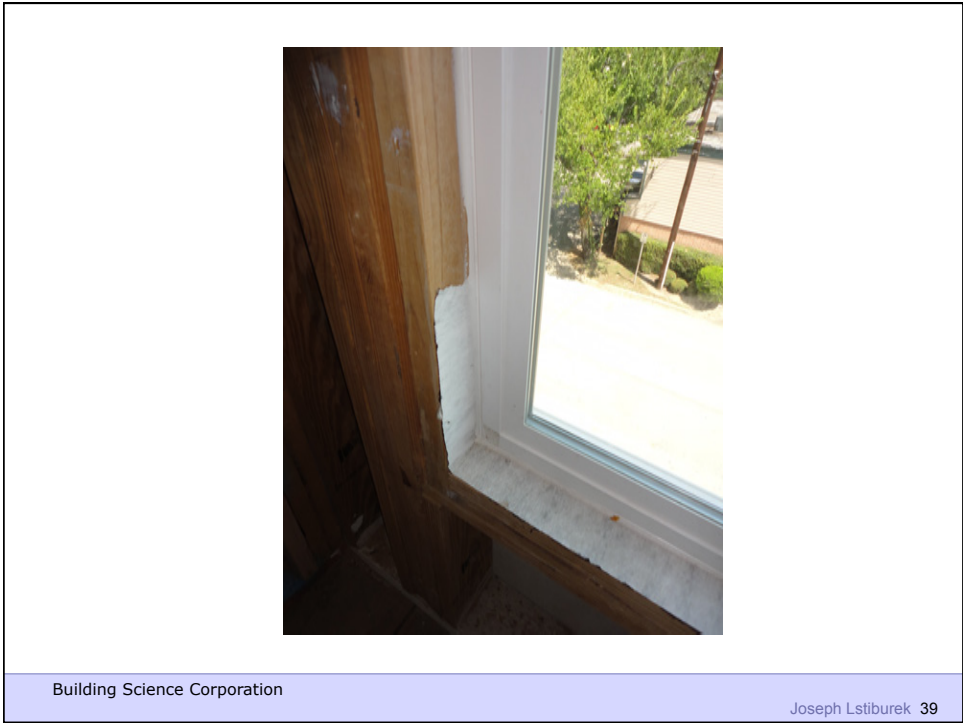














Building Science Corporation

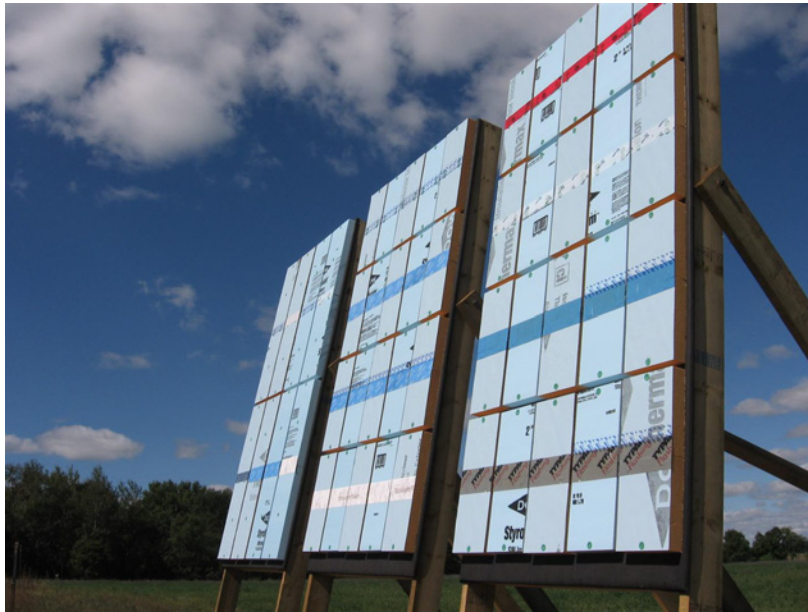
Joseph Lstiburek 41



Building Science Corporation

Joseph Lstiburek 42





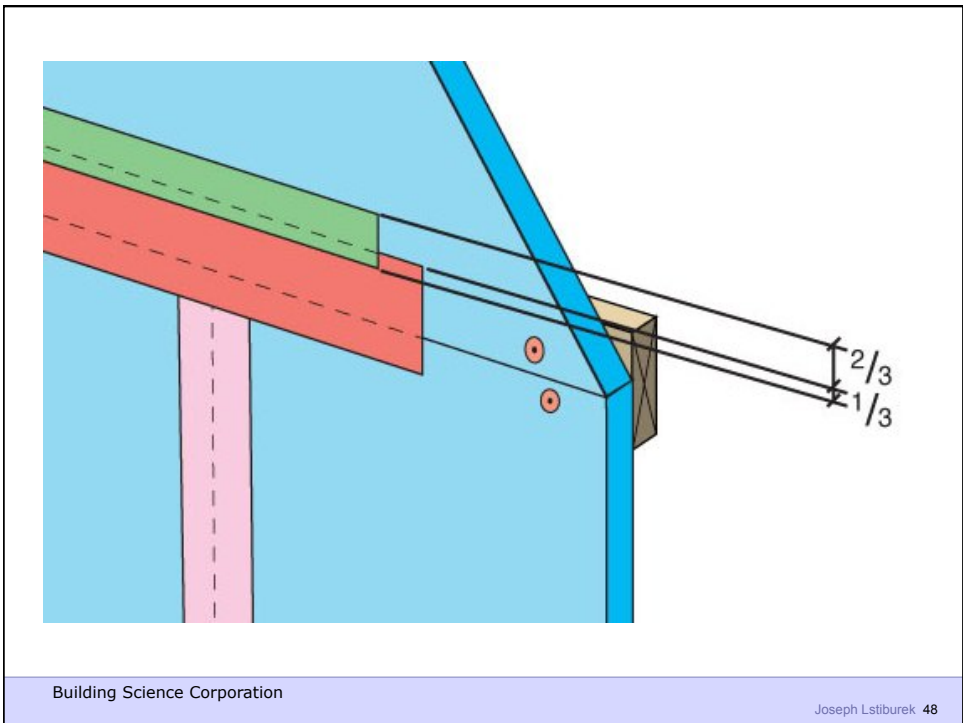
Building Science Corporation

Joseph Lstiburek 45



Building Science Corporation

Joseph Lstiburek 46



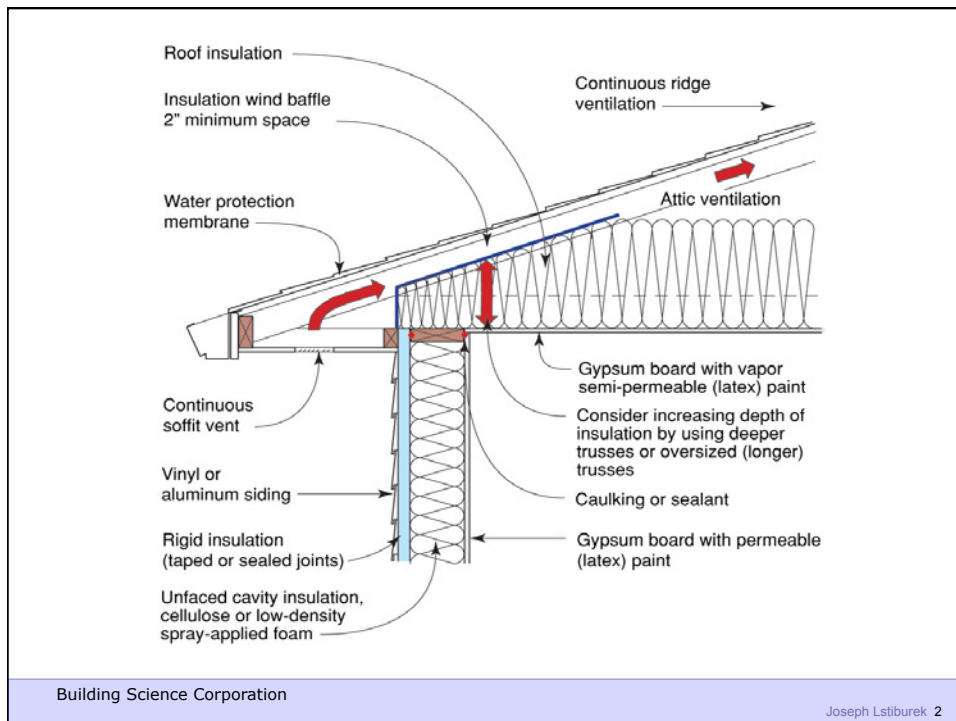


Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

Roofs

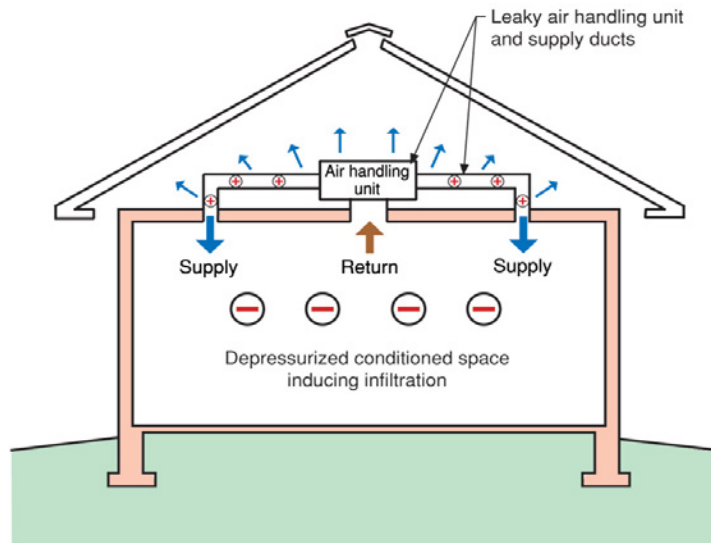
presented by www.buildingscience.com





Building Science Corporation

Joseph Lstiburek 3



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

Building Science Corporation

Joseph Lstiburek 4



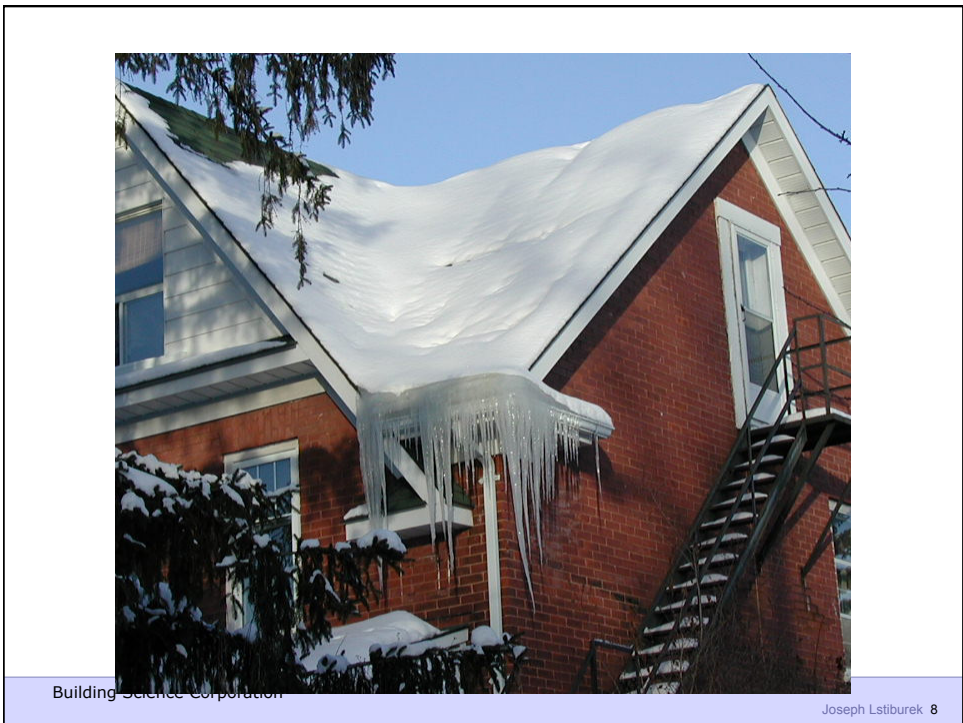
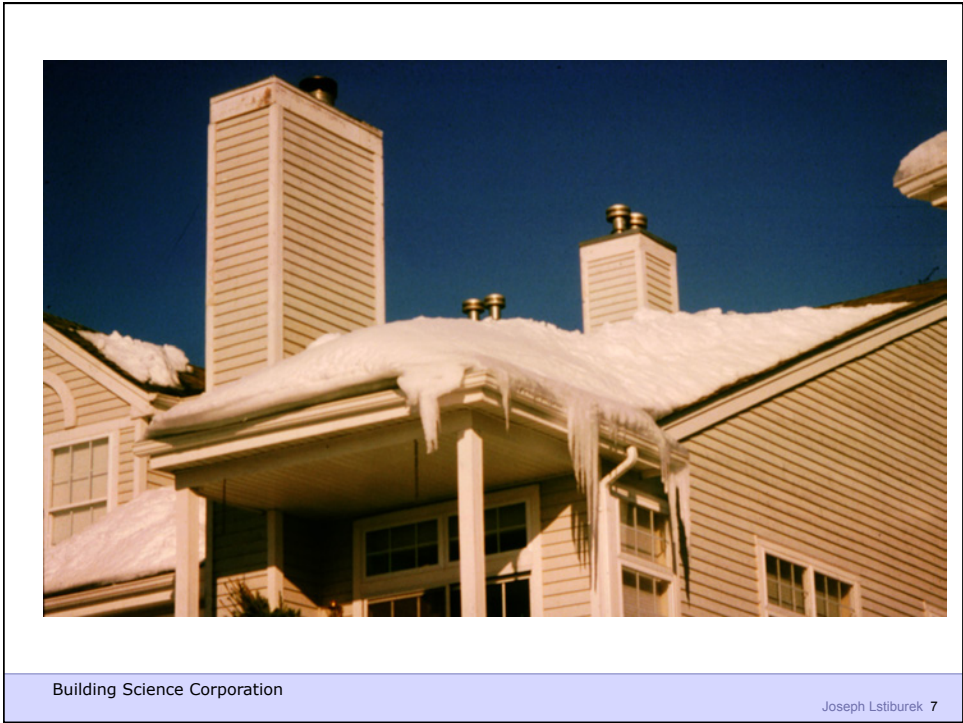
Building Science Corporation

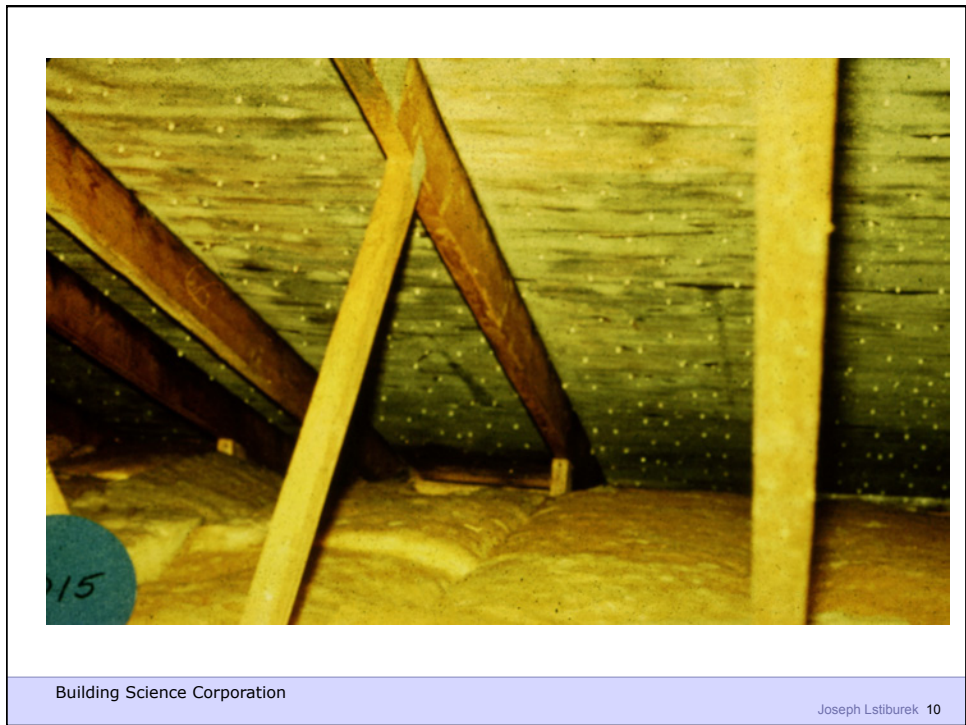
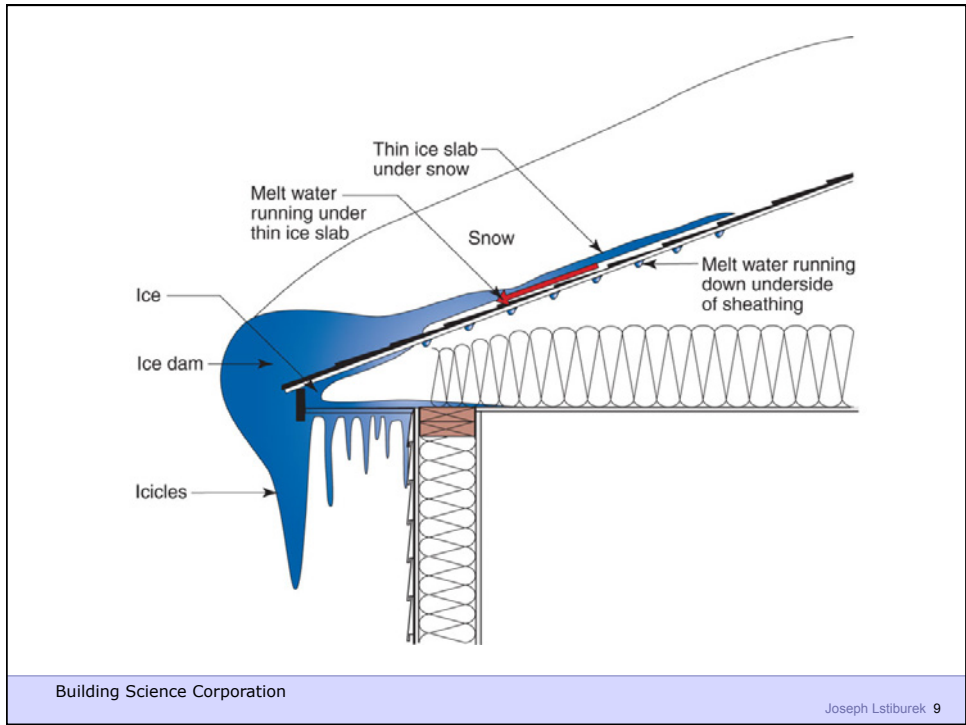
Joseph Lstiburek 5

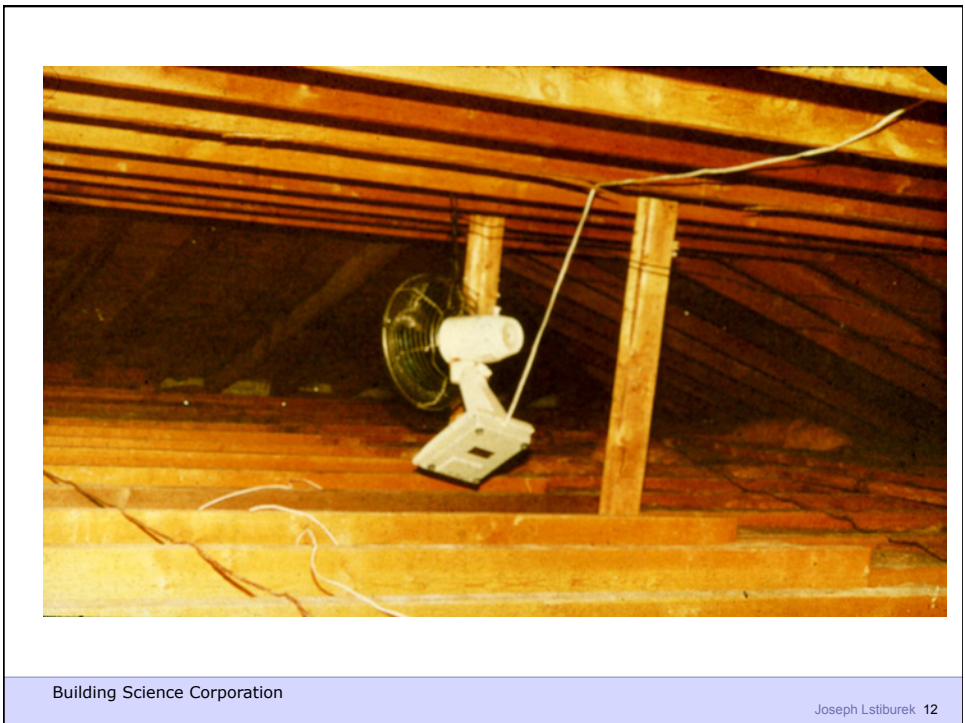


Building Science Corporation

Joseph Lstiburek 6









Building Science Corporation

Joseph Lstiburek 13



Building Science Corporation

Joseph Lstiburek 14



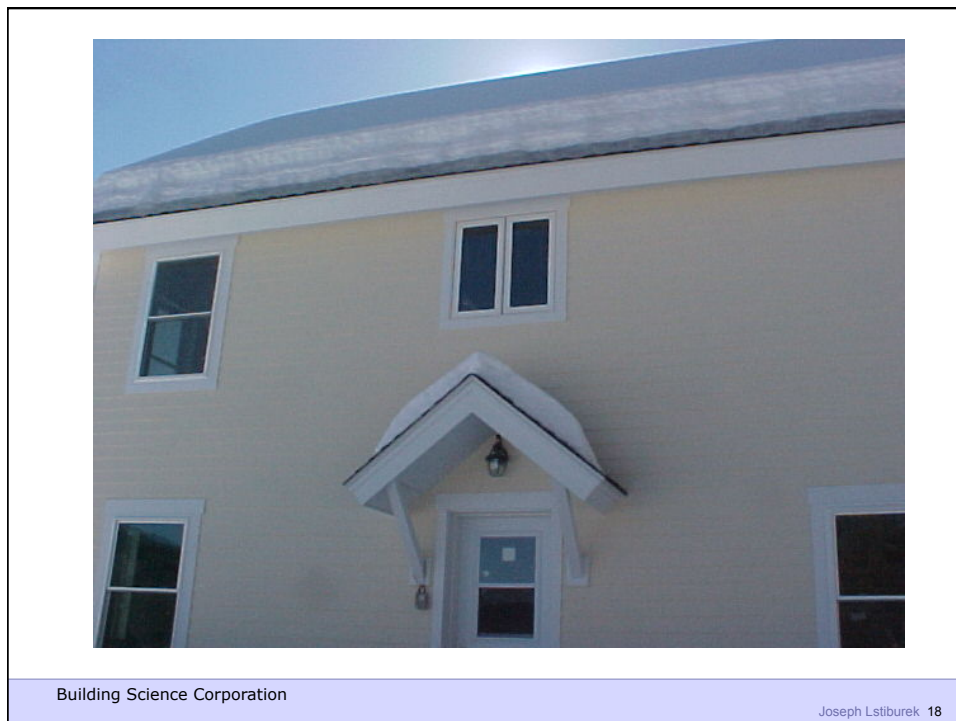
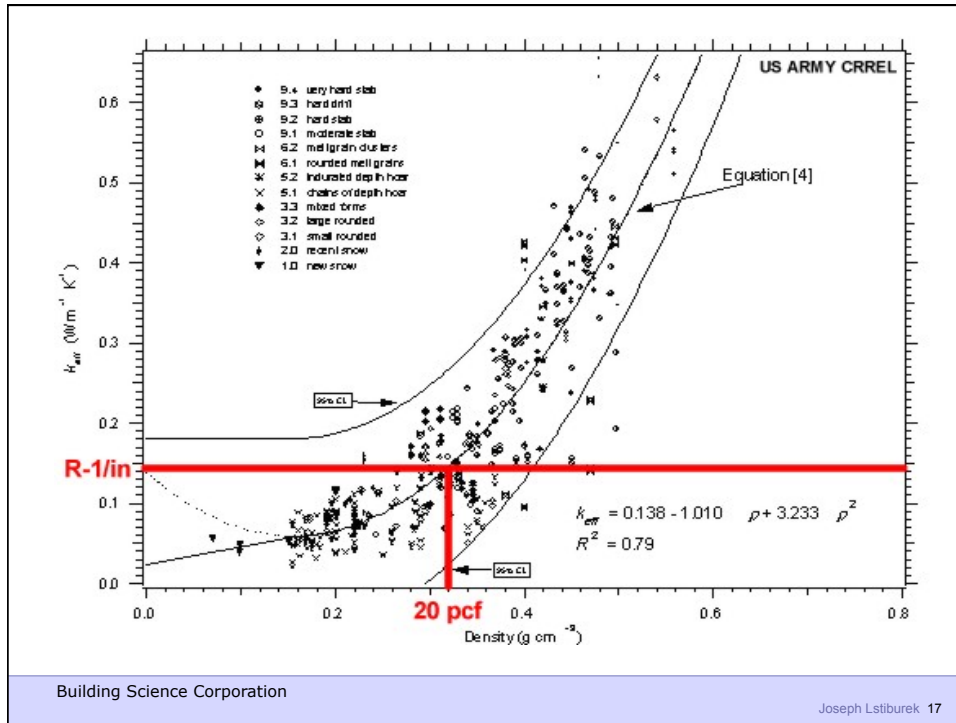
Building Science Corporation

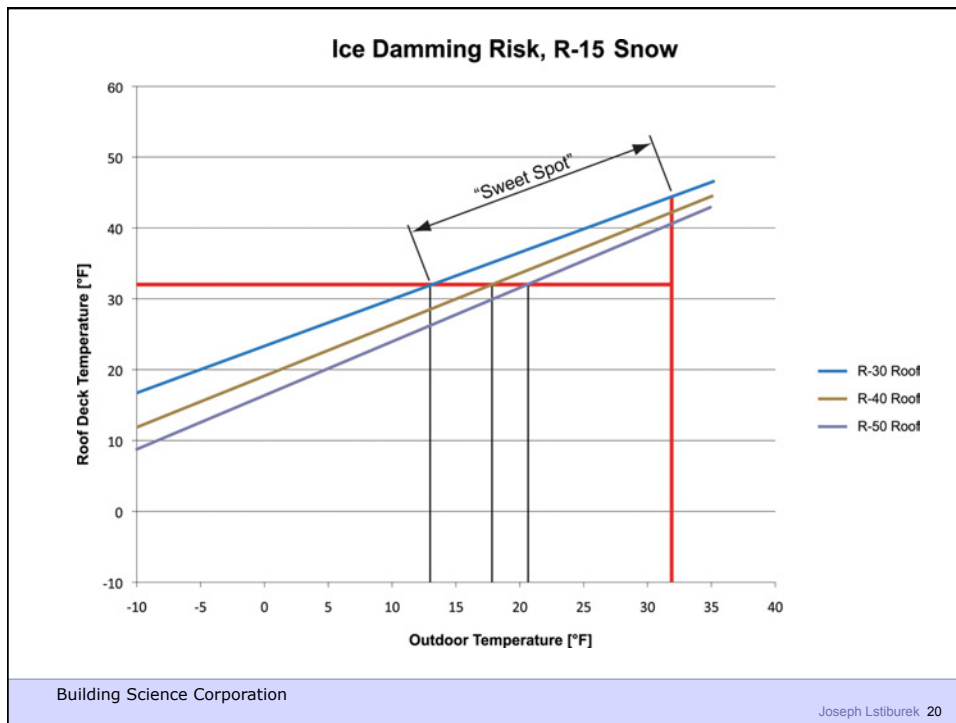
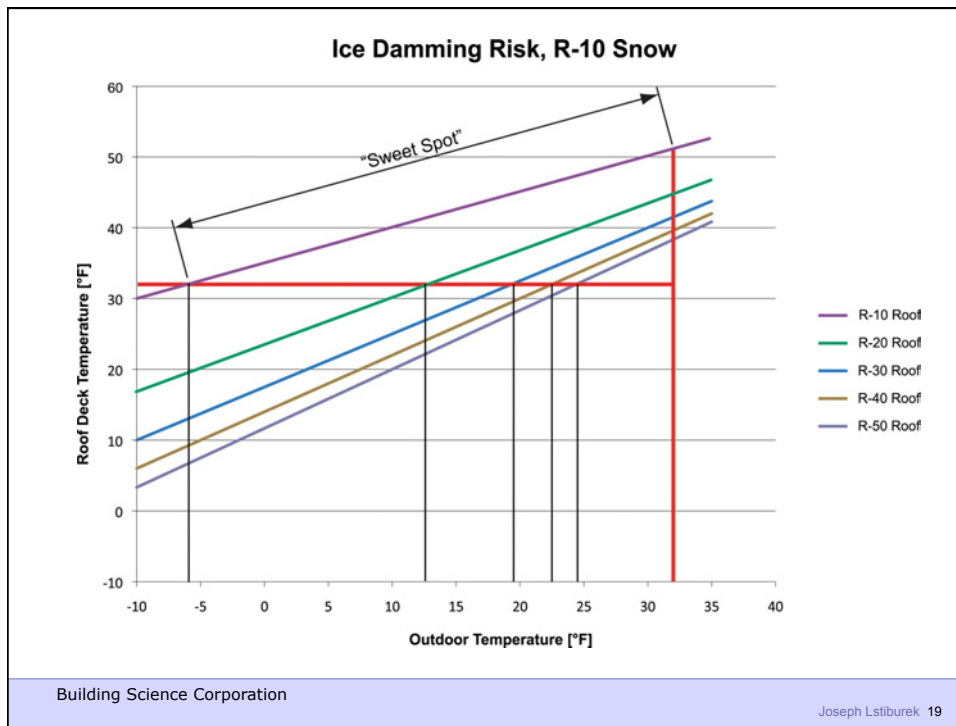
Joseph Lstiburek 15

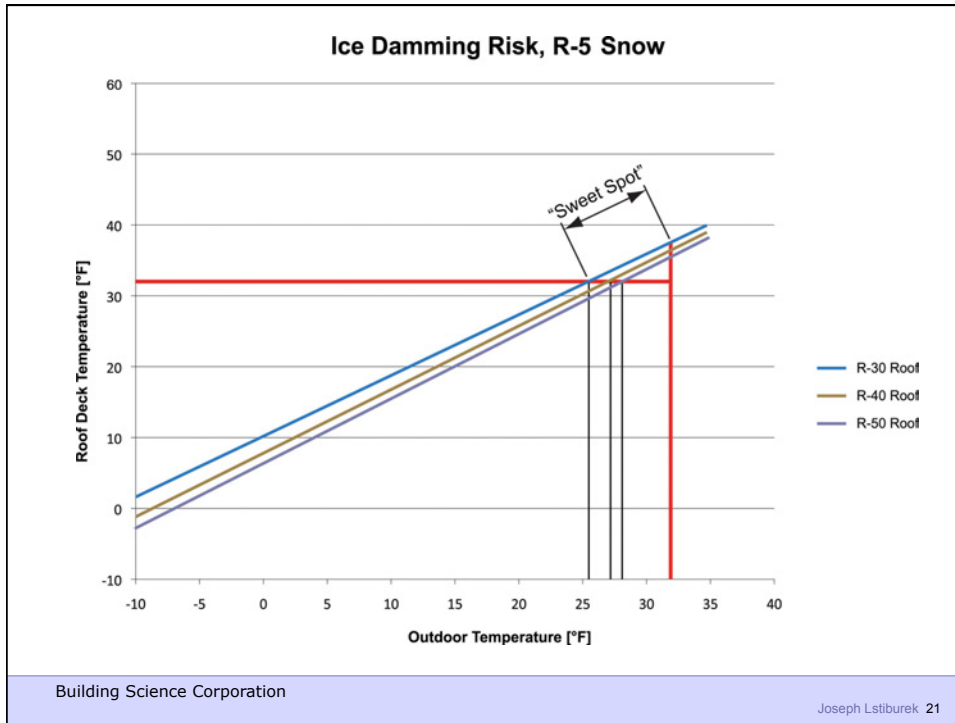


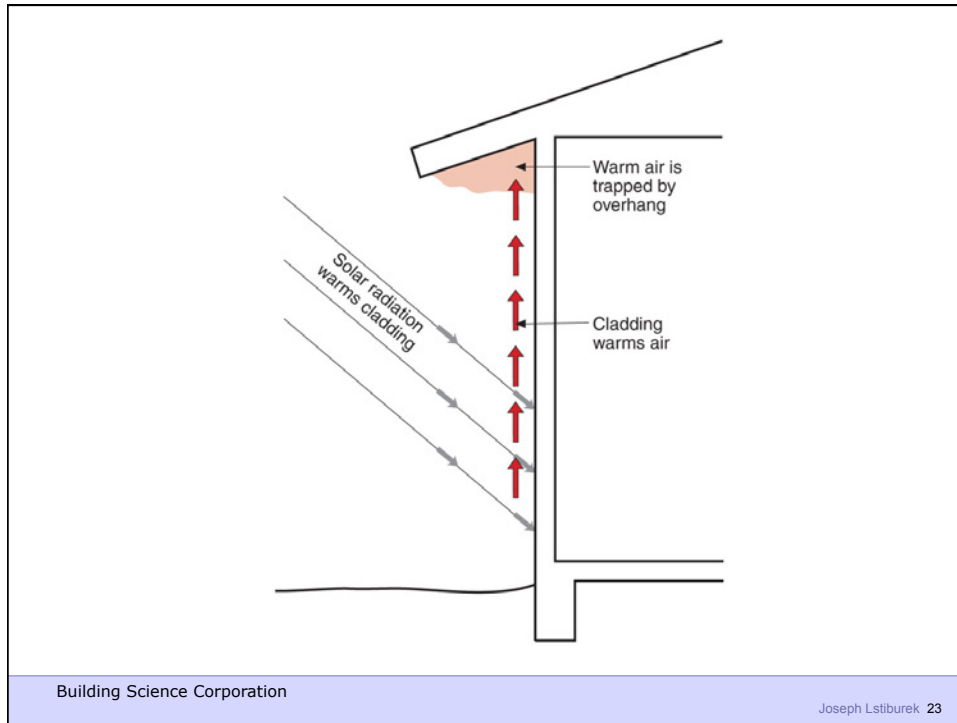
Building Science Corporation

Joseph Lstiburek 16











Building Science Corporation

Joseph Lstiburek 25



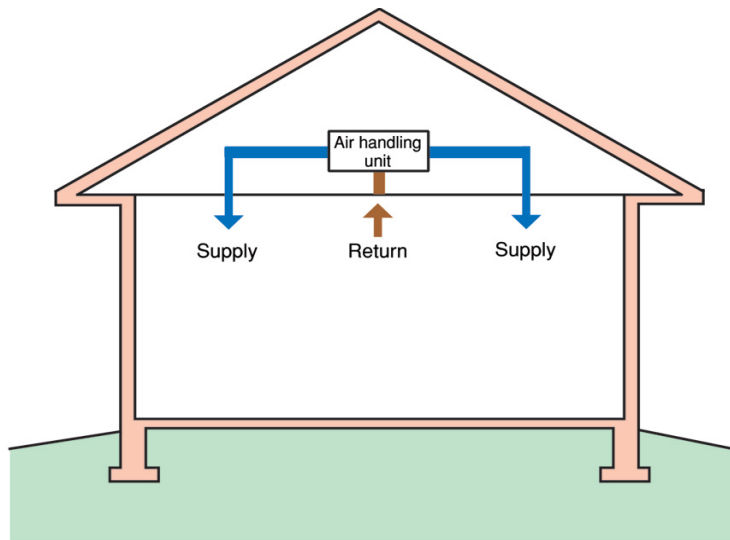
Building Science Corporation

Joseph Lstiburek 26



Building Science Corporation

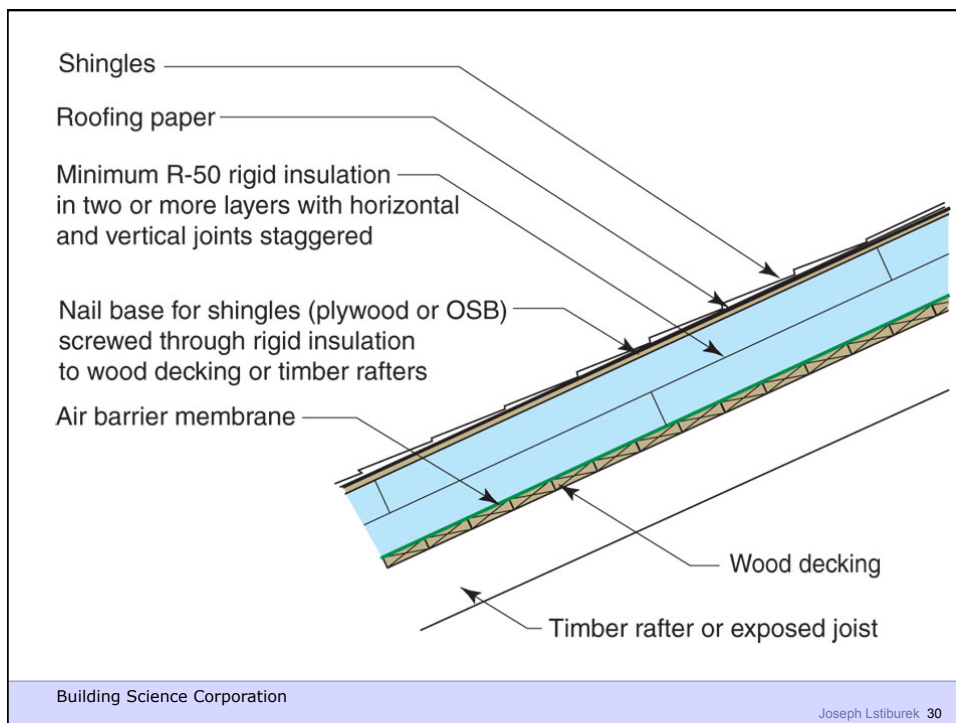
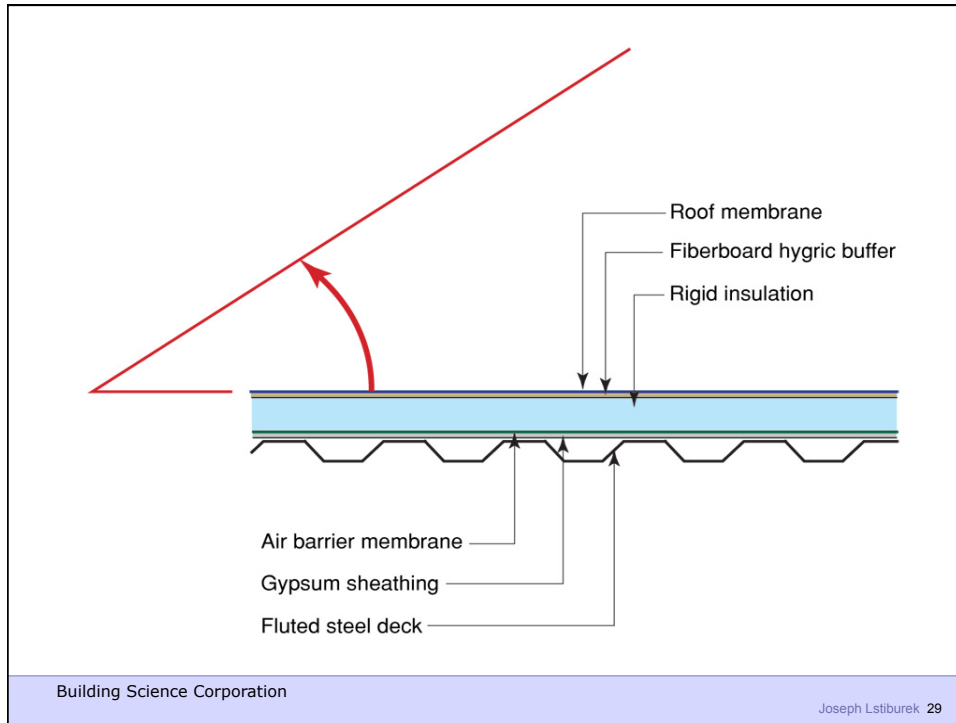
Joseph Lstiburek 27

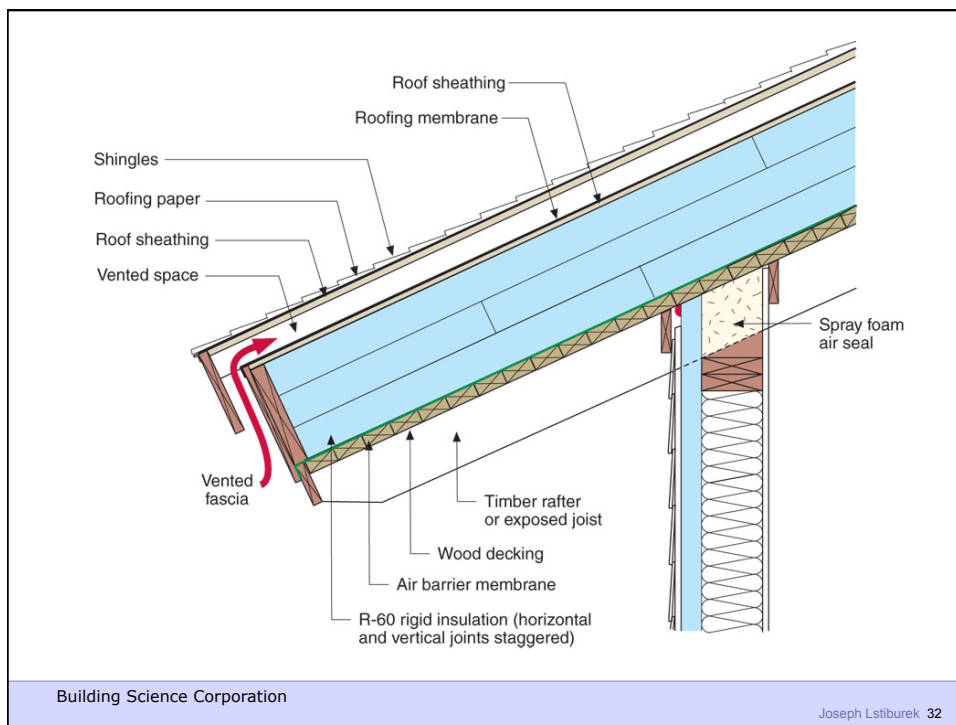
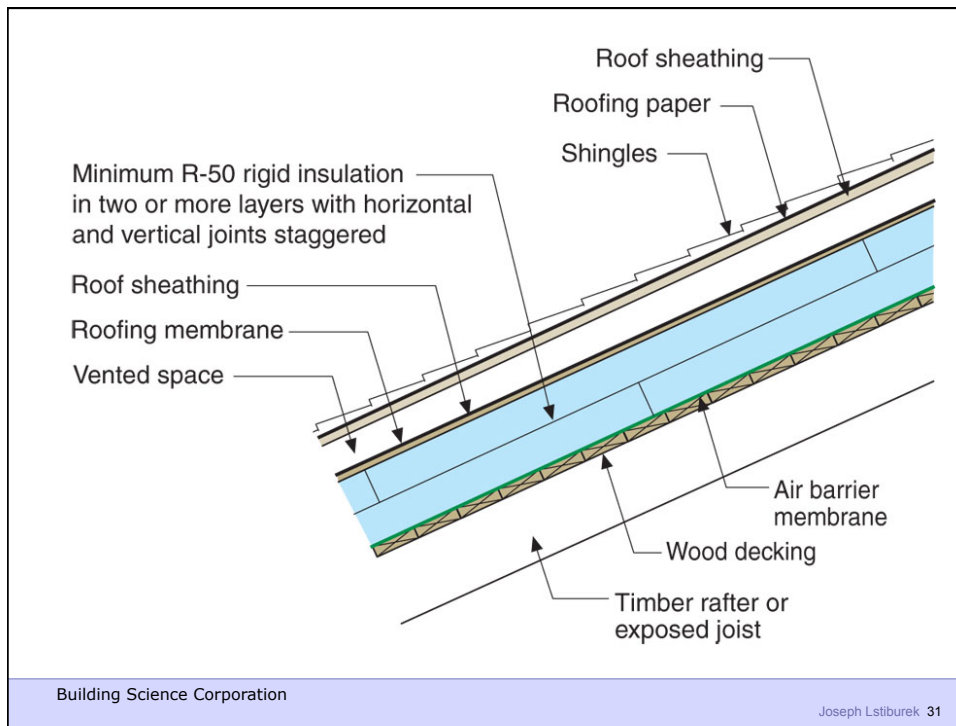


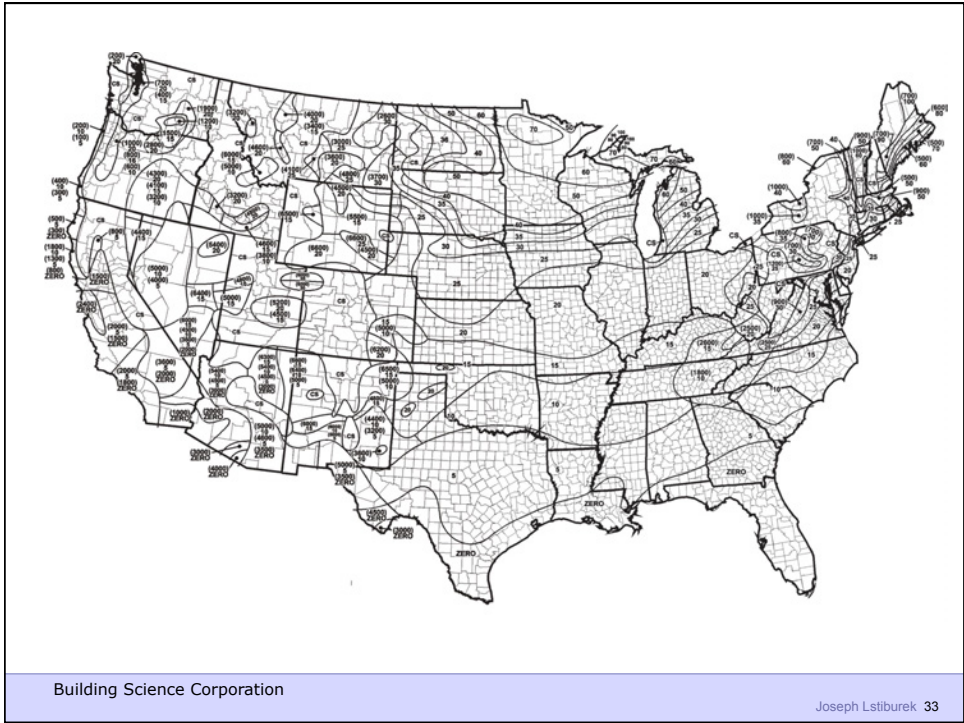
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

Building Science Corporation

Joseph Lstiburek 28









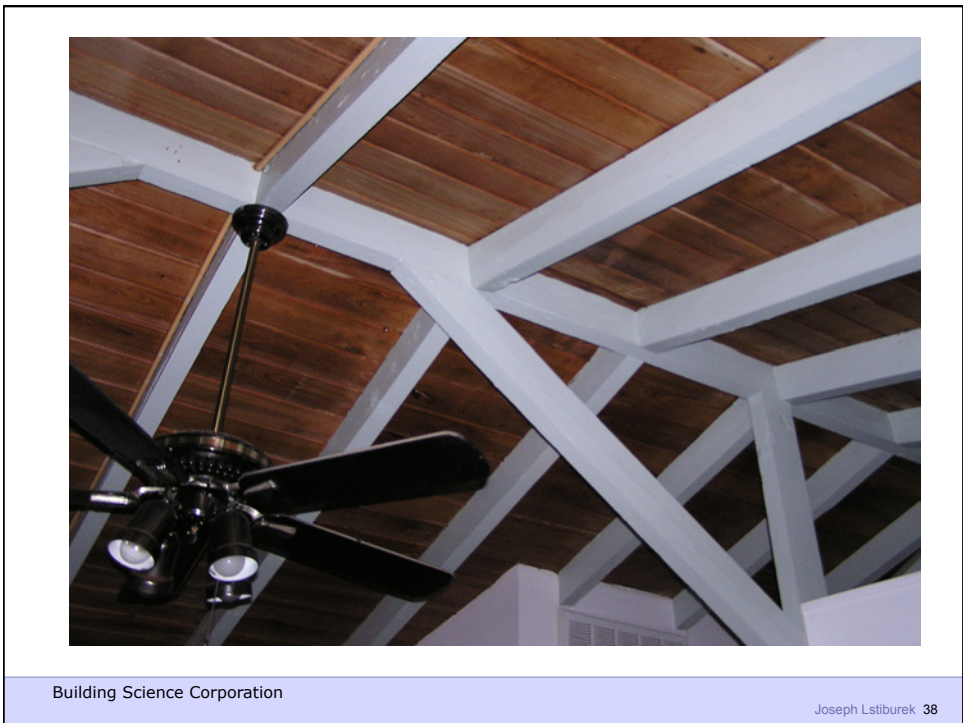
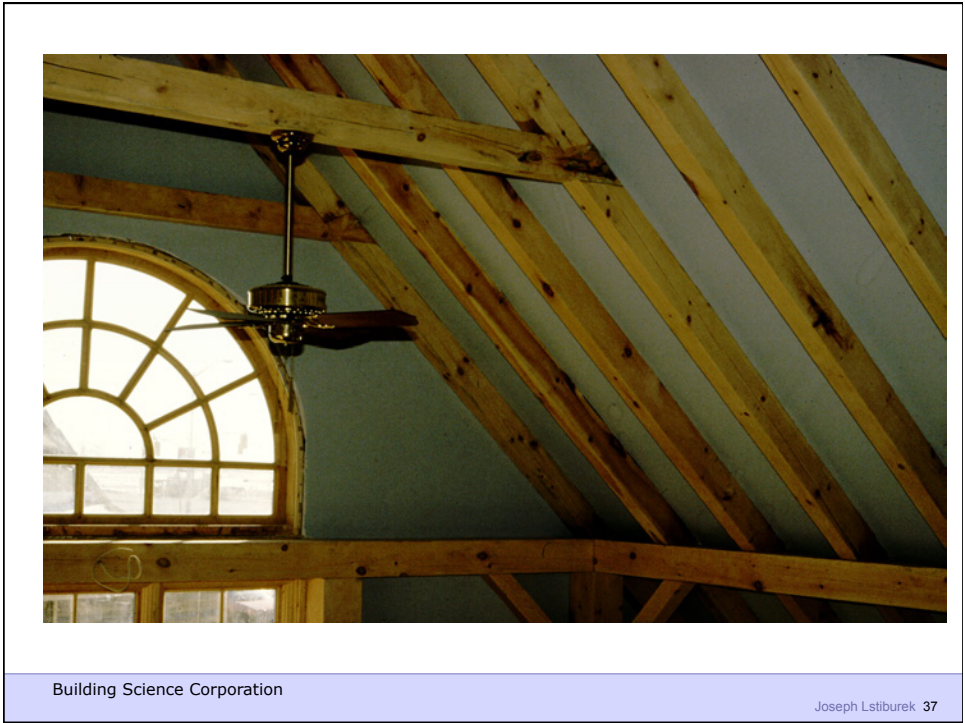
Building Science Corporation

Joseph Lstiburek 35



Building Science Corporation

Joseph Lstiburek 36





Building Science Corporation



Building Science Corporation





Building Science Corporation

Joseph Lstiburek 43



Building Science Corporation

Joseph Lstiburek 44



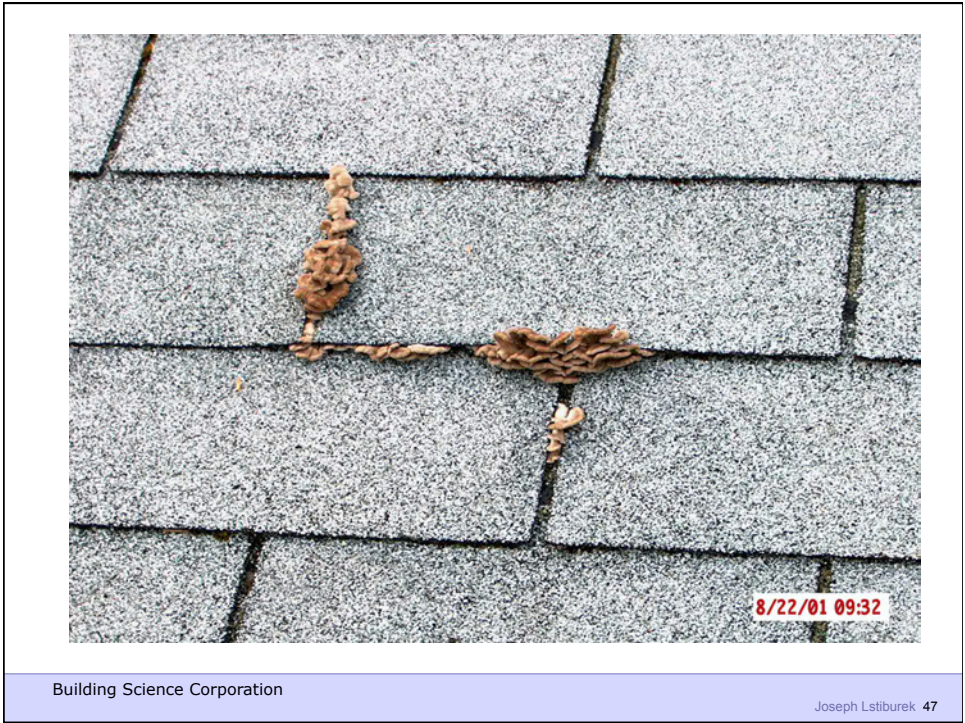
Building Science Corporation

Joseph Lstiburek 45



Building Science Corporation

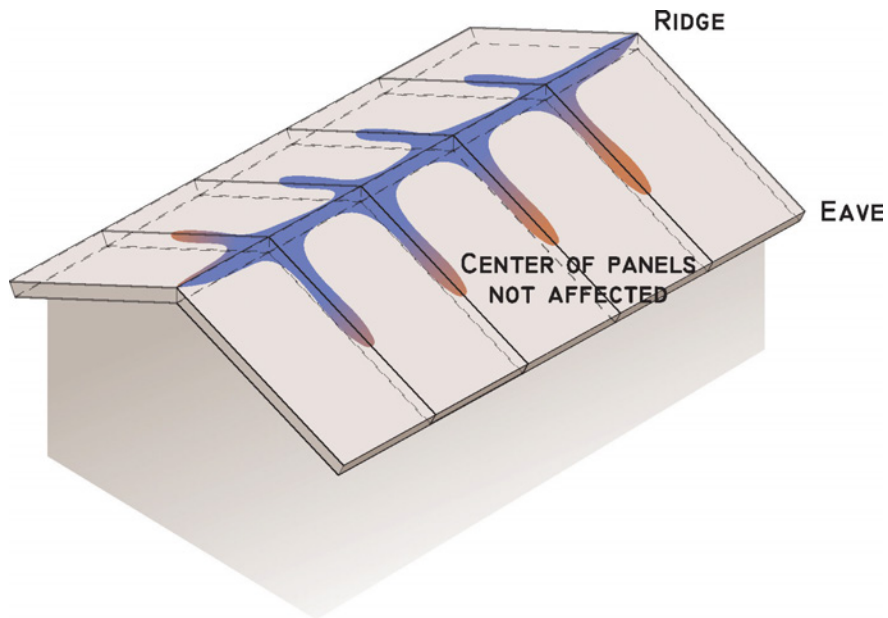
Joseph Lstiburek 46





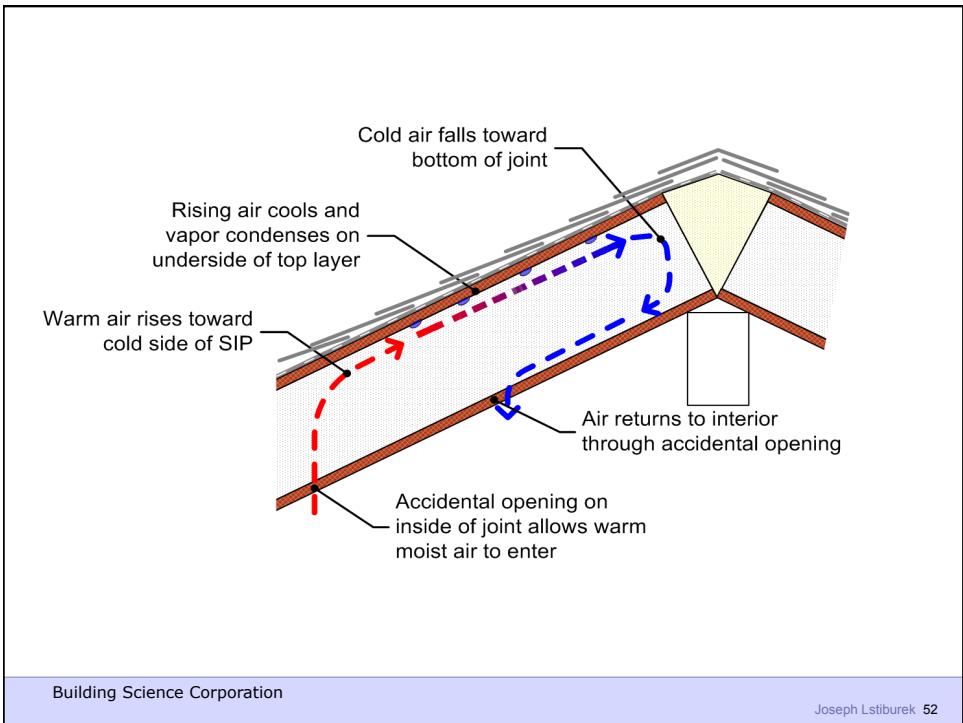
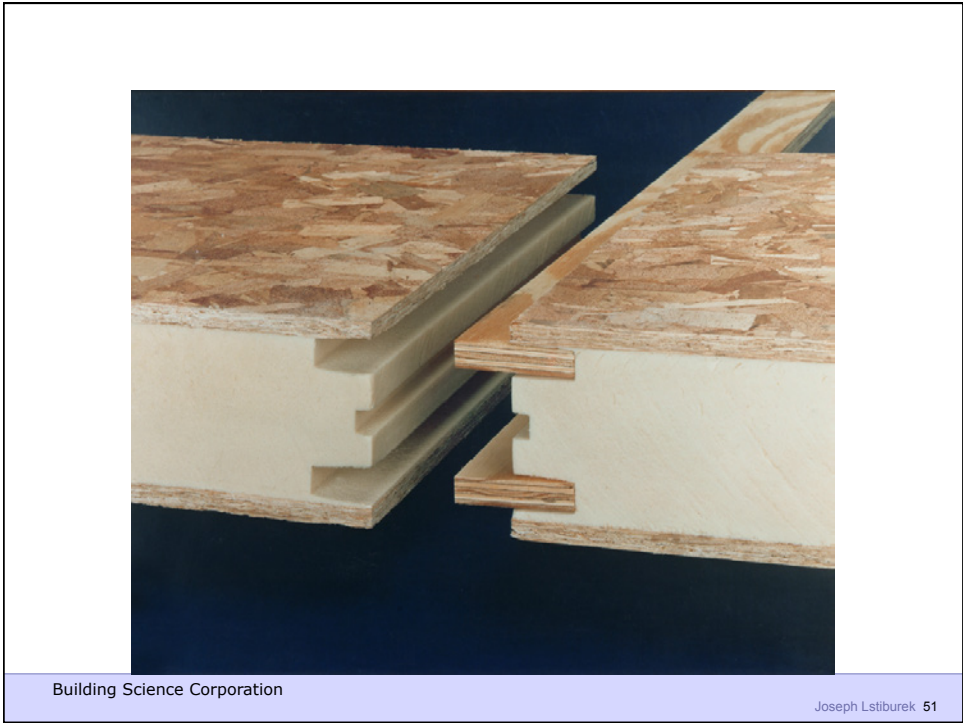
Building Science Corporation

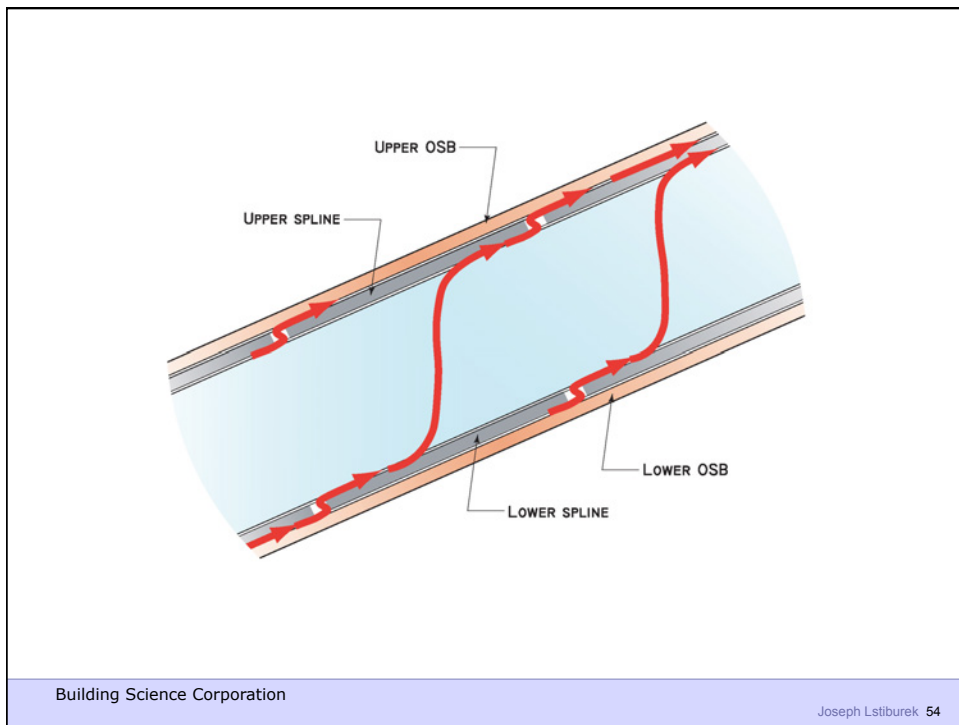
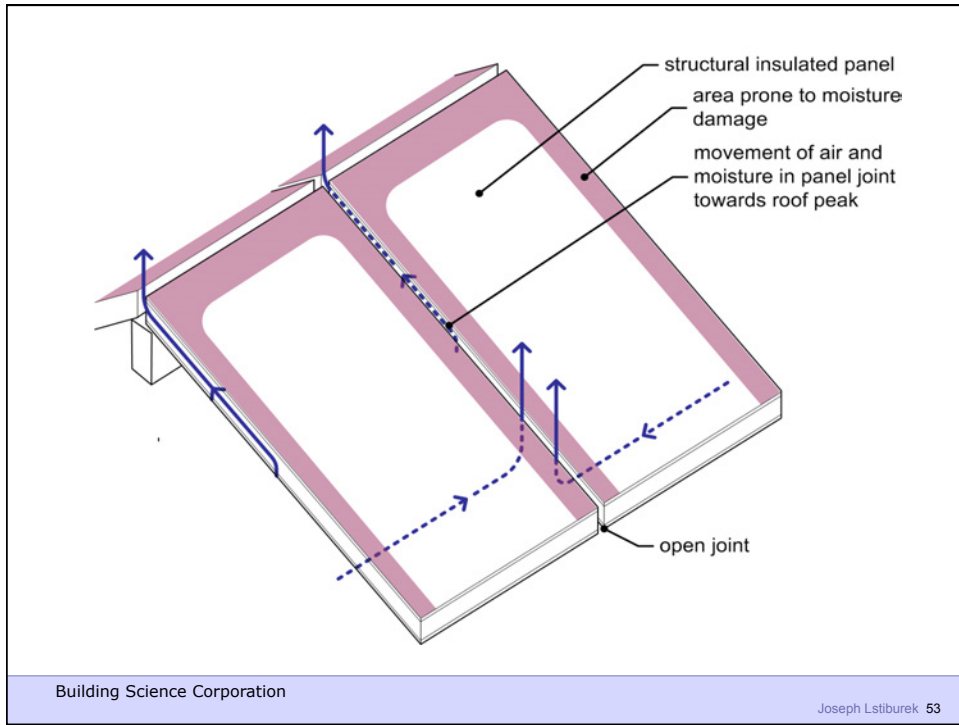
Joseph Lstiburek 49



Building Science Corporation

Joseph Lstiburek 50







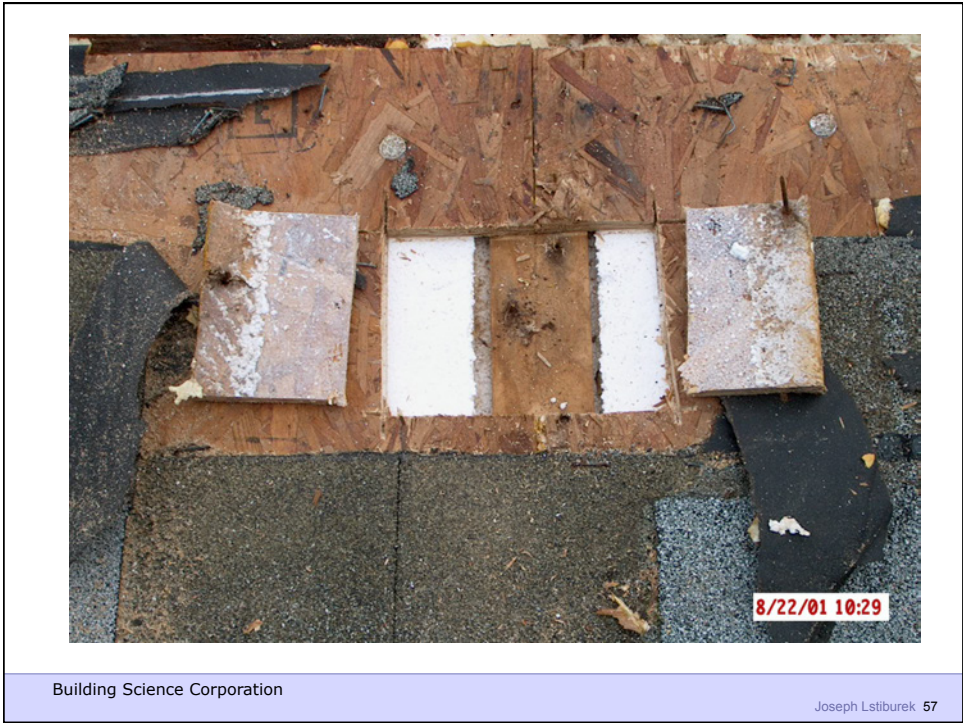
Building Science Corporation

Joseph Lstiburek 55



Building Science Corporation

Joseph Lstiburek 56





Building Science Corporation

Joseph Lstiburek 59



Building Science Corporation

Joseph Lstiburek 60



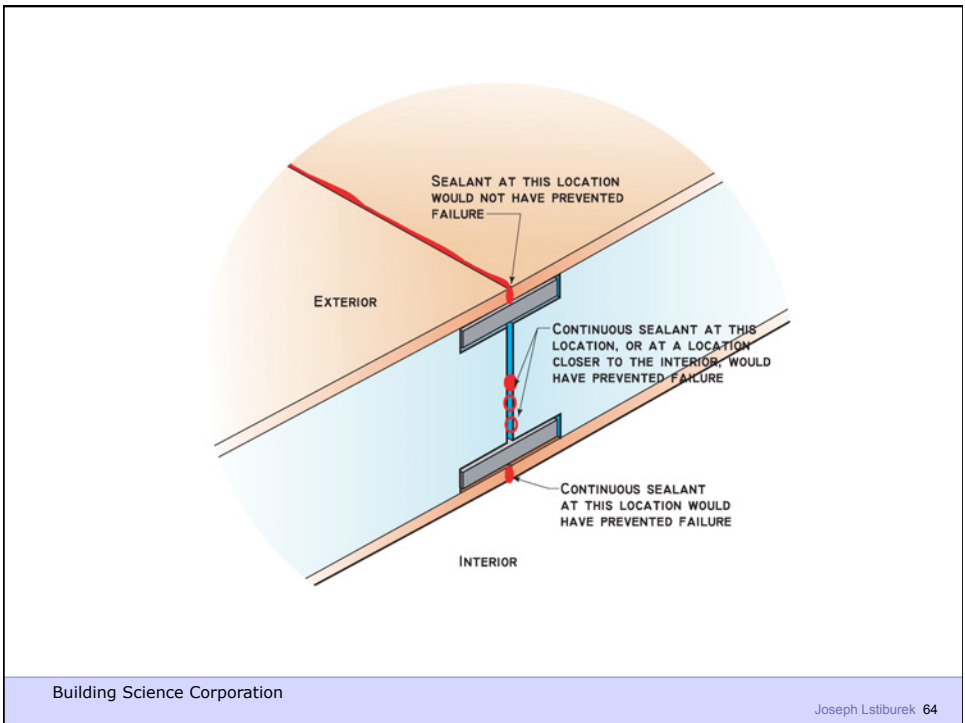
Building Science Corporation

Joseph Lstiburek 61



Building Science Corporation

Joseph Lstiburek 62



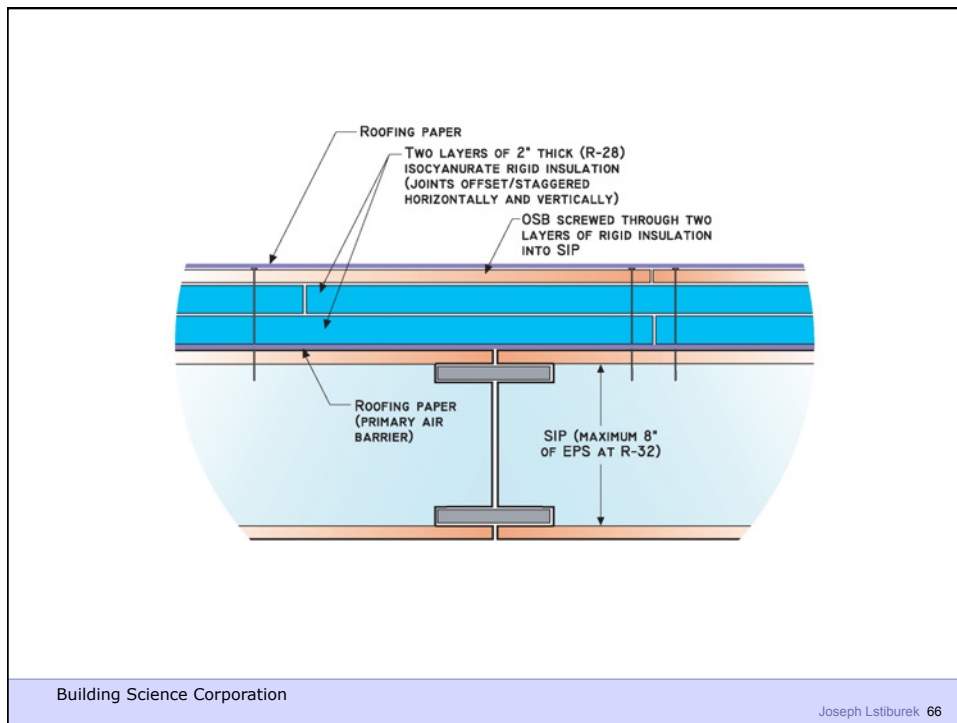
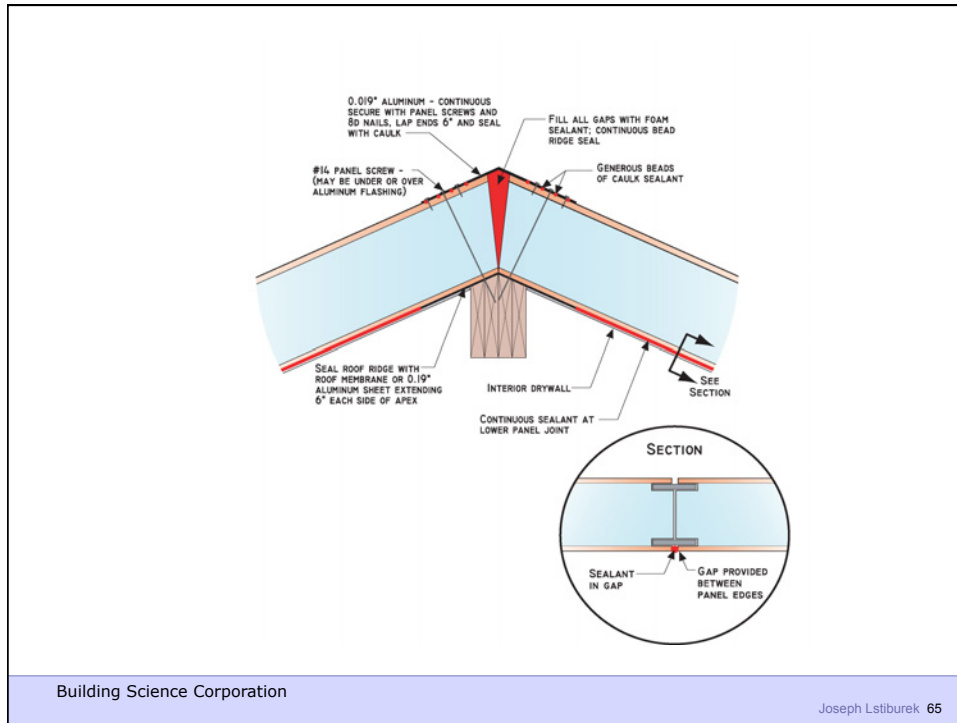


Figure 1

- Remove strip of OSB from each side of ridge

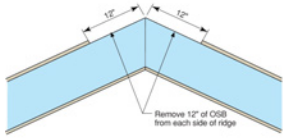


Figure 2

- Create air seal with strip of Tyvek® (tape seams of Tyvek®)
- Hold Tyvek® sheet in place with metal strapping

Tyvek® sheet sealed to OSB with acrylic caulk sealant

Metal strap nailed over top of Tyvek® sheet (acting as pressure bar)

Continuous bead of sealant between OSB and Tyvek® sheet

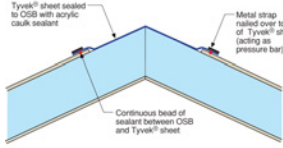
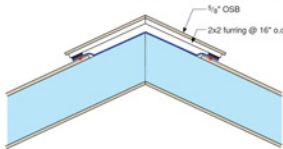


Figure 3

- Construct wood ridge vent with 2x2 furring
- Use Cobra® Ridge Vent roll mesh at edges of vent to control insect entry

1/4" OSB

2x2 furring @ 16" o.c.



Building Science Corporation

Joseph Lstiburek 67



Building Science Corporation

Joseph Lstiburek 68



Building Science Corporation

Joseph Lstiburek 69



Building Science Corporation

Joseph Lstiburek 70



Building Science Corporation

Joseph Lstiburek 71



Building Science Corporation

Joseph Lstiburek 72



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



Building Science Corporation

Joseph Lstiburek 79



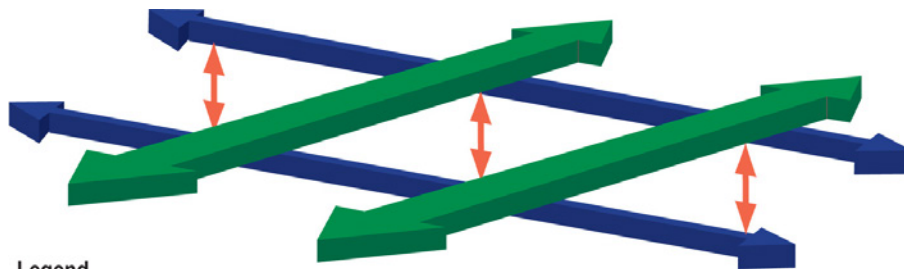
Building Science Corporation

Joseph Lstiburek 80



Building Science Corporation

Joseph Lstiburek 81

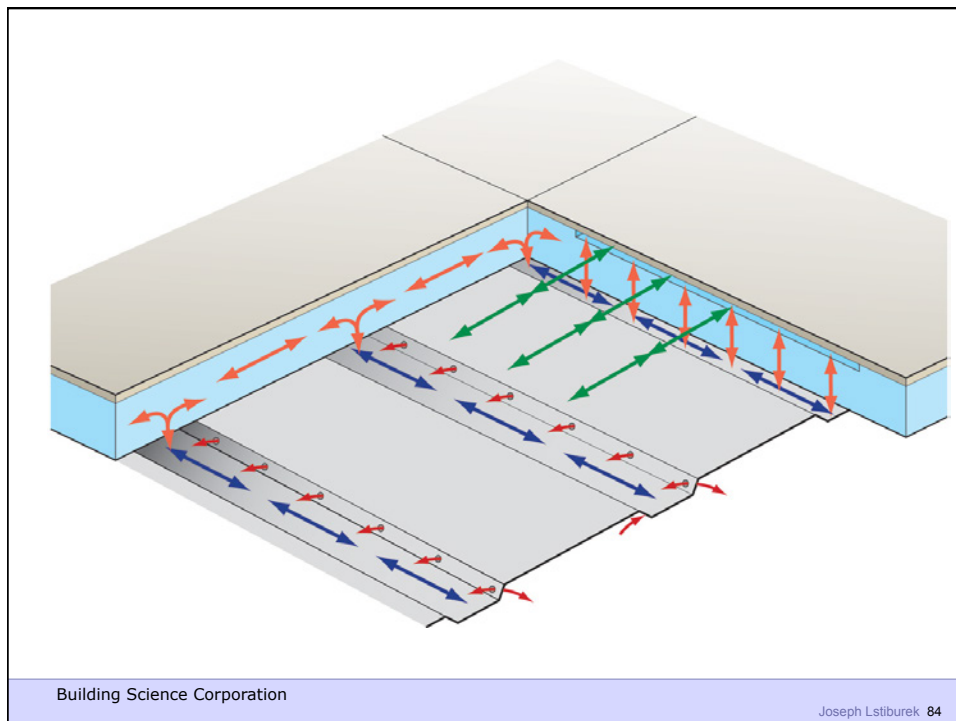
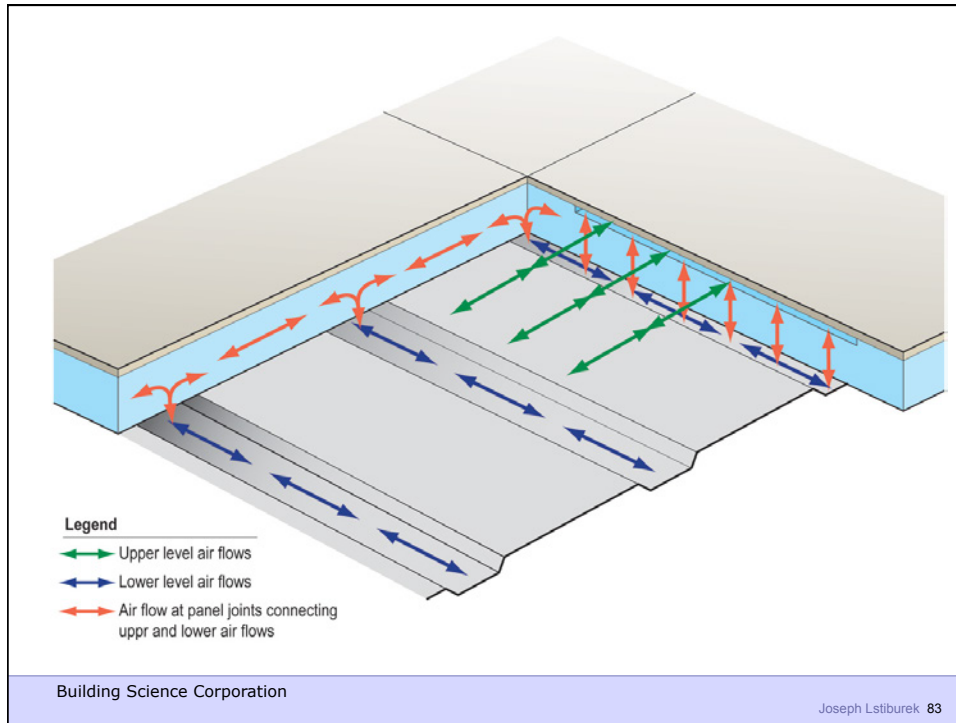


Legend

- ←→ Upper level air flows
- ←→ Lower level air flows
- ↕ Air flow at panel joints

Building Science Corporation

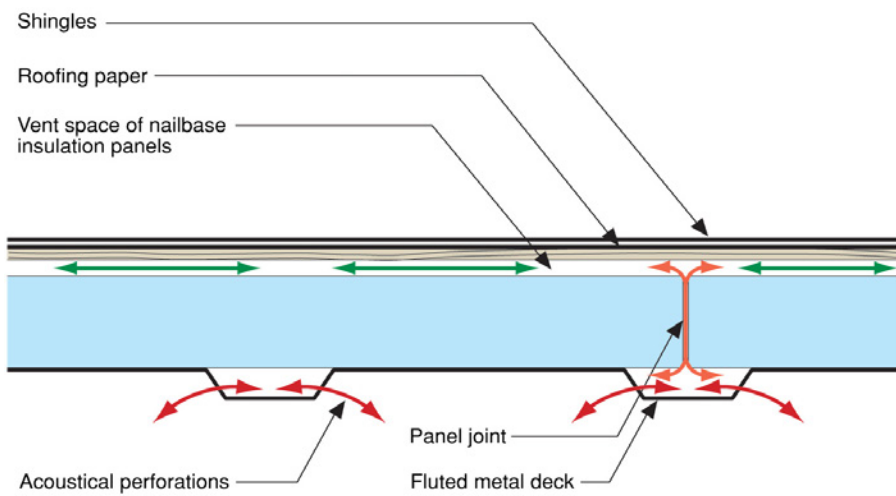
Joseph Lstiburek 82





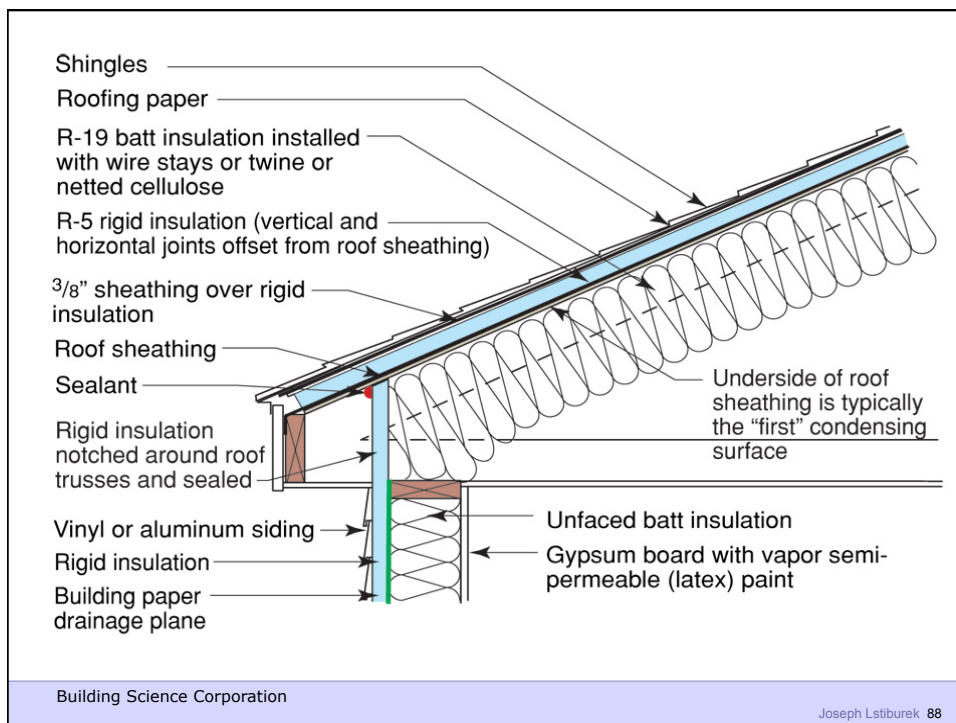
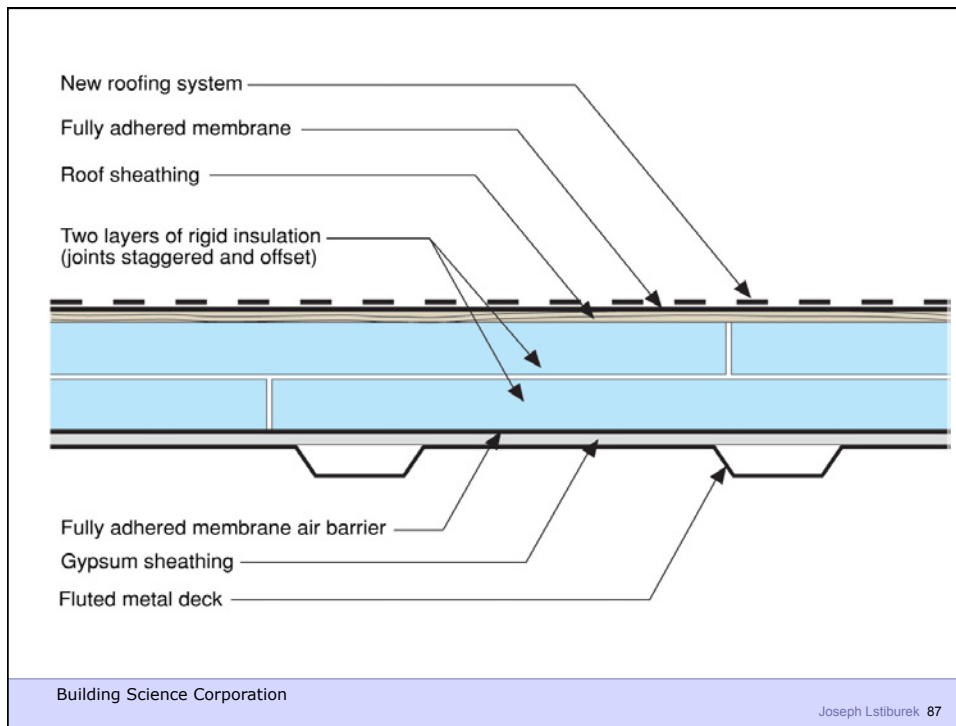
Building Science Corporation

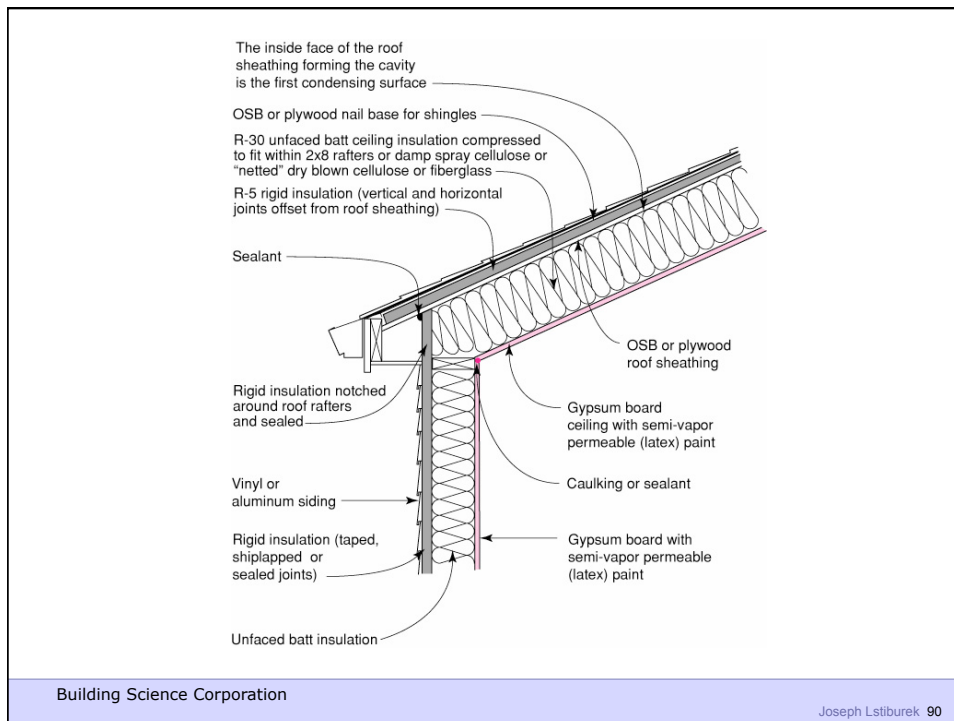
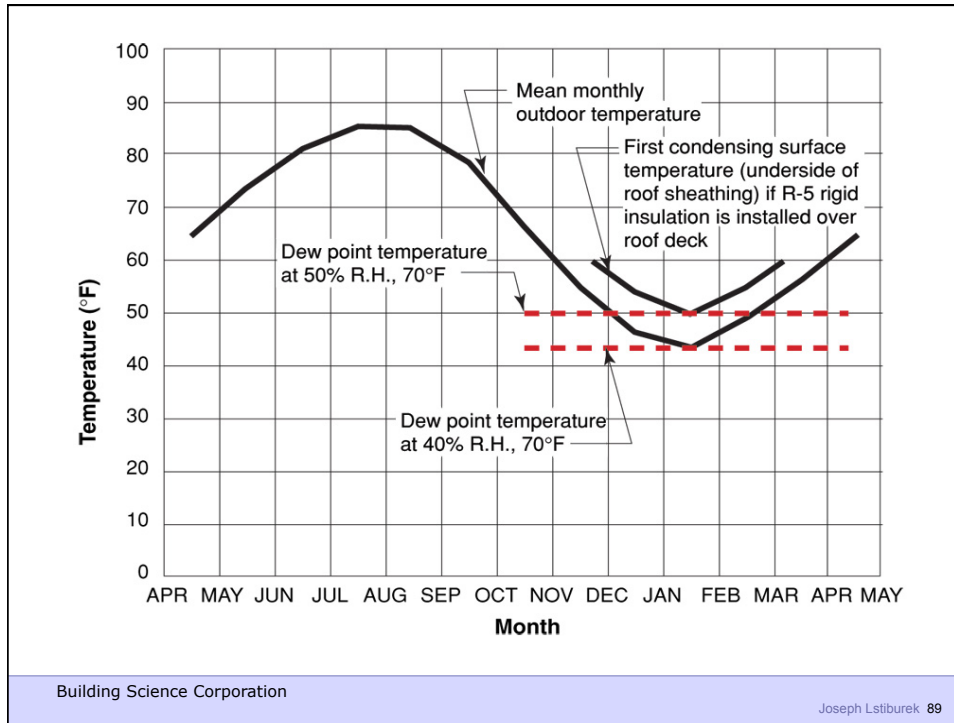
Joseph Lstiburek 85

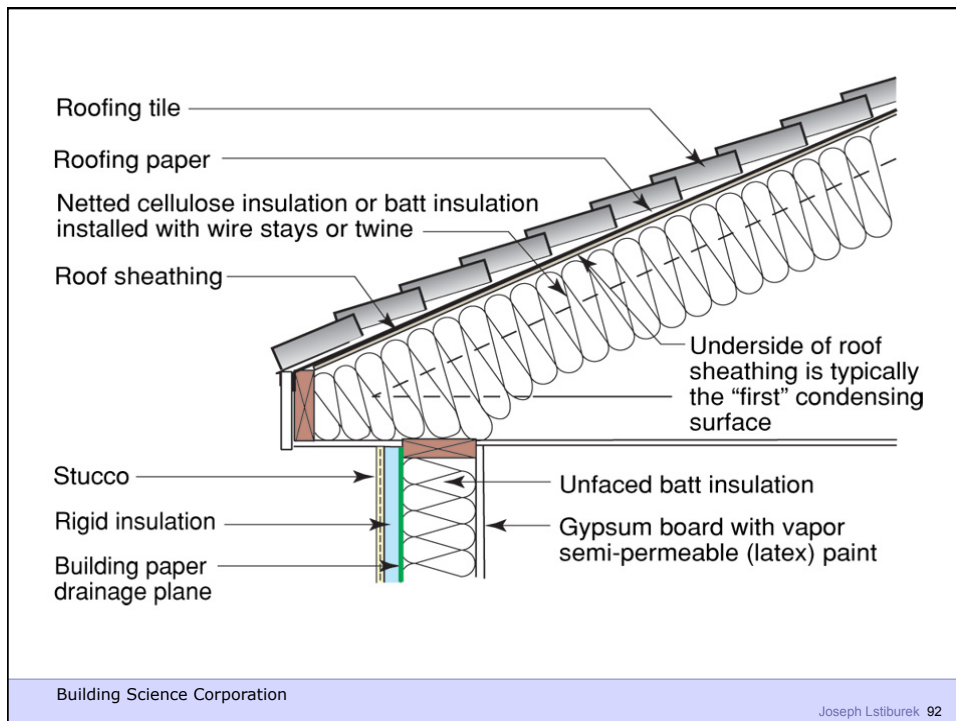
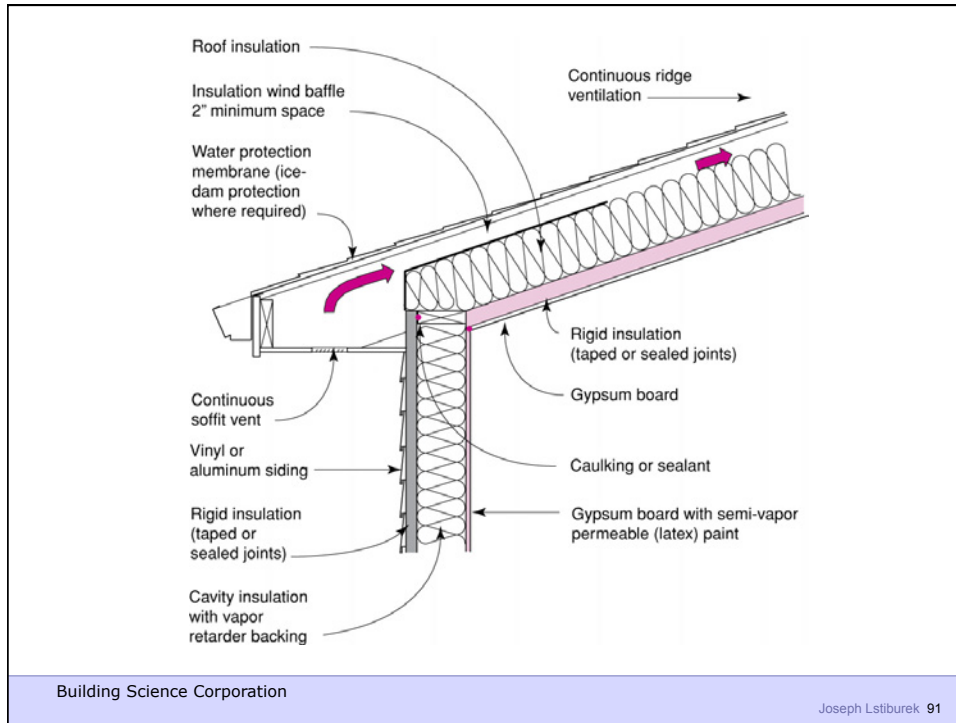


Building Science Corporation

Joseph Lstiburek 86









Building Science Corporation

Joseph Lstiburek 93



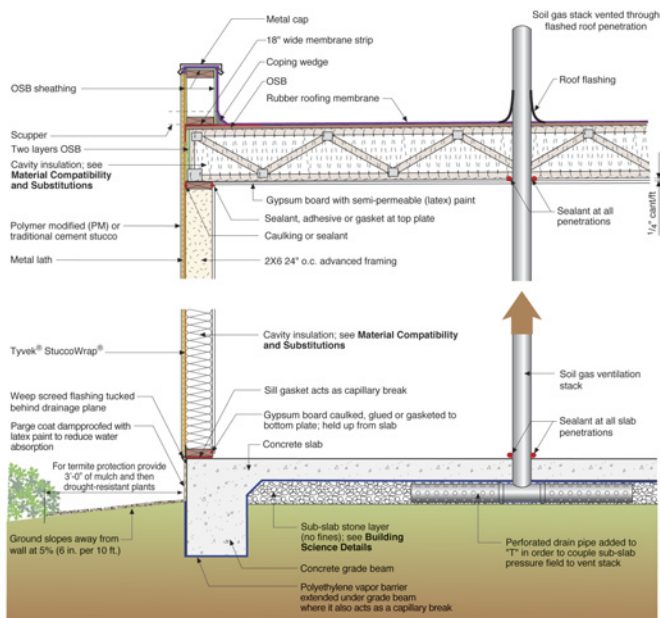
Building Science Corporation

Joseph Lstiburek 94



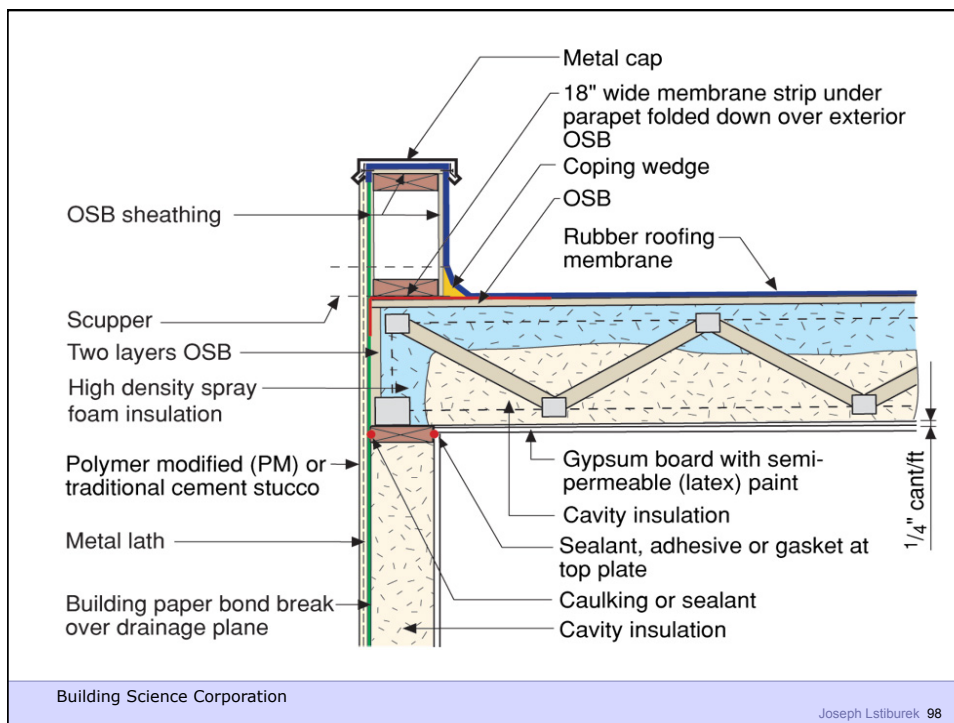
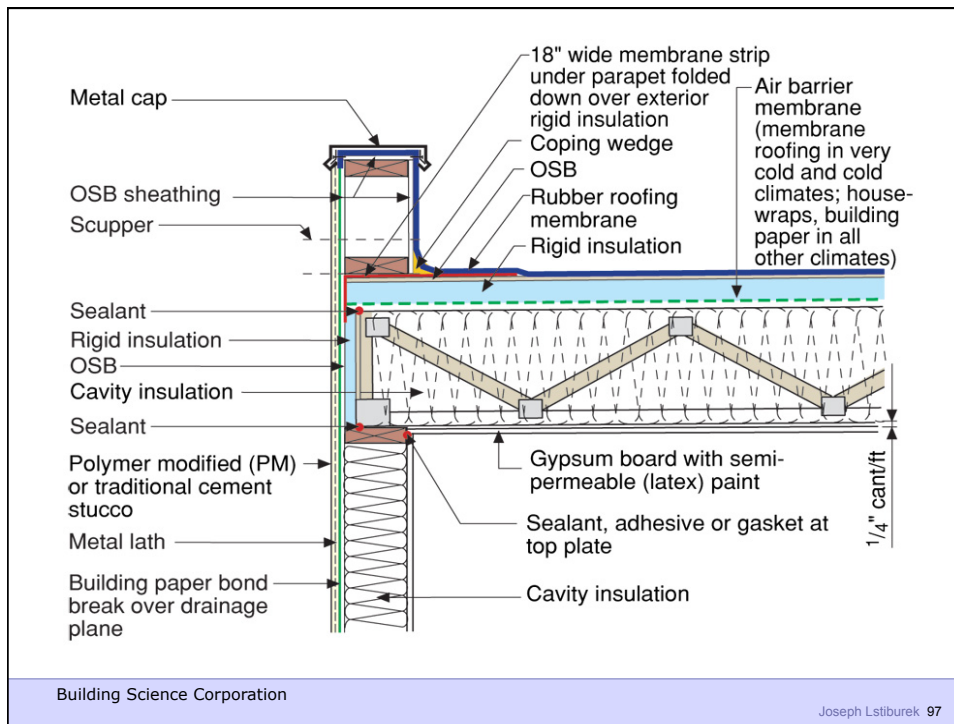
Building Science Corporation

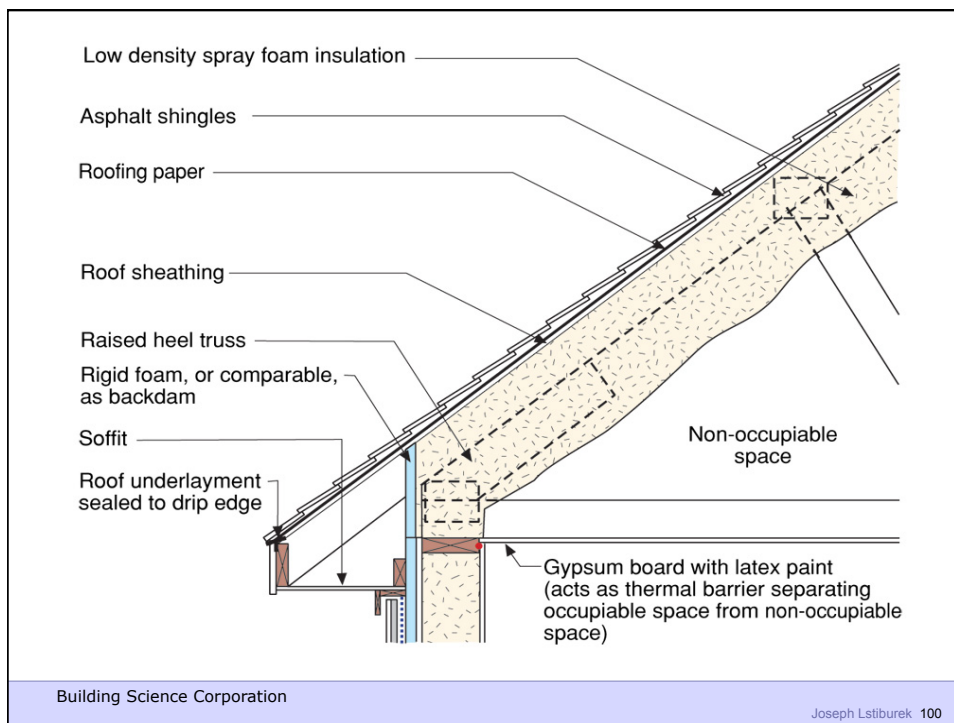
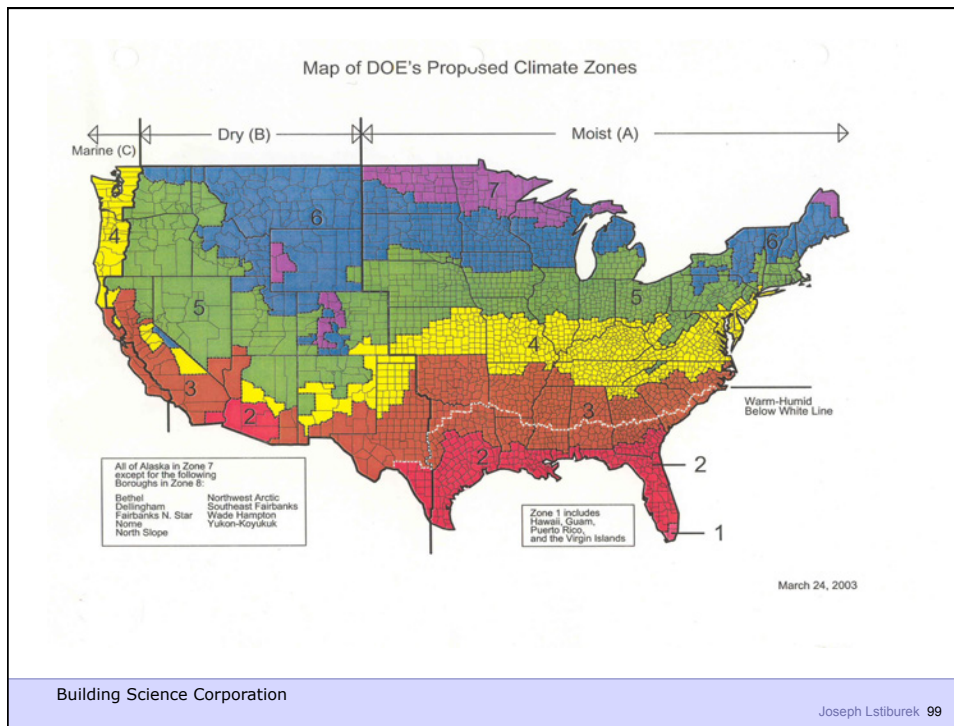
Joseph Lstiburek 95



Building Science Corporation

Joseph Lstiburek 96







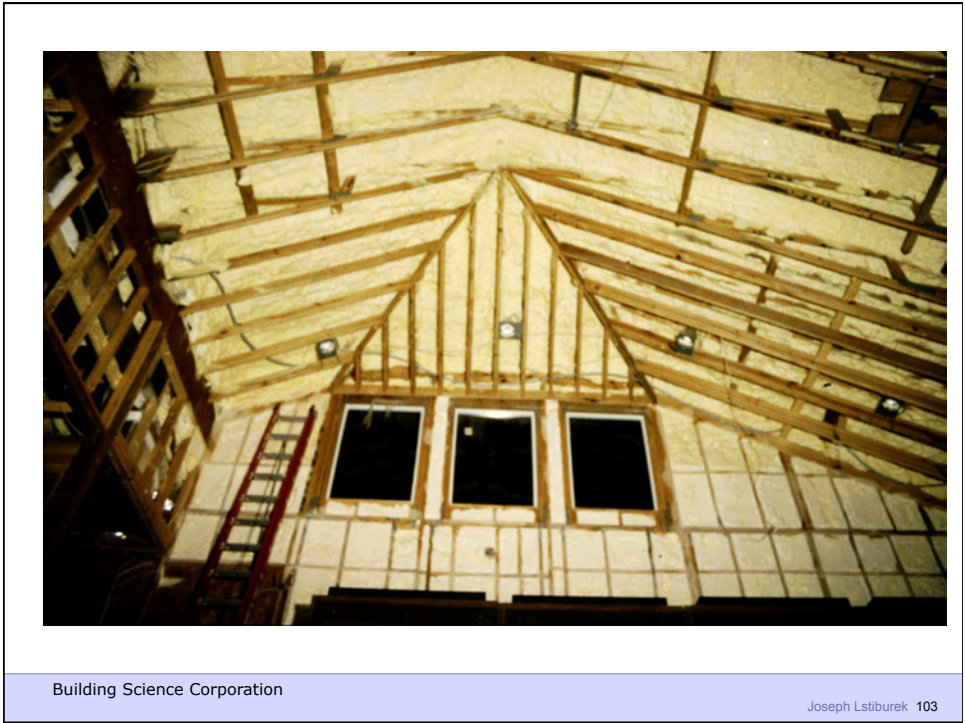
Building Science Corporation

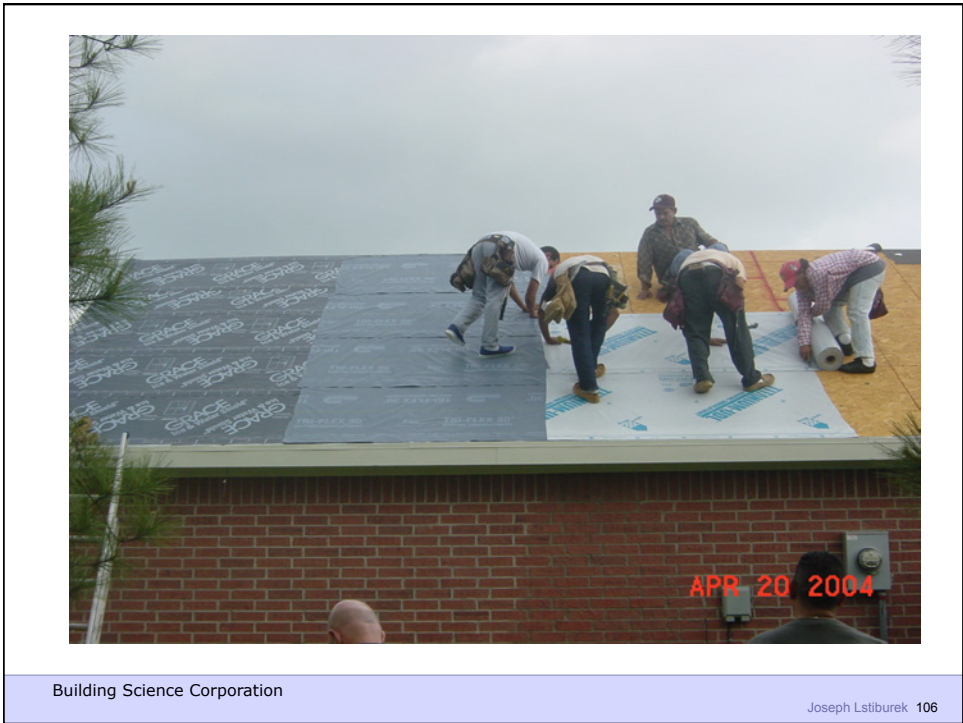
Joseph Lstiburek 101



Building Science Corporation

Joseph Lstiburek 102







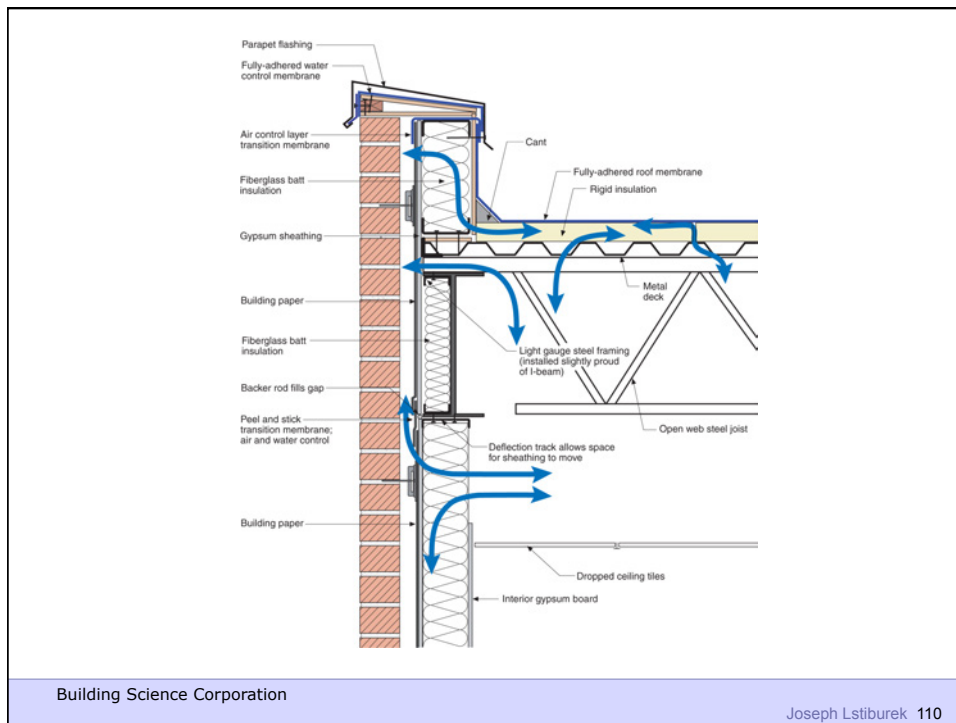
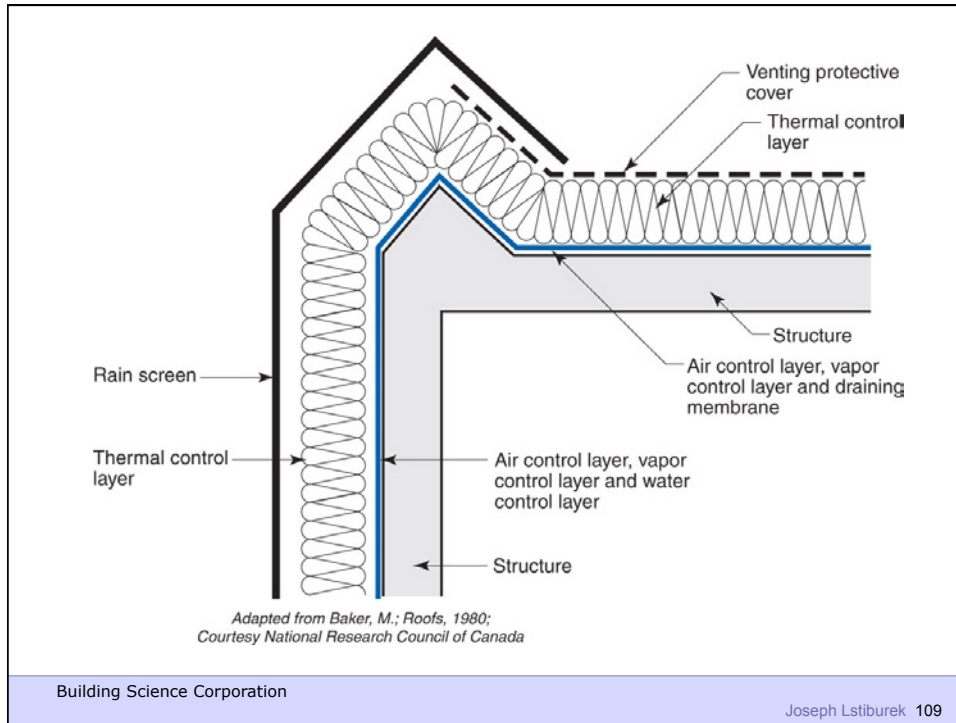
Building Science Corporation

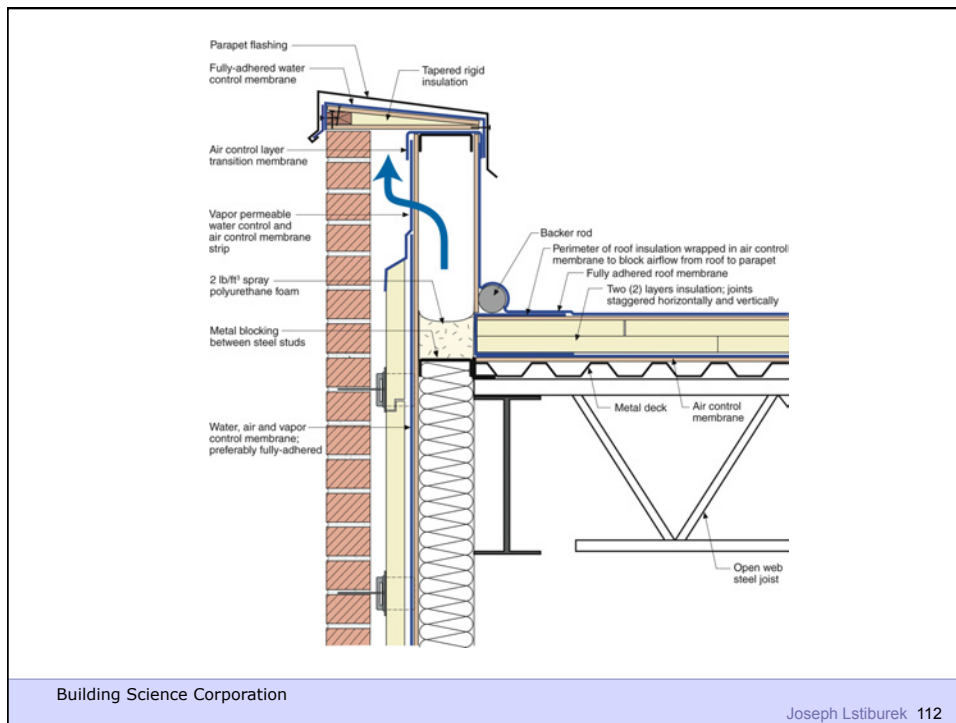
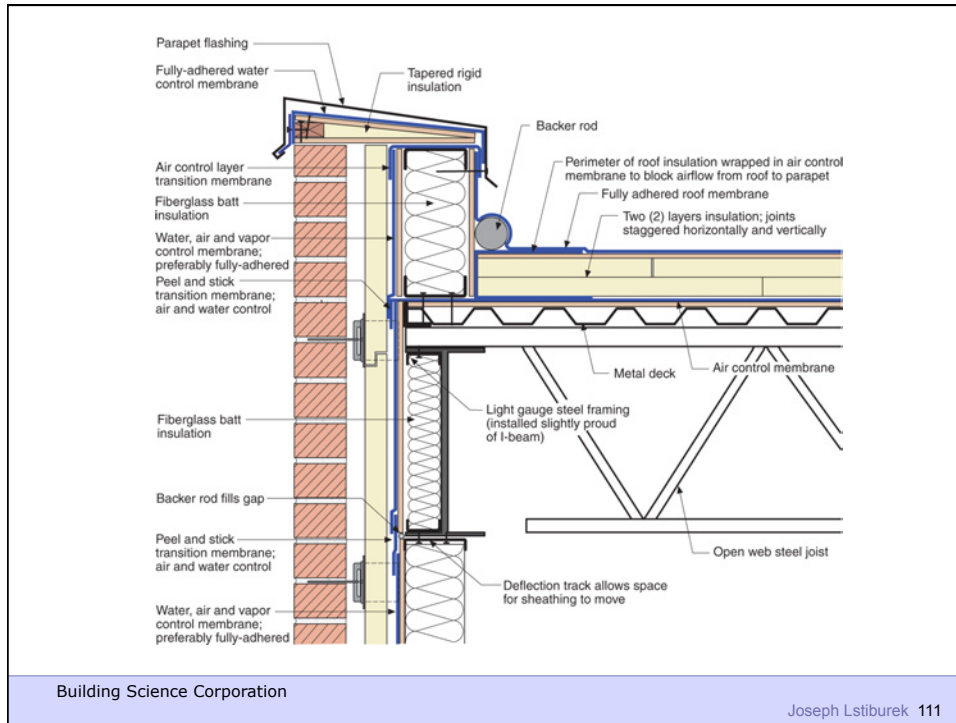
Joseph Lstiburek 107

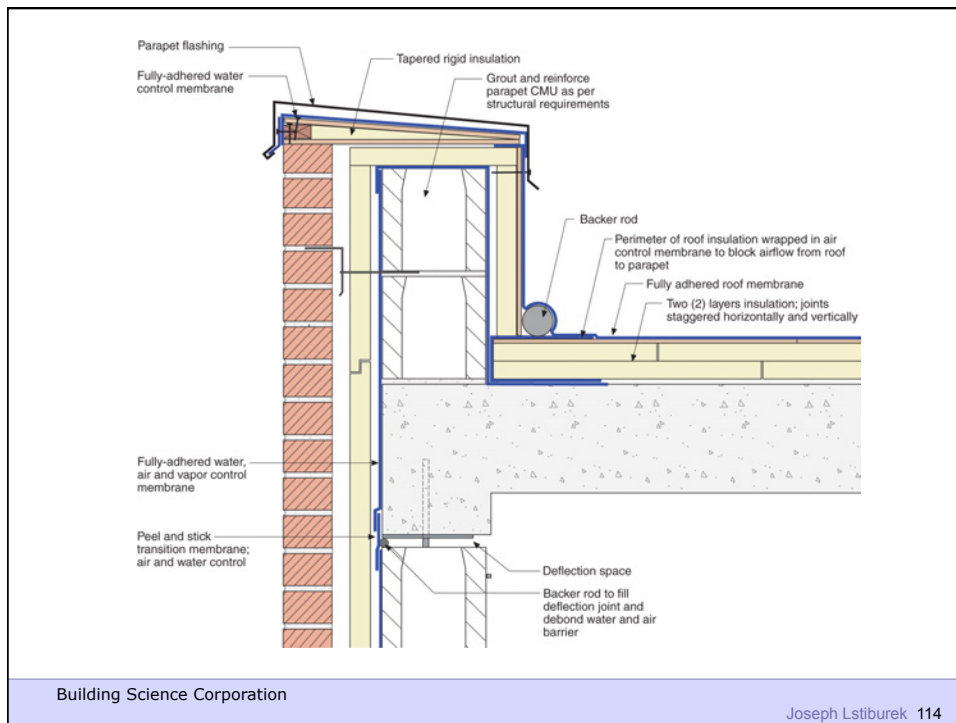
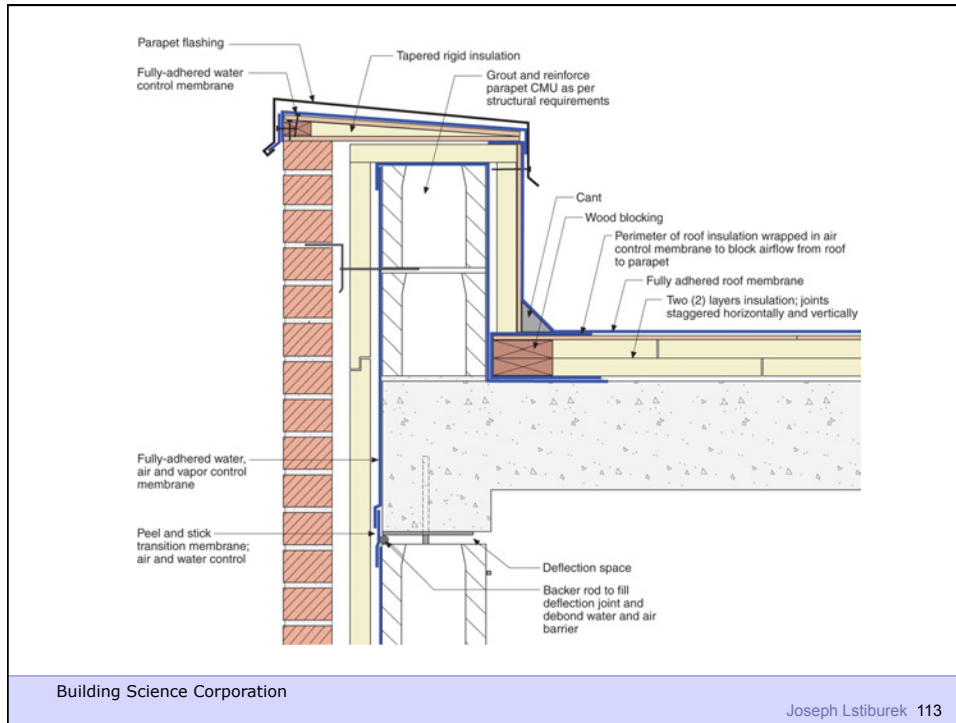


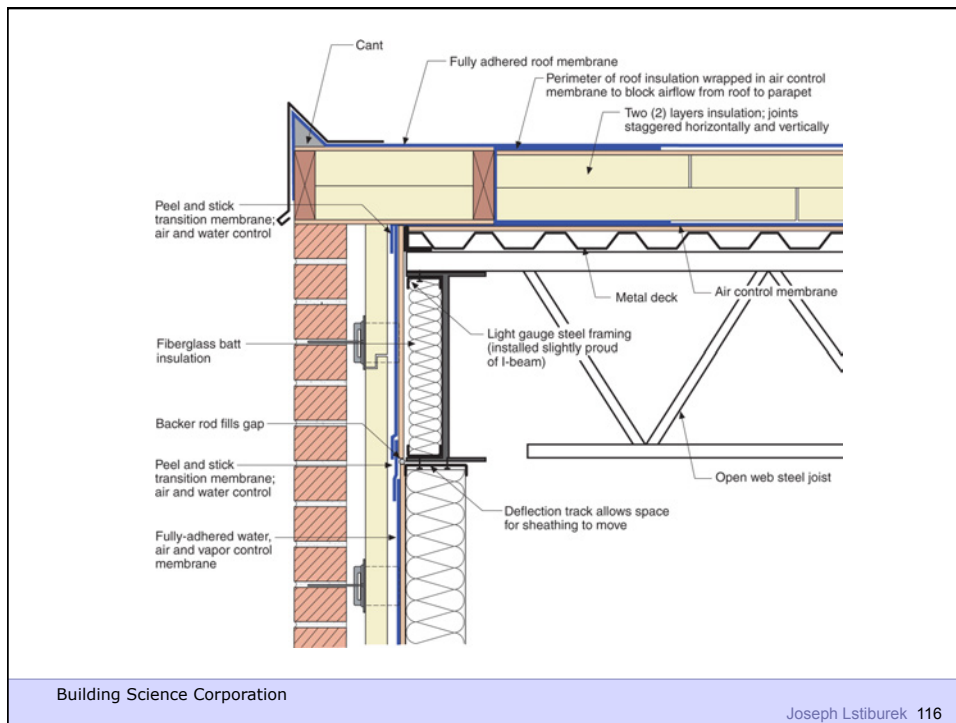
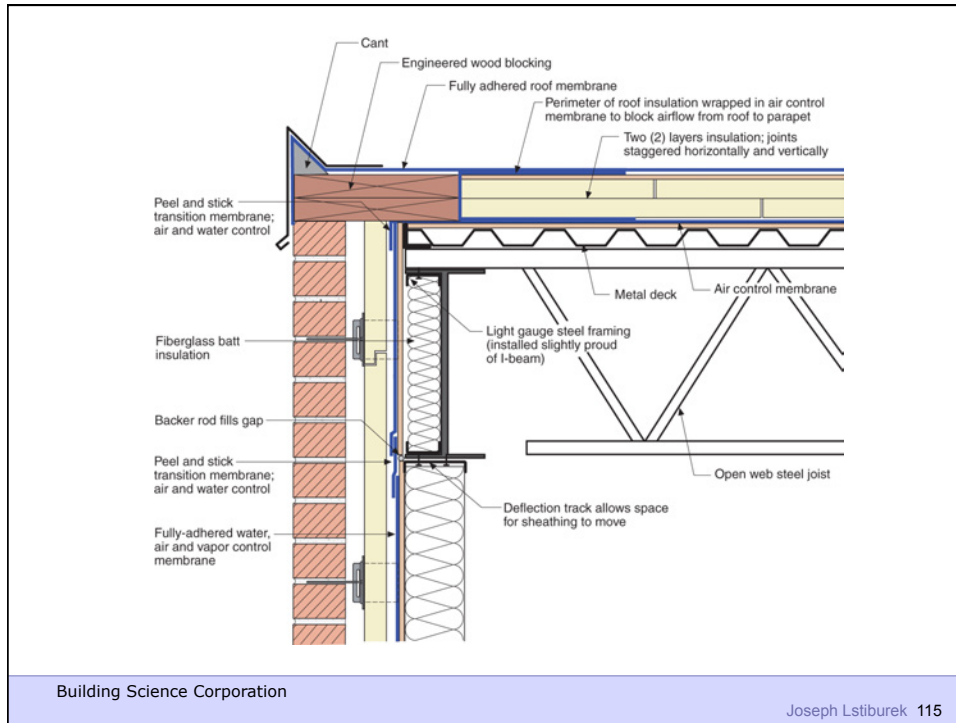
Building Science Corporation

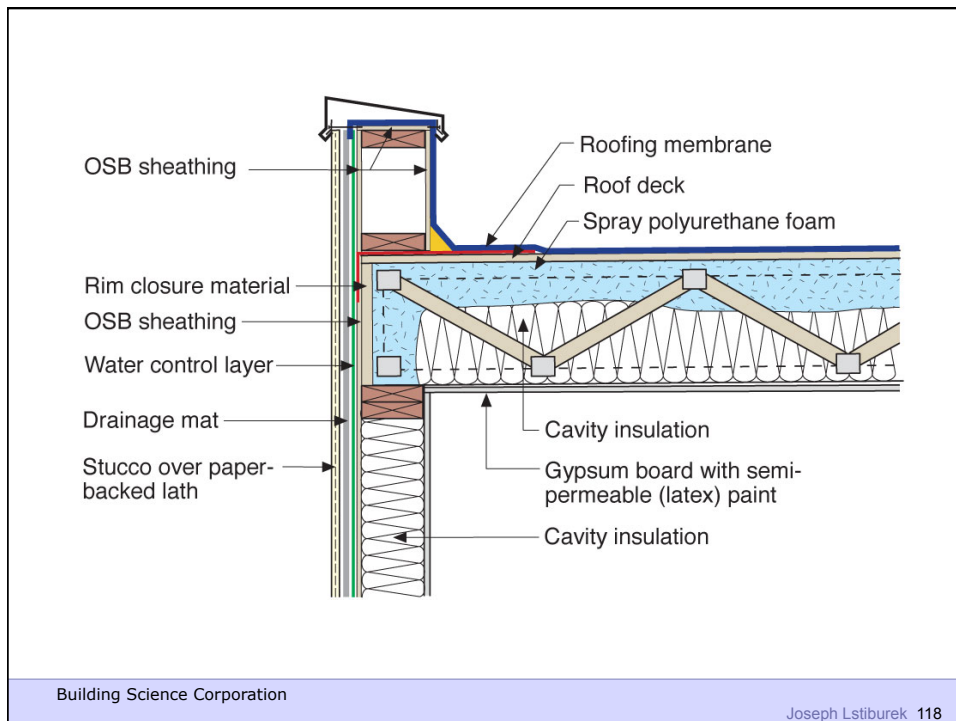
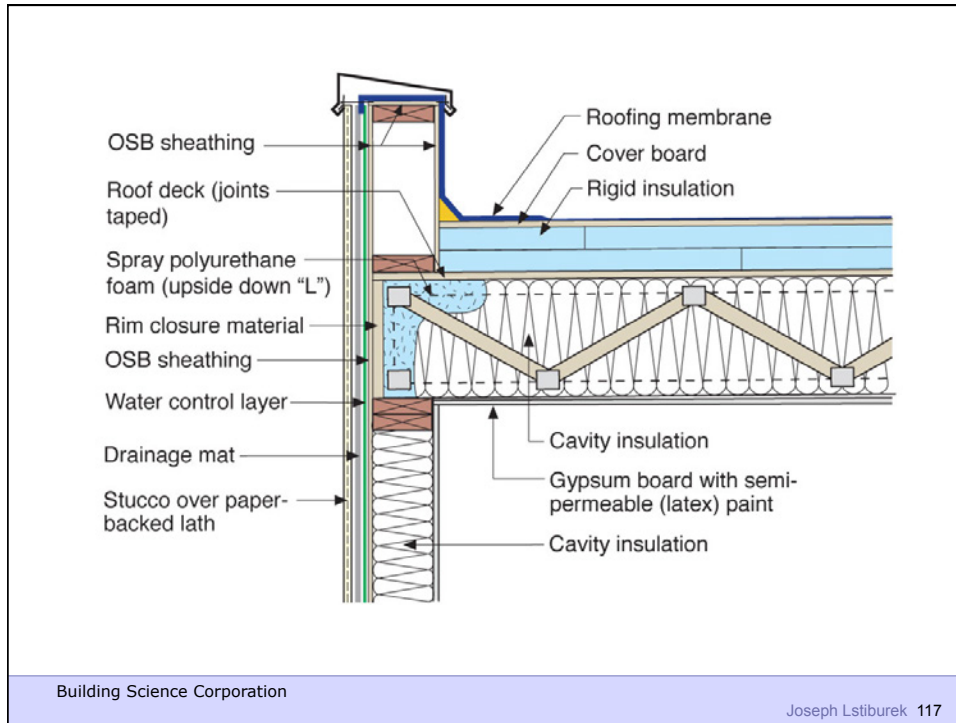
Joseph Lstiburek 108

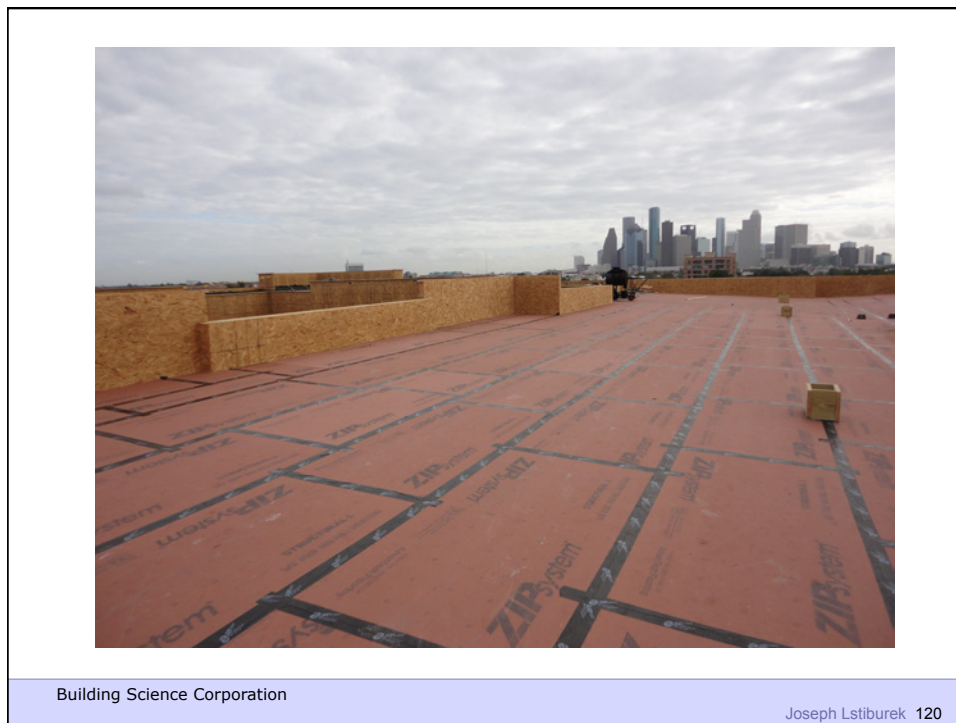
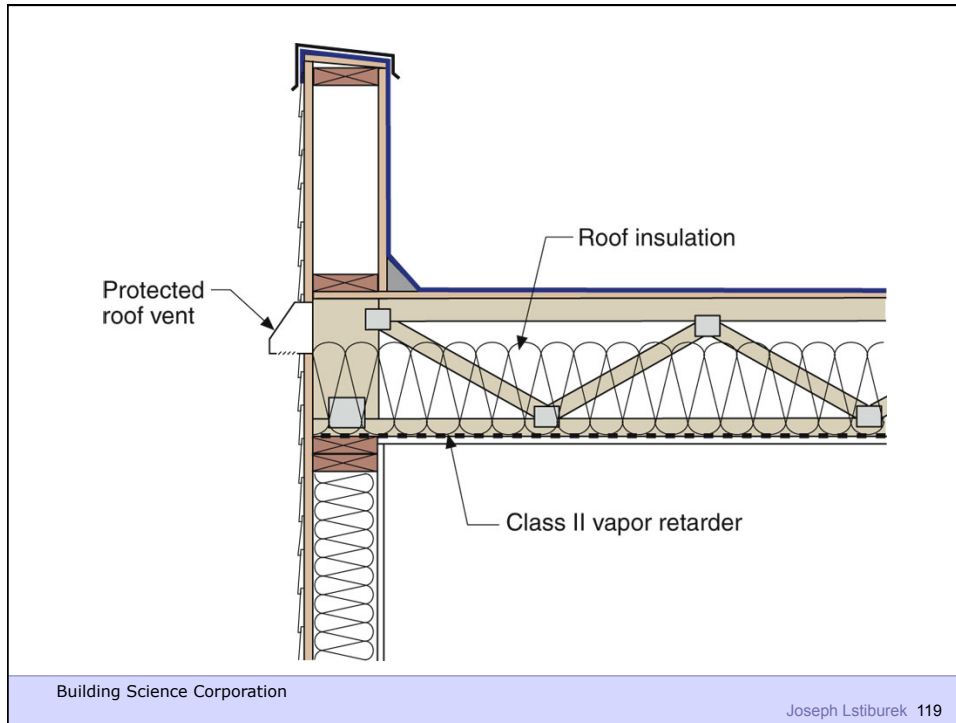














Building Science Corporation

Joseph Lstiburek 121



Building Science Corporation

Joseph Lstiburek 122



Building Science Corporation

Joseph Lstiburek 123



Building Science Corporation

Joseph Lstiburek 124



Building Science Corporation

Joseph Lstiburek 125



Building Science Corporation

Joseph Lstiburek 126



Building Science Corporation

Joseph Lstiburek 127