University of Waterloo

High Performance Enclosures

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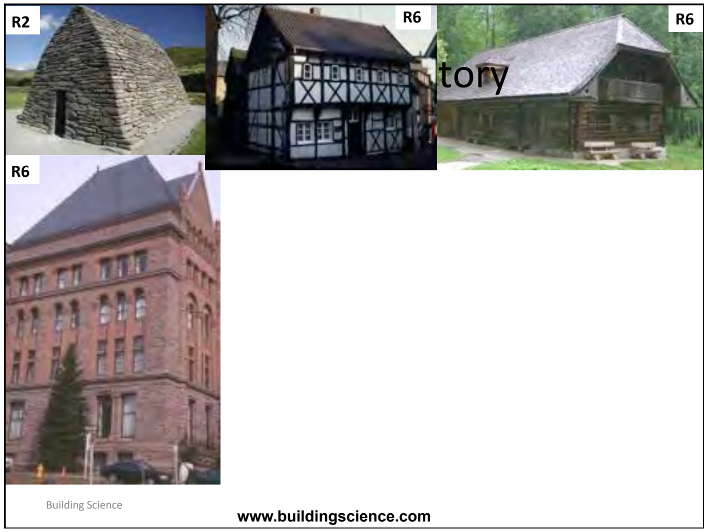
Insulation - History

tory


R2
R6
R6
tory
R6
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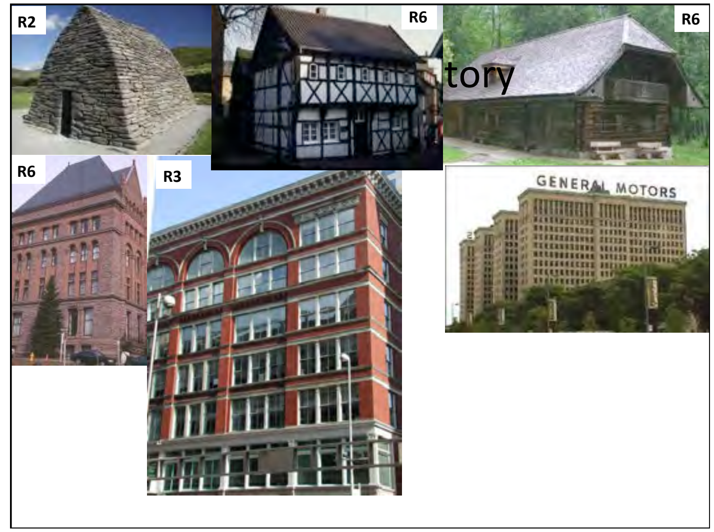
R2
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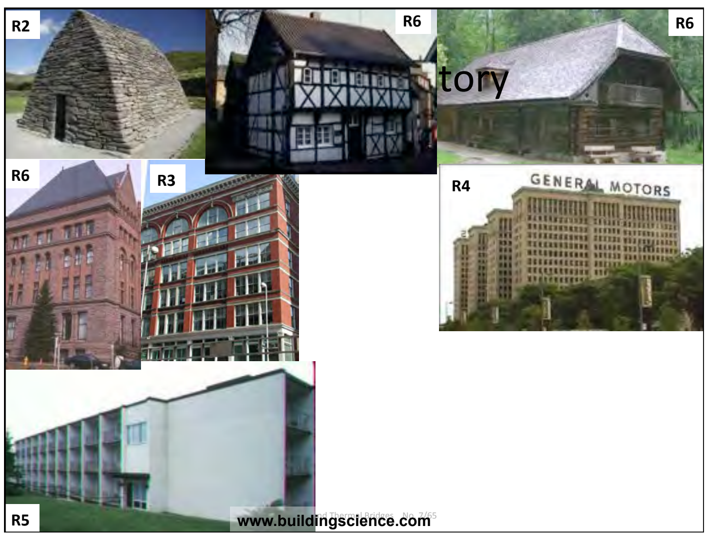
R3
GENERAL MOTORS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R4
GENERAL MOTORS
R5
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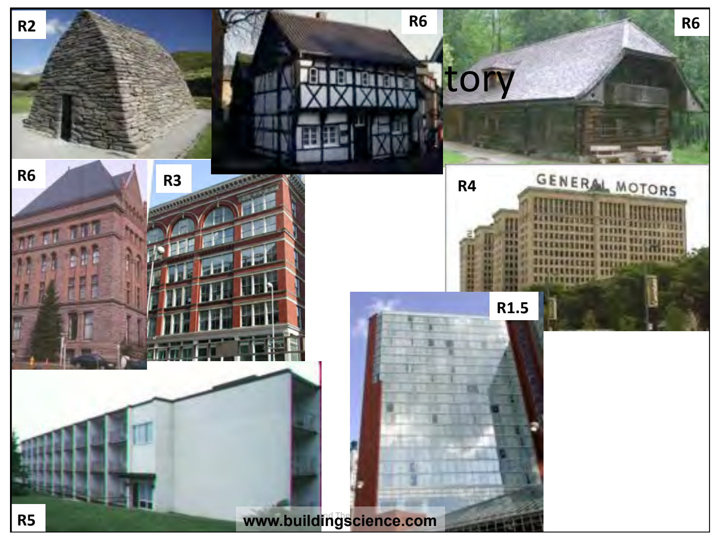
R2
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R5
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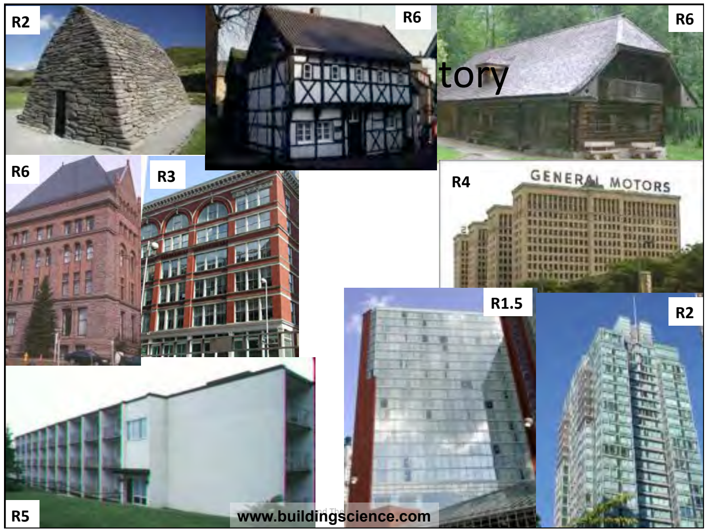
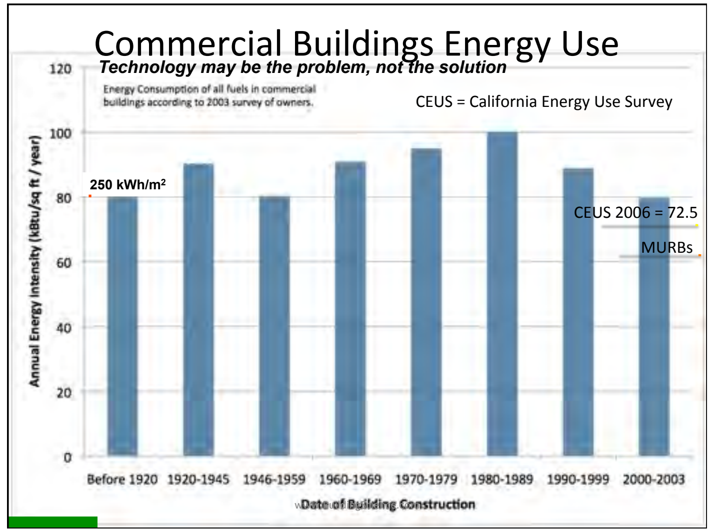
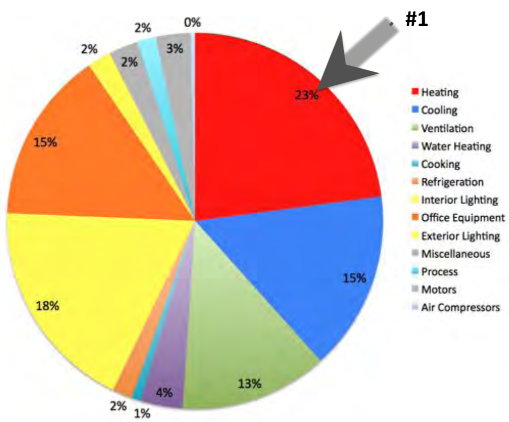




from: www.energy.ca.gov/ceus/

California Large Office: All Energy



Insulation

- Thermal bridges of concrete and steel dramatically reduce performance
  - 6" steel stud, R20 batt = R5!
  - 6" wood stud, R1 batt = R14
- Windows have R-values of around 2-3. Huge heat loss
- Airtightness becomes very important as enclosure insulation is increased

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Airtighten

- Must increase airtightness
  - Improve air quality: where is it coming from
  - Demand controlled ventilation
  - Typical buildings leak energy, humidity
- Codes and standard are beginning to demand it
- Can only really know tightness by testing
  - Must begin to test large buildings

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Solar Control

- Can make little use of solar heat gain in enclosure dominated buildings in marine climates
- Significant glass (WWR>30%) requires shade in marine climate buildings, esp. offices
- Glass area selection should be dominated by views and daylight, not solar heat gain

14/175 11-04-22

The Enclosure: An Environmental Separator

- The part of the building that physically ***separates*** the ***interior*** and ***exterior*** environments.
- Includes all of the parts that make up the wall, window, roof, floor, caulked joint etc.
- Sometimes, interior partitions also are environmental separators (pools, rinks, etc.)

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Climate Load Modification

- Building & Site (overhangs, trees…)
  - Creates microclimate
- Building Enclosure (walls, windows, roof…)
  - Separates climates
  - Passive modification
- Building Environmental Systems (HVAC…)
  - Use energy to change climate
  - Active modification

Enclosure Intro Summary

- Enclosure often defines the H/C load
  - Architecture defines massing, orientation, enclosure
- Enclosure **more critical** for skin-dominated
  - Heat flow, Solar control, air tightness
- Lighting, ventilation critical for deep plan

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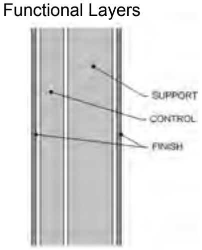
Basic Functions of the Enclosure

- 1. Support
  - Resist and transfer physical forces from inside and out
- 2. Control
  - Control mass and energy flows
- 3. Finish
  - Interior and exterior surfaces for people

- Distribution – a building function

Functional Layers



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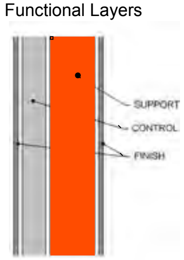
Basic Enclosure Functions

- **Support**
  - **Resist & transfer physical forces from inside and out**
    - Lateral (wind, earthquake)
    - Gravity (snow, dead, use)
    - Rheological (shrink, swell)
    - Impact, wear, abrasion
- Control
  - Control mass and energy flows
- Finish
  - Interior and exterior surfaces for people

Functional Layers



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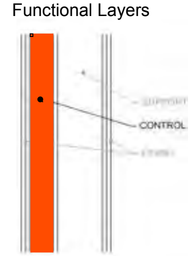
Basic Enclosure Functions

- Support
  - Resist & transfer physical forces from inside and out
- **Control**
  - **Control mass and energy flows**
    - **Rain** (and soil moisture)
      - Drainage plane, capillary break, etc.
    - **Air**
      - Continuous air barrier
    - **Heat**
      - Continuous layer of insulation
    - **Vapor**
      - Balance of wetting/drying
- Finish
  - Interior and exterior surfaces for people

Functional Layers



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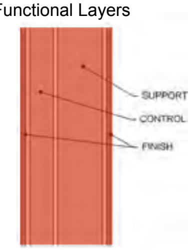
Other Control . . .

- Support
- **Control**
  - **Fire**
    - **Penetration**
    - **Propagation**
  - **Sound**
    - **Penetration**
    - **Reflection**
  - **Light**
    - **Diffuse/glare**
    - **View**
- Finish

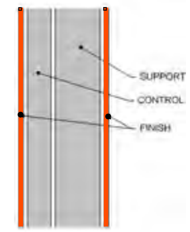
Functional Layers



Basic Enclosure Functions

- Support
  - Resist & transfer physical forces from inside and out
- Control
  - Control mass and energy flows
- **Finish**
  - **Interior & exterior surfaces for people**
    - Color, speculance
    - Pattern, texture

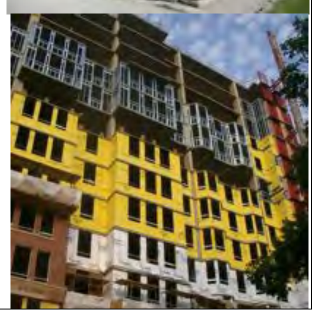
Functional Layers



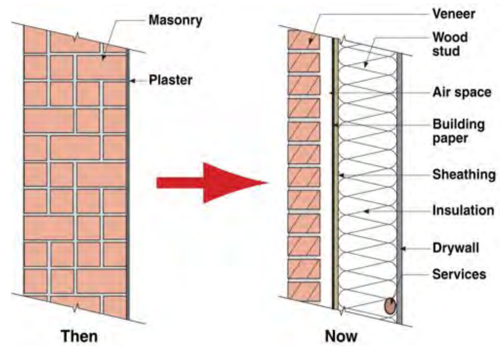
History of Control Functions

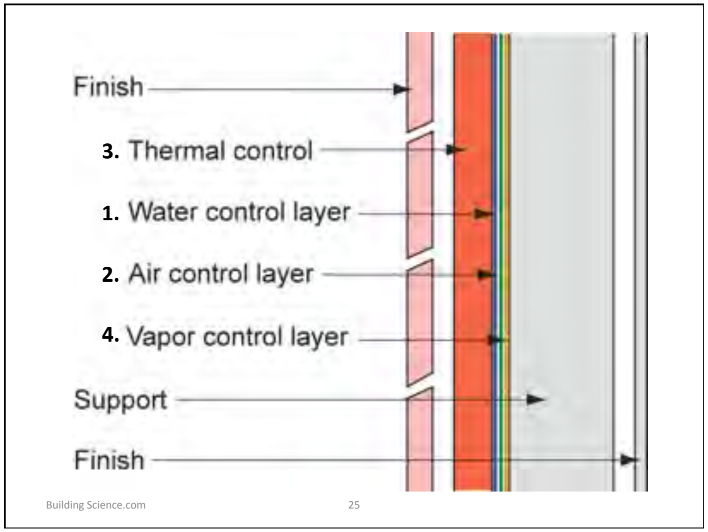
- Older Buildings
  - One layer does everything
- Newer Building
  - Separate layers,

    . . . separate functions



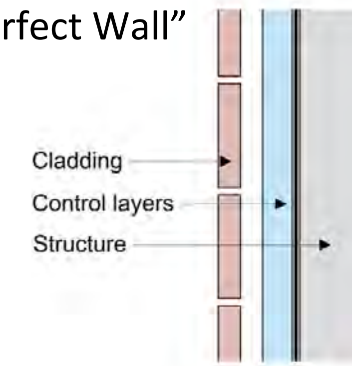
Changes





The "Perfect Wall"

- Finish of whatever
- Control continuity
  - 1. Rain control layer
    - Perfect barrier
    - Drained with gap
    - Storage
  - 2. Air control layer
    - Air barrier
  - 3. Thermal control layer
    - Aka insulation, radiant barriers
  - 4. Vapor control layer
    - Retarders, barriers, etc
- Structure can be anything



Fire Control may be needed
Sound Control optional

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What is a high performance enclosure?

- One which provides high levels of control
- Poor continuity limits performance
- Poor continuity causes most problems too:
  - E.g. air leakage condensation
  - Rain leakage
  - Surface condensation
  - Cold windows
- This course: continuity + high levels

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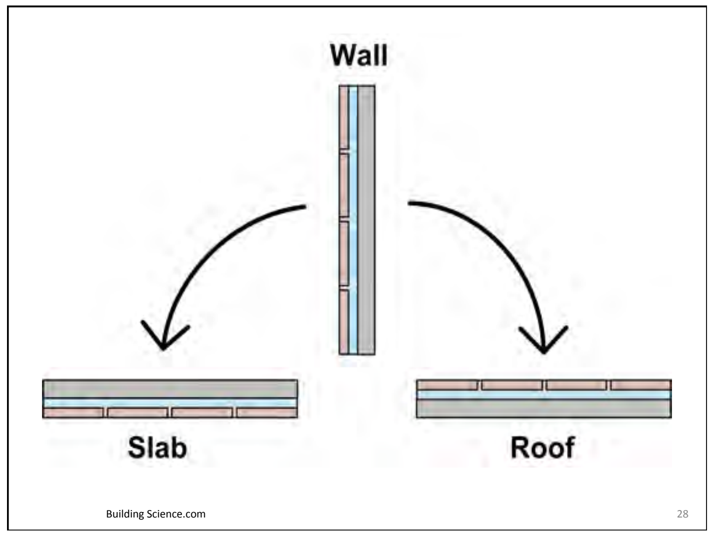

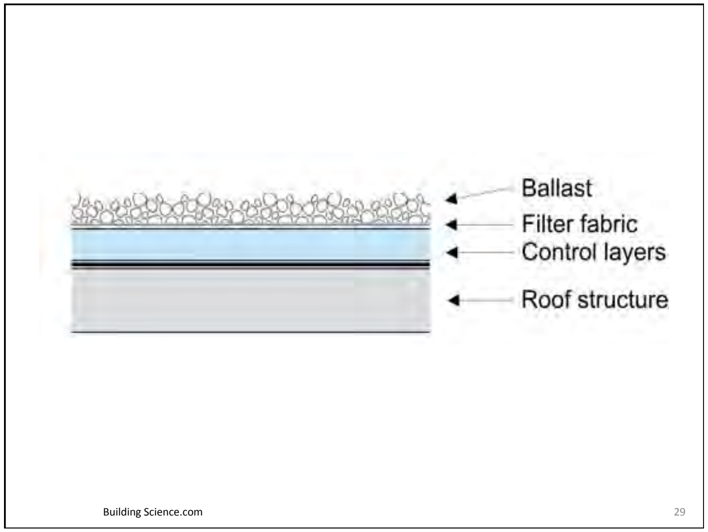
Ballast
Filter fabric
Control layers
Roof structure
Building Science.com
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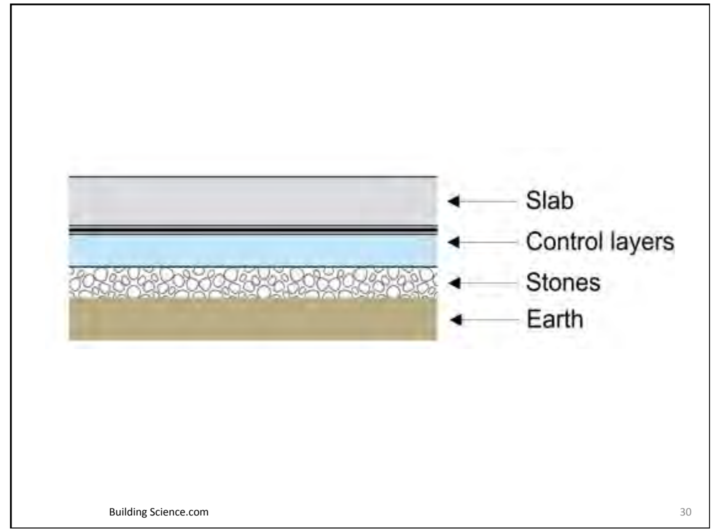
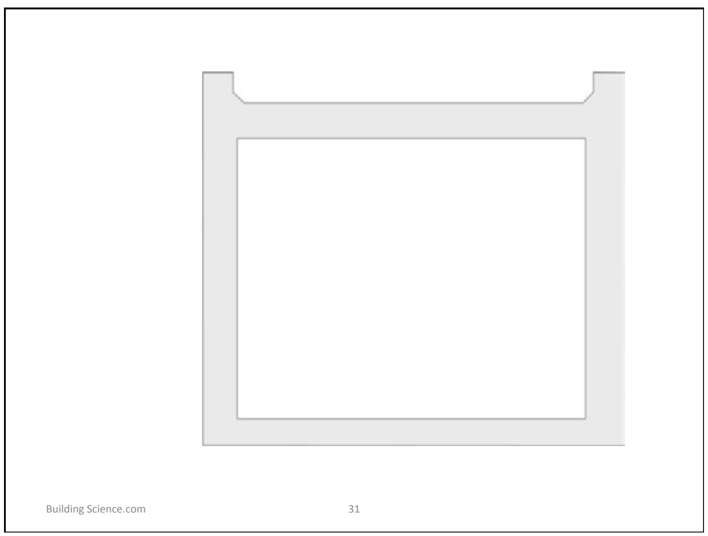

Slab
Control layers
Stones
Earth
Building Science.com
30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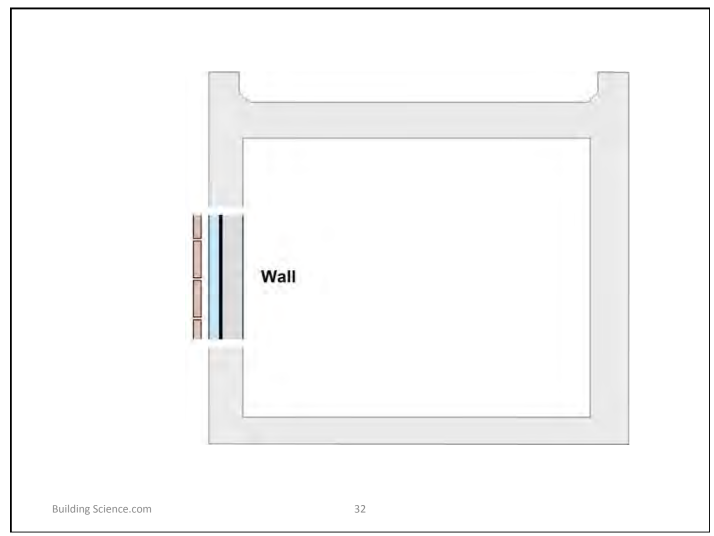
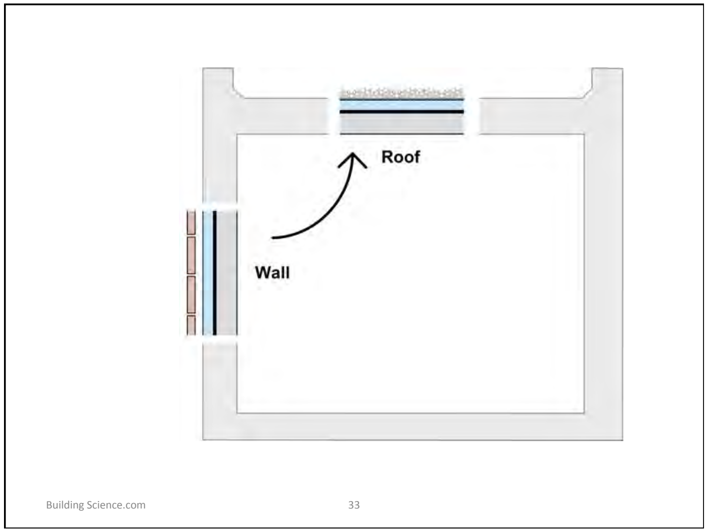
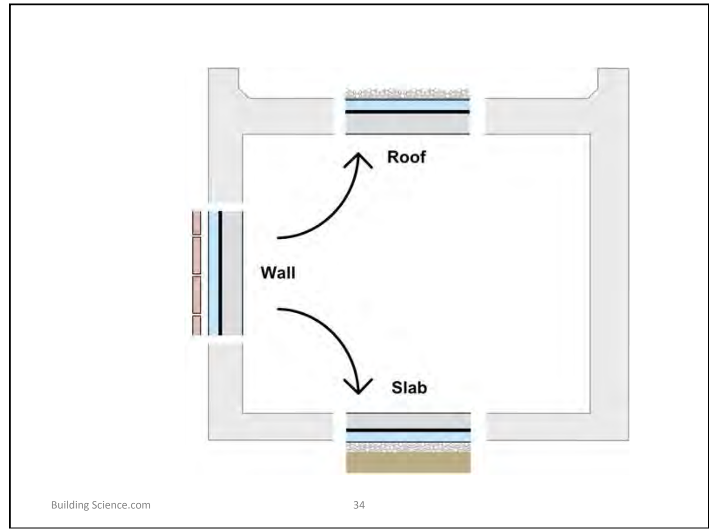
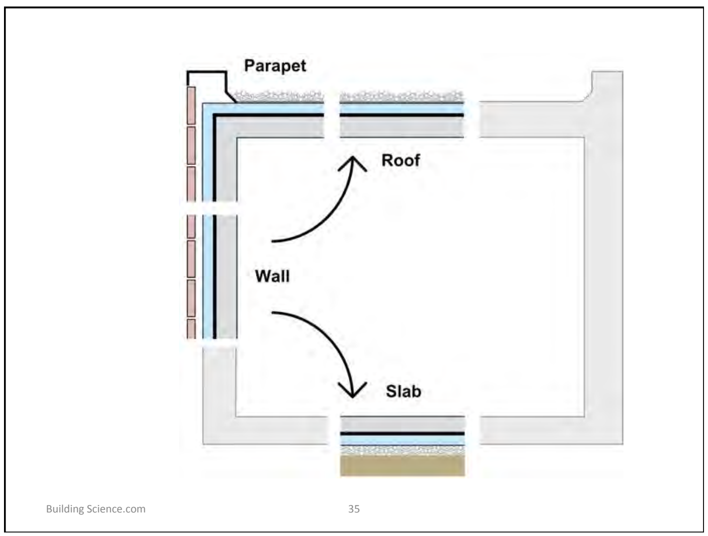
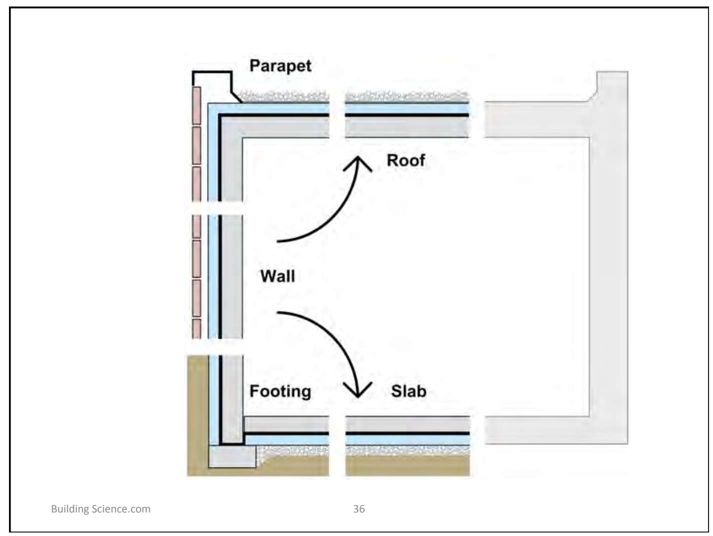
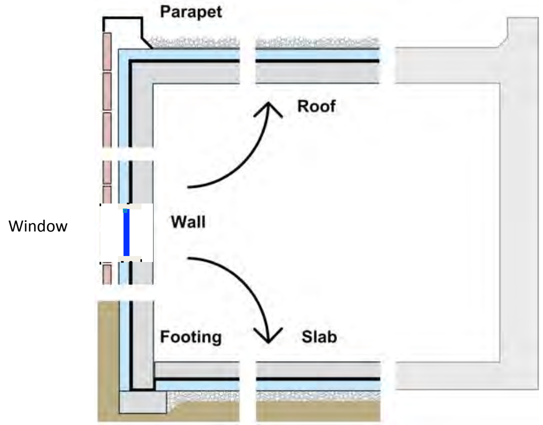

Wall
Building Science.com
32


Roof
Wall
Building Science.com
33


Roof
Wall
Slab
Building Science.com
34


Parapet
Roof
Wall
Slab
Building Science.com
35


Parapet
Roof
Wall
Footing
Slab
Building Science.com
36



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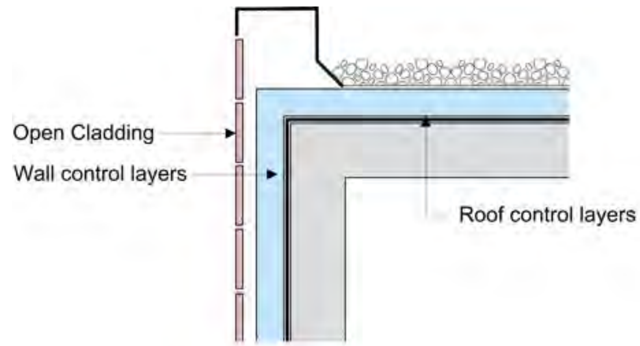
Connections: Who is in charge



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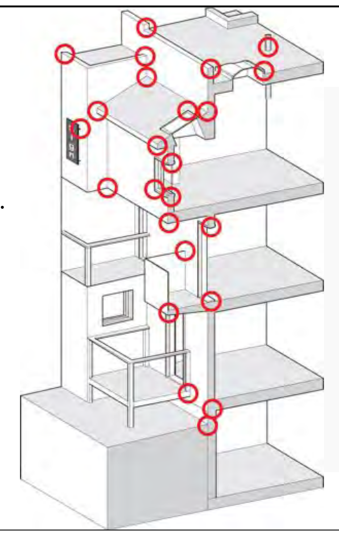
Enclosure Design: Details

- Details demand the same approach as the enclosure.
- Scaled drawings required at



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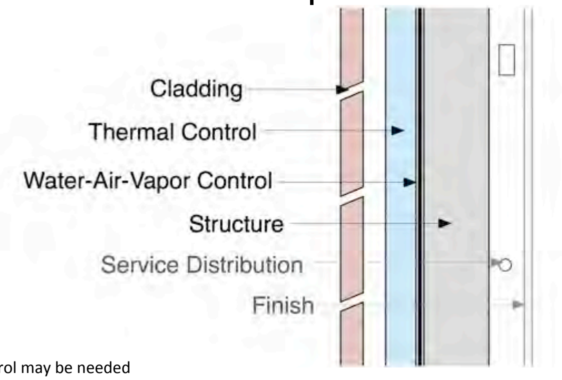
Perfect Wall expanded



Fire Control may be needed
Sound Control optional

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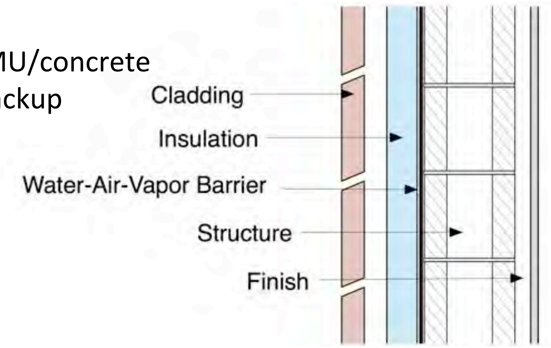
Perfect Wall

- CMU/concrete backup



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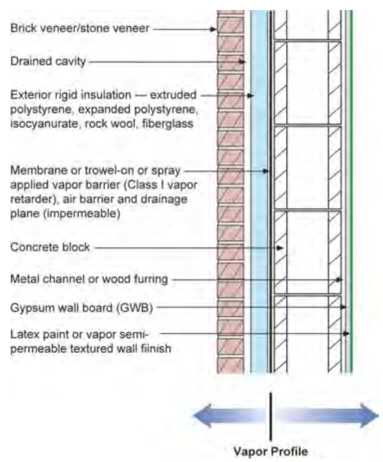
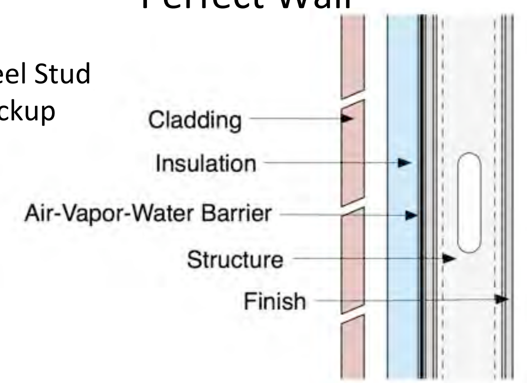
Any R-value, e.g.
4" PIC=R25
5"XPS =R25
6"MFI=R25



Perfect Wall

- Steel Stud Backup



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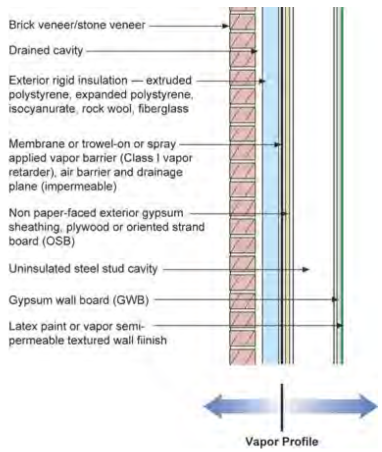
Any R-value, e.g.
4” PIC=R25
5”XPS =R25
6”MFI=R25



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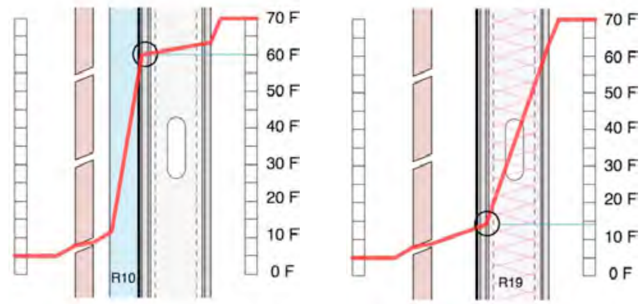
Condensation & Drying



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Rain Control

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Rain Control

- Next to structure, the most important, fundamental requirement
- Source of many serious building problems
- Major impact on durability
- Low-energy buildings & rain
  - Different enclosure assemblies
  - Reduced drying ability

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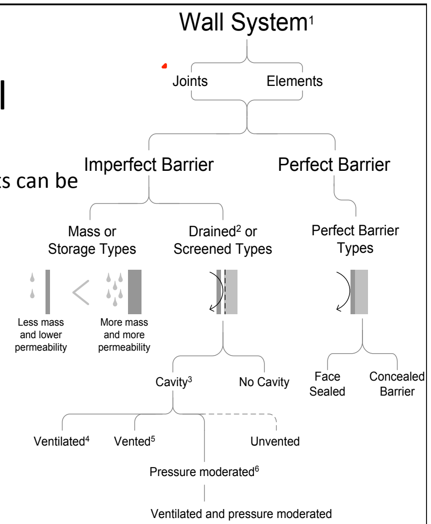
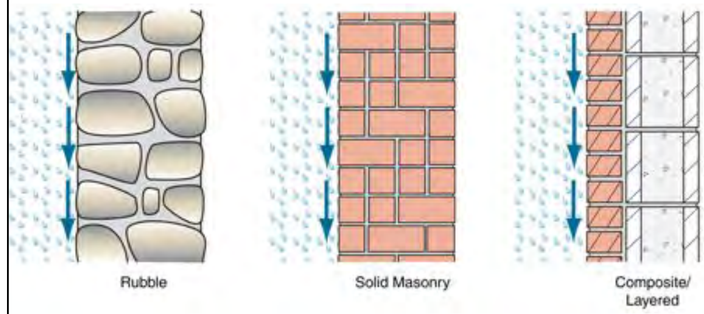
Rain Control

- Elements and joints can be different

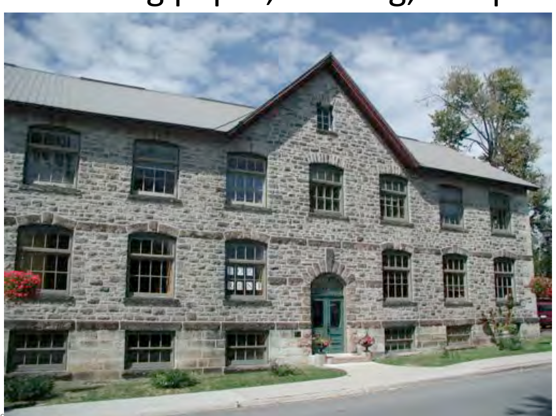


Mass/Storage/Reservoir Walls



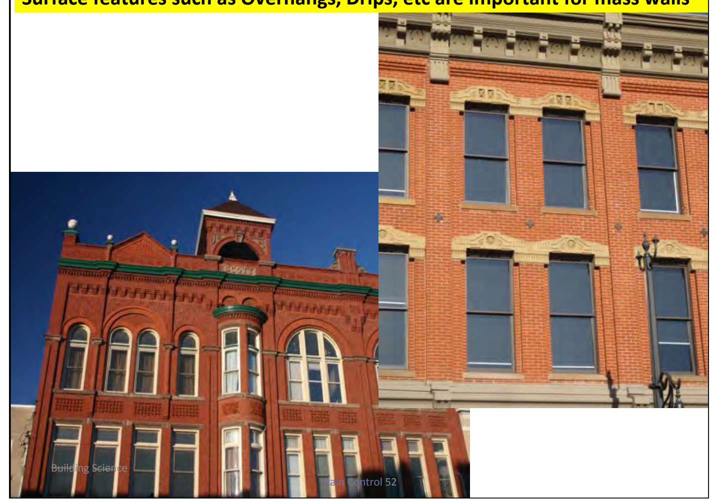
John Straube

No building paper, flashing, weepholes



– Rain Control 51

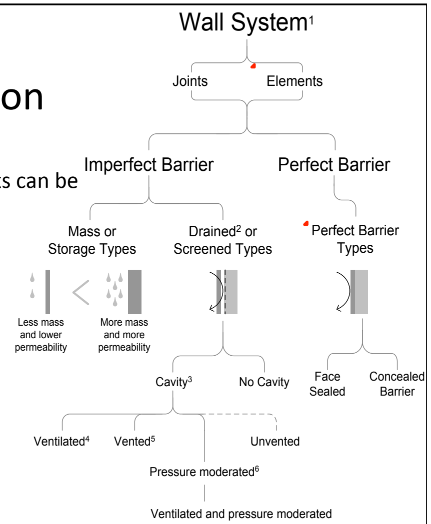
Surface features such as Overhangs, Drips, etc are important for mass walls



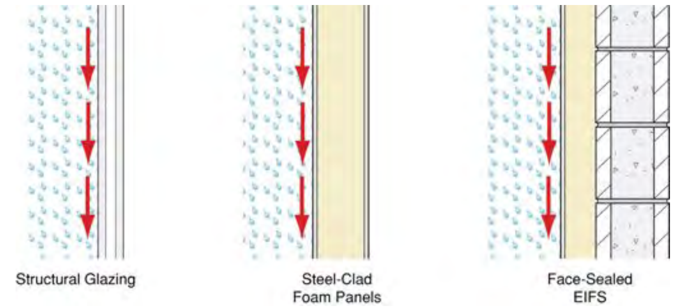
Rain Control 52

Categorization

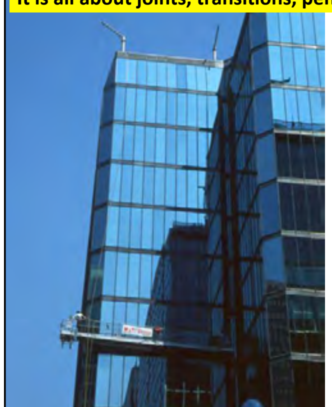
- Elements and joints can be different

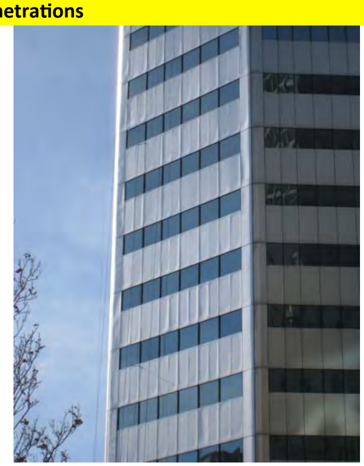


Perfect Barrier / Face Sealed



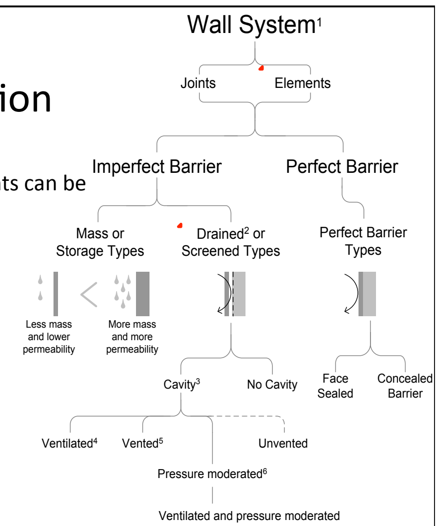
It is all about joints, transitions, penetrations





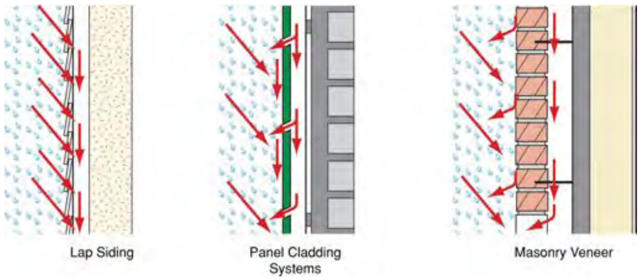
Categorization

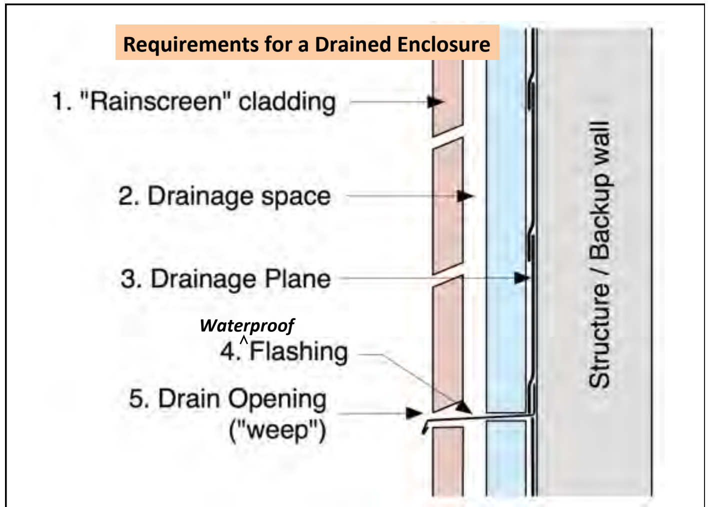
- Elements and joints can be different



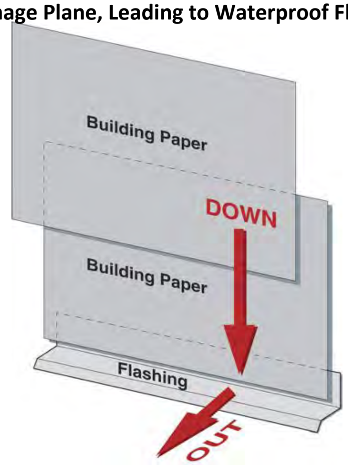
Drained Walls

- “Pressure Equalized Rainscreen” are a fictional sub-set of drained walls





Drainage Plane, Leading to Waterproof Flashing



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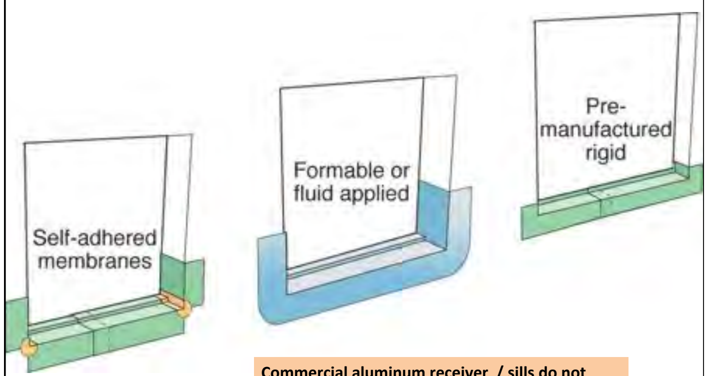
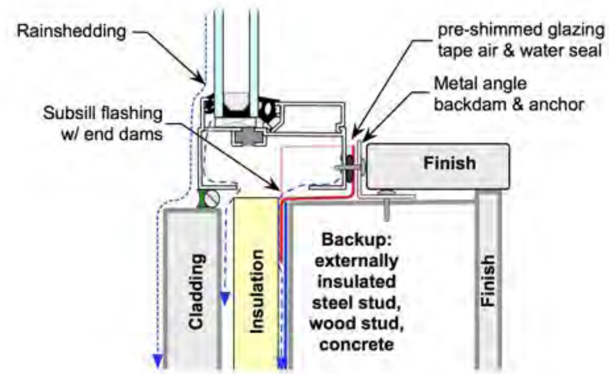
Window flashing is fundamental

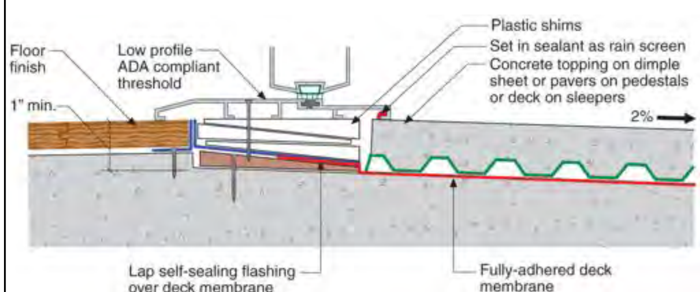


Commercial aluminum receiver / sills do not work: they don't have waterproof corners

Generic Window Installation



Example: ADA walkout



Air-Water-Vapor Membranes

- Often thin layers, membrane or fluid-applied
- *Can be*
  1. Water control (vapor permeable, not airtight), **or**
  2. Air & water control (vapor permeable), **or**
  3. Air, water & vapor (vapor impermeable).
- Examples
  - Building paper, untaped housewrap, sealed and supported housewrap, fluid applied, peel and stick

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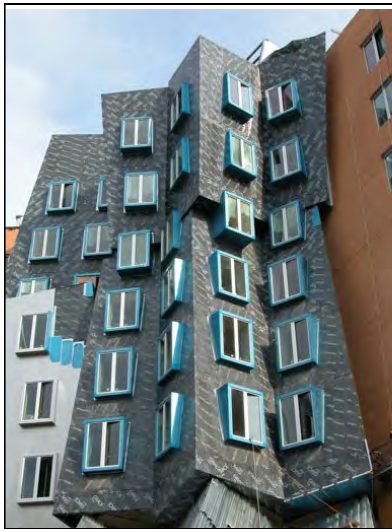


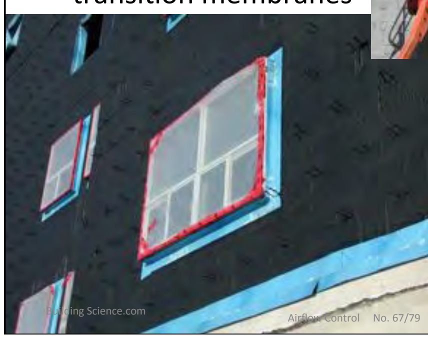
Air-Water Control Layers

Sloped and complex surfaces demand very high performance

Beware vapor barriers outside insulation

Details

- Air & water & vapor transition membranes



Mixed membrane + liquid

Often use membranes for transitions

Continuity is key!

- Must ensure no rain leaks
- Airflow control should be as continuous as practical
- Thermal control
  - We live with penetrations
  - Minimize steel and concrete to small local
- Vapor control
  - Not that important to ensure continuity

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Air Flow Control

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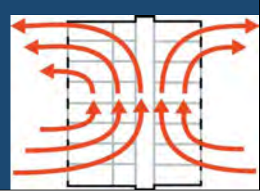

Air Barrier Systems

- Need an excellent air barrier in all buildings
  - Comfort & health
  - Moisture / condensation
  - Energy
  - Sound, fire, etc.
- Cant make it too tight.
- Multiple air barriers improve redundancy

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Air Barriers Requirements

- Requirements
  - **Continuous (most important)**
  - **Strong**
  - **Stiff,**
  - **Durable,**
  - **Air Impermeable (least important)**
- Easily 1/3 of total heat loss is due to air leakage in well-insulated building

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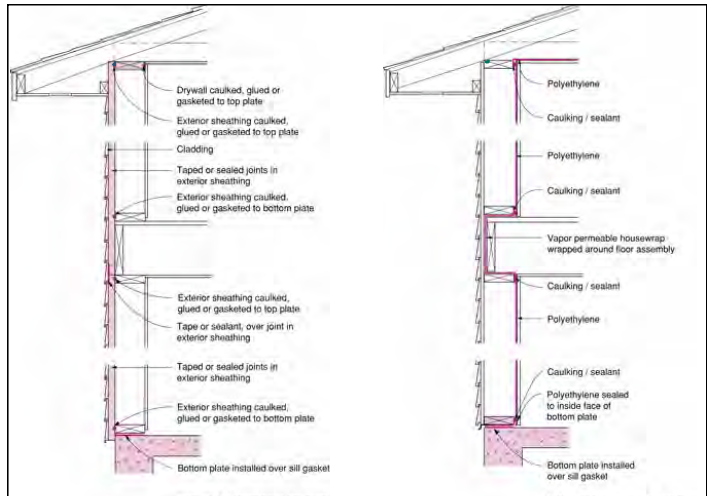
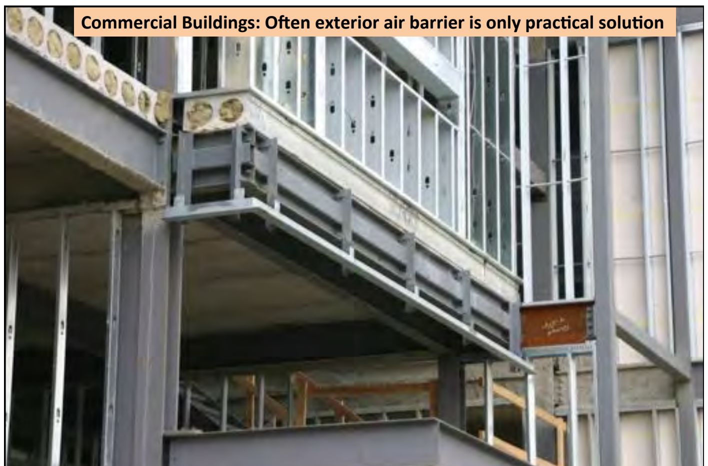


Building Science Airflow Control No. 78/79



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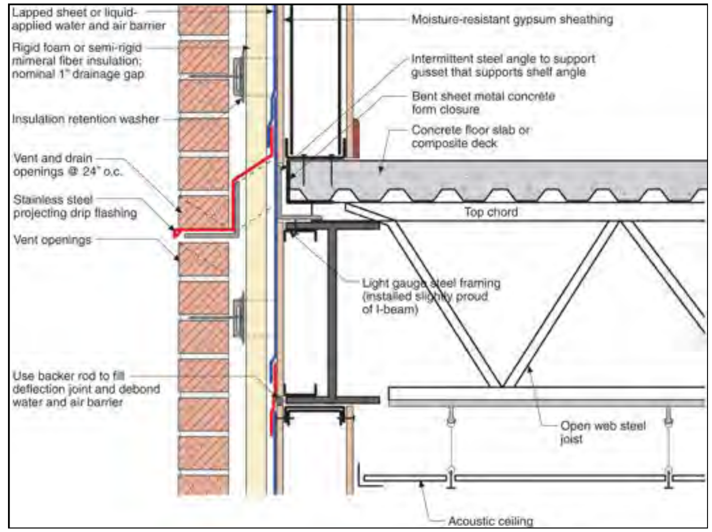
Poly combines air *and* vapour control
-Must be sealed and supported to be air barrier
-Cover most area and you have vapor control

Building Science.com Airflow Control 80

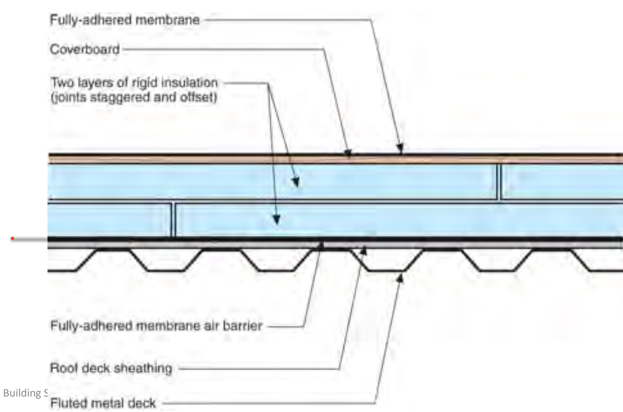
Rigid Exterior Air Barrier

Building Science.com 81

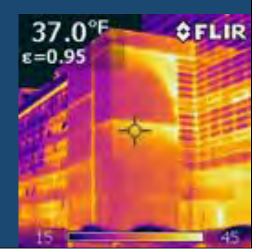


Deck level *vapor* control membrane rarely required if closed cell foam used

Roof air barrier



Thermal Control



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Thermal Continuity

- Some short circuiting is normally tolerated.
- High-performance walls tolerate few
- Major offenders / weak spots
  - Penetrating slabs (<R1)
  - Steel studs (<R1)
  - Windows (R2-R3)
- Area and low R matter to overall significance

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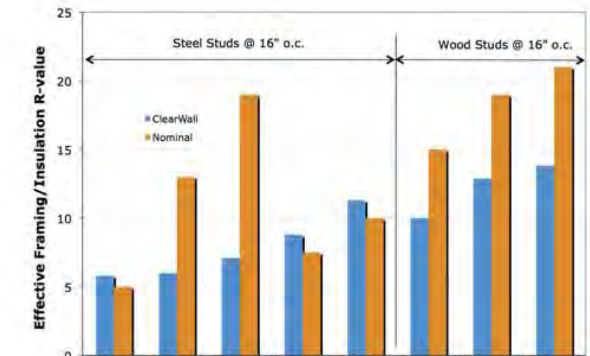
Best-case R-values for stud walls



	R5ci 3.5in	R-13 3.5in	R-19 6in	R7.5ci 6in	R10ci 6in	R-15 3.5in	R-19 6in	R-21 6in
ClearWall	5.8	6.0	7.1	8.8	11.3	10.0	12.9	13.8
Nominal	5	13	19	7.5	10	15	19	21

Source: ASHRAE 90.1-2007, Table A9.2B. ci denotes a layer of continous insulation with no framing penetrations

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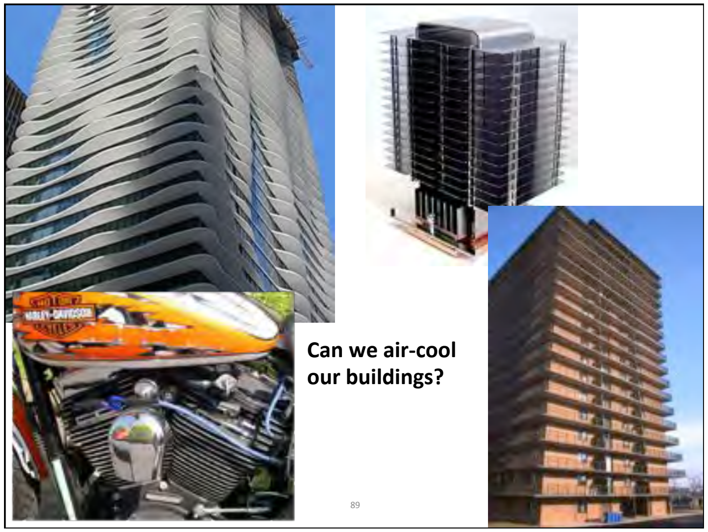

Can we air-cool our buildings?

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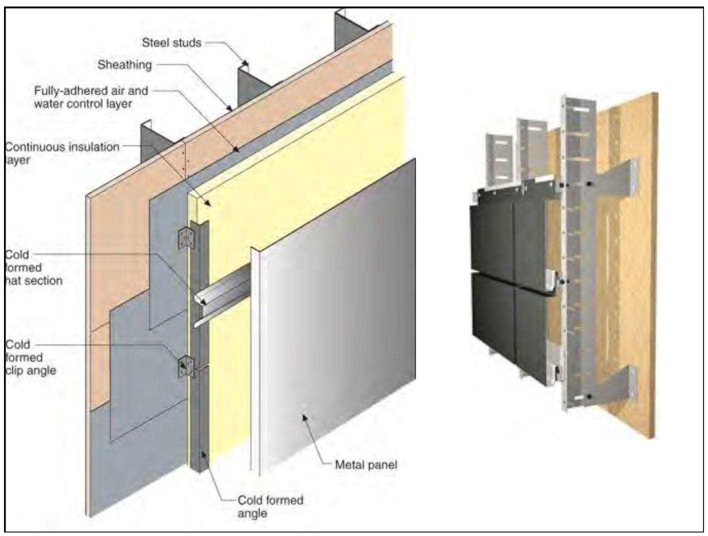
Thermal Bridge Examples

- Balconies, etc
- Exposed slab edges



Windows

- Our most expensive thermal bridges
- Aluminum is 4-5 times as conductive as aluminum
- Difficult to buy commercial aluminum windows / curtainwall over R3.
- Allow solar heat in
  - Useful in cold weather
  - Requires cooling in summer

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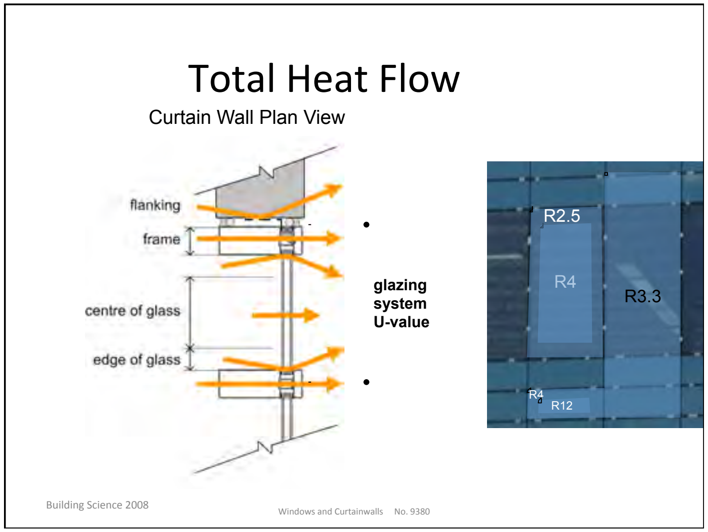
Total Heat Flow
Curtain Wall Plan View
flanking
frame
centre of glass
edge of glass
glazing
system
U-value
R2.5
R4
R3.3
R4
R12
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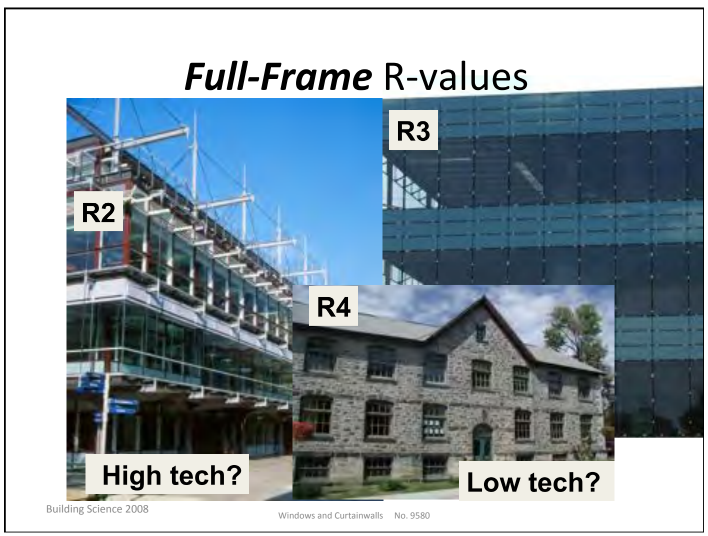
Windows and Curtainwalls No. 9380


PTB
Building Science
Windows and Curtain


Full-Frame R-values
R3
R2
R4
High tech?
Low tech?
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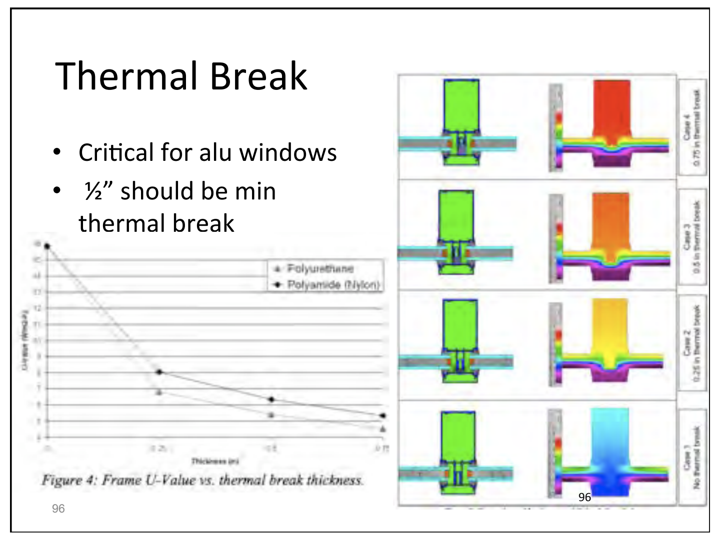
Windows and Curtainwalls No. 9580


Thermal Break
• Critical for alu windows
• ½" should be min thermal break
Polyurethane
Polyamide (Nylon)
Figure 4: Frame U-Value vs. thermal break thickness.
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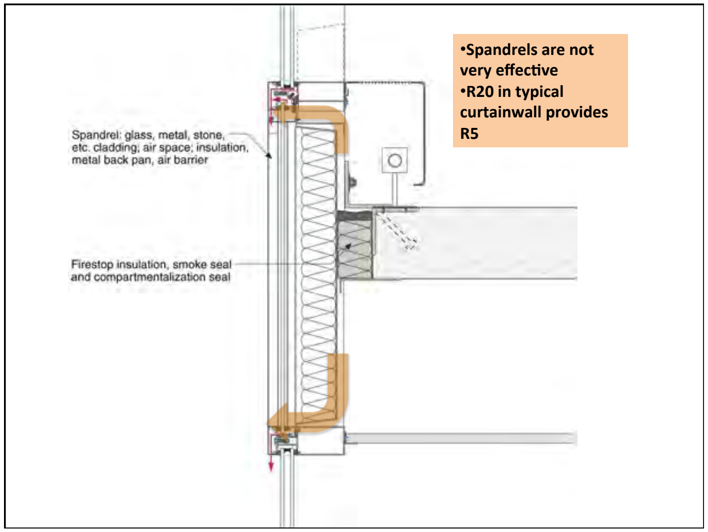
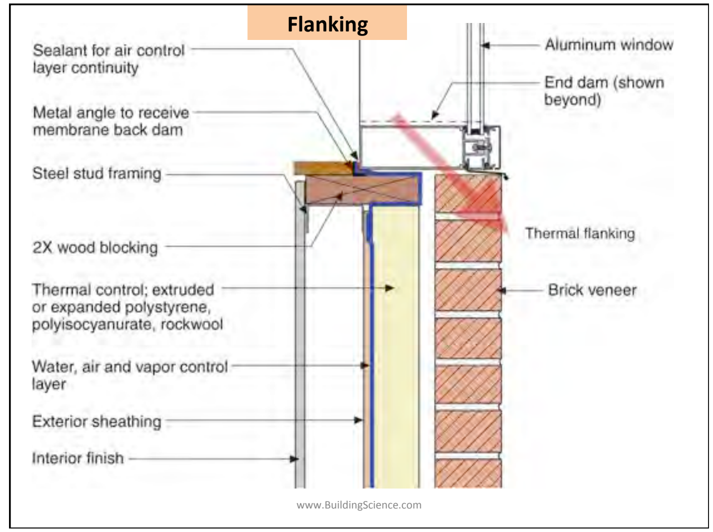

•Spandrels are not very effective
•R20 in typical curtainwall provides R5
Spandrel: glass, metal, stone, etc. cladding; air space; insulation, metal back pan, air barrier
Firestop insulation, smoke seal and compartmentalization seal


Flanking
Sealant for air control layer continuity
Metal angle to receive membrane back dam
Steel stud framing
2X wood blocking
Thermal control; extruded or expanded polystyrene, polyisocyanurate, rockwool
Water, air and vapor control layer
Exterior sheathing
Interior finish
Aluminum window
End dam (shown beyond)
Thermal flanking
Brick veneer
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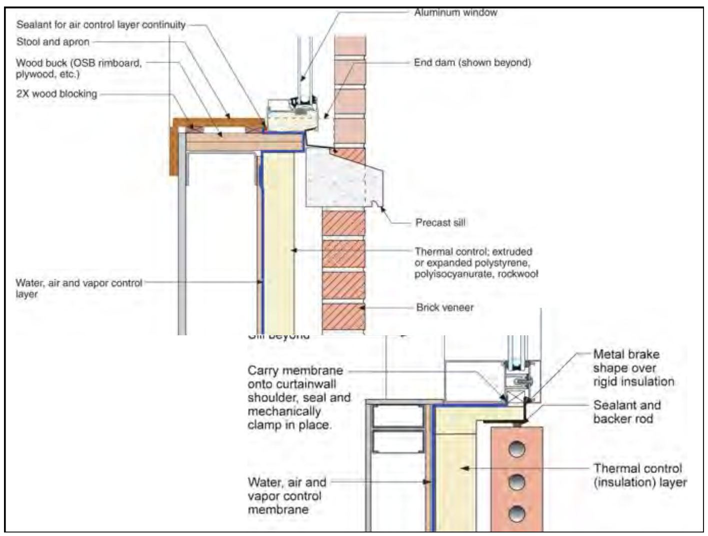
Sealant for air control layer continuity
Stool and apron
Wood buck (OSB rimboard, plywood, etc.)
2X wood blocking
Water, air and vapor control layer
Aluminum window
End dam (shown beyond)
Precast sill
Thermal control; extruded or expanded polystyrene, polyisocyanurate, rockwool
Brick veneer
Carry membrane onto curtainwall shoulder, seal and mechanically clamp in place.
Water, air and vapor control membrane
Metal brake shape over rigid insulation
Sealant and backer rod
Thermal control (insulation) layer


High Performance
Getting better . .
R10
Southwall
R7
R24
Kawneer
R6
Visionwall
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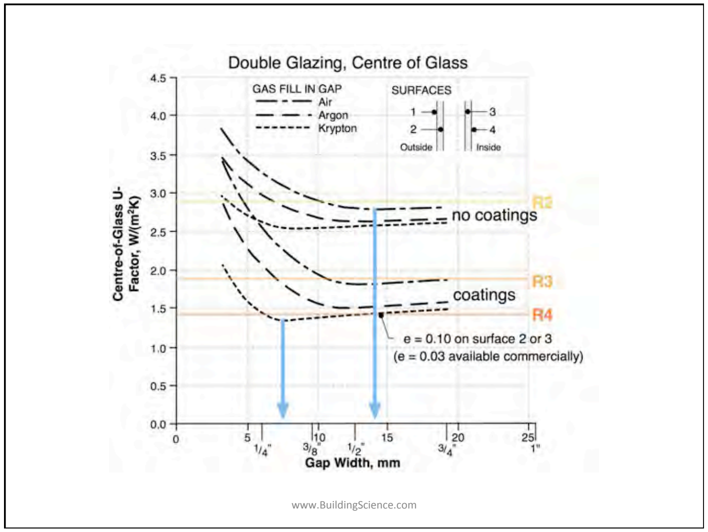
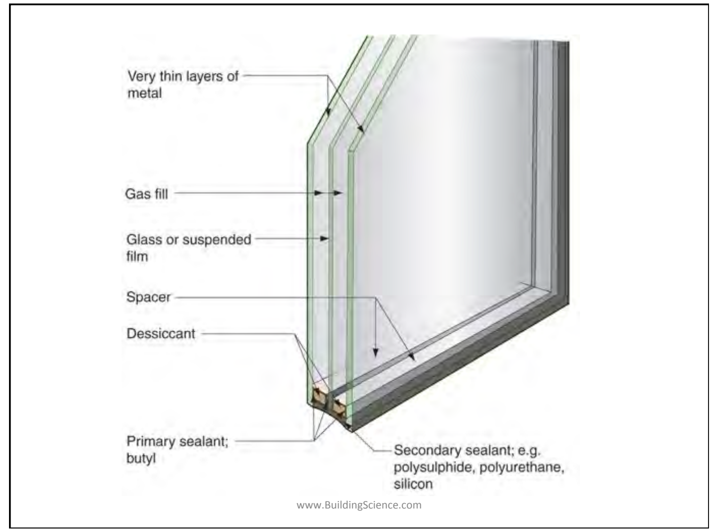
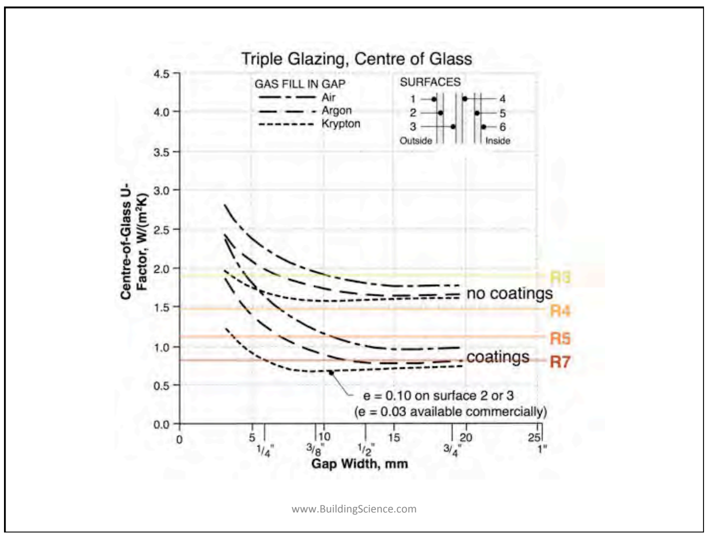
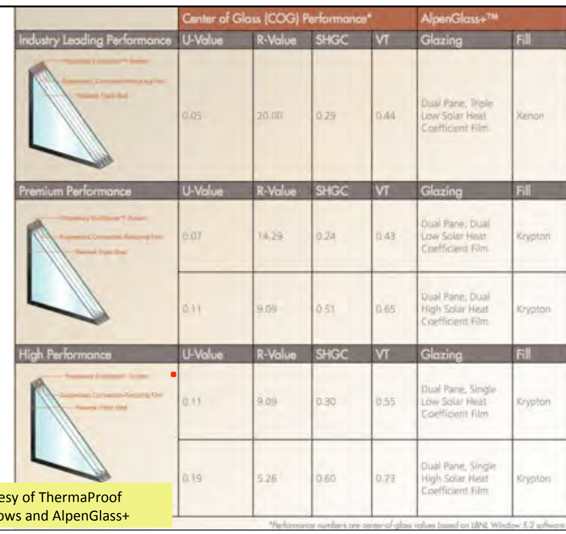
Windows and Curtainwalls No. 10080





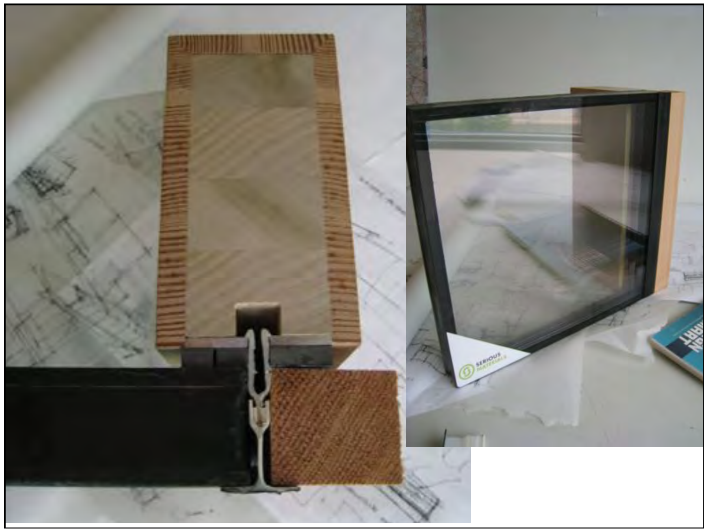




	Center of Glass (COG) Performance*				AlpenGlass+™	
Industry Leading Performance	U-Value	R-Value	SHGC	VT	Glazing	Fill
	0.05	20.00	0.29	0.44	Dual Pane, Triple Low Solar Heat Coefficient Film	Xenon
Premium Performance	U-Value	R-Value	SHGC	VT	Glazing	Fill
	0.07	14.29	0.24	0.43	Dual Pane, Dual Low Solar Heat Coefficient Film	Krypton
	0.11	9.09	0.51	0.65	Dual Pane, Dual High Solar Heat Coefficient Film	Krypton
High Performance	U-Value	R-Value	SHGC	VT	Glazing	Fill
	0.11	9.09	0.30	0.55	Dual Pane, Single Low Solar Heat Coefficient Film	Krypton
	0.19	5.26	0.60	0.73	Dual Pane, Single High Solar Heat Coefficient Film	Krypton

*Performance numbers are center-of-glass values based on LBNL Window 5.2 software

Courtesy of ThermaProof Windows and AlpenGlass+



Solar Gain

- Measured by SHGC
- Solar gain useful during cold sunny weather
- But least heating is needed during daytime for commercial buildings
- Overheating discomfort is a real risk
- Must size glass Area x SHGC carefully
  – High values = air conditioning and discomfort

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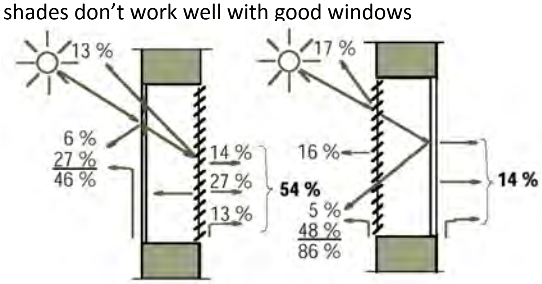
Interior or Exterior Shade

- Operable Solar Control of windows may be necessary for ultra-low energy buildings
- Exterior Shades always beat low SHGC glazing
  – But the cost capital and maintenance
- Interior shades don't work well with good windows



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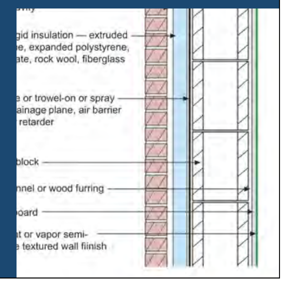
Enclosure Systems



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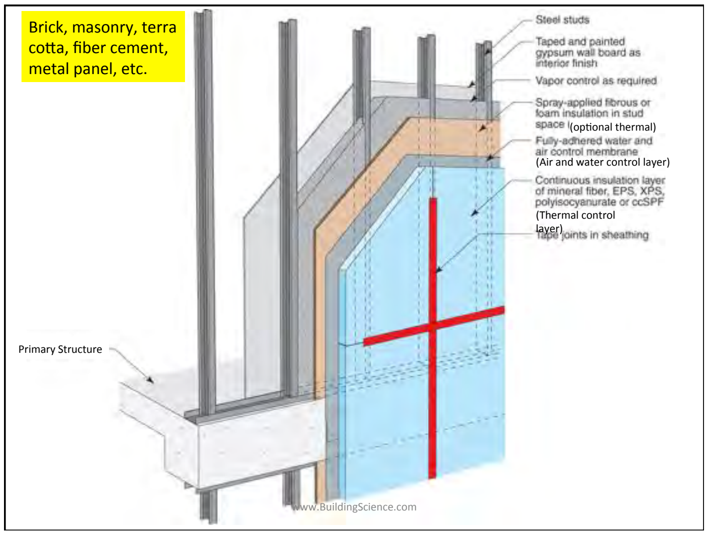

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GP
DENSGLASS GOLD
GP
DENSGLASS GOLD


Blueskin


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116


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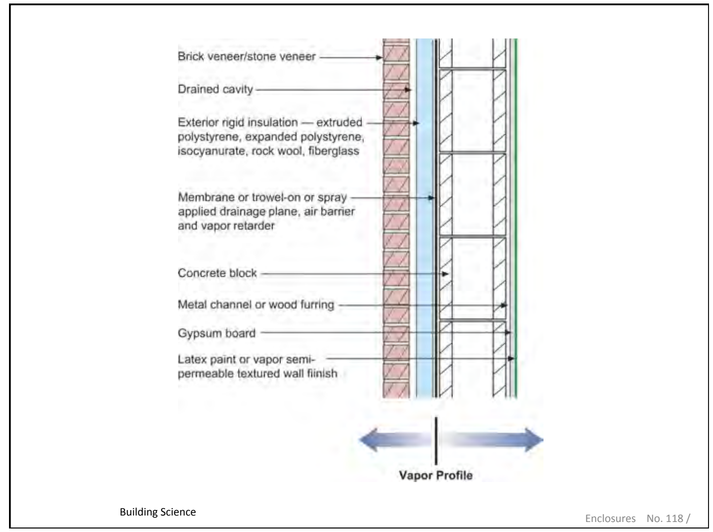
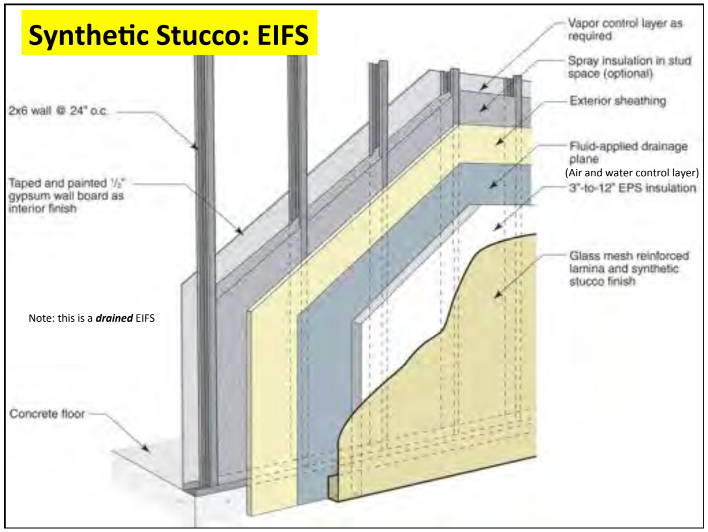
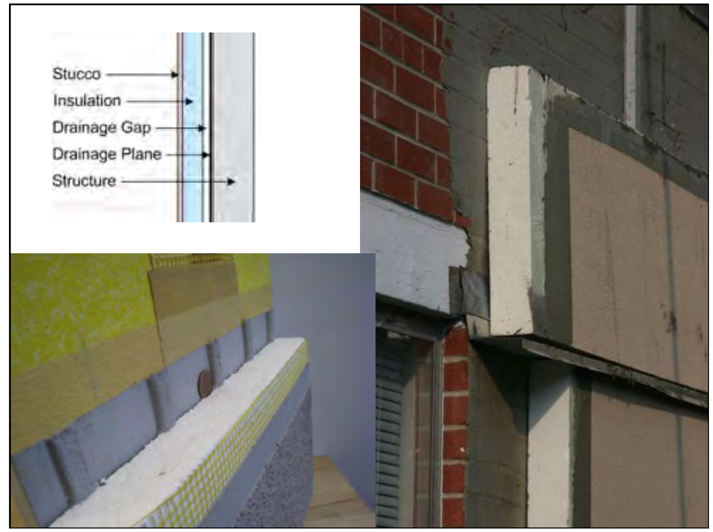
117

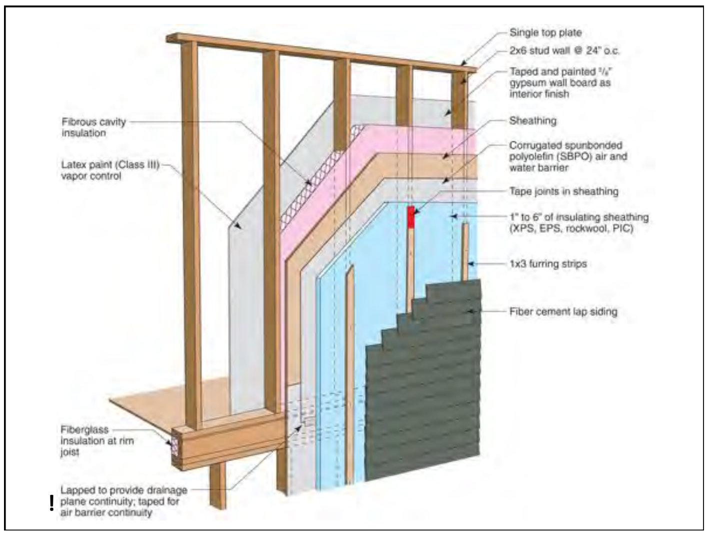

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Concrete block
Metal channel or wood furring
Gypsum board
Latex paint or vapor semi-permeable textured wall finish
Vapor Profile
Building Science
Enclosures No. 118 /

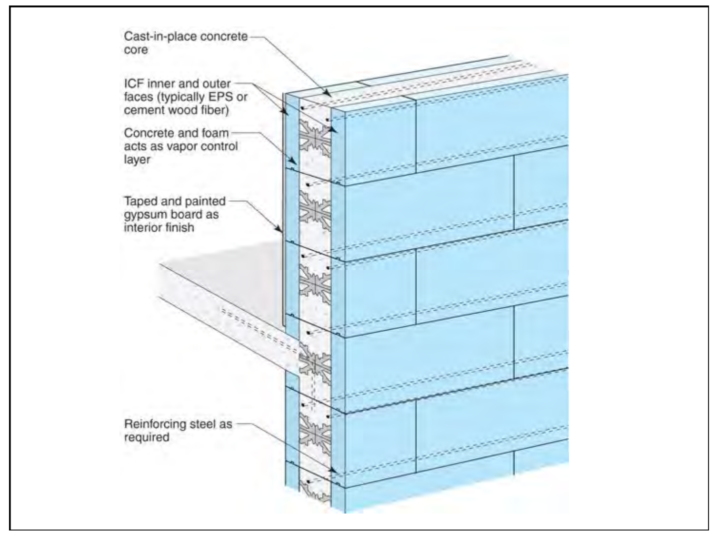

Interior finish-whatever
Structure: Concrete Block
Drainage Air Vapor Barrier: Asphalt
Rockwool Insulation
Finish- whatever


Wilfrid Laurier
University


Synthetic Stucco: EIFS
Vapor control layer as required
Spray insulation in stud space (optional)
2x6 wall @ 24" o.c.
Exterior sheathing
Fluid-applied drainage plane
(Air and water control layer)
Taped and painted ½" gypsum wall board as interior finish
3"-to-12" EPS insulation
Glass mesh reinforced lamina and synthetic stucco finish
Note: this is a ***drained*** EIFS
Concrete floor

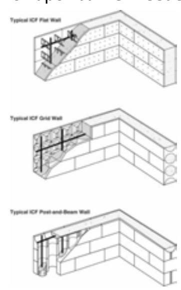

Stucco
Insulation
Drainage Gap
Drainage Plane
Structure


Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ⅝" gypsum wall board as interior finish
Fibrous cavity insulation
Sheathing
Latex paint (Class III) vapor control
Corrugated spunbonded polyolefin (SBPO) air and water barrier
Tape joints in sheathing
1" to 6" of insulating sheathing (XPS, EPS, rockwool, PIC)
1x3 furring strips
Fiber cement lap siding
Fiberglass insulation at rim joist
! Lapped to provide drainage plane continuity; taped for air barrier continuity

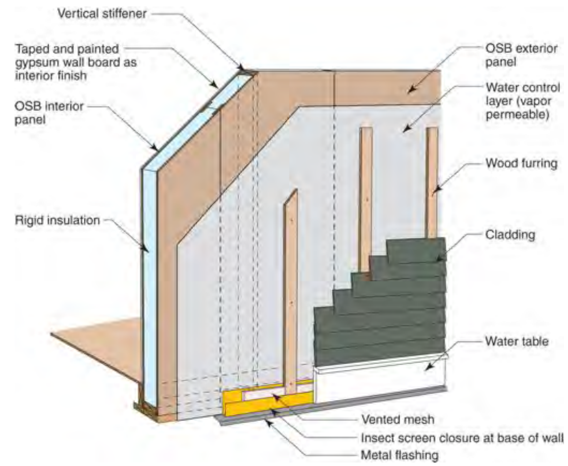

Cast-in-place concrete core
ICF inner and outer faces (typically EPS or cement wood fiber)
Concrete and foam acts as vapor control layer
Taped and painted gypsum board as interior finish
Reinforcing steel as required

Insulated Concrete Fo

- Excellent thermal control
- Concrete acts as air barrier
- Rain Control! Drain all penetrations
- No vapor barrier needed



Building Science Insulation



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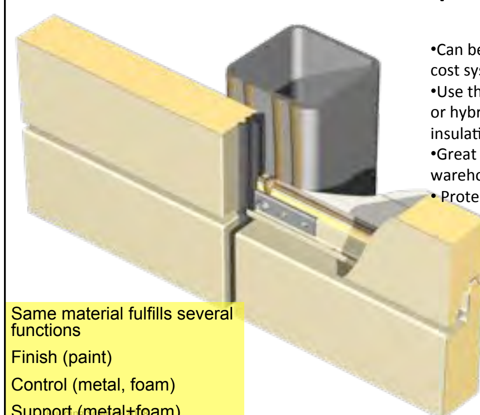
Insulated metal panels



- •Can be high-performance low-cost system
- •Use thicker panels (4-8") and/or hybrid with interior fibrous insulation
- •Great for arenas, pools, warehouses, big box stores
- • Protect from impact at grade

Same material fulfills several functions

Finish (paint)

Control (metal, foam)

Support (metal+foam)

Summary

- Define the control layers
- Ensure continuity
- Then increase control performance of each

- Window area, performance, and integration into walls becomes critical

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See also "Seminars / Recent Presentations"