Architectural Design for the 2030 Challenge

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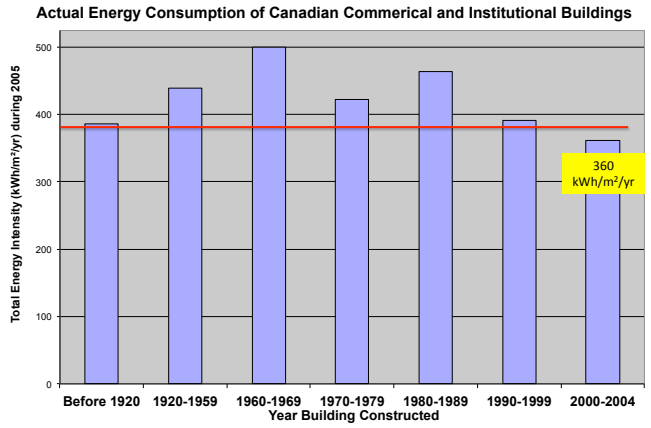
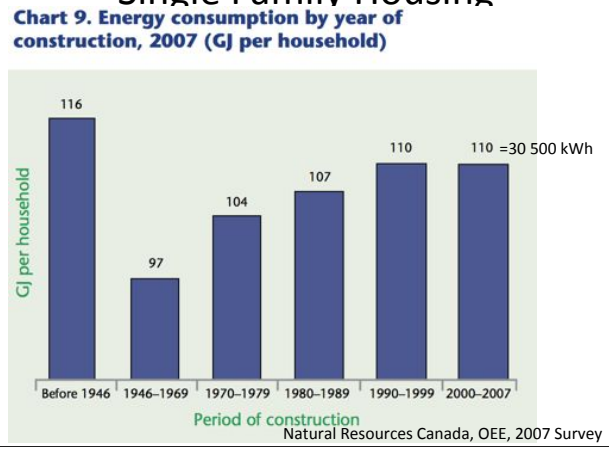
Architecture 2030

- Focus on energy consumption
  - Real targets, not "% below something"
- Goal is Net Zero Energy
  - 60% until 2015
  - 100% by 2030
- Baseline is approximately the energy use of all buildings of same type and location in 2003 or so



Data from NRCan, OEE

Single Family Housing



Natural Resources Canada, OEE, 2007 Survey

2030 CHALLENGE Targets: Canadian Commercial Regional Averages

Averages for Site Energy Use and 2030 Challenge Energy Reduction Targets by Commercial Space/Building Type[1]

Commercial Space/Building Type	Average Site EUI (GJ/m²/yr)	2030 Challenge Site EUI Targets (GJ/m²/Yr)				
		50% Target	60% Target	70% Target	80% Target	90% Target
Canada						
Wholesale Trade	1.470	**0.735**	0.588	0.441	0.294	0.147
Retail Trade	1.707	**0.854**	0.683	0.512	0.341	0.171
Transportation and Warehousing	1.323	**0.661**	0.529	0.397	0.265	0.132
Information and Cultural Industries	1.892	**0.946**	0.757	0.568	0.378	0.189
Offices	1.382	**0.691**	0.553	0.415	0.276	0.138
Educational Services	1.696	**0.848**	0.678	0.509	0.339	0.170
Healthcare and Social Assistance	2.212	**1.106**	0.885	0.664	0.442	0.221
Arts, Entertainment and Recreation	2.156	**1.078**	0.863	0.647	0.431	0.216
Accommodation and Food Services	4.670	**2.335**	1.868	1.401	0.934	0.467
Other Services	1.439	**0.719**	0.576	0.432	0.288	0.144
Ontario						
Wholesale Trade	1.853	**0.926**	0.741	0.556	0.371	0.185
Retail Trade	1.622	**0.811**	0.649	0.487	0.324	0.162
Transportation and Warehousing	1.398	**0.699**	0.559	0.419	0.280	0.140
Information and Cultural Industries	1.734	**0.867**	0.693	0.520	0.347	0.173
Offices	1.421	**0.710**	0.568	0.426	0.284	0.142
Educational Services	1.768	**0.884**	0.707	0.530	0.354	0.177
Healthcare and Social Assistance	2.038	**1.019**	0.815	0.611	0.408	0.204
Arts, Entertainment and Recreation	2.677	**1.338**	1.071	0.803	0.535	0.268
Accommodation and Food Services	2.597	**1.299**	1.039	0.779	0.519	0.260
Other Services	1.568	**0.784**	0.627	0.470	0.314	0.157
Ontario						
Single Detached	0.830	**0.415**	0.332	0.249	0.166	0.083
Single Attached	0.830	**0.415**	0.332	0.249	0.166	0.083
Apartments	0.677	**0.339**	0.271	0.203	0.135	0.068
Mobile Homes	1.203	**0.602**	0.481	0.361	0.241	0.120

395 kWh/m²/yr
490 kWh/m²/yr
190 kWh/m²/yr

Design Principles

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Process and Philosophy

- Decide to value low energy consumption
- Set ***measurable targets***, predict usage, measure performance
- Stamp out waste everywhere
- Use energy efficiently when you need to use it
- *Do **not*** sacrifice safety, comfort, health and durability

www.BuildingScience.com Buildings,Energy, Environment No. 7/84

Available Strategies

- Siting (small impact)
  - Orient with sun, wind, rain, earth shelter?
- Shape and Form (small to moderate impact)
  - Small, Compact, simple
- Exceptional building enclosure (mod to large impact)
  - Insulated, airtight, durable, solar control
- Efficient Equipment (mod impact)
  - Not there or off is best, controls help
- Renewable Energy Generation (impact varies)
  - Only after very significant reductions

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Basic Goals (cold/mixed)

- Keep heat in
  - When it is cold
- Keep heat / sun out
  - When it is warm/hot

Insulation
Airtightness
Solar Control

- Last a long time
  - Reduce construction/repair resources over time

Rain Control

- Use efficient equipment
  - Efficient lighting
  - Efficient computers, elevators

Off is very efficient

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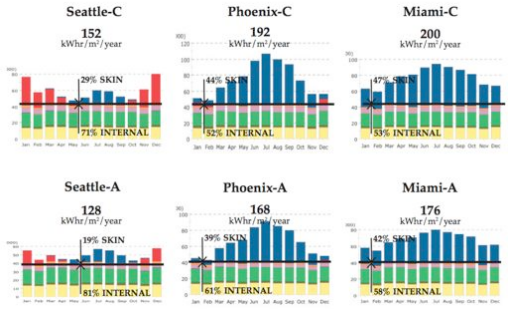
Climate matters



- Beware architecture magazines

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Typical market Building in Toronto 55% heat+cool

Other things use energy

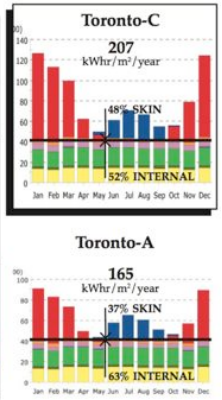
MD40SQ-C
4-storey, square floor plate
50,000 sf GFA
40% w-w-r (N, S, E, & W)
Enclosure "C-Institutional"

Space Heating | Space Cooling
Water Heating | Ventilation Fans
Pumps & Auxiliary | Plug & Miscellaneous
Task Lighting | Area Lighting

MD40SQ-A

similar to above, except:
Enclosure "A-Exemplary"

From: Ross, B., "Design with Energy in Mind", M.Arch. Thesis, University of Waterloo, 2009.



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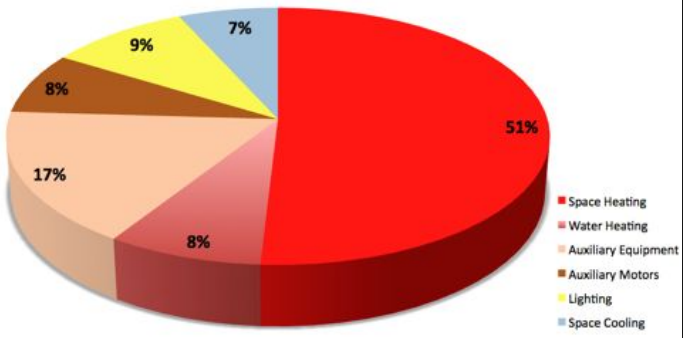
Canadian Offices 2007



207 million m²
Average 394 kWh/m²

Source: NRCan Office of Energy Efficiency

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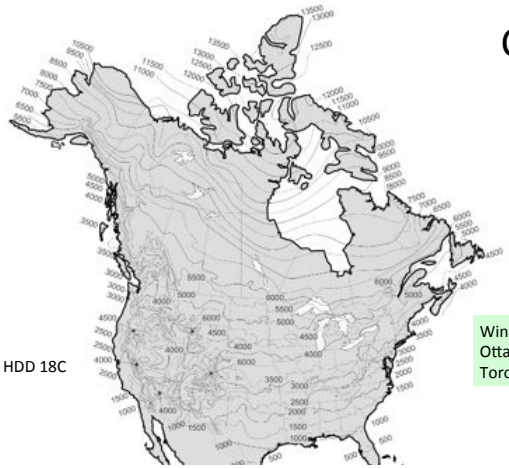
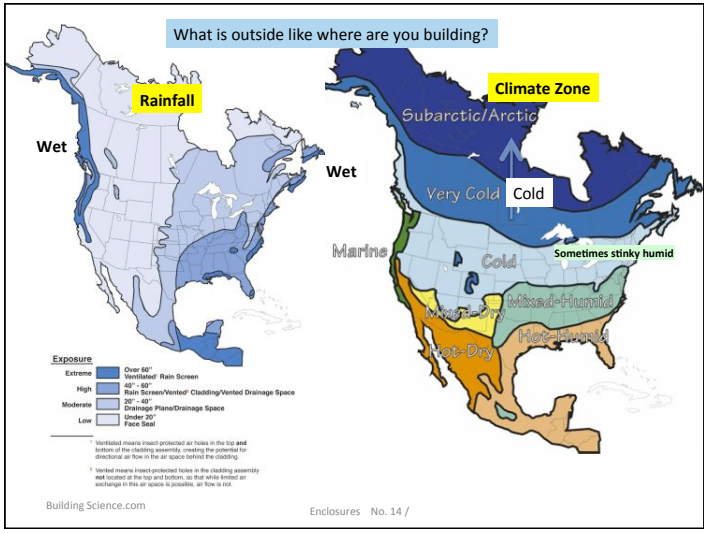


Canada:

Significant heating demand, especially Prairies and North

Winnipeg 5750
Ottawa 4600
Toronto 4000



Can we do it?

- Is it possible or practical to drop energy use by 60% in cold-climate Canada?
- Standard Ontario office uses almost 400 kWh/m^2/yr
- Can we get an office to 200? 100? kWh/m^2/yr?

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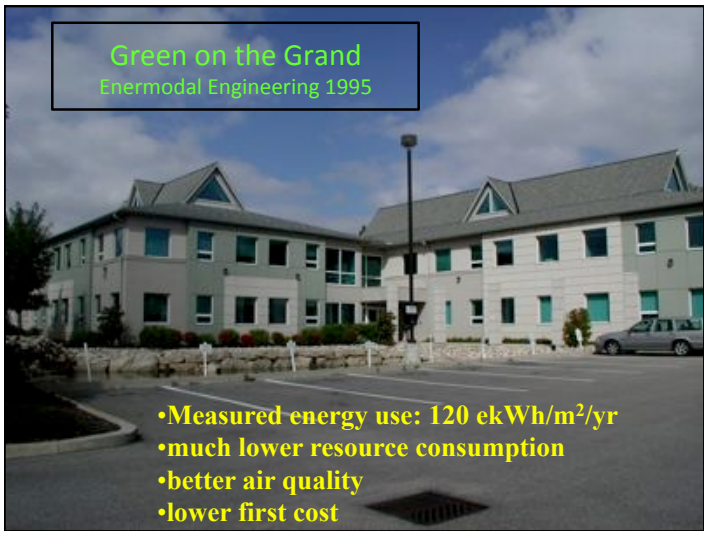
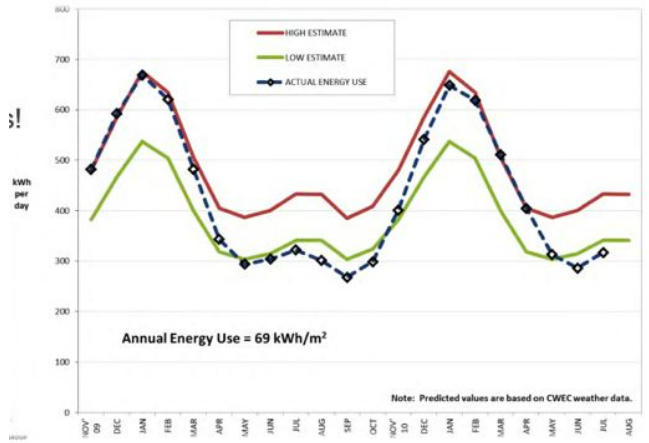
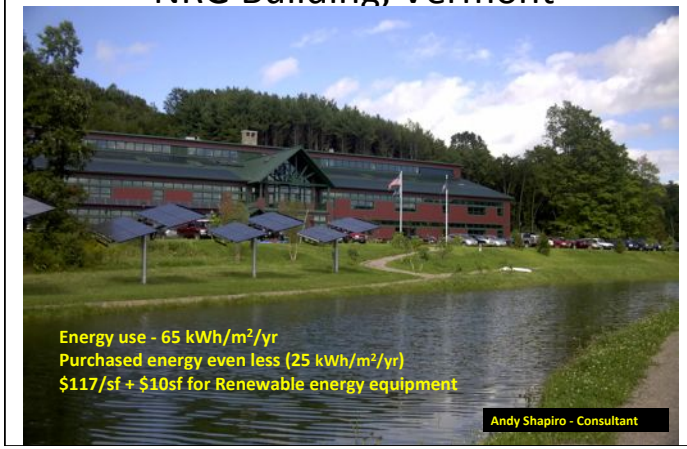


Grander View, 2010

- Mostly simple, standard technology
- Modest cost premium



NRG Building, Vermont



Waterloo Apartment / Office

- Built for median cost in 2005
- Around 100 ekWh/m² (Ont avg around 250)
- All standard products

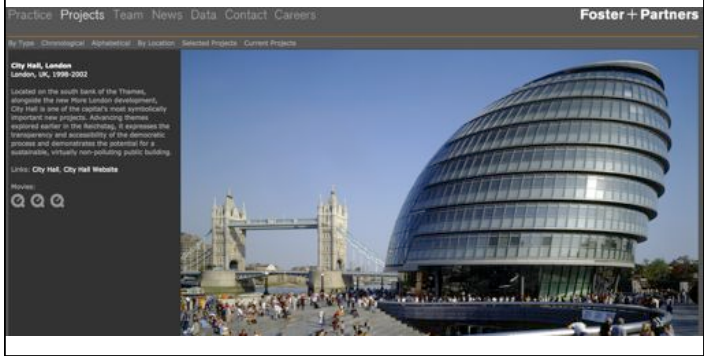
John Straube

Waterloo Region Health & Welfare

- Built 1990. 160 ekWh/m^2/yr.

London City Hall

"Greenest city hall in the world" 2002
"Virtually non-polluting" 2011



London UK City Hall

- **Measured: 376 kWh/m^2/yr**

Top Ten List

Commercial and institutional mid-size buildings, Canadian climates

- **Limit window-to-wall ratio** (WWR) to the range of 20-40%, 50% with ultra-performance windows
- **Increase window performance** (lowest U-value affordable in cold climates, including frame effects)
- Increase wall/roof **insulation** (esp. by controlling thermal bridging) and **airtighten**
- Separate **ventilation** air supply from heating and cooling.
- Use **occupancy** and **daylighting controls** for lights and equipment
- **Reduce** equipment/plug & lighting **power densities**
- Don't over ventilate, use **heat recovery** & **demand controlled ventilation**
- Improve boiler and **chiller efficiency** & recover waste heat (eg IT rooms!)
- Use **variable speed controls** for all large pumps and fans and implement **low temperature hydronic** heating and cooling where appropriate.
- Use a simple and compact building form, oriented to the sun, with a depth that allows daylight harvesting.

HVAC

- Architect helps select
- Critical role, as HVAC offers about half the possible savings
- Fancy, complex, expensive not often the lowest energy choice

Enclosures

- Enclosures **reduce** space heating/cooling
  - and help with lighting, ventilation
- We still need **energy** for other things
  - Lights, appliances, computers, elevators, etc
- Still need to provide some **HVAC**!
- Great enclosures reduce demand & hrs of operation
- Can't "insulate to zero"

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.)

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

Form & Massing

- Keep it simple
- Cheaper, easier, faster
- Fewer
  - thermal bridges, air leaks
  - Material volumes
  - construction challenges

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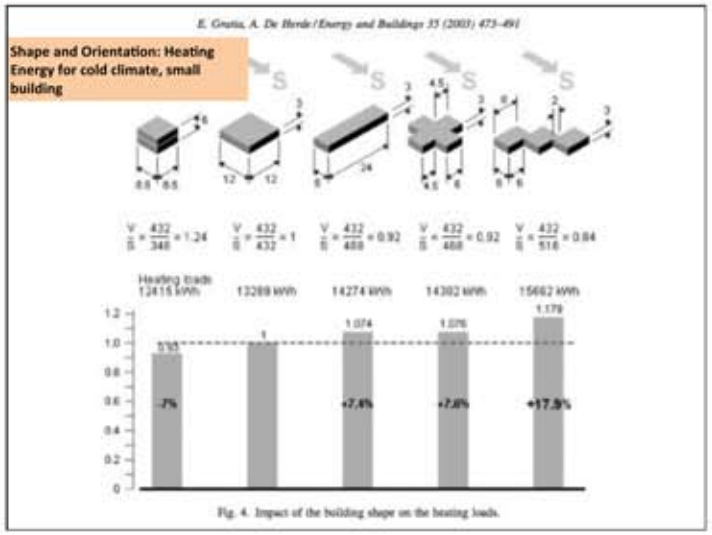
Size: Floor Area to Enclosure Area

The higher the ratio, the more enclosure design & climate impact performance

Small, Compact Form

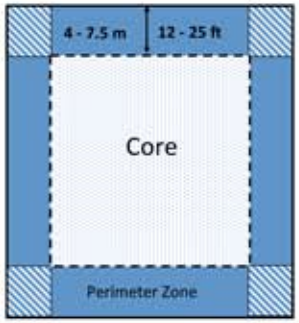
- Fewer resources
- Less heat loss and gain



Large Buildings

Many buildings with large cores require cooling in winter while heating the perimeter

Core / Perimeter

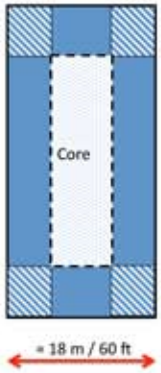


- Perimeter Zone
  - performance dominated by climate and enclosure
- Core Zone
  - dominated by interior use. Climate/enclosure almost irrelevant
- In most occupancies, core needs ***cooling and lighting all year long, all day***

Define "perimeter"

- Maximum distance about 25 ft/ 7.5 m
  - Classrooms often 25-30 ft, open plan office
- Minimum often set by walls/partitions of exterior offices
  - Cellular offices often 15 ft/ 4.5m deep

Skin Dominated Building



- "Skin-dominated": Perimeter Zone over most of floor area
- Excellent daylighting and cross ventilation opportunities
- Best massing for many commercial buildings
- ***Demands good building enclosure because of increased enclosure area***

Building Shape

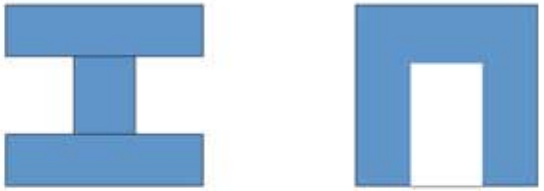
- Alphabet Soup
  - H I A B E

Usually skin dominated

Daylight access, view Cross Ventilation

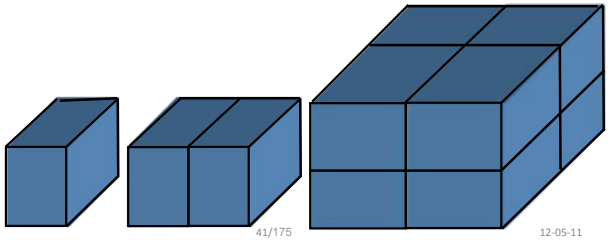
Expanded Plans

- Better daylight, easier ventilation but more enclosure heat loss and gain and air leaks



Grouping buildings

- Grouping units reduces heat loss/gain through shared walls
- Reduces resource use per unit



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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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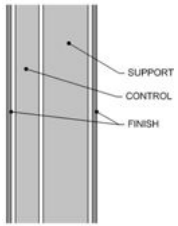
Basic Functions of the Enclosure

- 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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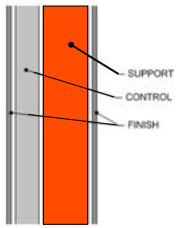
Basic Enclosure Functions

- **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

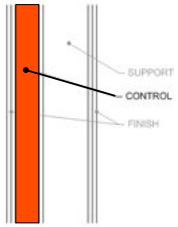


Building Science Enclosures No. 44 /

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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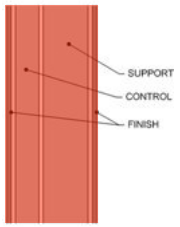
Other Control . . .

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

Functional Layers



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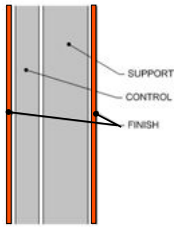
Basic Enclosure Functions

- 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



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History of Control Functions

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

    . . . separate functions

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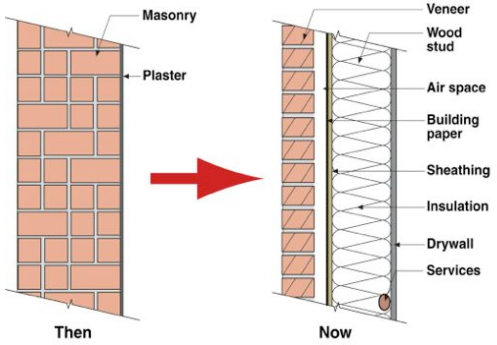
Changes



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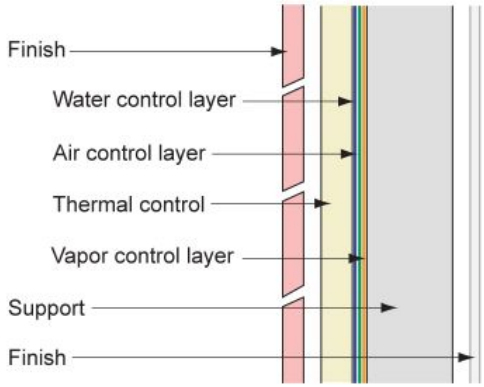
Enclosure Control Layers



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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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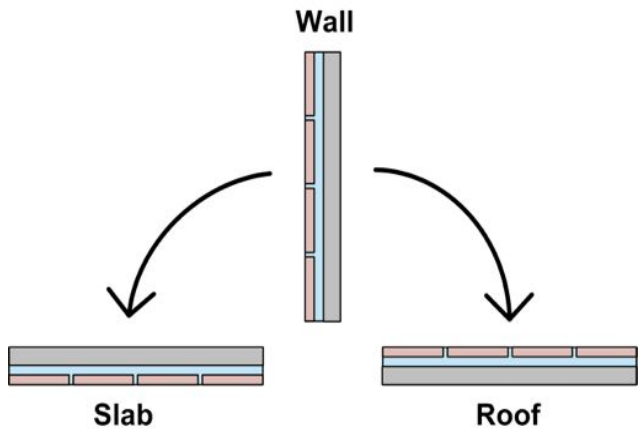

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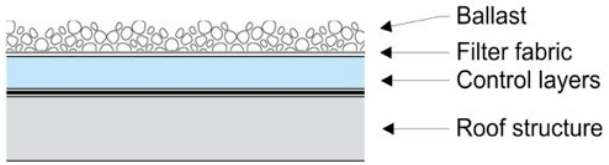

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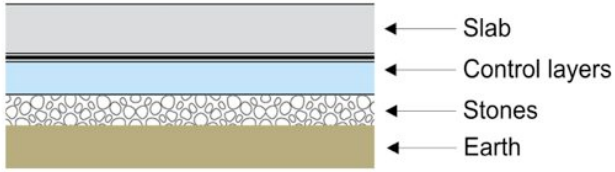

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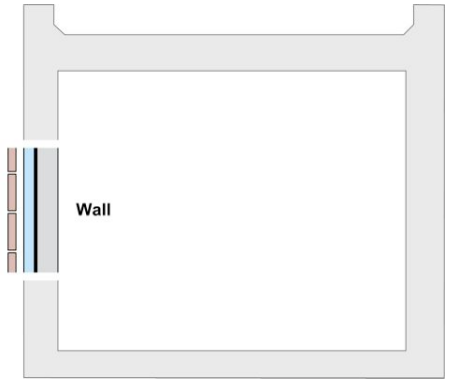

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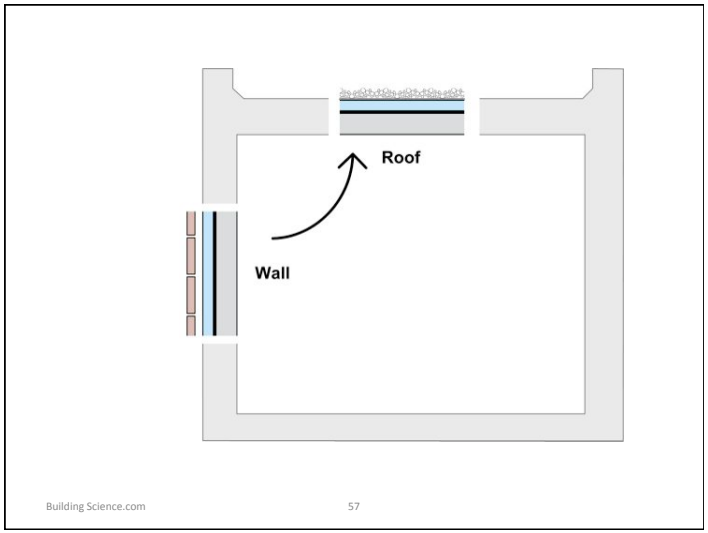
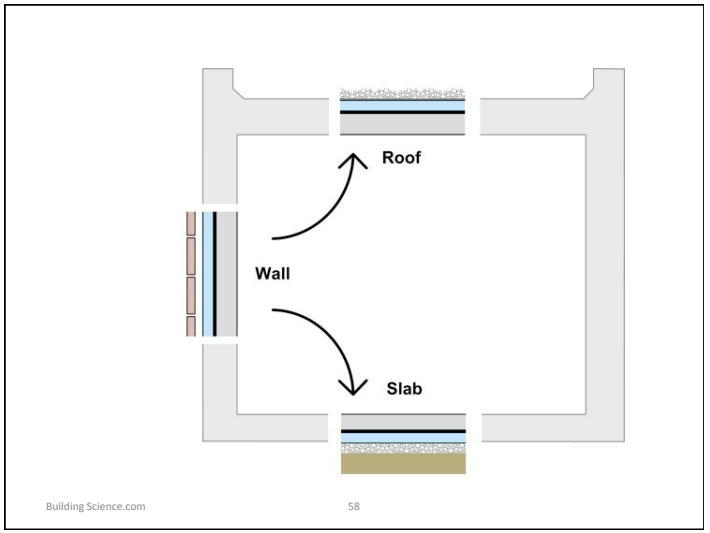

Roof
Wall
Building Science.com
57


Roof
Wall
Slab
Building Science.com
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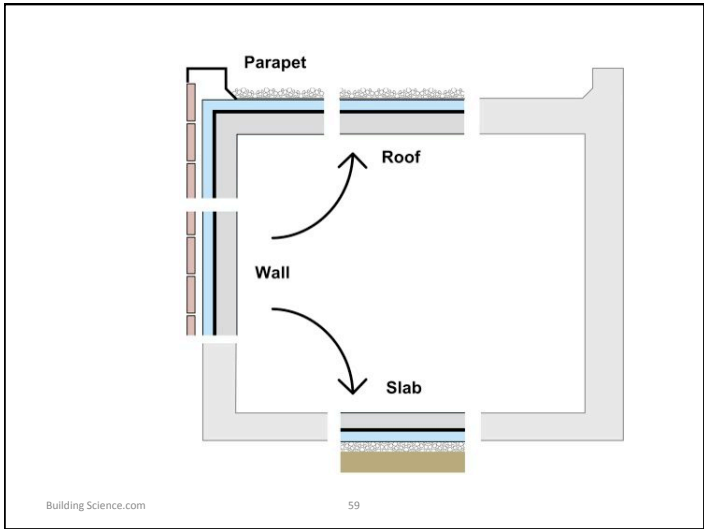
Parapet
Roof
Wall
Slab
Building Science.com
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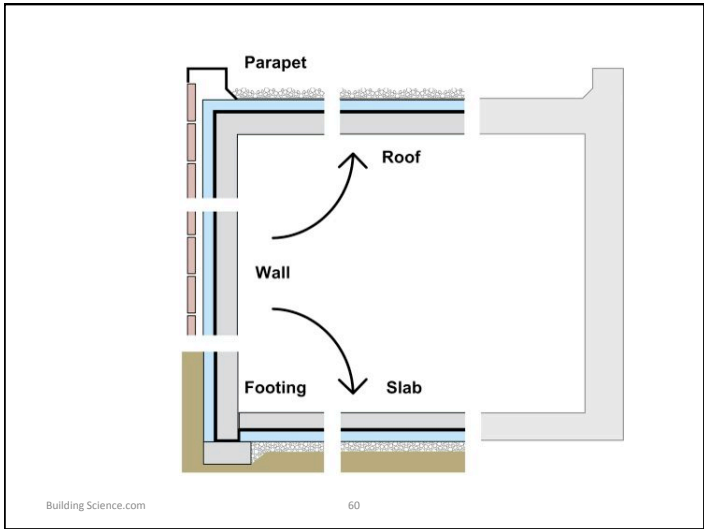
Parapet
Roof
Wall
Footing
Slab
Building Science.com
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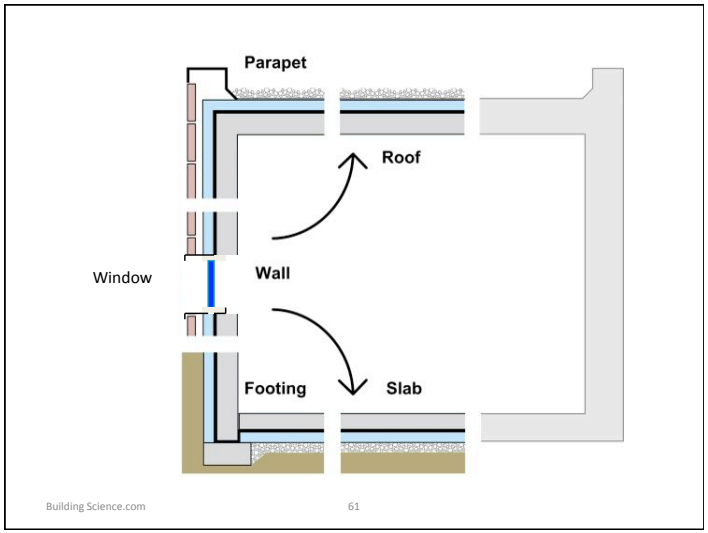
Parapet
Roof
Window
Wall
Footing
Slab
Building Science.com
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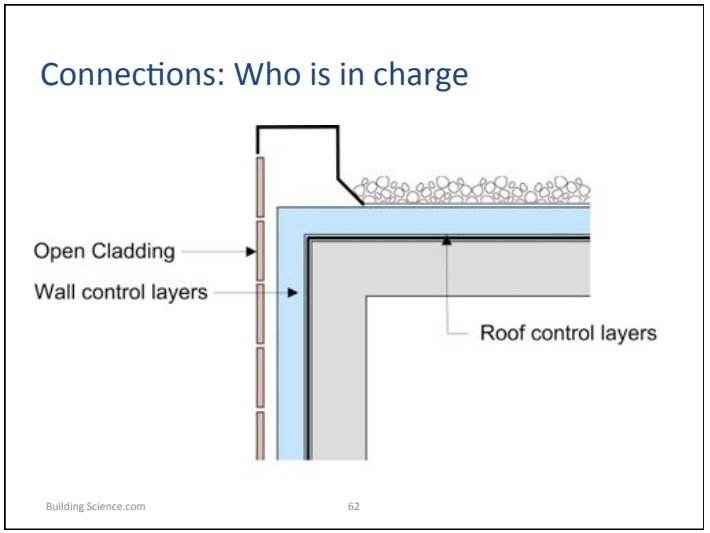
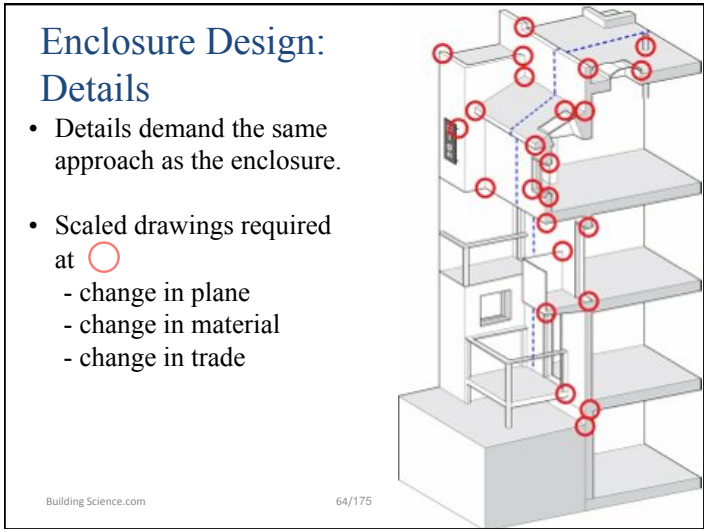
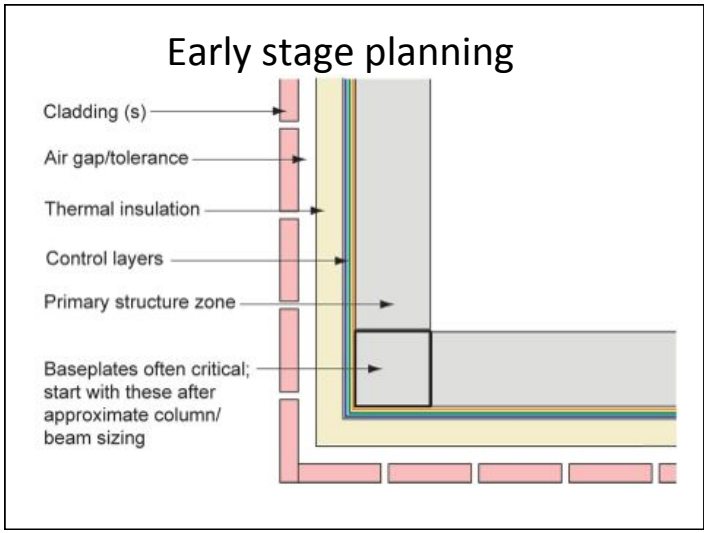
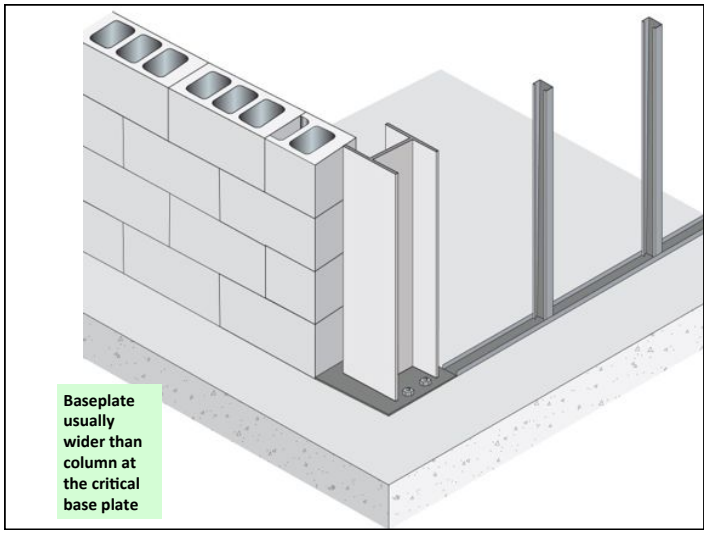
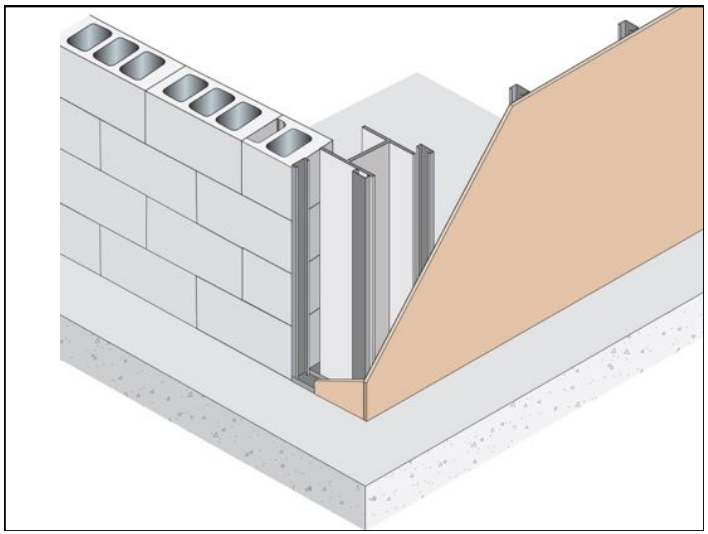

Connections: Who is in charge
Open Cladding
Wall control layers
Roof control layers
Building Science.com
62

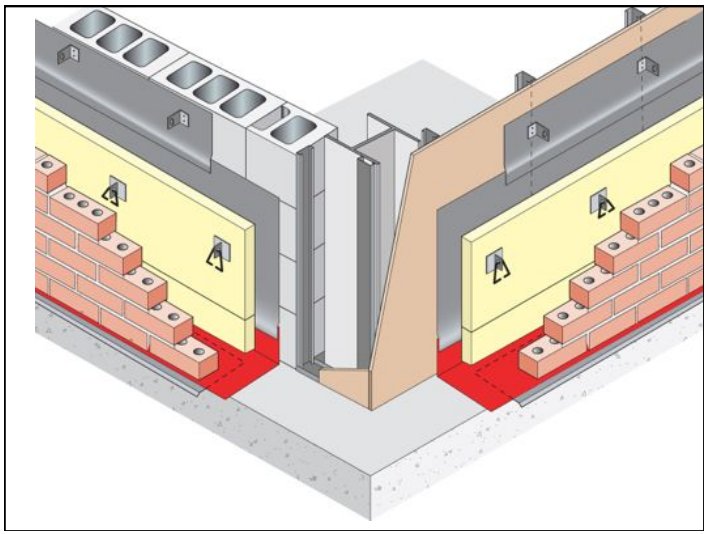

Complexity increases detailing effort / risk of failure / cost
reduces performance
Building Science.com
Enclosures No. 63 /


Enclosure Design:
Details
• Details demand the same approach as the enclosure.
• Scaled drawings required at
- change in plane
- change in material
- change in trade
Building Science.com
64/175

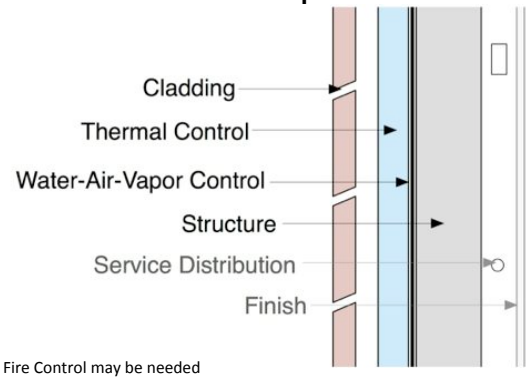

Early stage planning
Cladding (s)
Air gap/tolerance
Thermal insulation
Control layers
Primary structure zone
Baseplates often critical; start with these after approximate column/ beam sizing


Baseplate usually wider than column at the critical base plate





Perfect Wall expanded



Additional Fire Control may be needed
Sound Control optional

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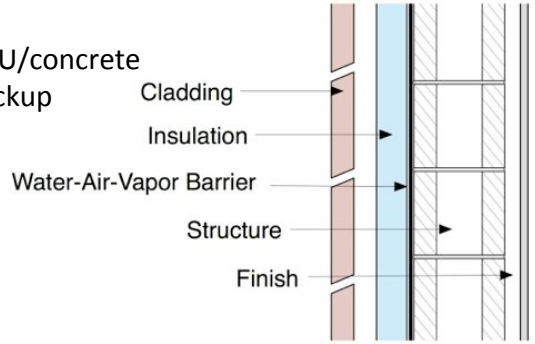
Perfect Wall: Institutional

- CMU/concrete backup



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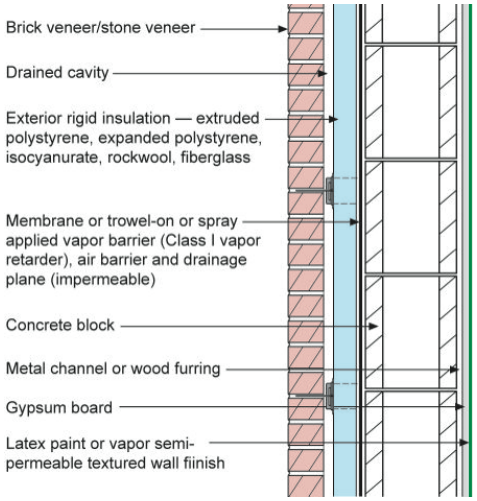
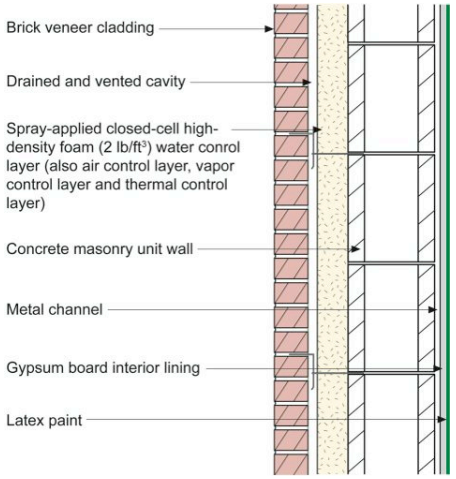
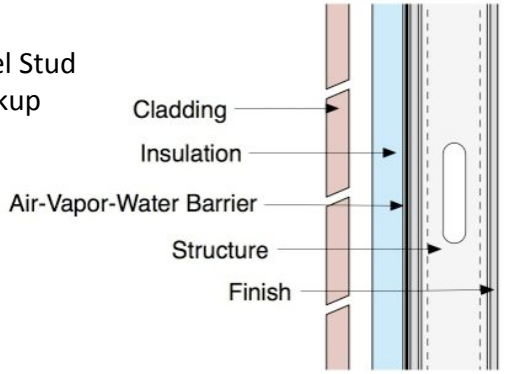
Any R-value, e.g.
4" PIC=R25
5"XPS =R25
6"MFI=R25





Perfect Wall: Commercial

- Steel Stud Backup



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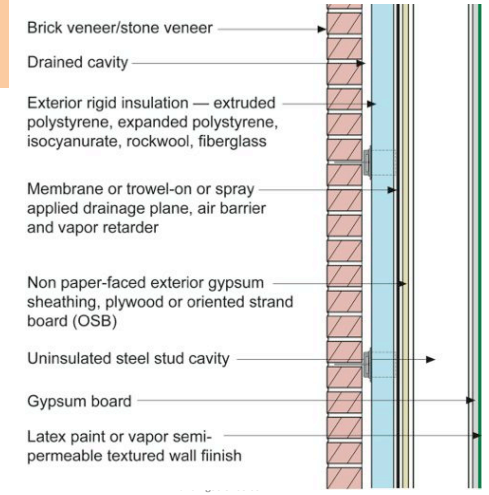
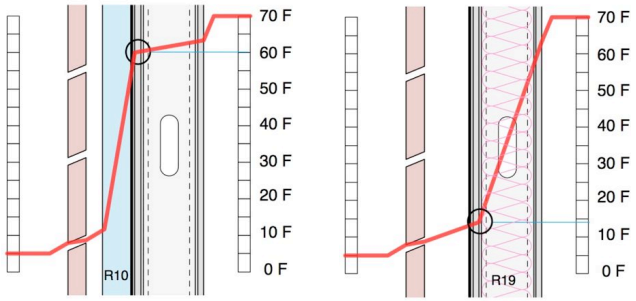
Any R-value, e.g.
4" PIC=R25
5"XPS =R25
6"MFI=R25



Condensation & Drying



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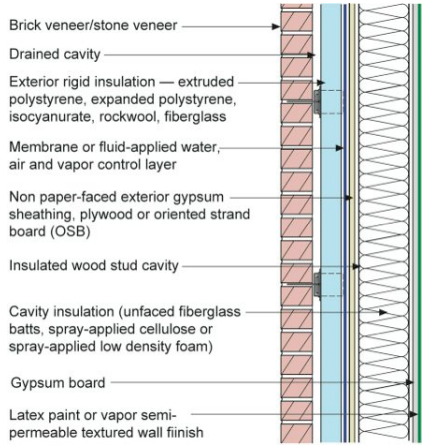
Ratio: $\frac{\text{Exterior R-value}}{\text{Studbay R-value}}$ controls risk of condensation

Steel studs compromise the thermal performance Wood studs, not so much

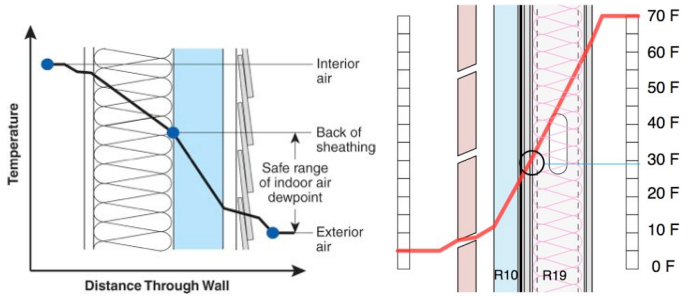
Compromise



Any R-value, e.g.
6" wood stud+
2" PIC= R30
3"XPS= R32
4"SPF= R40

BSD-163

Compromise= Risks



$T_{sheathing} = T_{in} - (T_{in}-T_{out})*R_{cavity}/R_{total}$

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Specifics

- Now we will look at
  - Rain Control
  - Air Flow Control
  - Thermal Control

  } Energy & Comfort } Durability, Health
- In some detail

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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= need for better control!

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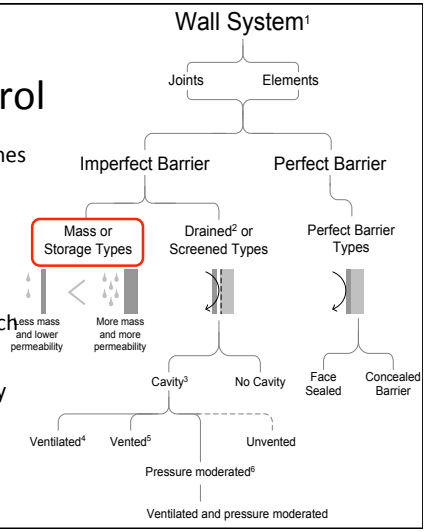
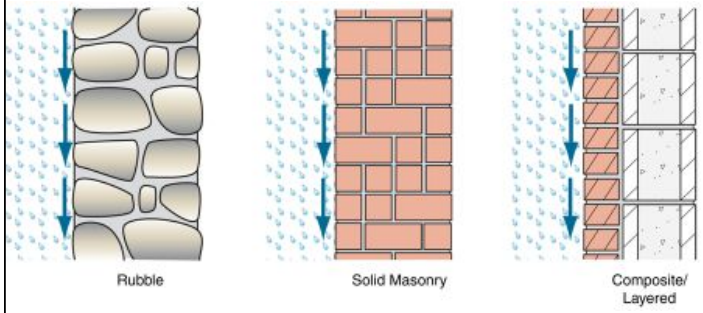
1. Rain Control

- Three possible approaches
  - Mass
  - Drained
  - Perfect Barriers
- Element and joint can be different approach
- Perfect Barriers are risky



Mass/Storage/Reservoir Walls



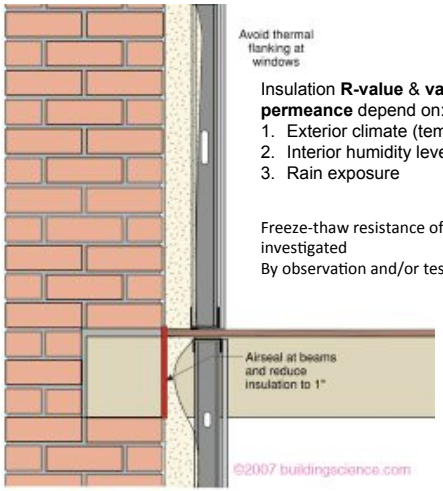
John Straube

No building paper, flashing, weepholes

Rain Control 83

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

Rain Control 84

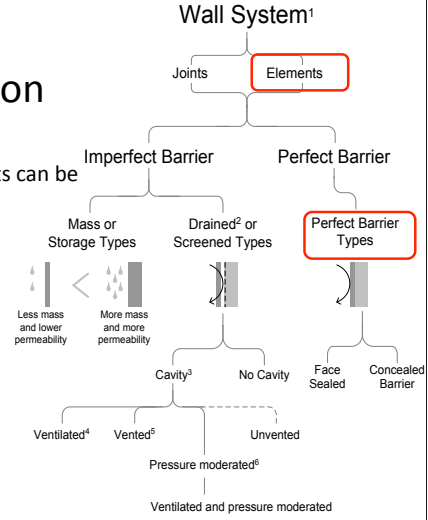


Insulation **R-value** & **vapor permeance** depend on:
1. Exterior climate (temp / drying)
2. Interior humidity levels
3. Rain exposure

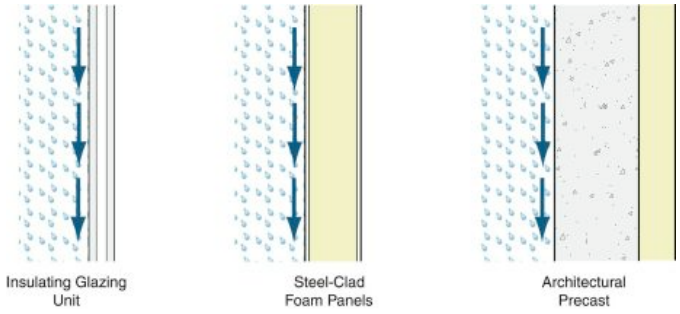
Freeze-thaw resistance of brick should be investigated
By observation and/or testing

Categorization

- Elements and joints can be different



Perfect Barrier / Face Sealed



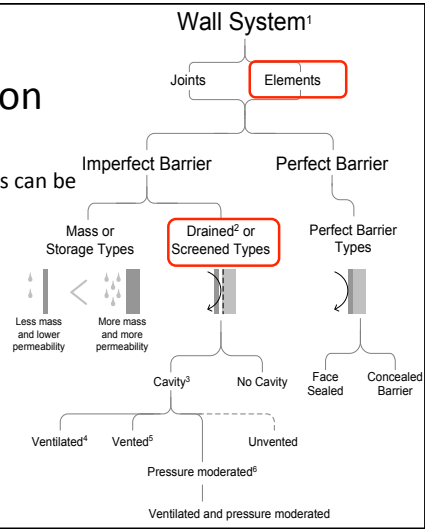
Perfect Barrier Walls

It is all about joints, transitions, penetrations which may not be built, or remain, perfect

Precast is often a functional perfect barrier wall .. but the joints leak

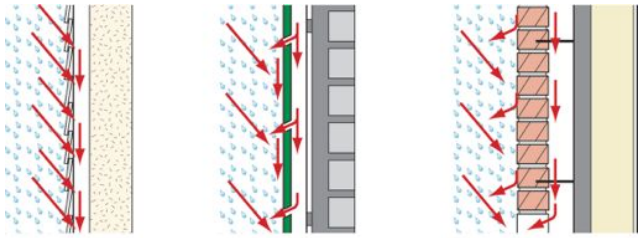
Categorization

- Elements and joints can be different

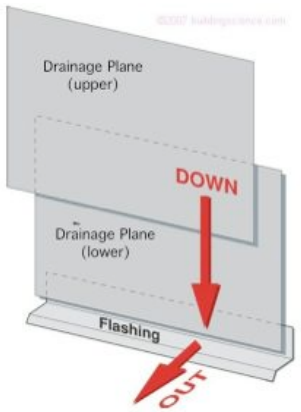


Drained Walls

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

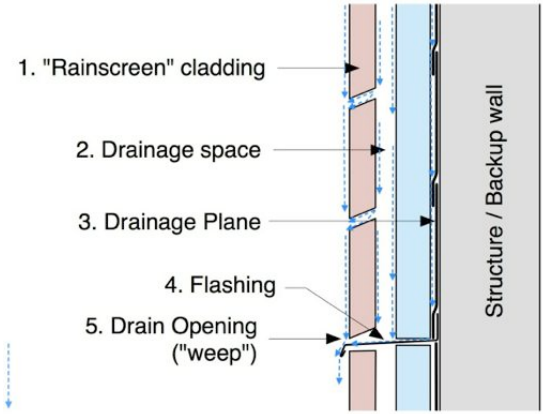


"shingle fashion" lapping

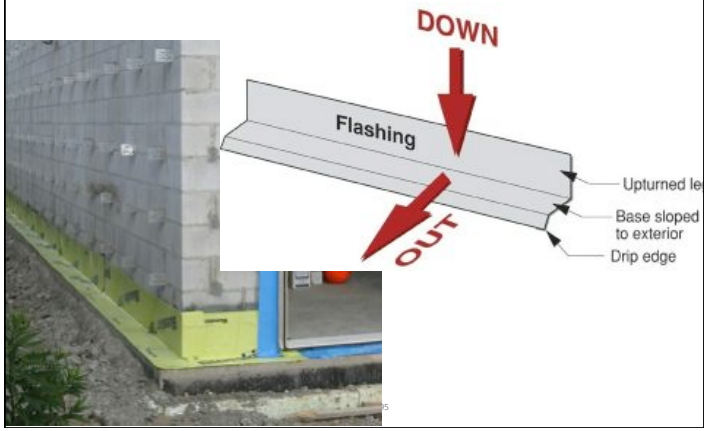


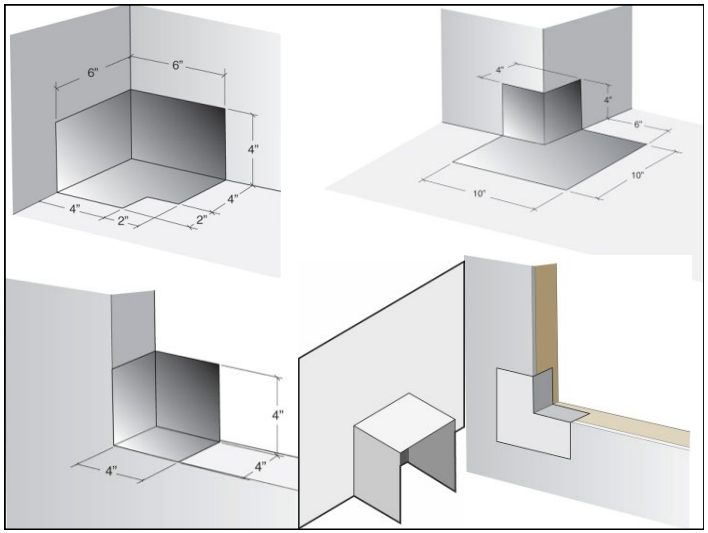
Lapped Drainage Plane

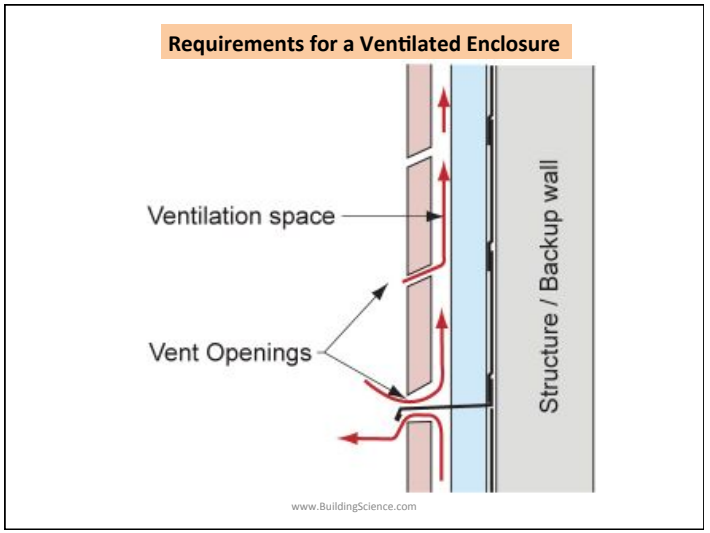
Requirements for a Drained Enclosure

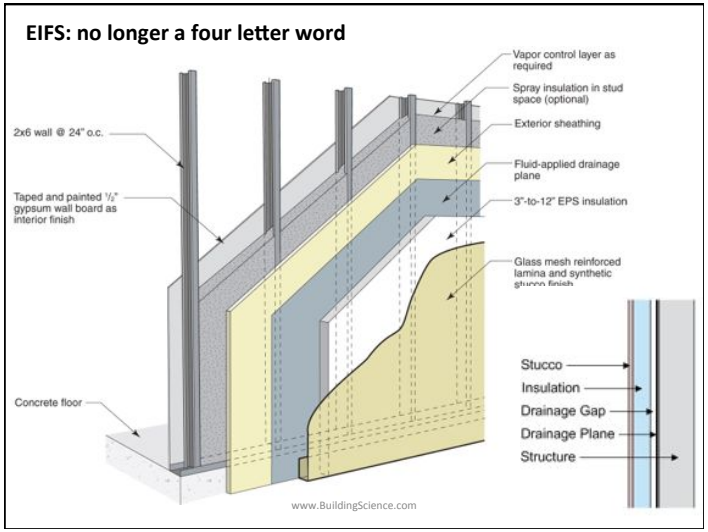


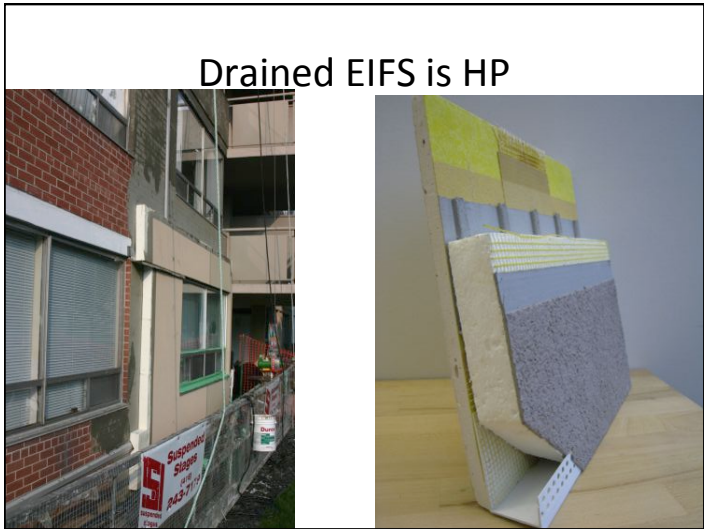
Flashing must be waterproof

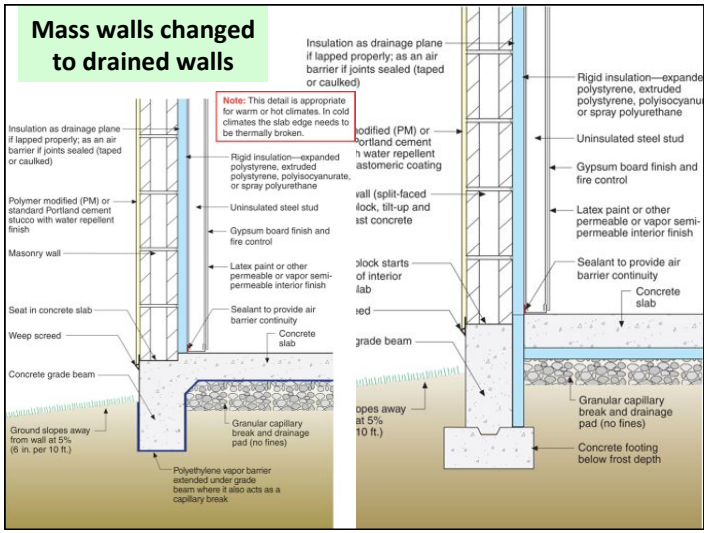


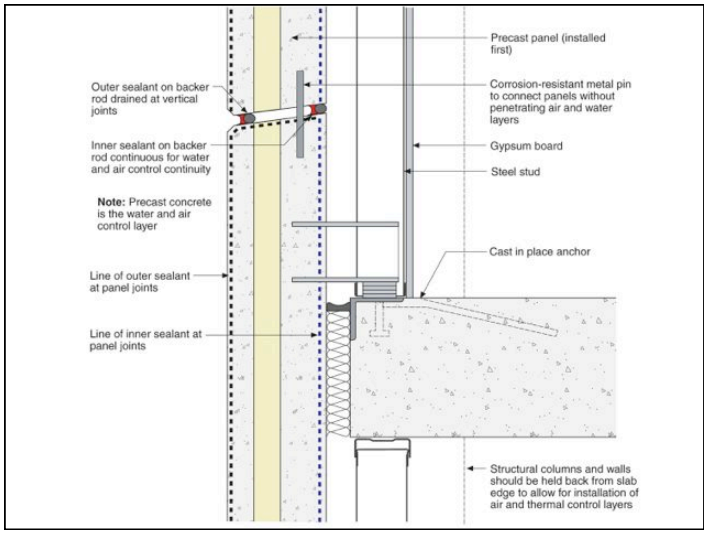

6"
6"
4"
4"
2"
2"
4"
4"
10"
10"
4"
4"
4"
4"


Requirements for a Ventilated Enclosure
Ventilation space
Vent Openings
Structure / Backup wall
www.BuildingScience.com


EIFS: no longer a four letter word
Vapor control layer as required
Spray insulation in stud space (optional)
Exterior sheathing
Fluid-applied drainage plane
3"-to-12" EPS insulation
Glass mesh reinforced lamina and synthetic
2x6 wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Concrete floor
Stucco
Insulation
Drainage Gap
Drainage Plane
Structure
www.BuildingScience.com


Drained EIFS is HP



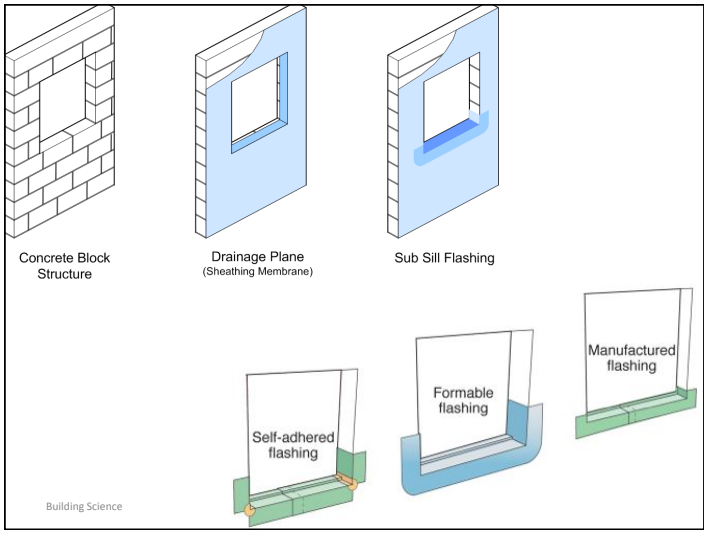


Windows and Doors

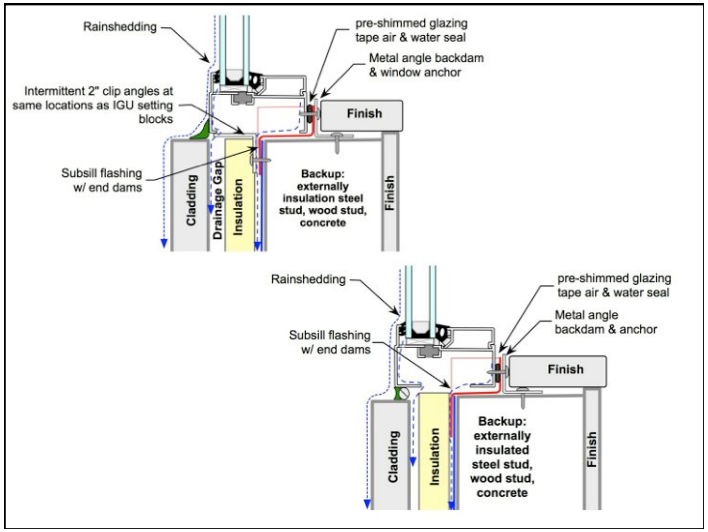
- All penetrations should be drained
  - regardless of the approach taken to the element
- Windows/doors are most critical penetrations
- Drain rough opening

Leaky windows

- Windows / openings leak

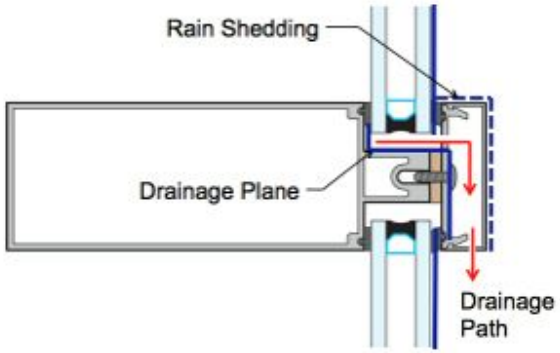


Backdams / Slopes are Important



Continuous interior angle provides backdam and airseal continuity

Rain Control



Air-Water-Vapor Layers

- Often thin layers
- *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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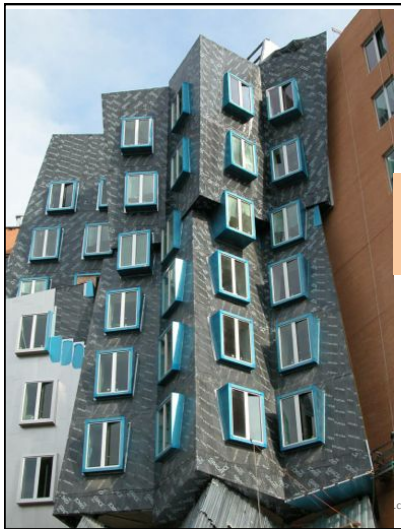

Air-Water Control Layers

Sloped and complex surfaces demand very high performance. LAPPING very Important

Details

- Air & water & vapor transition membranes

Fully-adhered air-water barrier

Vapor Permeable!

www.BuildingScience.com

Non-adhered, vapor permeable =modest performance

Supported **flexible membrane is better**

Closed-cell spray polyurethane foam: ccSPF
-Rain control
-Air Control
-Thermal Control
- Vapor Control

Rain Control Summary

- Rain control should be top priority
- Not just drained systems!
  - Avoid dogma
- Perfect barrier
  - Glazing, precast
- Mass
  - Historic masonry

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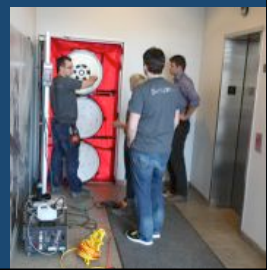
Air Flow Control



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Air Barrier Systems

- Need an excellent air barrier in all buildings
  - Comfort & health
  - Moisture / condensation
  - Energy
  - Sound, fire, etc.
- Can't make it too tight.
- Multiple air barriers improve redundancy

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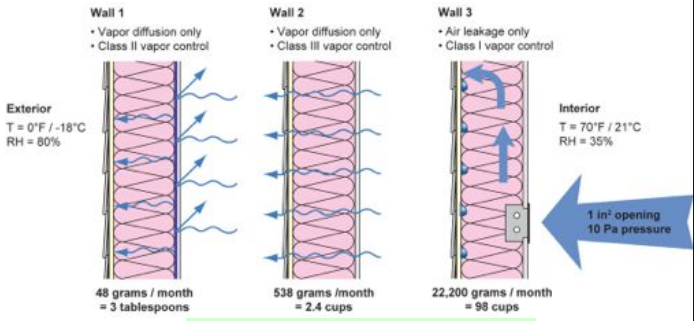
Air moves more vapor than diffusion!



Diffusion is rarely a big deal
Air leakage almost always is!

Calculations for a single stud bay, 8 ft tall, 16" wide

www.BuildingScience.com

Air leakage

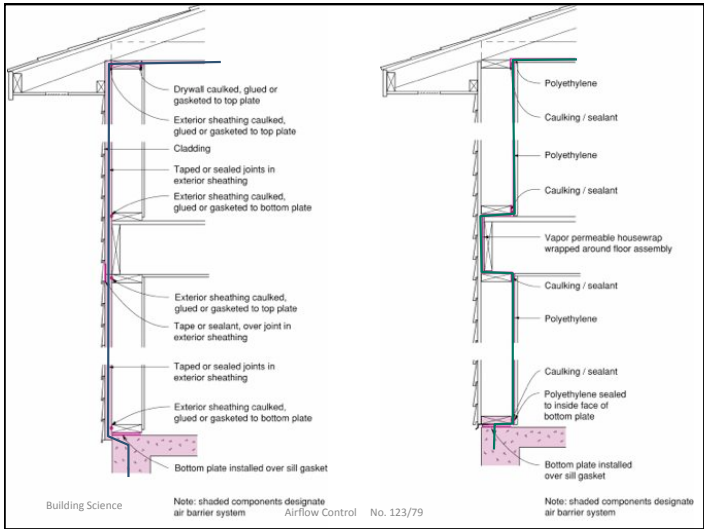
- Hard to save energy with the door open
- Buildings getting tighter, but . . .
  - Many still leak way too much
  - We can't identify the leakers
  - Need to test! Commission!
- Ventilation: Many try to improve air quality by increasing quantity
  - Target good air when and where needed

121/175 12-05-11

Air Barriers and Energy

- 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

122/175 12-05-11

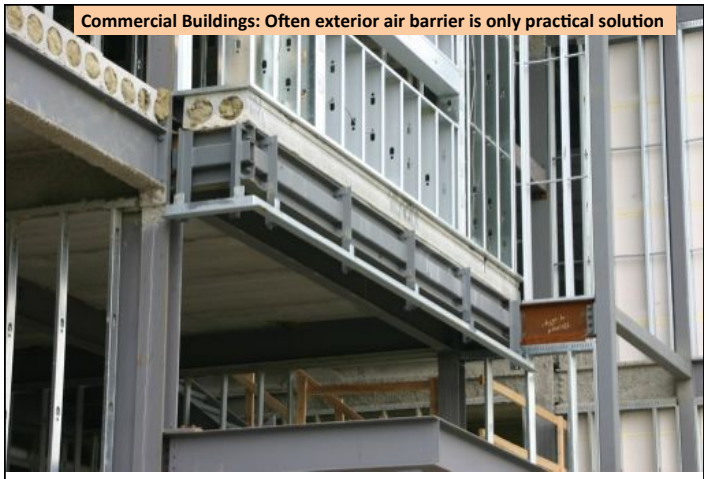


Building Science Airflow Control No. 123/79

Building Science.com Airflow Control 124

Rigid Exterior Air Barrier

Building Science.com 125



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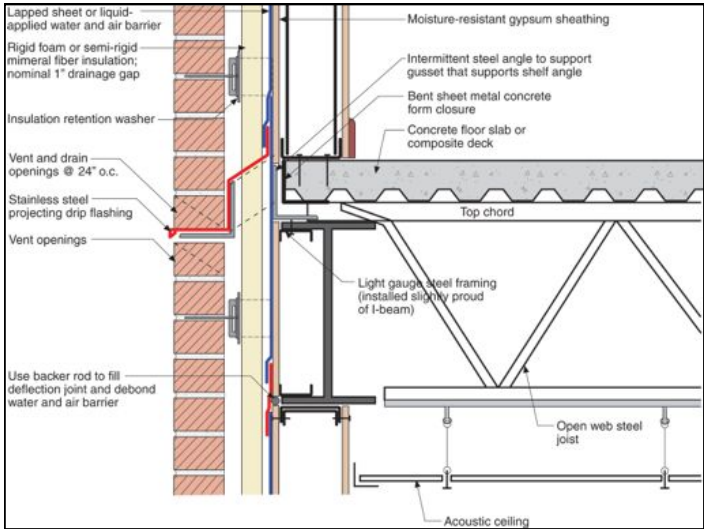
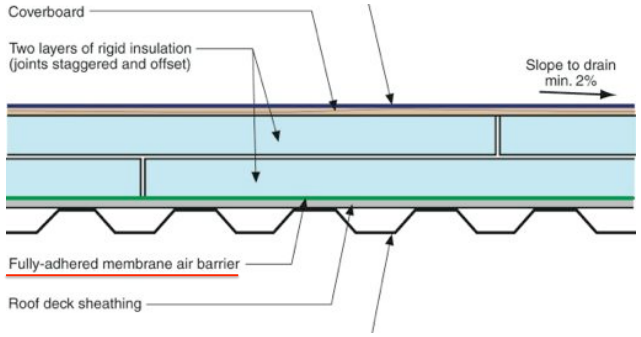


Deck level vapor control membrane rarely required if closed cell foam used

Roof air barrier



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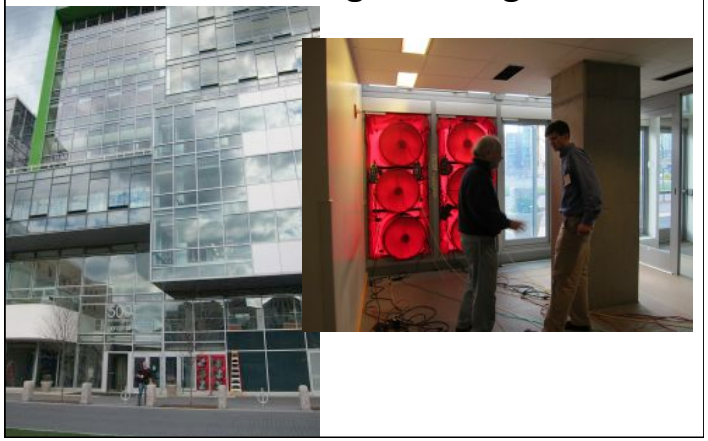
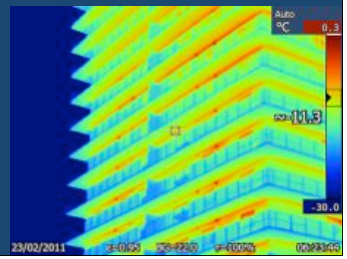
Air Leakage Testing

Air Leakage Testing



Air Leakage Testing

Thermal Control



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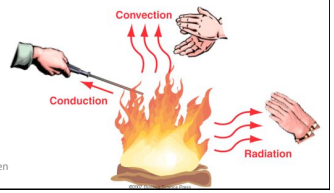
Thermal control

- Ensure Comfort
  - Avoid hot/cold interior surfaces
- Warms surfaces = durability
  - Avoids condensation in hot and cold weather
  - hence, a durability and health strategy
  - Keep structure warm and dry and stable
- Save Energy
  - Reduce heat flow

12-05-11

Thermal Control

- Insulation
  - Slows heat flow in and out
- Windows
  - Slow heat flow in and out
  - Control solar gain : allow or reject?
- "cool" roofs
  - Reduce solar gain
- Radiant barriers



Thermal Insulation

Insulation	R-value/inch	k (W/mK)
Empty airspace 0.75"-1.5" (20-40 mm)	R2.0 - 2.75	0.36 –0.50 W/m²K
Empty airspace 3.5"-5.5" (90-140 mm)	R2.75	0.50 W/m²K
Batt (mineral fiber)	3.5-3.8	0.034 - 0.042
Extruded polystyrene (XPS)	5.0	0.029
Polyisocyanurate (PIC)	6.0-6.5	0.022 - 0.024
Expanded polystyrene (EPS)	3.6-4.2	0.034 - 0.040
Semi-rigid mineral fiber (MFI)	3.6-4.2	0.034 - 0.040
Spray fiberglass	3.7-4.0	0.034 - 0.038
Closed-cell spray foam (2 pcf) ccSPF	5.8-6.6	0.022 - 0.025
Open-cell spray foam (0.5 pcf) ocSPF	3.6	0.040
Aerogel	8-12	0.012-0.018
Vacuum Insulated Panels (VIP)	20-35	0.004-0.008

How much Insulation

- Heat Flow = $\frac{\text{Area} * (T_{inside} - T_{outside})}{\text{R-value}}$
- Double R-value, halve heat flow. Always.
- Optimum depends on
  - Cost of energy over life of building
  - Cost of adding more insulation
  - Savings in mechanical equipment, controls

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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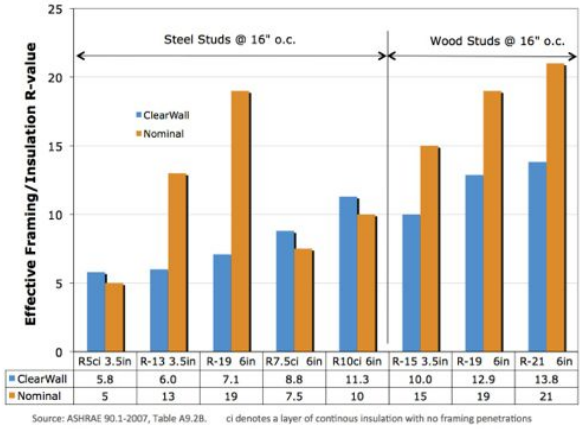
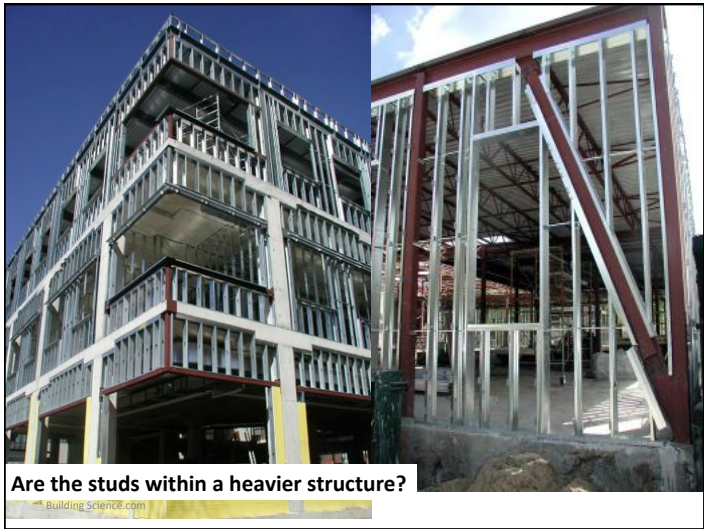
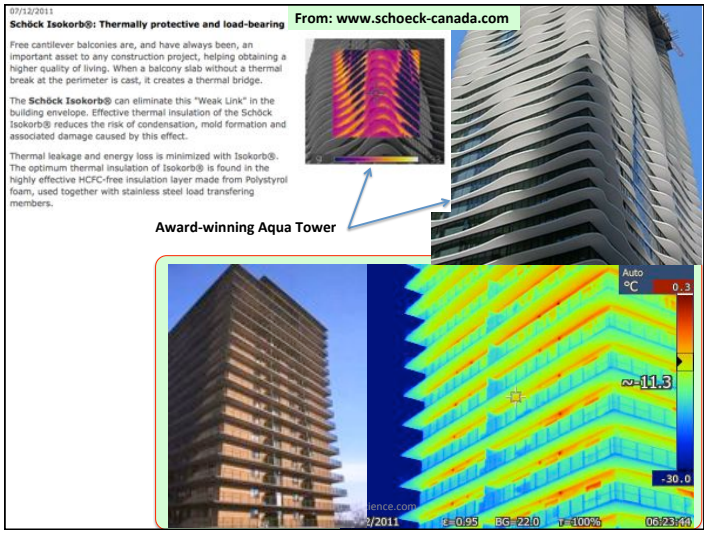
Best-case R-values for stud walls



	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

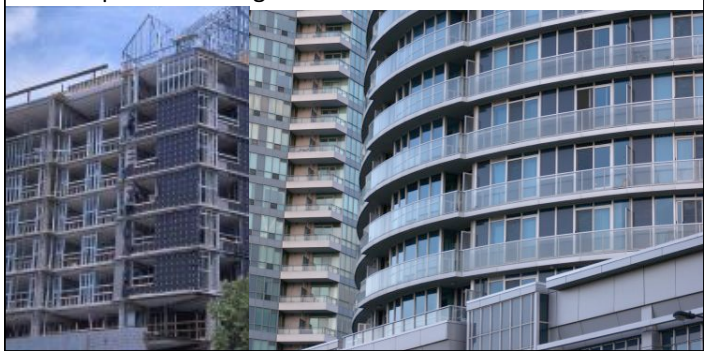
Source: ASHRAE 90.1-2007, Table A9.2B. ci denotes a layer of continous insulation with no framing penetrations

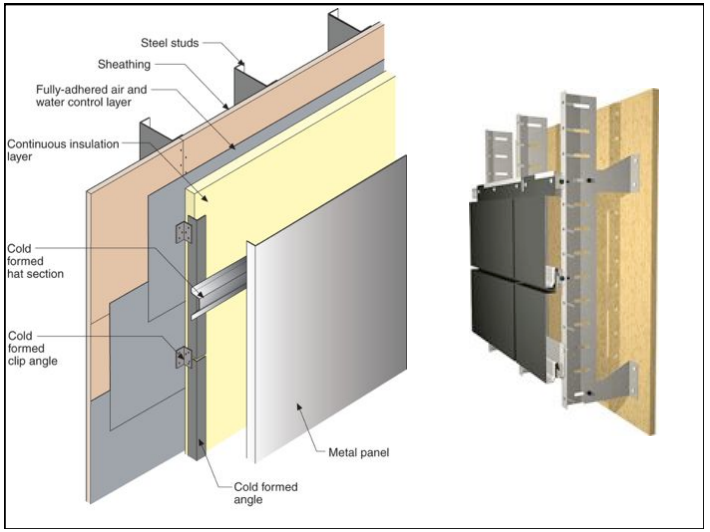




Thermal Bridge Examples

- Balconies, etc
- Exposed slab edges





Furring Strips: least thermal performance impact

Just screws meets "ci" requirement of ASHRAE 90.1

Structural penetrations

- Relieving/Shelf angles
- Balconies
- Canopies
- Signs

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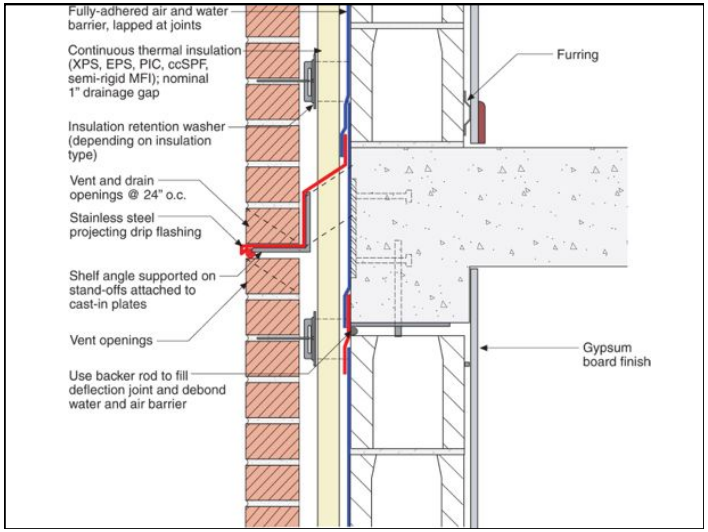
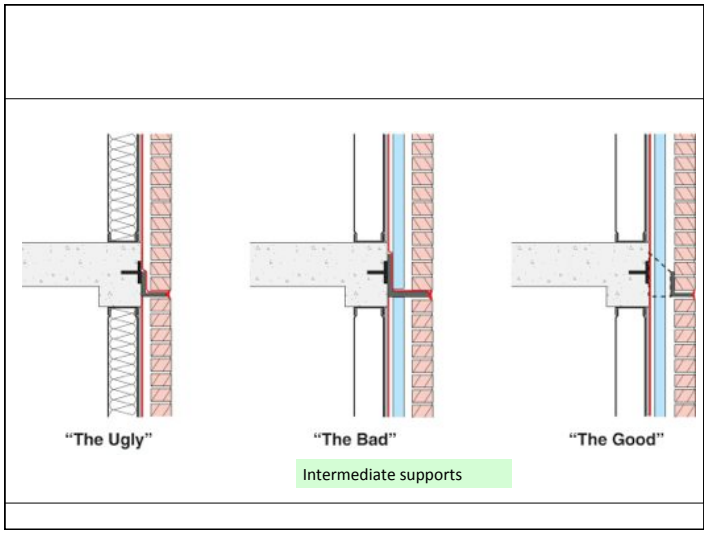
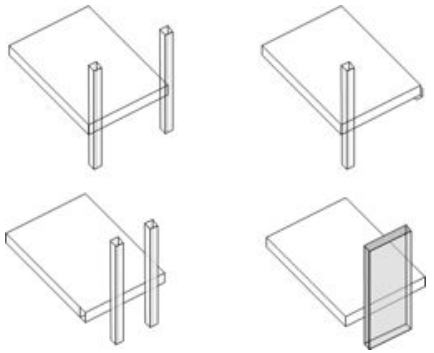



"The Ugly"
"The Bad"
"The Good"
Intermediate supports


Small metal clips dramatically reduce thermal bridging

Balconies

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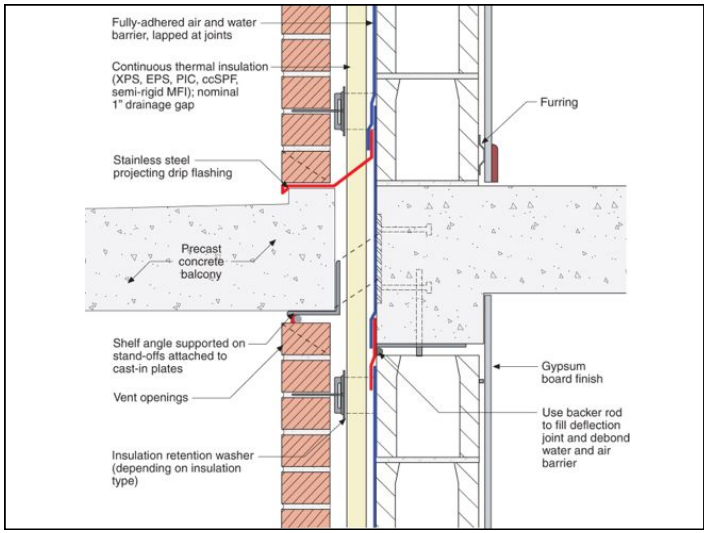
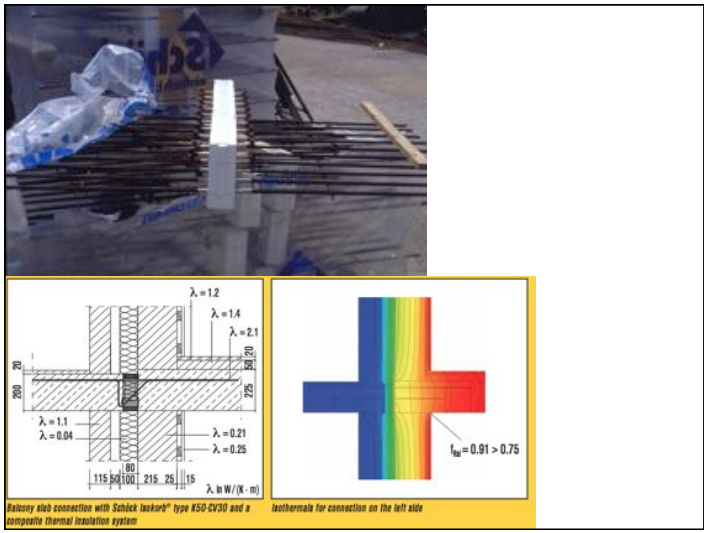
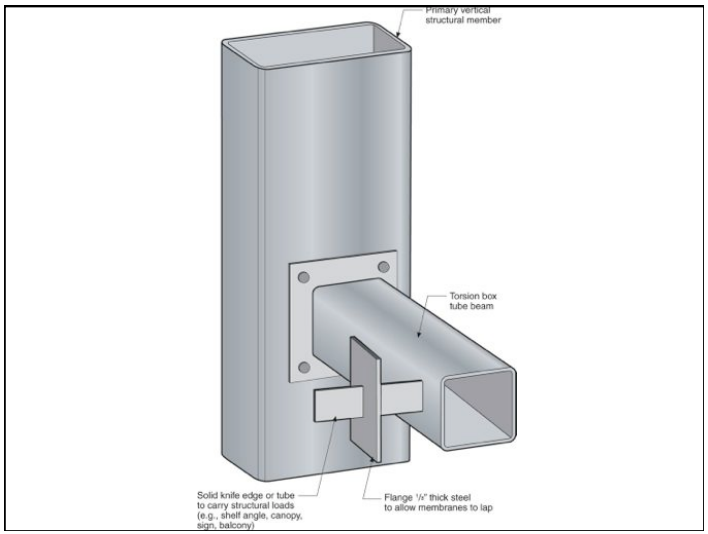
Insulation and Thermal Bridges No. 153/65

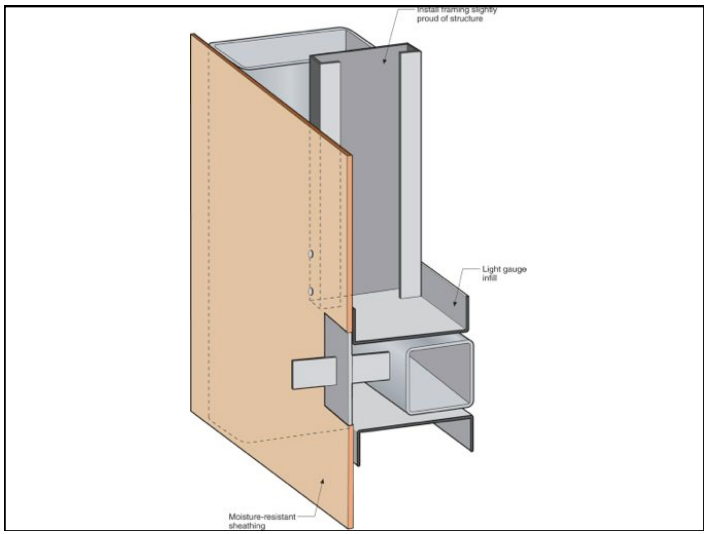

Philly's Best

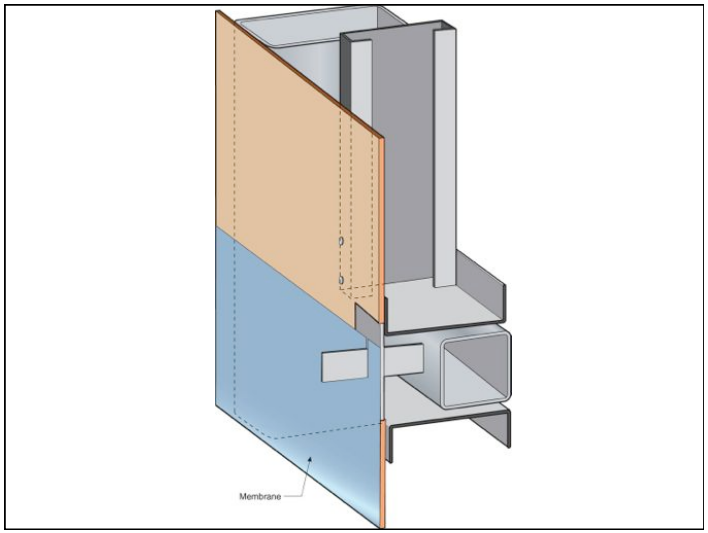

Precast balcony supported on knife edge supports to limit thermal losses

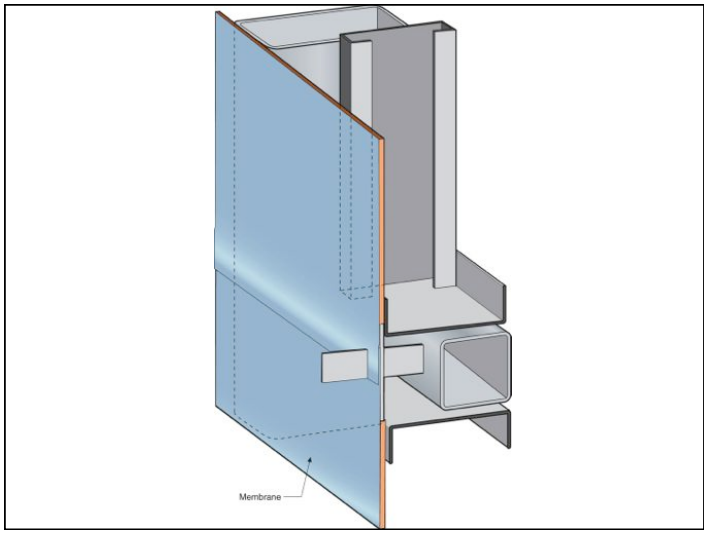

Fully-adhered air and water barrier, lapped at joints
Continuous thermal insulation (XPS, EPS, PIC, ccSPF, semi-rigid MFI); nominal 1" drainage gap
Stainless steel projecting drip flashing
Precast concrete balcony
Shelf angle supported on stand-offs attached to cast-in plates
Vent openings
Insulation retention washer (depending on insulation type)
Furring
Gypsum board finish
Use backer rod to fill deflection joint and debond water and air barrier


λ = 1.2
λ = 1.4
λ = 2.1
λ = 1.1
λ = 0.04
λ = 0.21
λ = 0.25
λ, in W/(K · m)
Balcony slab connection with Schöck Isokorb® type KSO-CV30 and a composite thermal insulation system
Isothermals for connection on the left side


Primary vertical structural member
Torsion box tube beam
Solid knife edge or tube to carry structural loads (e.g., shelf angle, canopy, sign, balcony)
Flange ½" thick steel to allow membranes to lap


Light gauge infill
Moisture-resistant sheathing





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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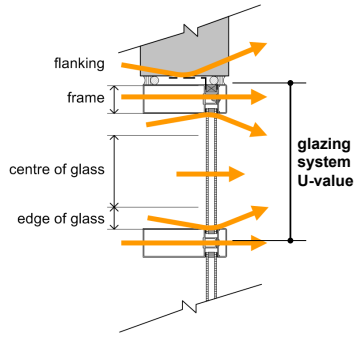
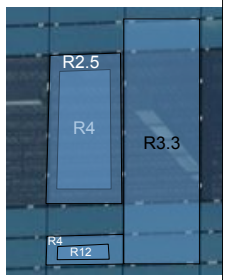
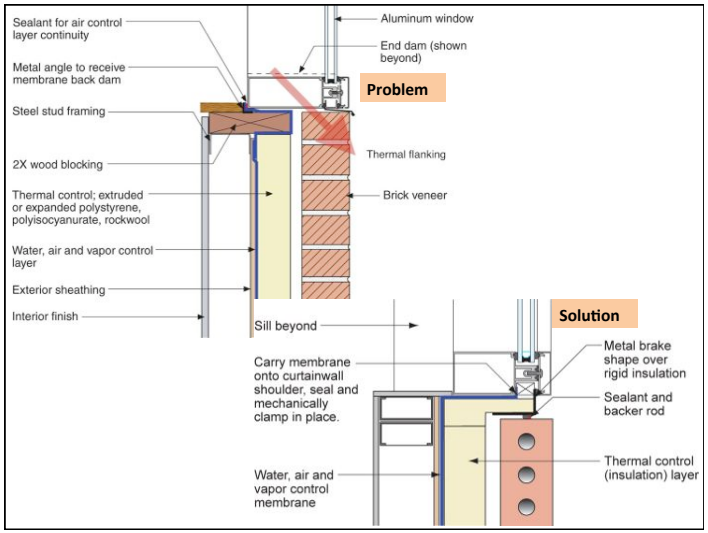
Total Heat Flow

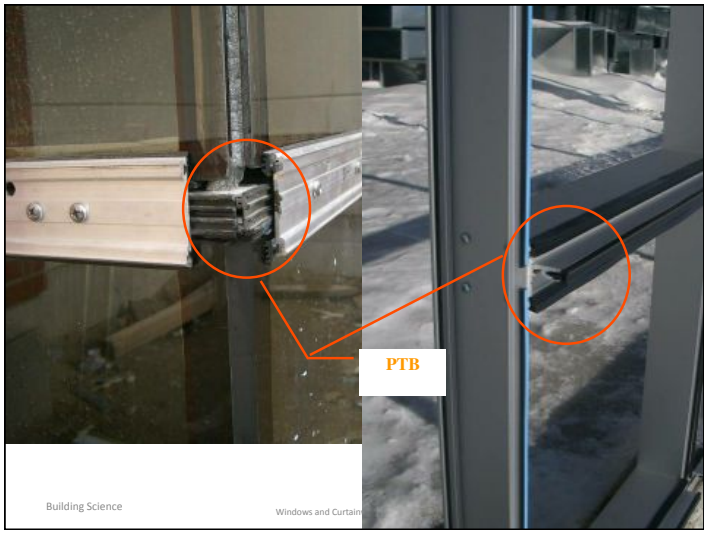
Curtain Wall Plan View



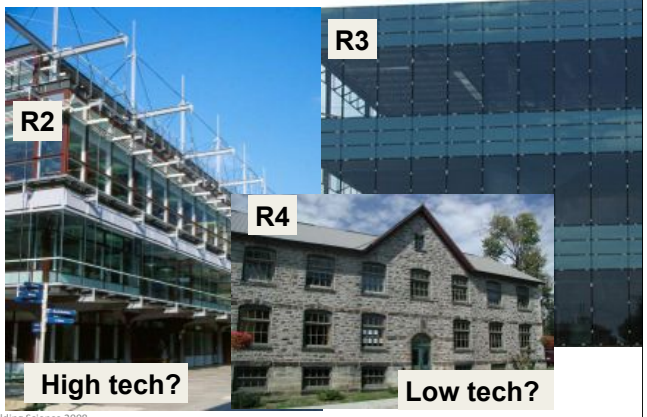


Building Science 2008 Windows and Curtainwalls No. 16480





Full-Frame R-values



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Thermal Break

- Critical for alu windows
- ½" should be min thermal break

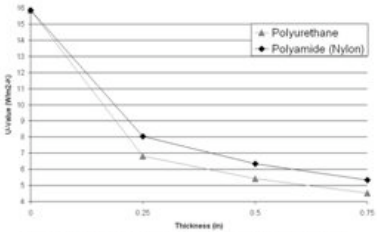
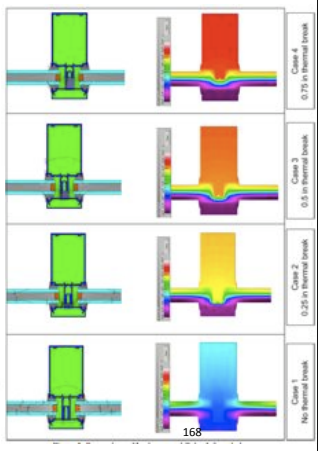


Figure 4: Frame U-Value vs. thermal break thickness.



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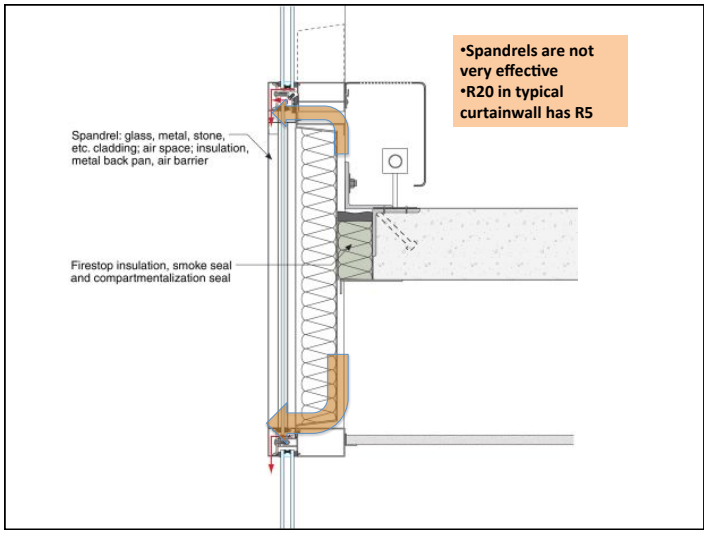
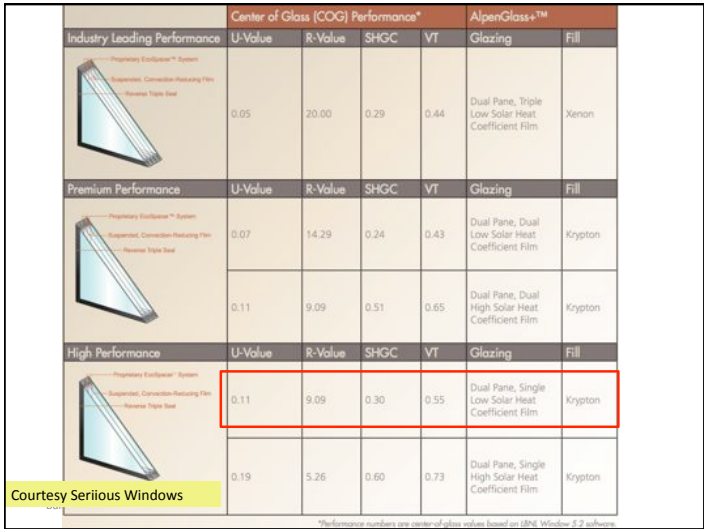
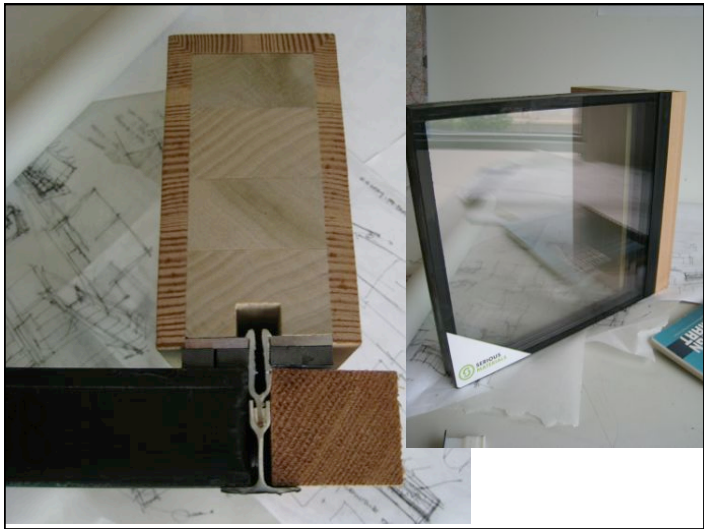
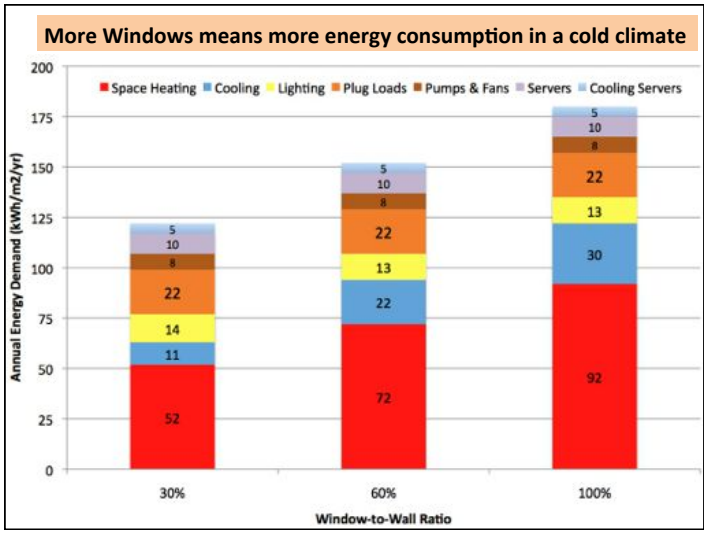
High Performance
Getting better . .
R8
Southwall
R6
R24
Kawneer
R6
Visionwall
Building Science.com


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


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
Courtesy Seriious Windows





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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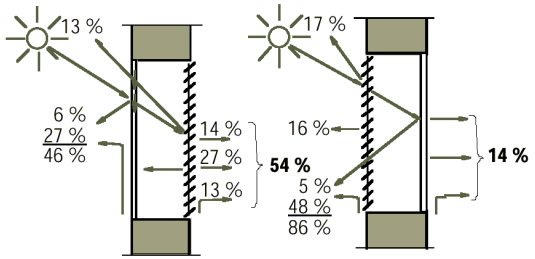
Interior or Exterior Shade

- 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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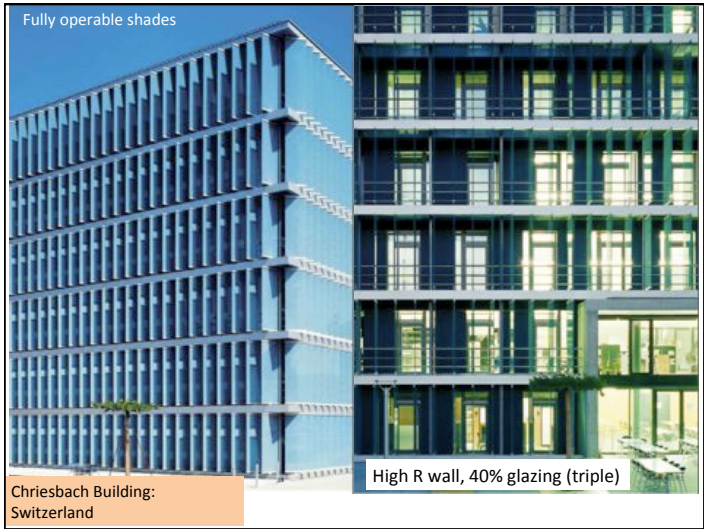

Chriesbach Building: Switzerland

ROOFS

Low-Slope Roofs

- Not flat. Ponding is not acceptable.
- Get water right, then worry about energy!
- Components
  - Rain barrier is roof membrane
    - Drainage gap is the outdoors
  - Air barrier can be roof membrane
    - Better to install interior
  - Insulation is rigid, polyiso, XPS, EPS, rockwool

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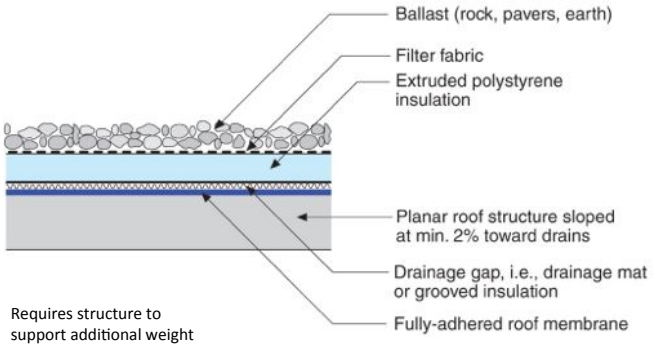
Perfect Roof (PMR / IRMA)



Requires structure to support additional weight

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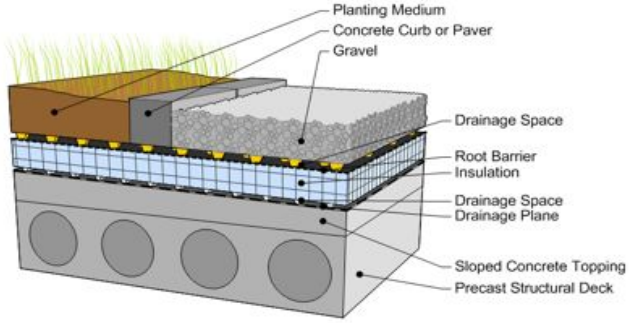

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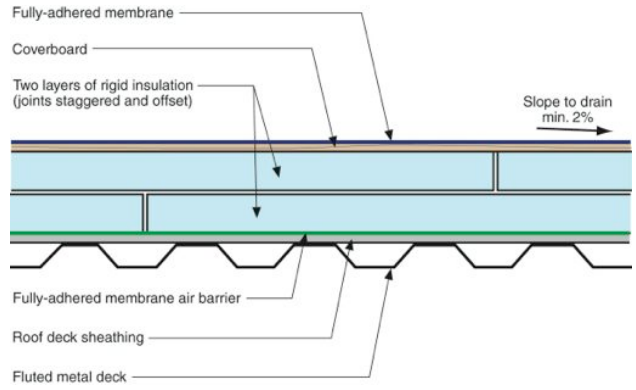
Good Compromise



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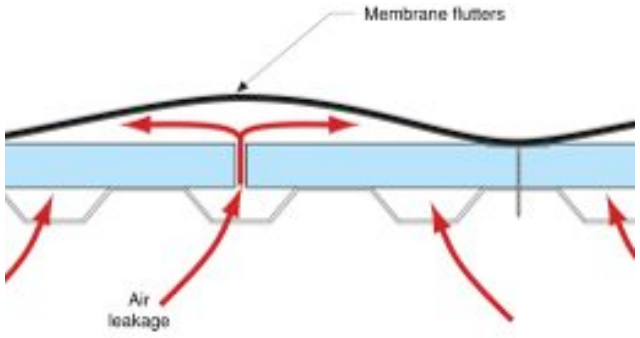
Why fully adhered?



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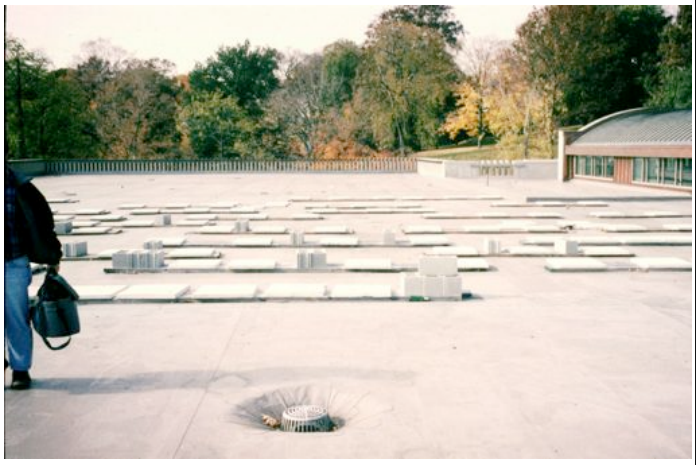

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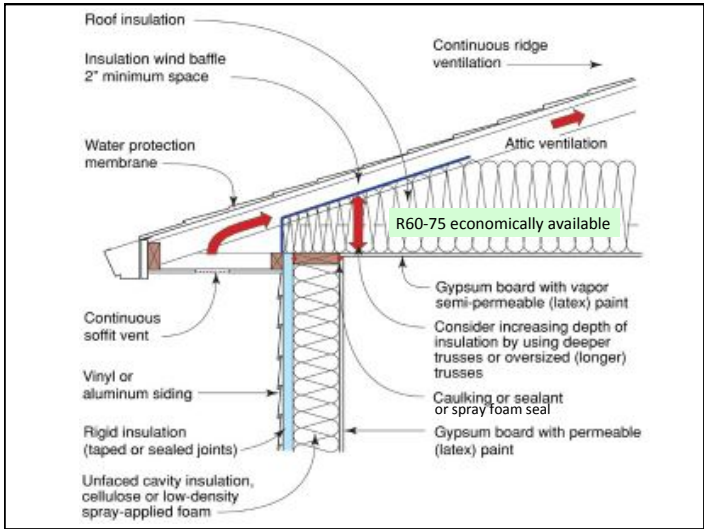

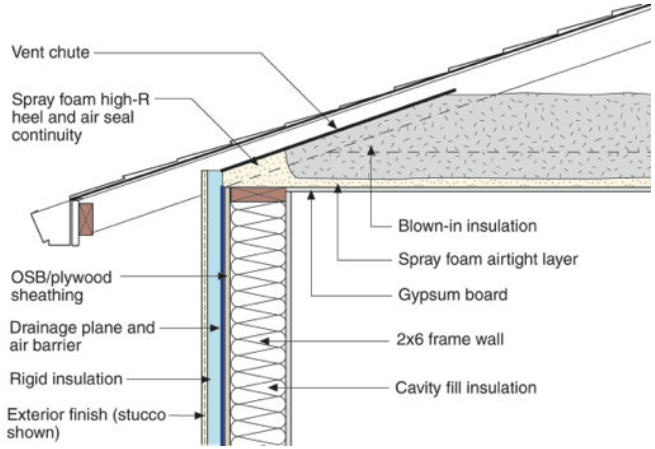

Unvented Cathedralized Attics

- Move air and insulation control from ceiling plane to roof plane
- Moves HVAC into conditioned space
  - Saves lots of energy, reduce problems with comfort, extends life of equipment
- Avoids wind blown rain, snow, and burning wildfire embers

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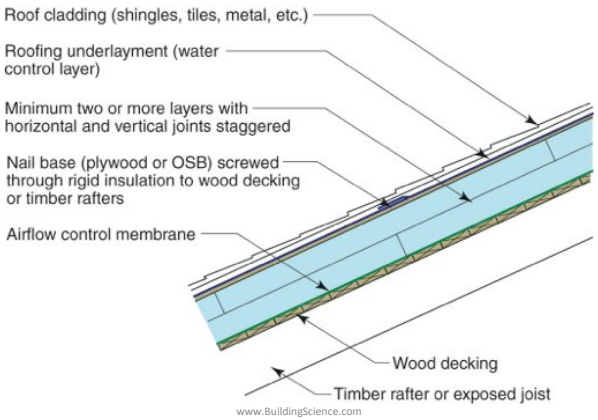
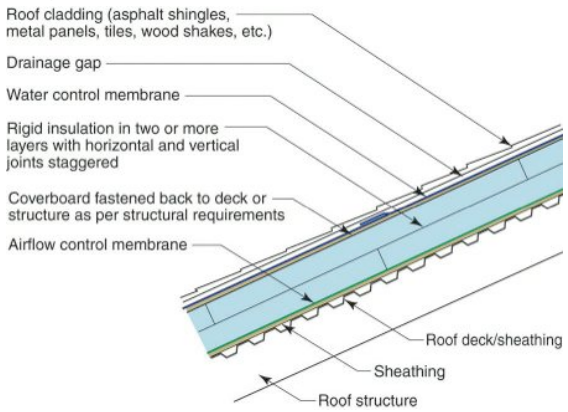
High-Performance Pitched Roof



High-Performance Pitched Roof



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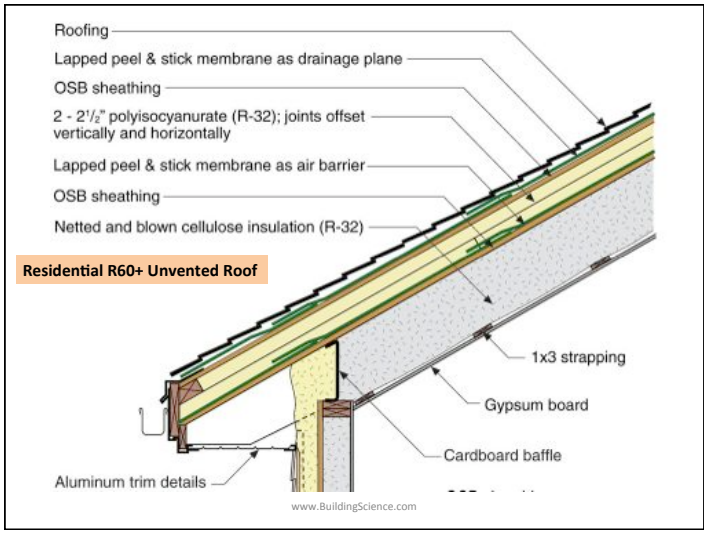
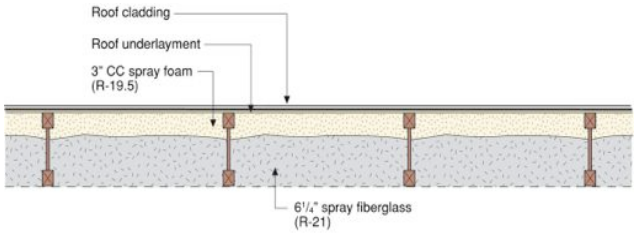


R40+ roof, fire protection



R40 10" TJI Cold climate Solution shown
R50 12" TJI with 4" ccSPF (R24)+ 8" FG (R30) for drier interiors

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Parapets

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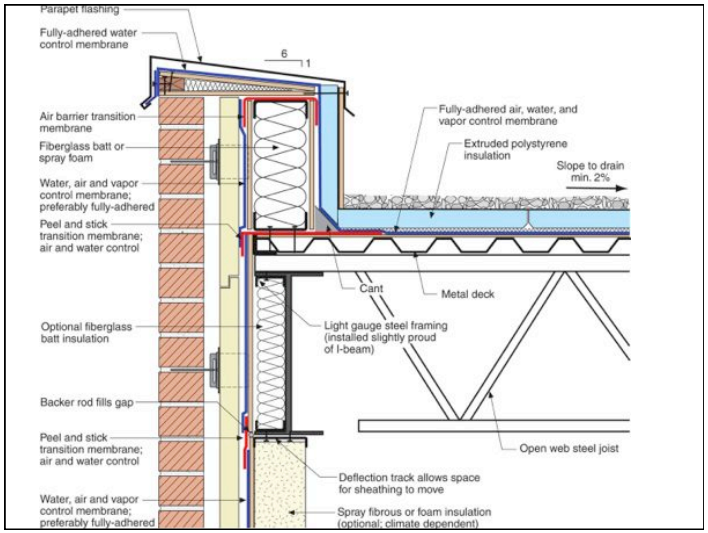

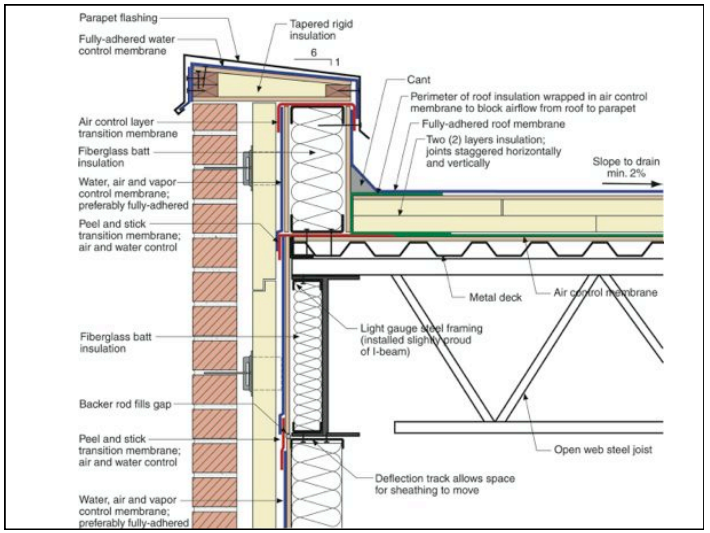

Enclosure Summary

- Simple compact form, oriented to the sun
- Identify functional control layers
  - Rain, air, heat, vapor
- Provide continuity of control layers
  - Details, thermal bridging
- Select high levels of performance

- … now install a good HVAC system

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