Dr John Straube, P.Eng.
Associate Professor, University of Waterloo
Principal, Building Science Corporation

Adventures in Building Science

Enclosures

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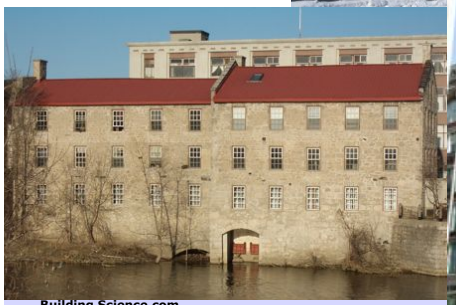
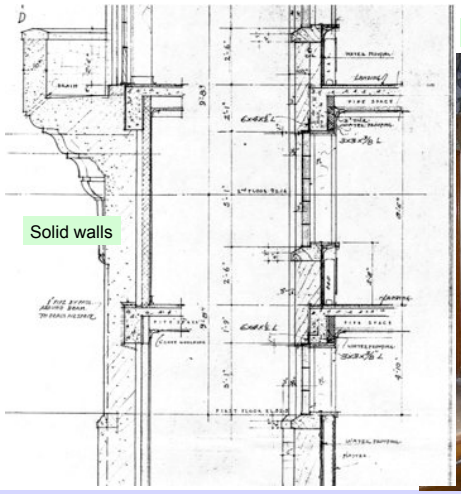
Western Building Tradition





Solid walls

Wet Applied Plaster

Residential Tradition

Old Growth Timber

Pre-WWII Buildings

- No added insulation (or very little)
- Heating systems and some natural ventilation
  - No air conditioning
- No vapor barriers
- Few explicit air-tightening or “draft-stopping” details
- Masonry & old-growth solid timber structures
- Plaster is the dominant interior finish
  - No paper-faced drywall, ceiling tiles

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Five Fundamental Changes

1. Increasing Thermal Resistance
2. Changing Permeance of Enclosure Linings
3. Water/Mold Sensitivity of Materials
4. Moisture Storage Capacity
5. 3-D Airflow Networks

1. Thermal

- Old buildings used energy leakage to dry materials and assemblies
- Increased airtightness = colder surfaces
- Increased insulation = colder surfaces
  - Condensation occurs on cold surfaces
  - Warm materials dry faster than cold ones
- White roofs, efficient lights, etc.

2. Vapor Permeability

- Low permeance exterior layers
  - Metal panels, precast concrete
  - OSB and foam vs skip wood sheathing
- Low permeance interior layers
  - Polyethylene, vinyl wall paper
  - Vinyl sheet flooring, linoleum

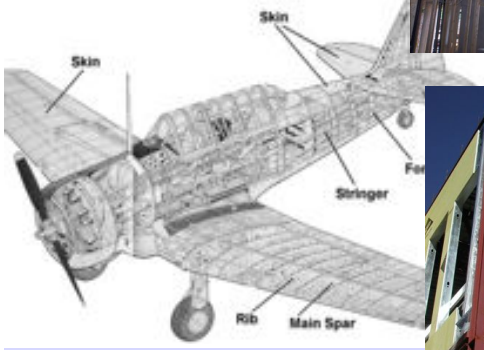
3. Water/Mold Sensitivity

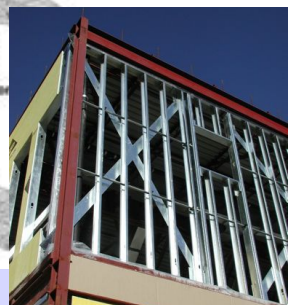
- Organic materials = mold food
- Moisture= mold growth
- Wood products
  - New growth vs old
  - Processing: plywood, OSB, particle board
  - Paper, Veneers
- Finishes
  - Drywall, ceiling tile

4. Moisture Storage Capacity

- Changing moisture storage
  - Concrete block / terra cotta /plaster
  - Rough cut wood / skip sheathing
  - Steel stud with exterior gypsum
- Orders of magnitude!
- Lightweight assemblies dominate often low-impact

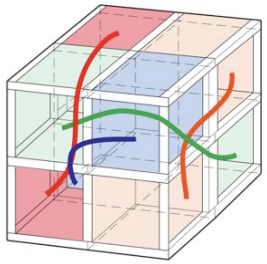
Low mass= resource efficient

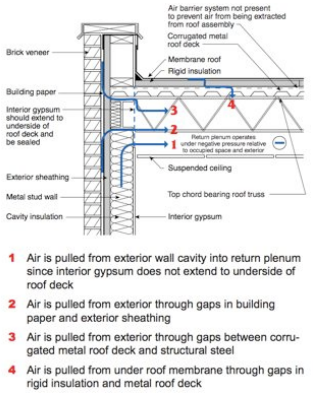




5. Three-D Airflow Networks

- Hollow walls
- Taller buildings





Hollow Buildings

- Inter-connected voids

Hollow Buildings

Interconnected interstitial voids

Five Fundamental Changes

1. Increasing Thermal Resistance
2. Less Vapor Permeance of Linings
3. Water/Mold Sensitivity of Materials
4. Moisture Storage Capacity
5. 3-D Airflow Networks

Addressing these changes

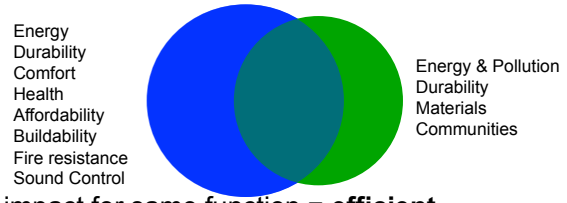
- Get back in balance
  - . . . and we need more insulation
- Provide better moisture control
  - drainage, airtight, construction moist. control
- Allow drying of moisture
  - E.g., use vapor barriers with care
- Compartmentalize
  - Air seal within buildings as well

Enclosure design for the future

- Need to understand what we are doing from *first* principles
- Cant “learn by trying”
- Tradition is no longer our sole guide
- Building Science can provide direction

Building Science=Green Buildings

- Building Science?
  - The science of making buildings that work
- Green Buildings?
  - Buildings that reduce environmental damage



- Less impact for same function = **efficient**

Building Science & Energy

- Increasing resistance to heat flow
  - Better insulation values
  - Reduced thermal bridges
  - Better air leakage resistance
  - Better windows
  - Better solar control / white roofs
- This will impact moisture & hence durability

Design Goals for our Buildings

Safe

Healthy

Comfortable

Durable

Affordable

Environmentally Responsible

Building Functions

- Human needs… more than shelter
  (e.g. Location, Shelter, Utility, Comfort & Delight)
- …function of a building:

"Provide the desired environment for human use and occupancy"

"Durability, Convenience, and Beauty"
Vitruvius, 70 BC

Building Components

- Buildings are made of several large systems
- The systems that make up a a building can be grouped in four categories
  - Superstructure
  - Enclosure
  - Service Systems
  - Fabric

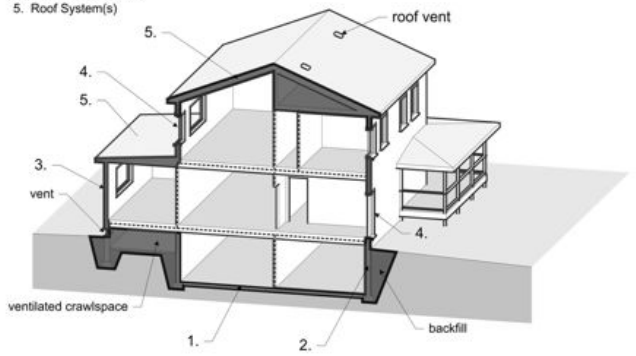
The Enclosure: An Environmental Separator

- 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, etc… from the innermost to the outermost layer.
- Sometimes, interior partition also are environmental separators (pools, rinks, etc.)

Building Enclosure Components:

1. Basement Floor System(s)
2. Foundation Wall System(s)
3. Above Grade Wall System(s)
4. Windows and Doors
5. Roof System(s)

Where is inside?
Where is outside?



Exterior Environment

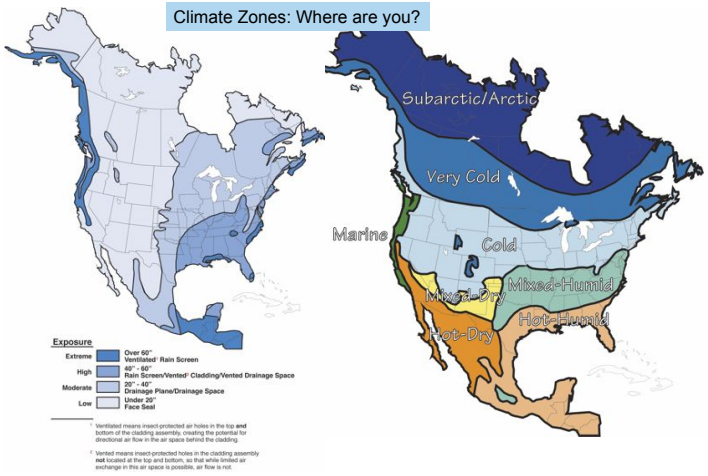
- Design for
  - Climate zone
  - Site
  - Building height, shape, complexity

Seattle ≠ Sacramento
Miami ≠ Minneapolis
Edmonton ≠ Toronto

Marcus Vitruvius Pollio

These are properly designed, when due regard is had to the country and climate in which they are erected. For the method of building which is suited to Egypt would be very improper in Spain, and that in use in Pontus would be absurd at Rome: so in other parts of the world **a style suitable to one climate, would be very unsuitable to another**: for one part of the world is under the sun's course, another is distant from it, and another, between the two, is temperate.

Climate Zones: Where are you?



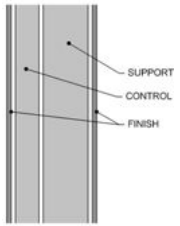
Climate Load Modification

- 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

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

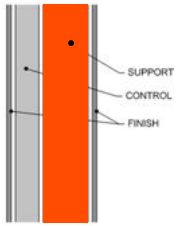
Functional Layers



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

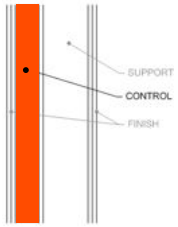
Functional Layers



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

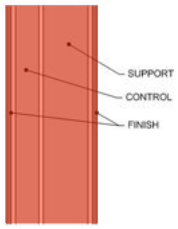
Functional Layers



Other Control . . .

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

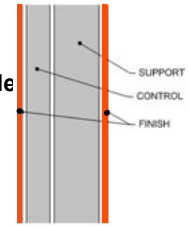
Functional Layers



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



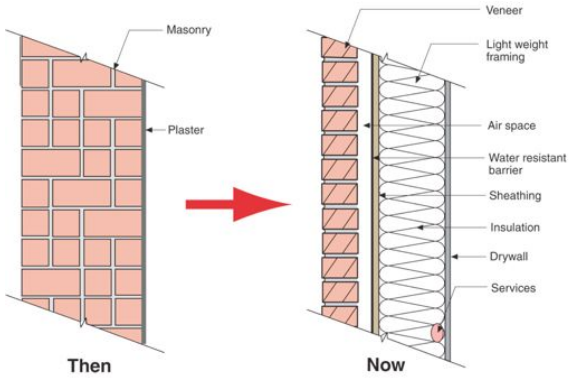
Distribution

- A *Building* Function imposed on enclosure
- Distribute services or utilities to from through, within, the enclosure, e.g.,
  - Power
  - Communication
  - Water (Potable, sewage, etc.)
  - Gas
  - Conditioned air
  - Cold or hot water

History of Control Functions

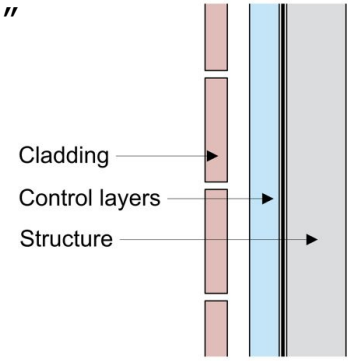
- Older Buildings
  - One layer does everything
- Newer Building
  - Separate layers,
    . . . separate functions

Changes

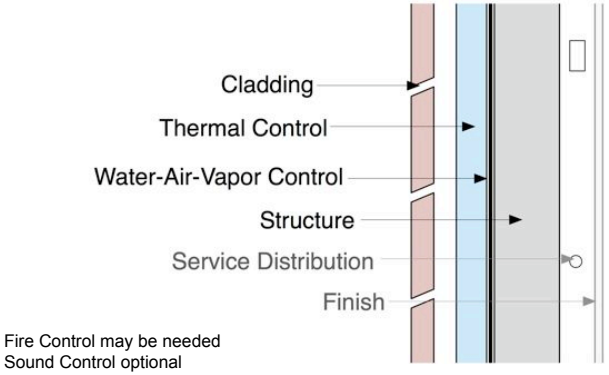


The "Perfect Wall"

- Finish of whatever
- Control continuity
  - Rain control layer
    - Perfect barrier
    - Drained with gap
    - Storage
  - Air control layer
  - Thermal control layer
    - Aka insulation, radiant barriers
  - Vapor control layer
    - Retarders, barriers, etc
- Structure can be anything
  - Fire Control may be needed
  - Sound Control may be needed



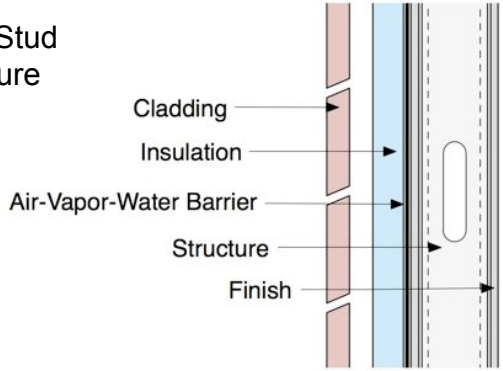
Perfect Wall expanded



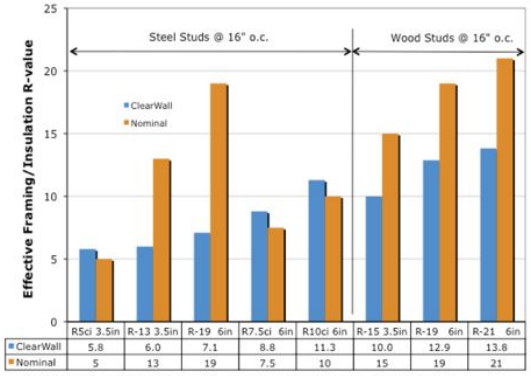
Fire Control may be needed
Sound Control optional

Perfect Wall

- Steel Stud Structure



Steel Studs: heat bridge

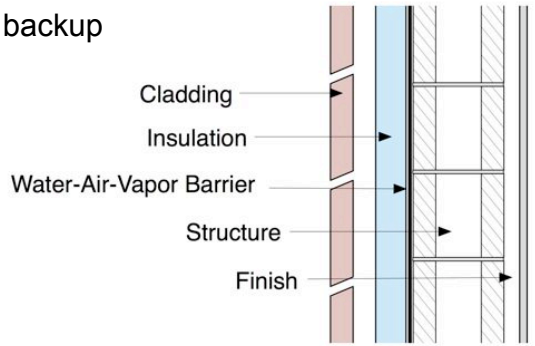


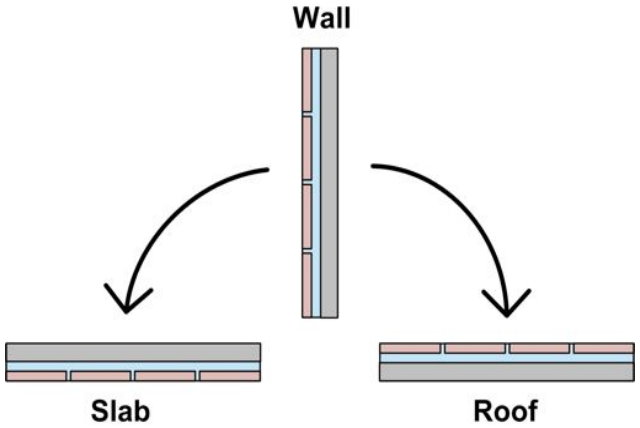
	R5ci 3.5in	R-13 3.5in	R-19 6in	R7.5ci 6in	R10ci 6in	R-15 3.5in	R-19 6in	R-21 6in
ClearWall	5.8	6.0	7.1	8.8	11.3	10.0	12.9	13.8
Nominal	5	13	19	7.5	10	15	19	21

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

Perfect Wall

- CMU backup





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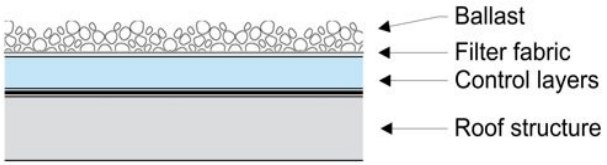

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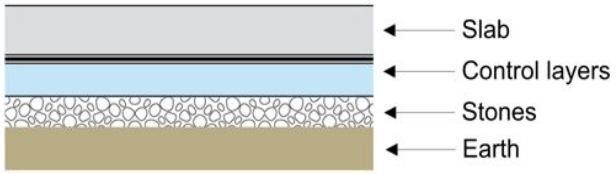

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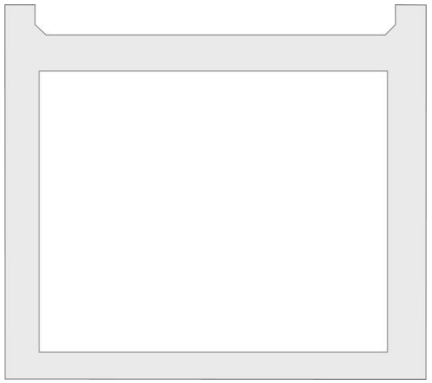

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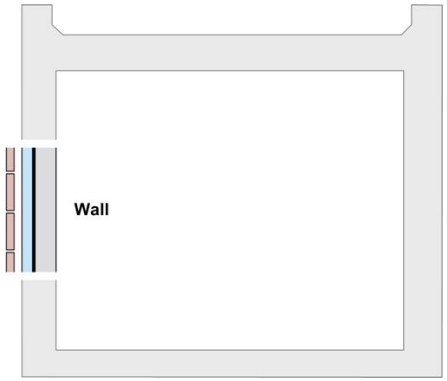

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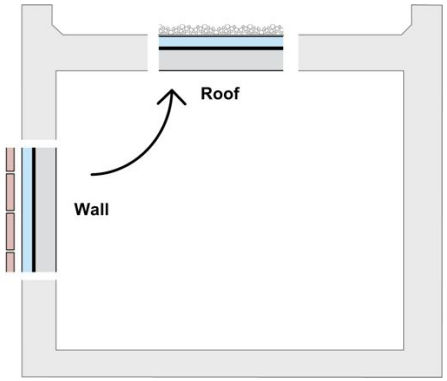

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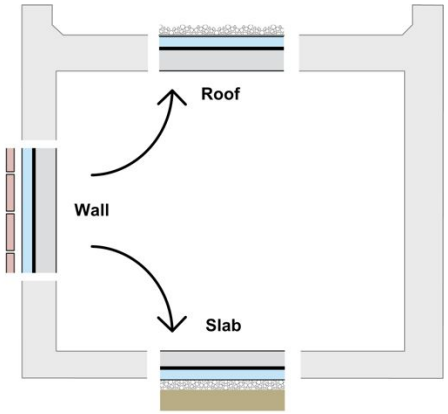

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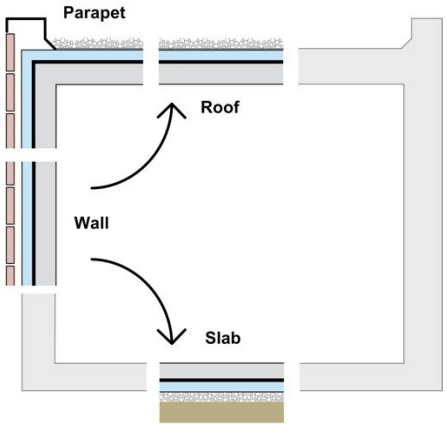

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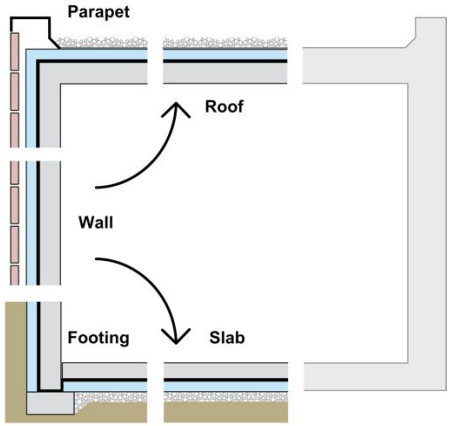
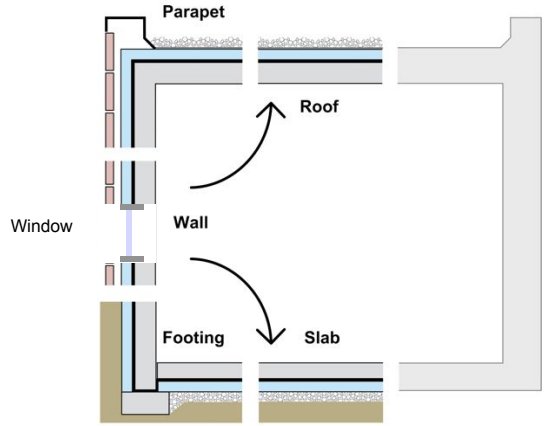
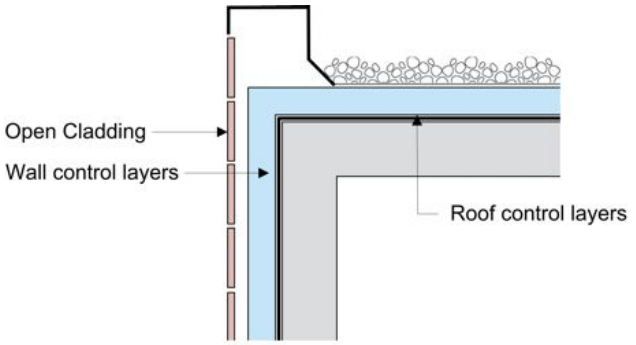


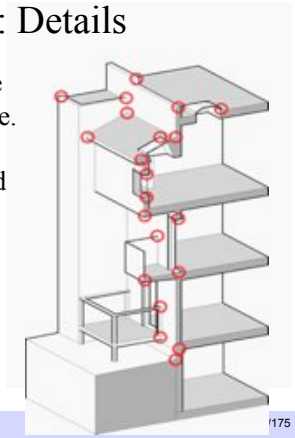


Connections: Who is in charge



Enclosure Design: Details

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



Conclusions

- Buildings have changed, are changing
  - Low energy, low resource, “green”?
- Require new approaches
- Moving too fast to rely on tradition and rules of thumb
- Building Science / Building Physics must become the foundation of design

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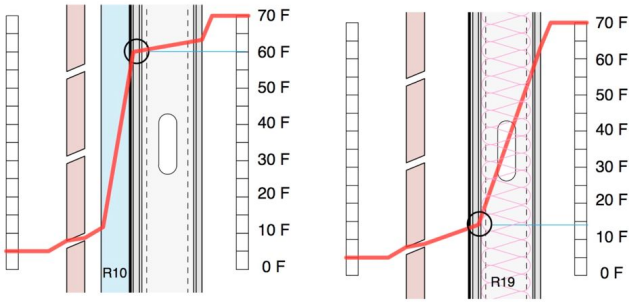

The Rules

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 Always Acts Down