

## Mom's Rules of Building Science

- Close the window / door / fridge
  - Airtightness matters
- Wear a hat
  - Sunshade, rain protection, drip edges
- Don't tuck pants into boots
  - Drainage and shingling
- Wear your jacket, sweater, mittens
  - Insulate on the outside

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Enclosures No. 1 /

Joseph Lstiburek, Ph.D., P.Eng  
John Straube, Ph.D., P.Eng

## Building Science 2012

Environmental Separation

presented by [www.buildingscience.com](http://www.buildingscience.com)



## 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 and old-growth solid timber structures
- Plaster is the dominant interior finish

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## Mold, Rot, Corrosion, Decay, Recladding



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## Performance?

- More than on-time, on-budget, to code
  - Safe
  - Healthy
  - Comfortable
- A growing clamor for....
  - Durable
  - Low-energy
  - Maintainable
  - Modifiable
  - Repairable
- All delivered reliably, predictably

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## Why High Performance? Green?

- Changing needs
- Rising comfort/amenity expectations
- Control energy / maintenance costs

## 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

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## Building Components

- Buildings are made of several large systems
- Can be grouped in four categories
  - Superstructure
  - Service Systems
  - Fabric
  - Enclosure



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## Importance of the Enclosure

- Image
  - People see it!
- Building problems
  - Often heat, moisture and the enclosure
- Energy consumption
  - Driven by enclosure performance
- Durability often less than building
  - Roof 15-30 yrs, Windows 20-40 yrs  
Sealants 5-25 yrs

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## 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.)

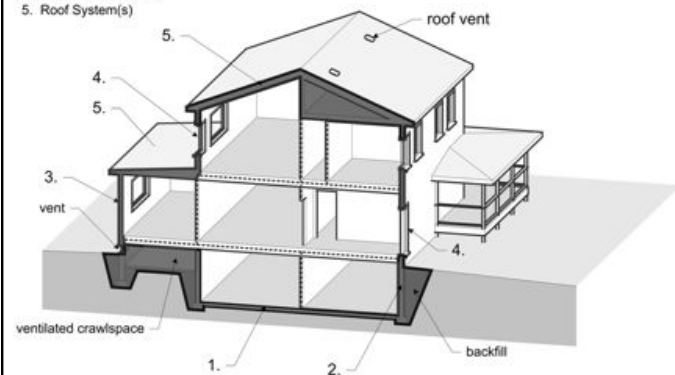
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### Building Enclosure Components:

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

We will cover: roofs, walls,  
basements/slabs and windows



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## Enclosure Loadings


- The separation function generates *loads*
- *Load*: any event, phenomenon or characteristic that can affect the enclosure
  - Heat, Air, Moisture
  - Fire, Sound
  - UV, Ozone
  - Gravity, impacts, abrasion
  - Insects
  - Etc...

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## Loads: Climate / Site

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



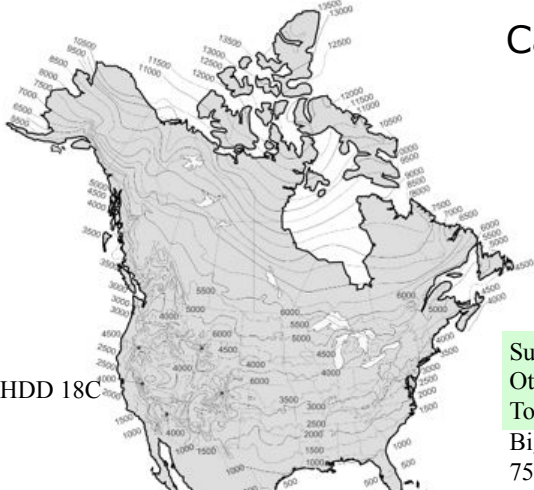
Seattle ≠ Sacramento  
Miami ≠ Minneapolis  
Edmonton ≠ Vancouver

### 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.

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## Canada:




Significant heating demand, especially Prairies and North

Sudbury 5300  
Ottawa 4500  
Toronto 4000  
Big Trout Lake 7500

HDD 18C

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## Climate Zones



**Exposure**

Extrem	Over 60"
High	40" - 60"
Moderate	20" - 40"
Low	Under 20"

Overlaid means: insect protection, air seals in the top and bottom of the cladding assembly, ensuring the detailing for directional air flow in the air space before the cladding.

Overlaid means: insect protection holes in the cladding assembly seal located at the top and bottom so that while under air exchange in that air space is possible, air flow is not.

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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...)
  - Active modification
  - Use energy to change indoor weather

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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

The diagram shows a vertical cross-section of a wall with three layers. The top layer is labeled "SUPPORT", the middle layer is "CONTROL", and the bottom layer is "FINISH".

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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

The diagram shows a vertical cross-section of a wall with three layers: "SUPPORT", "CONTROL", and "FINISH". The "SUPPORT" layer is highlighted in orange.

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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

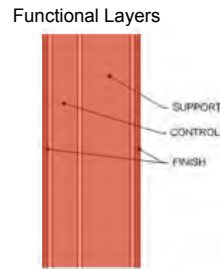
The diagram shows a vertical cross-section of a wall with three layers: "SUPPORT", "CONTROL", and "FINISH". The "CONTROL" layer is highlighted in orange.

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## Other Control Functions . . .

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



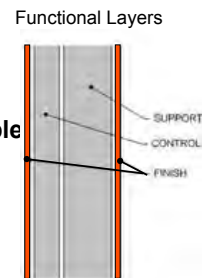
## History of Control Functions

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

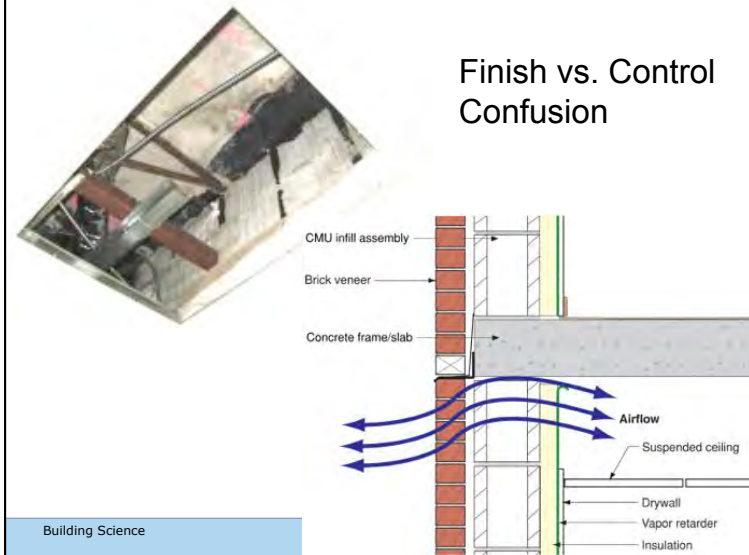


## Basic Enclosure Functions

- 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



## Finish vs. Control Confusion



## 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 ←

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Enclosures No. 25 /

## Enclosure Design Principles 1

- Design a complete structural load transfer path
  - Structure, windows, ties, etc
  - All loads go to ground
- Understand site, use, and climate *loadings*
  - Rain, sun, high rise or low-rise, pool, office, school
- Continuous rain control plane
  - Control with surface features and detailing
  - Drained, storage, or perfect barrier strategy
- Continuous plane of air barrier tightness
  - Fastidious attention to detail 3-D

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## Enclosure Design Principles 2

- Provide a continuous plane of insulation
  - Ideally separate structure from enclosure
  - *Avoid thermal bridges*
- Provide a moisture tolerant design
  - Balance wetting, drying, and storage (matl's, climate)
  - Use appropriate levels of vapour control
    - No cold vapor barriers, allow drying
- Accommodate movements and tolerances
- Draw all of the Details!

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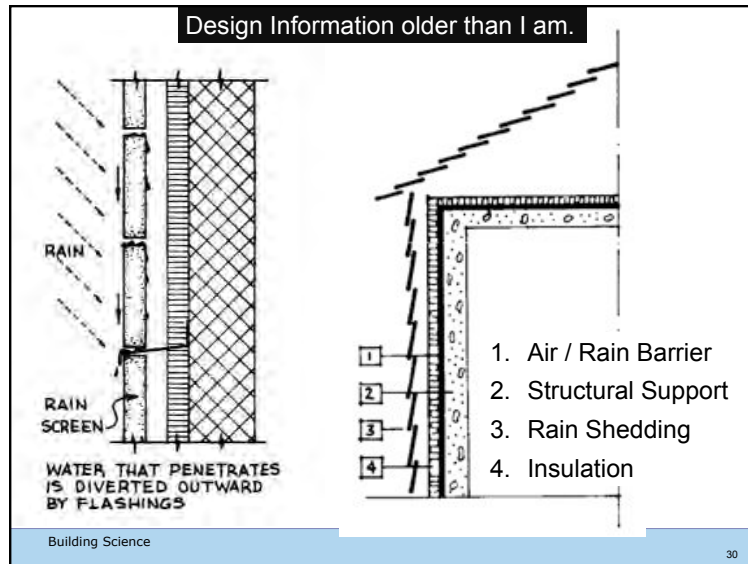
## The Enclosure: Adding the Layers



- Structure
- Air-Rain Barrier
- Insulation
- Finish

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Enclosures No. 28 /



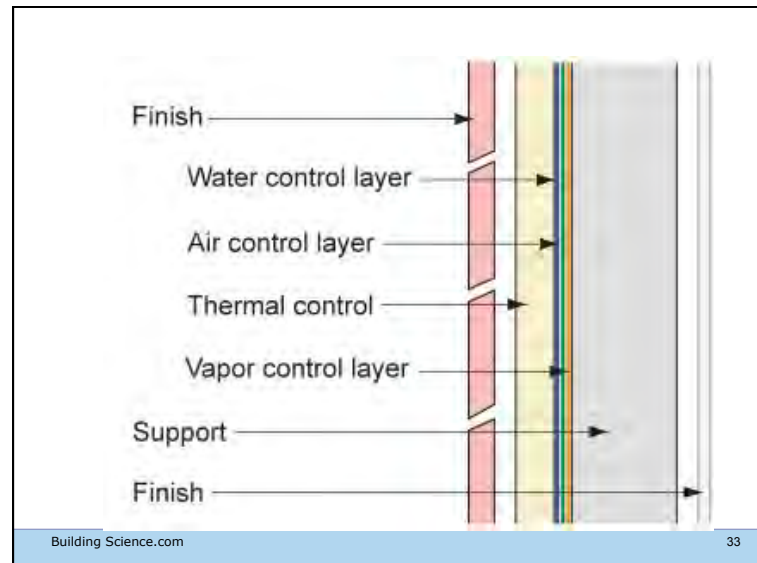
What is a high performance enclosure?

- High levels of control
- **But**, poor continuity limits performance
- **&** Poor continuity causes most problems too:
  - E.g. air leakage condensation
  - Rain leakage
  - Surface condensation
  - Cold windows
- Thus: *continuity + high levels of control*

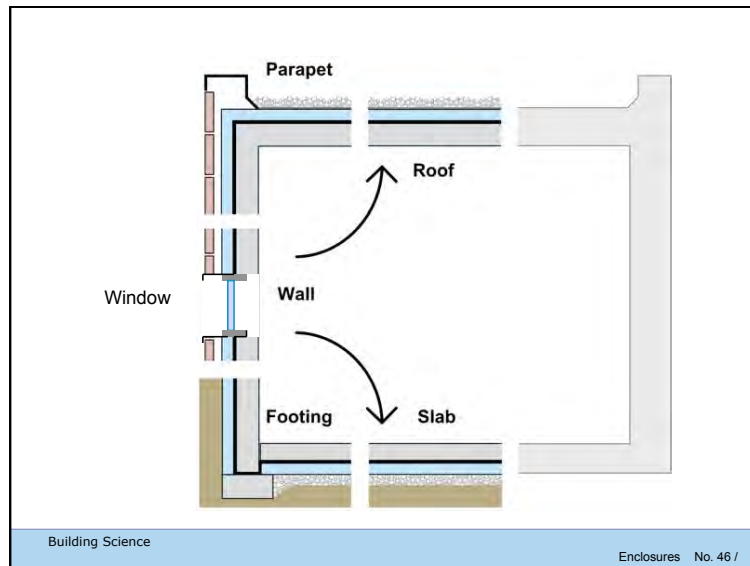
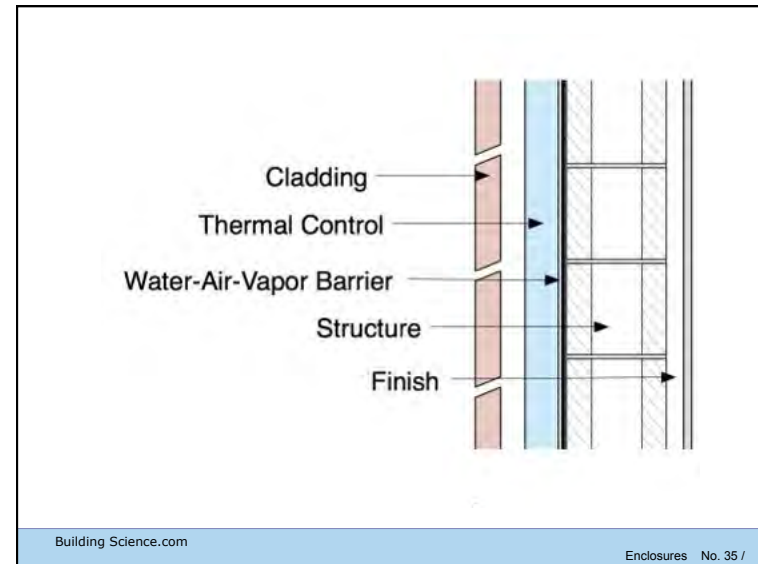
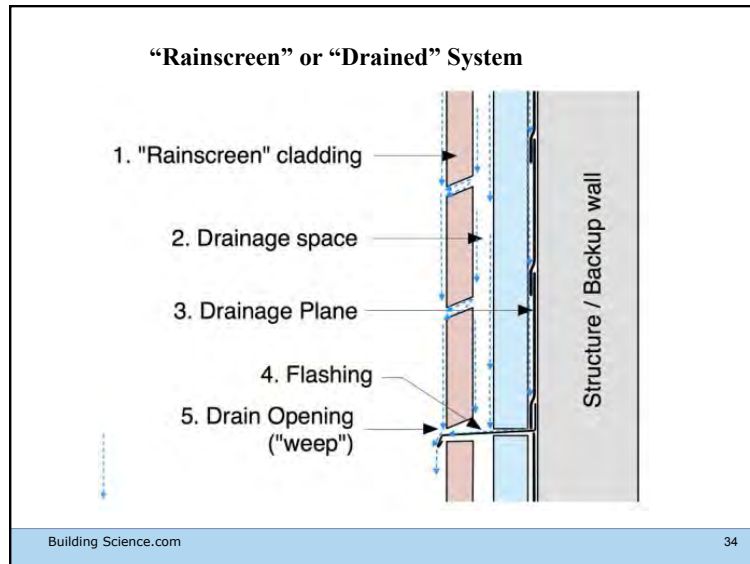
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## High Performance


- No leaks = continuous = no holes
- 1. Rain
- 2. Air
- 3. Thermal

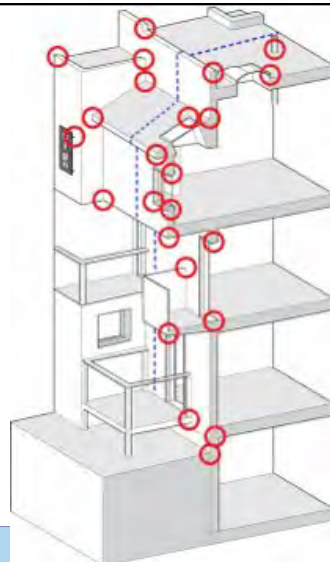






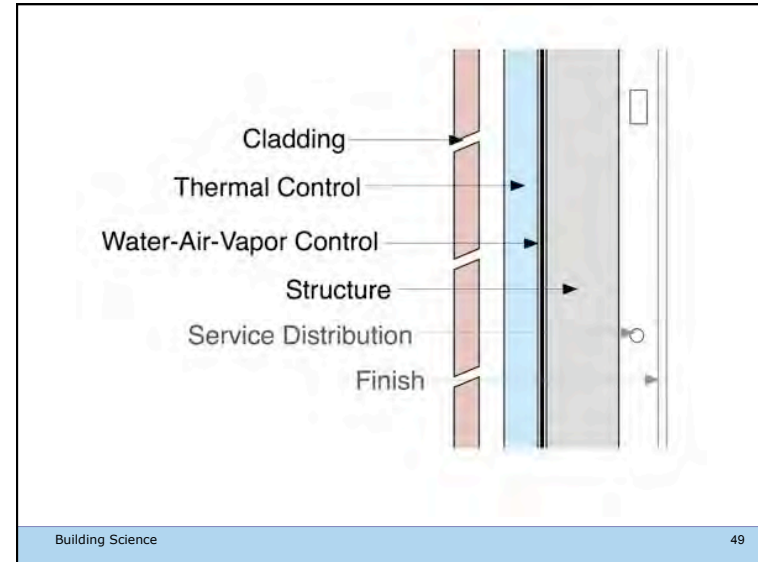
### Enclosure Design: Details

- Details demand the same approach as the enclosure.
- Scaled drawings required at 
  - change in plane
  - change in material
  - change in trade



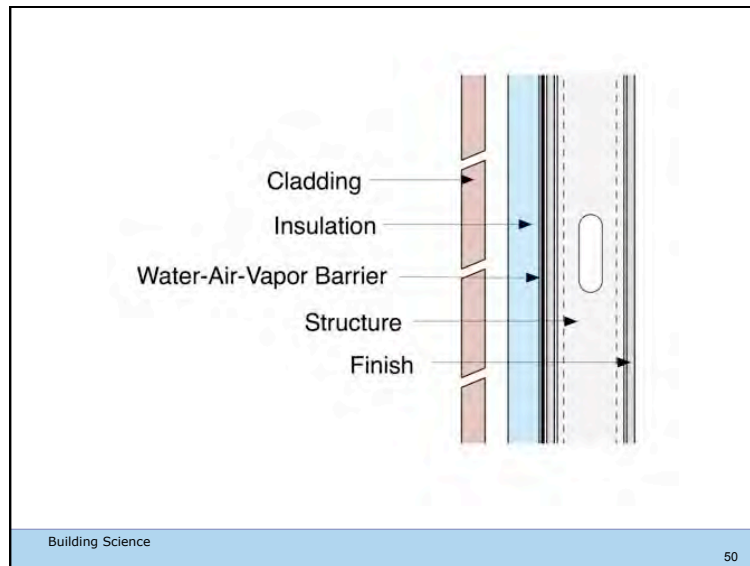
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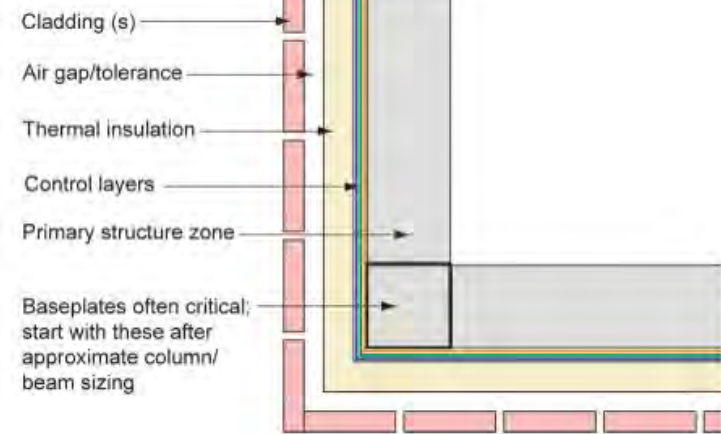
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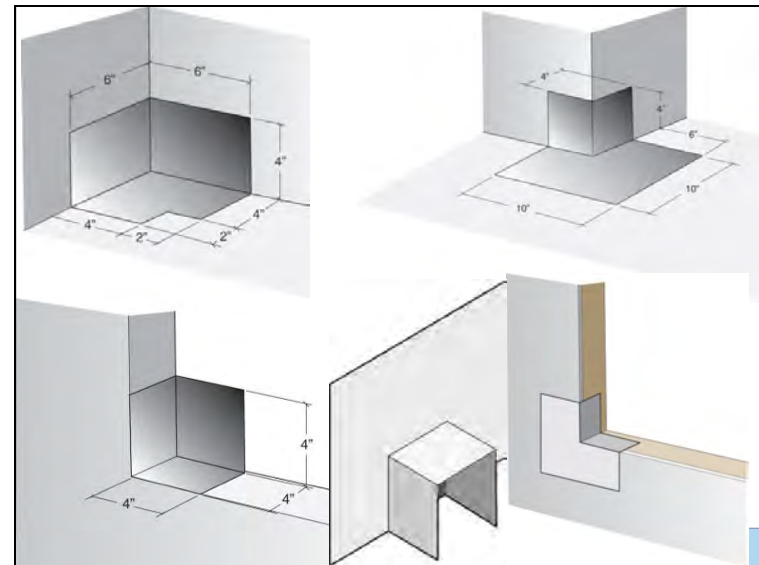
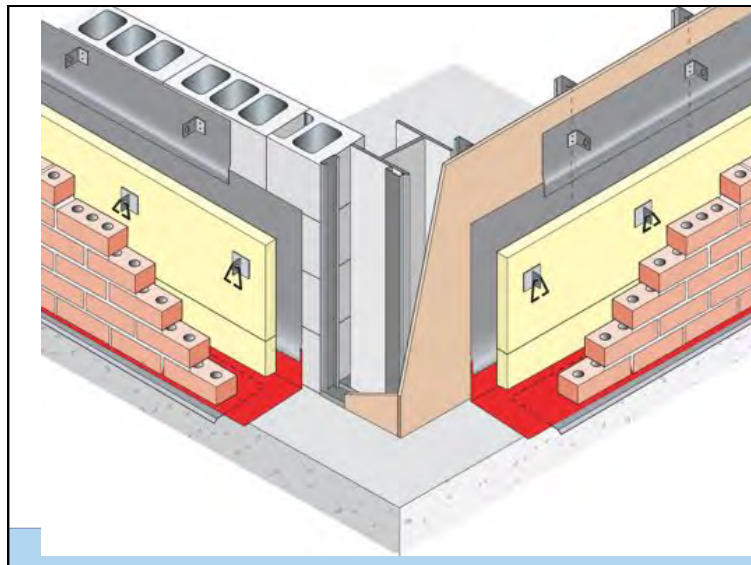
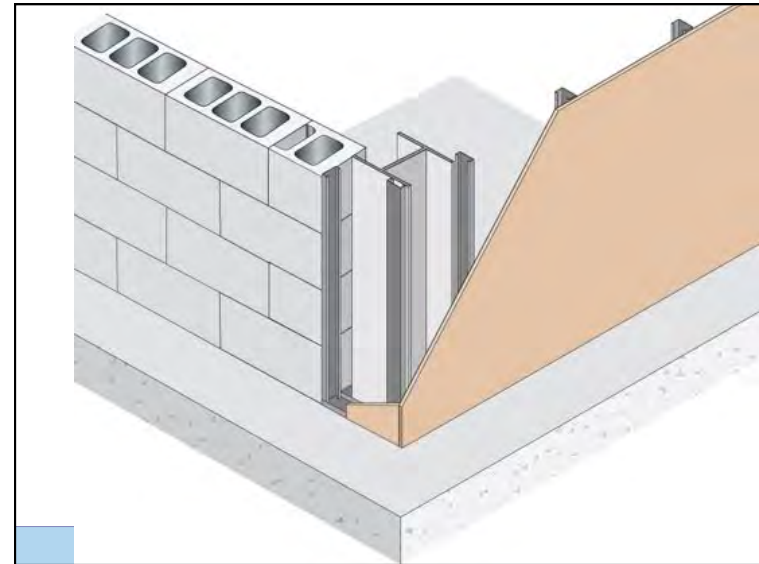
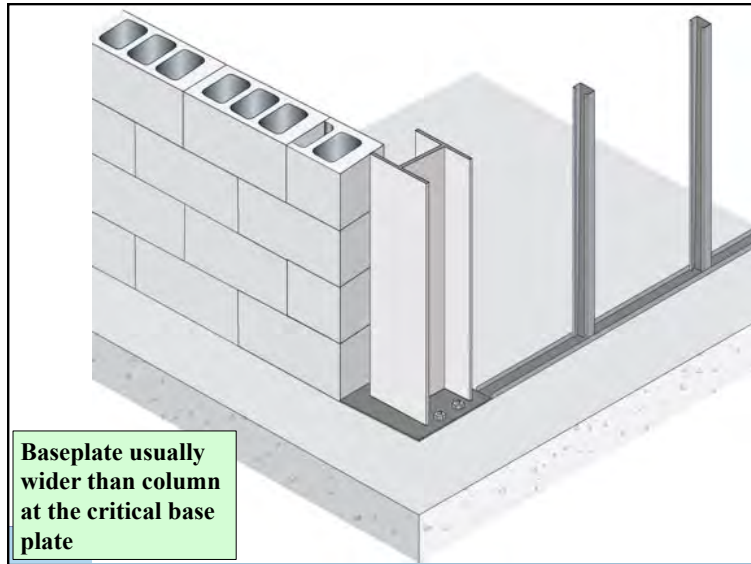
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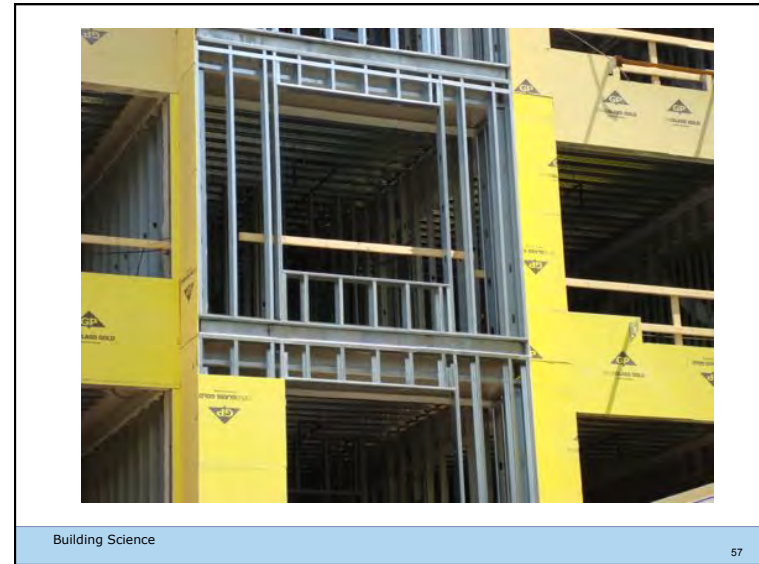
### Plan Dimensions

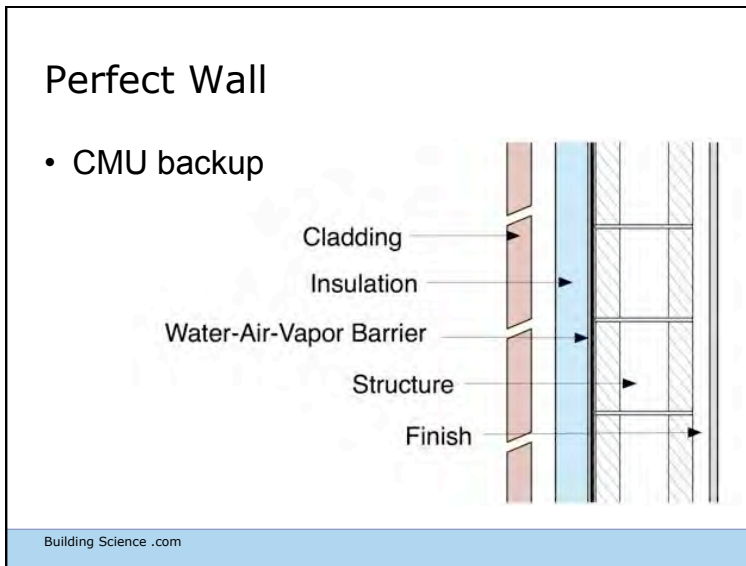


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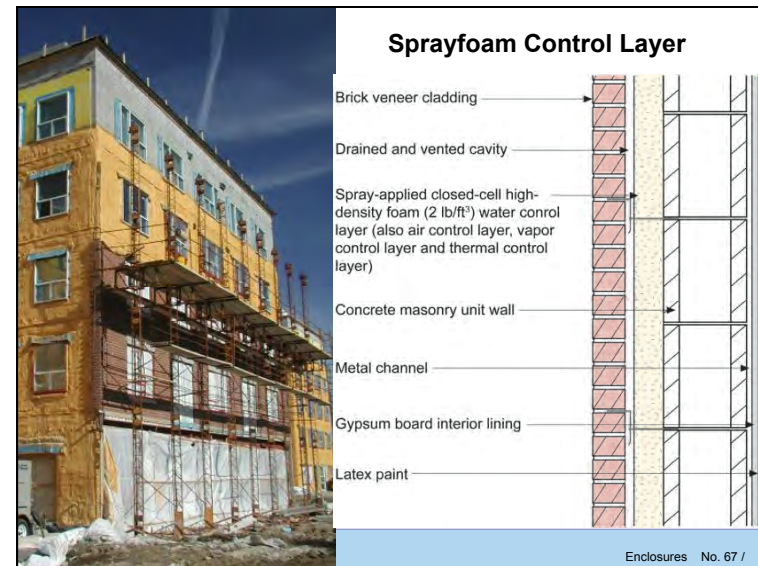
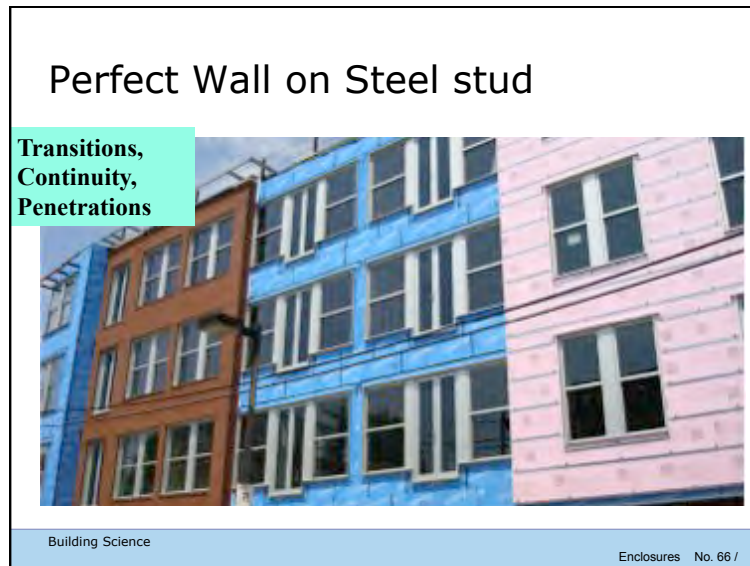
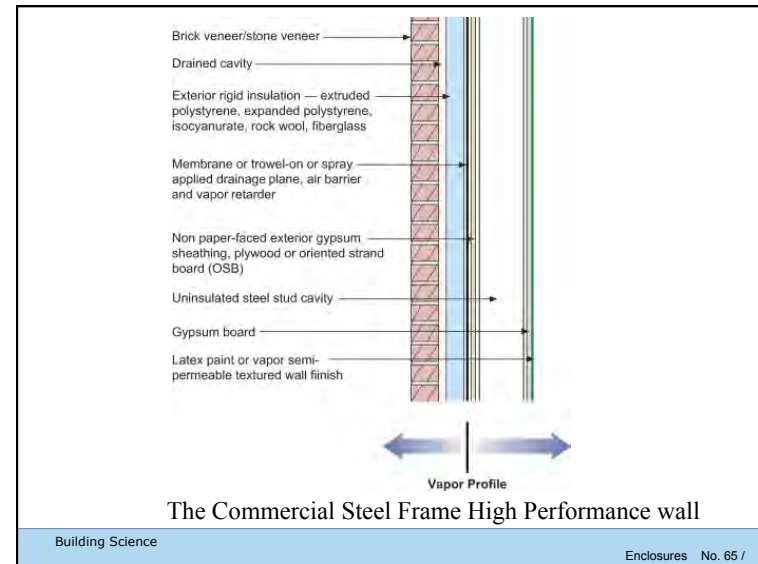
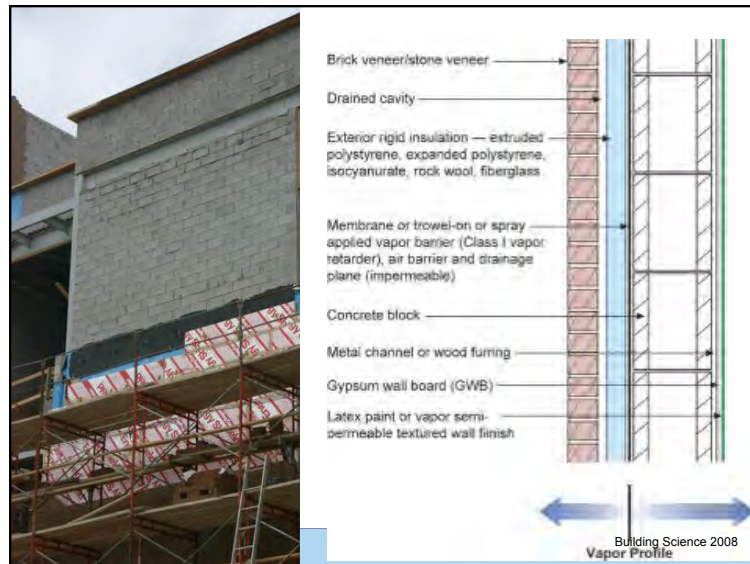




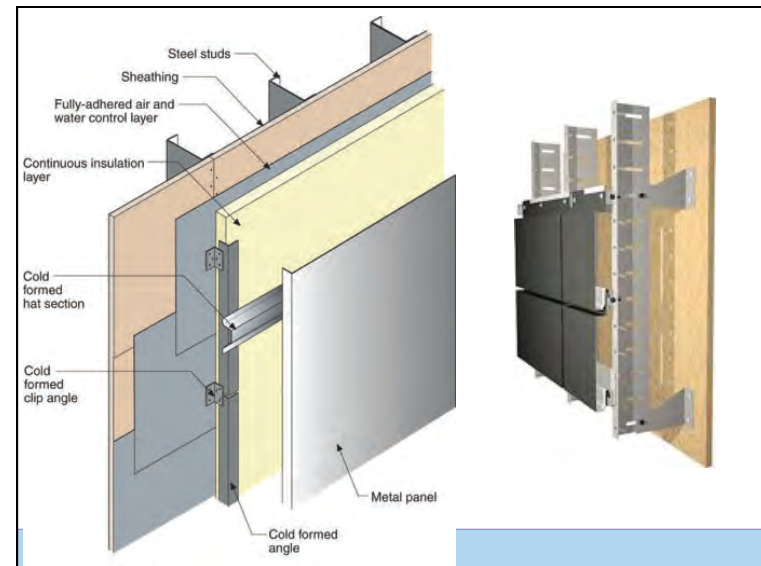
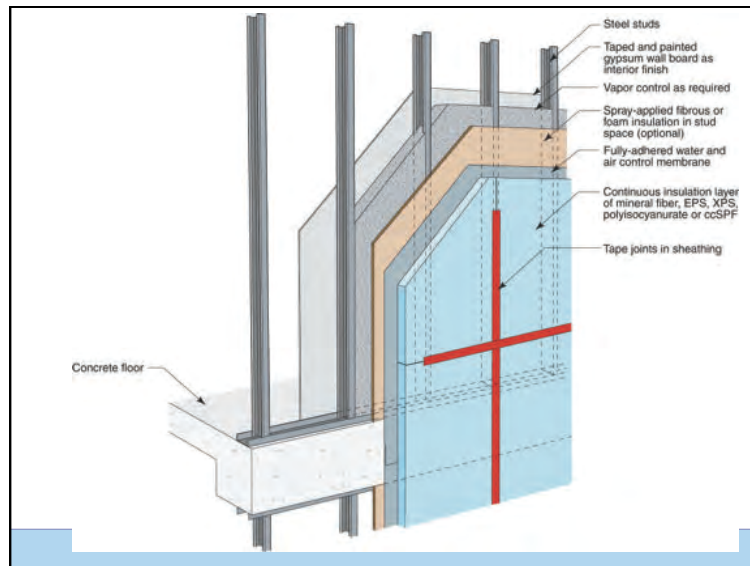
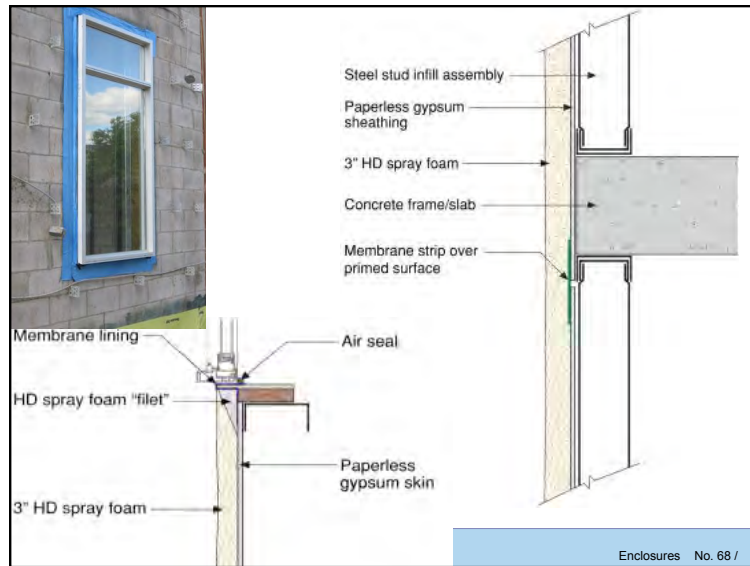


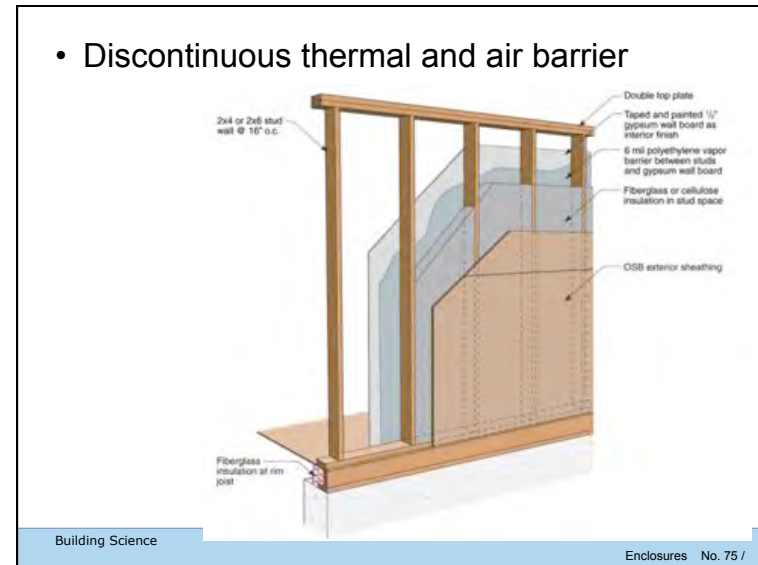
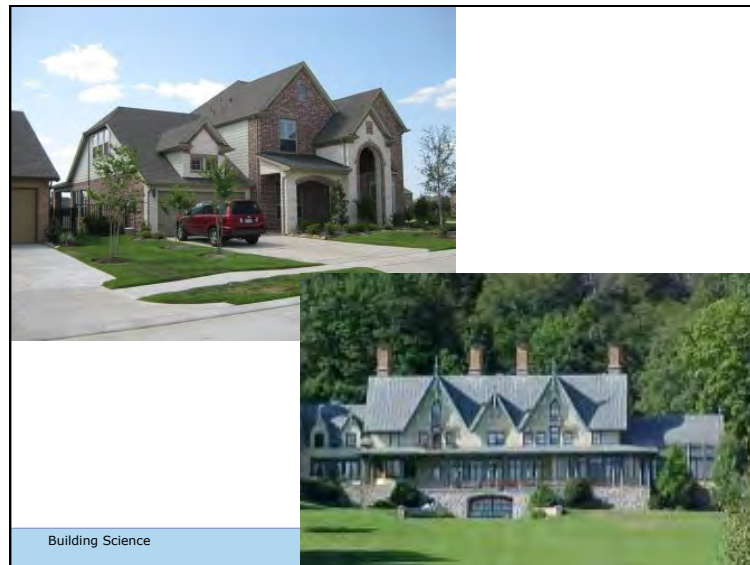
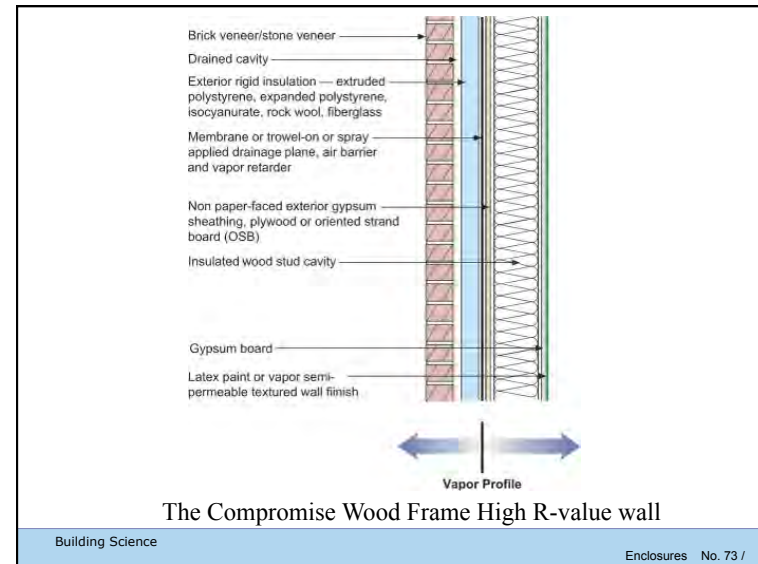
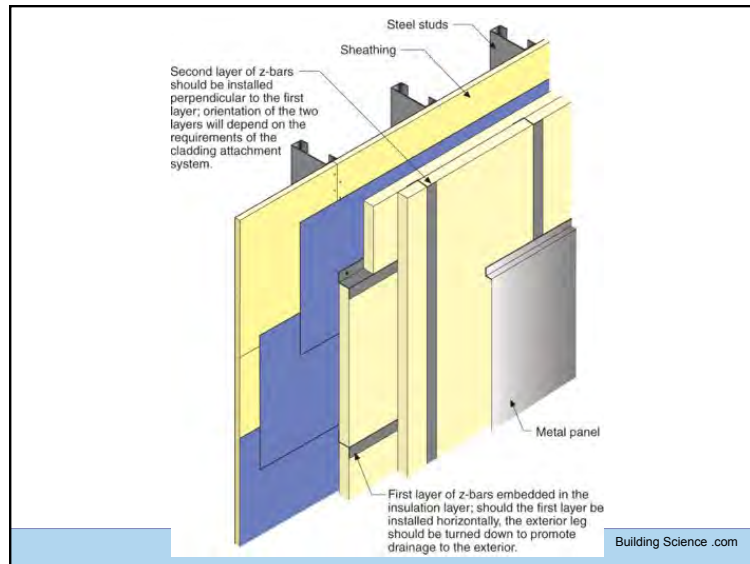


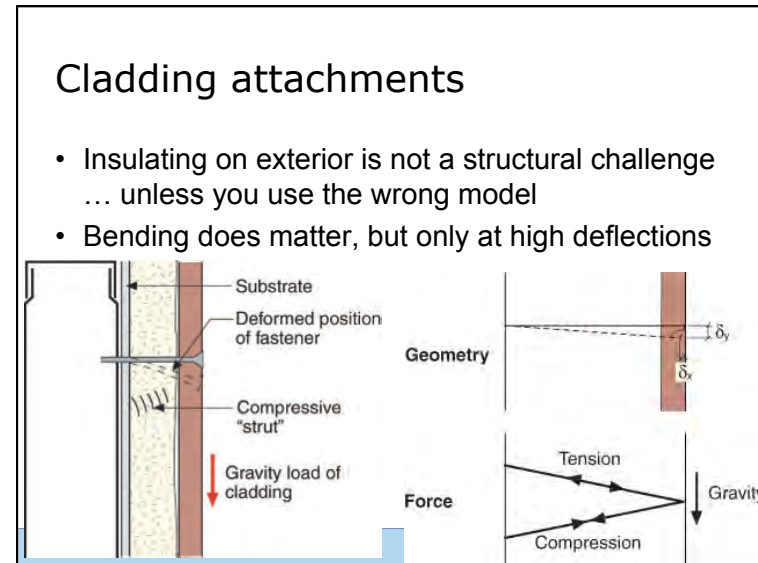
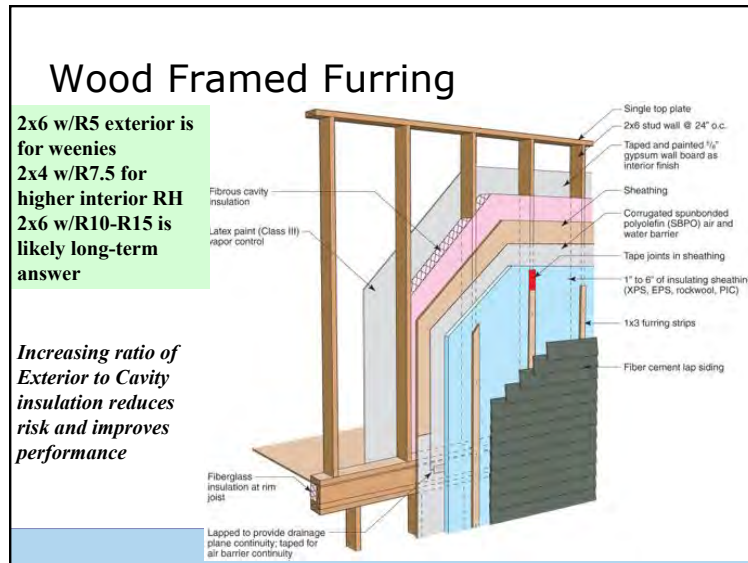




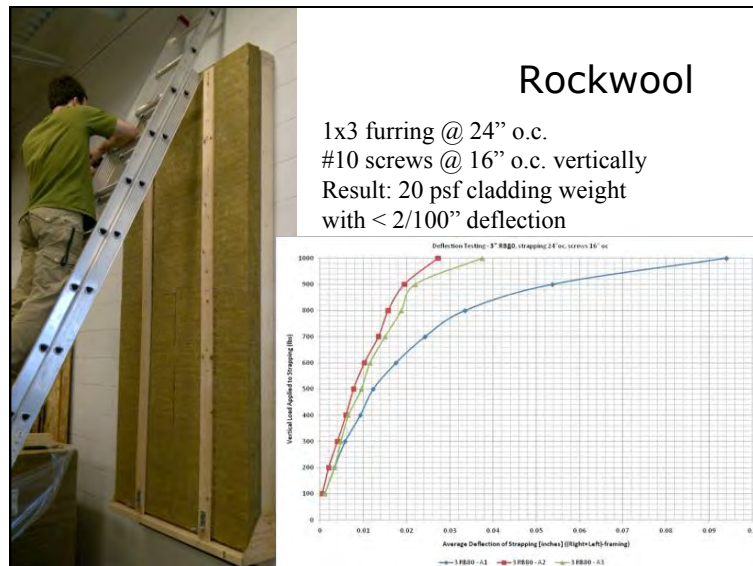
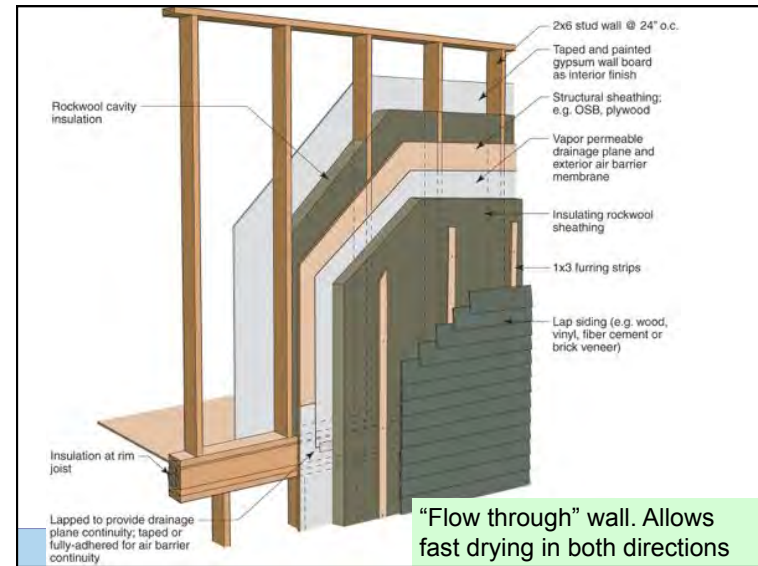
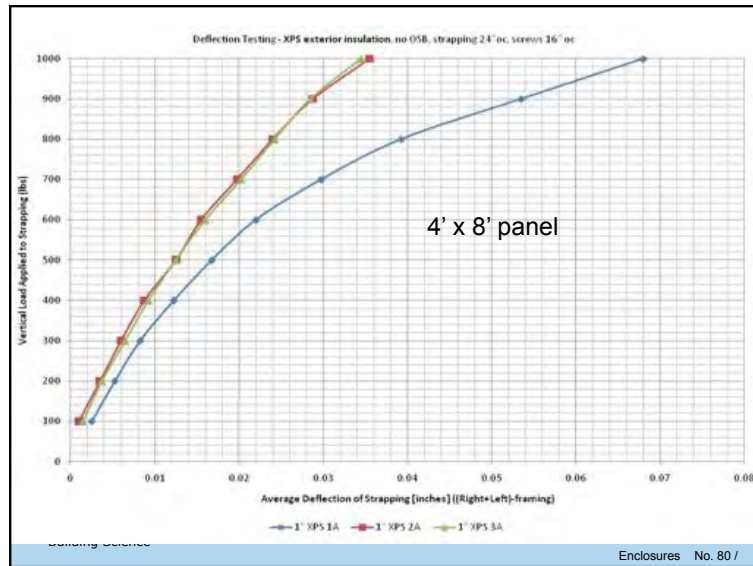












## Houses

- Rain — blue line
- Heat — red line
- Air — green line

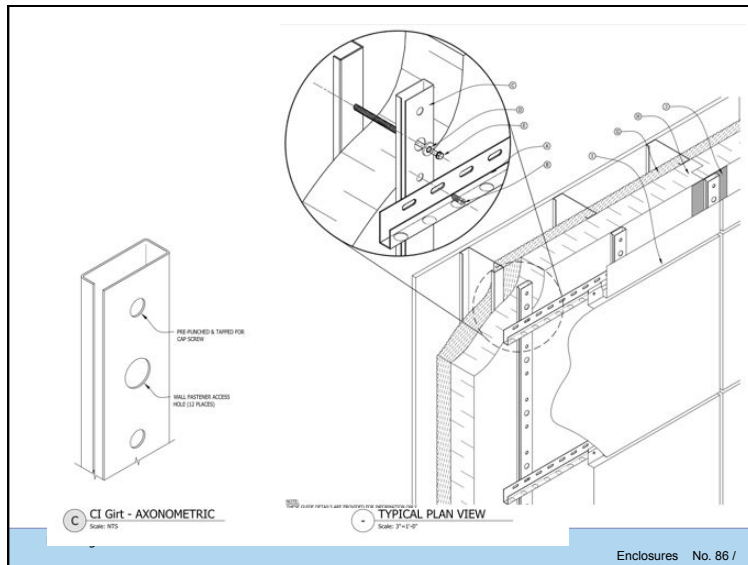
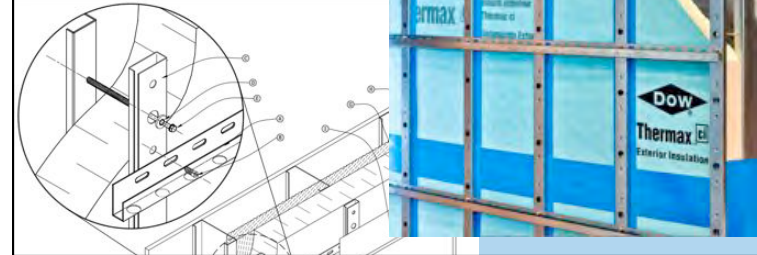
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has many different enclosure sections



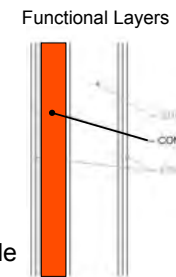
### Metal Panels Furring

- Commercially available
- Only fasteners penetrate insulation



### Recall: 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



## Enclosure Types

- Typically define enclosure by
  - Finish, e.g. “brick veneer, granite” etc
  - Support e.g., “steel stud, concrete block” etc.
- Should define by what we use and where we put:
  - insulation,
  - water and
  - air barriers
- And where they are located relative to structure

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Enclosures No. 89 /

## Cladding “Types”

- Masonry veneer, adhered veneer
- Architectural precast
- EIFS and stucco
- Panel systems: Metal, fibre cement, glass, natural stone
- Windows, curtainwalls, storefronts
- Lap siding, board and batten
- ....are all just cladding, not enclosures

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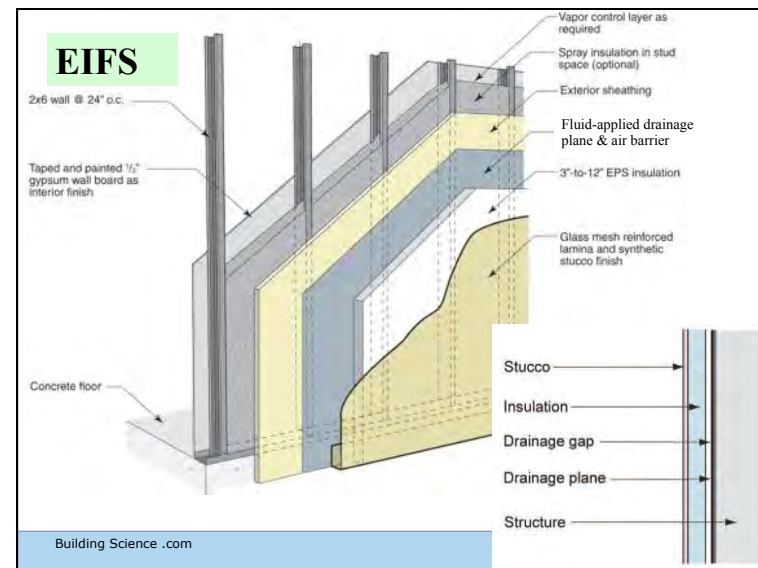
## Brick Veneer/Steel Studs

- Very common system
- Steel studs are thermal bridging nightmare
- Brick is Drained system
- Beware drainage/flashing
- Detail air barrier
- Insulate on exterior
  - Beware balcony/canopy



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Enclosures No. 91 /



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## Metal Panels



- Lightweight, durable
- Should be drained & vented system
  - Some are not!
- Have high performance potential
- High tech look

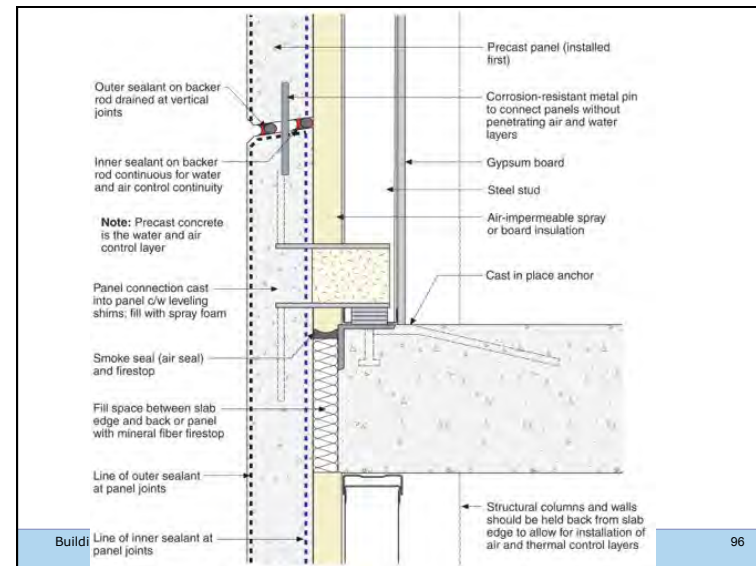
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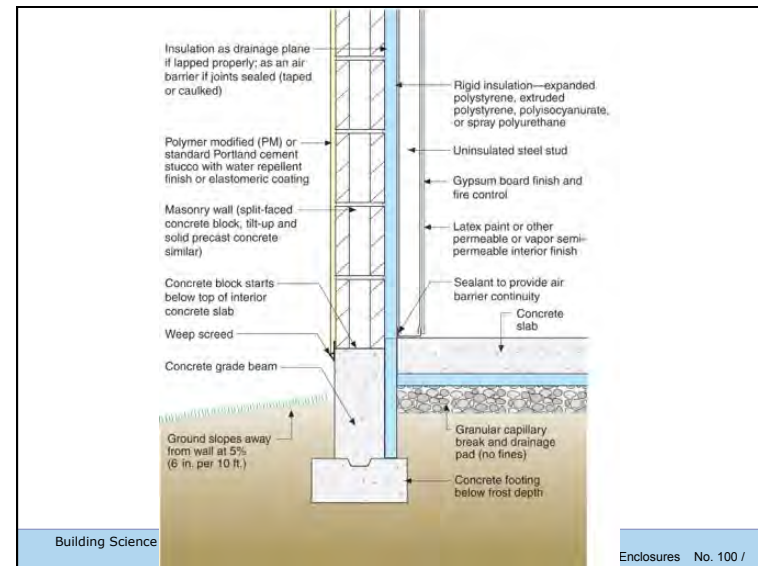
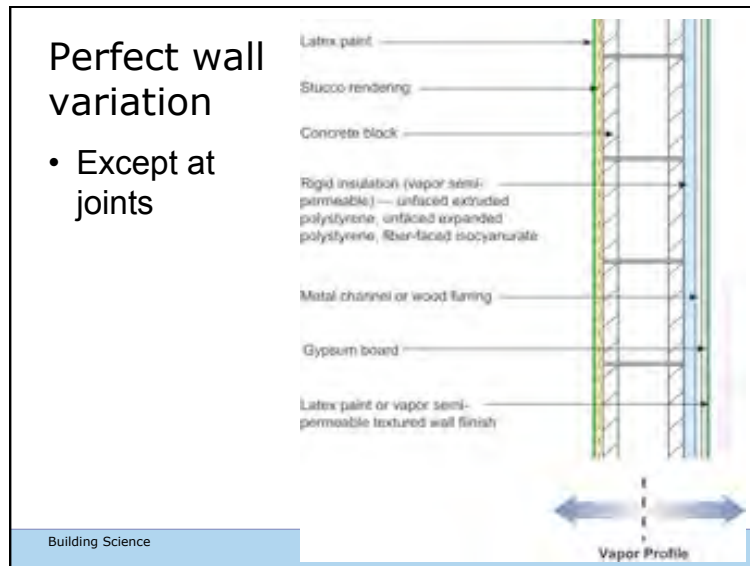
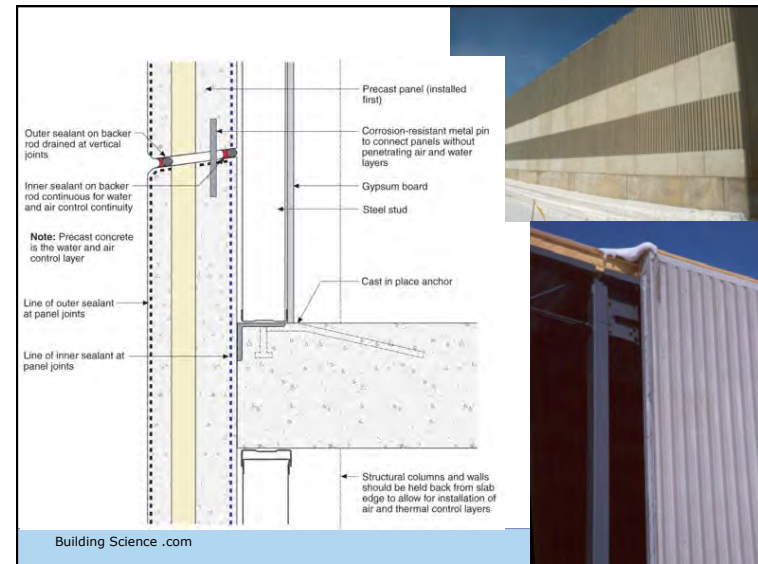
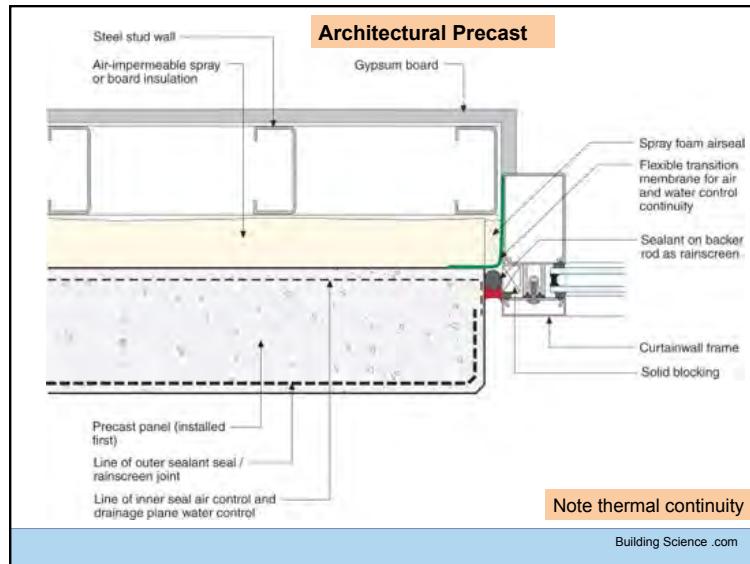
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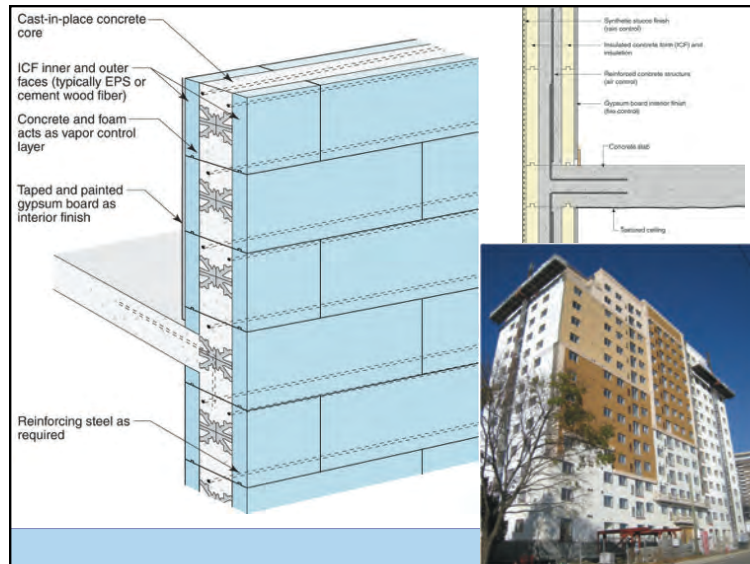
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### Insulated Concrete Forms

- Excellent enclosure system
- Concrete acts as air barrier
- No vapor barrier needed
- Expensive, but high performance

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### Insulated metal panels

Same material fulfills several functions

- Finish (paint)
- Control (metal, foam)
- Support (metal+foam)

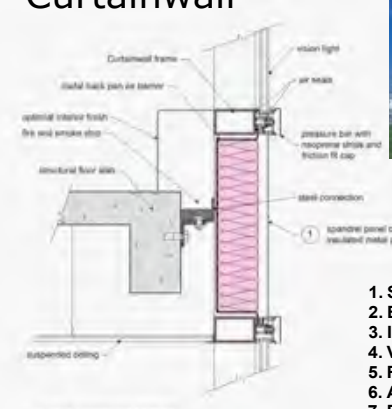

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Enclosures No. 103 /





## Curtainwall

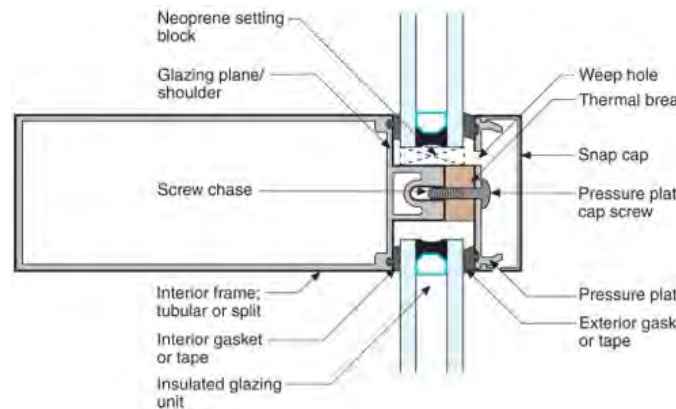
Geometrically complex & require detailed analysis. Should be drained! ("rainscreen"?)

1. Structure
2. Exterior Screen / finish
3. Interstitial heat flow control system
4. Vapor diffusion control system
5. Rain control system
6. Air flow control system
7. Exterior continuous heat flow control
8. Interior Finishes
9. Service Distribution

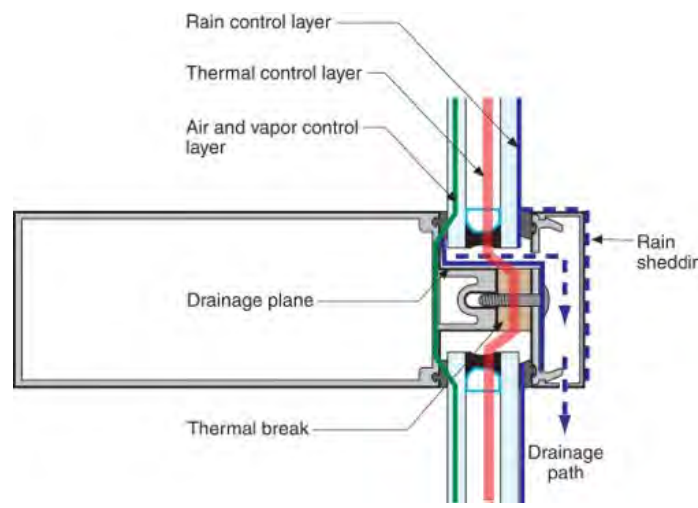
**Typical Construction Materials**

- 1 Metal Panels
- 2 Glass (both with numerous varieties of finish, textures and colors)

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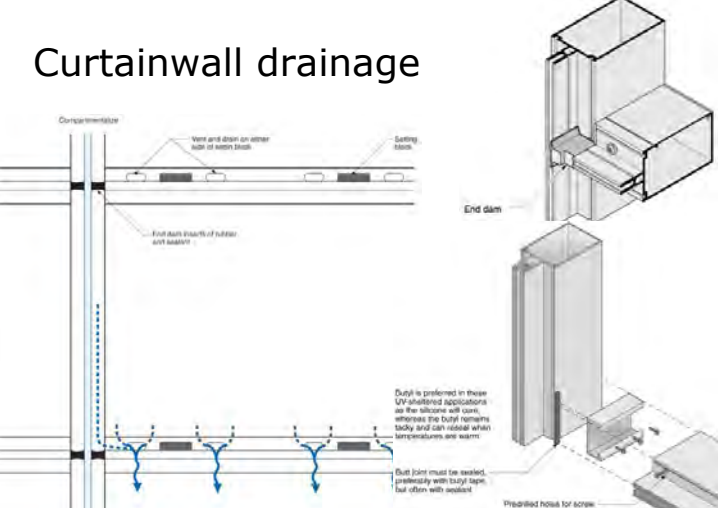


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## Curtainwall drainage



Dural is preferred in these UV-shielded applications as the silicone will cure, otherwise the Dural remains tacky and can reflow when temperatures are warm.  
 Butt joint must be sealed, preferably with Dural tape, but often with sealant.  
 Pre-drilled holes for screws attached into spline cap with sealant.

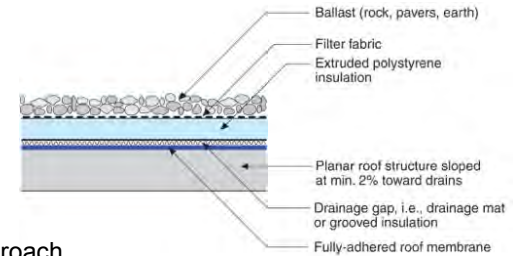
## Roofs

- Roofs are significant proportion of the area of low-rise buildings
  - Significant to total cost
  - Major area for heat loss / gain
  - Low-slope membranes usually need replacement in every 15-25 yrs.
- Wide range of membrane choices
- Insulation on top *or* bottom of membrane
- Green roofs = organic ballast

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## Inverted Roof



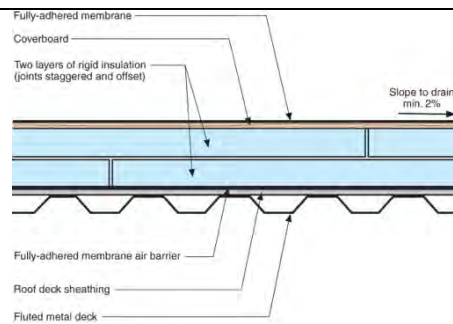
- Pros:
  - Preferred approach
  - Exterior insulation eliminates thermal bridges
  - Protects membrane
- Cons:
  - Added weight of ballast
  - Can only use XPS



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## Exposed membranes



- Pros:
  - Lightest weight
  - Wide variety of insulation and membranes
- Cons:
  - Exposed membrane!



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## Windows

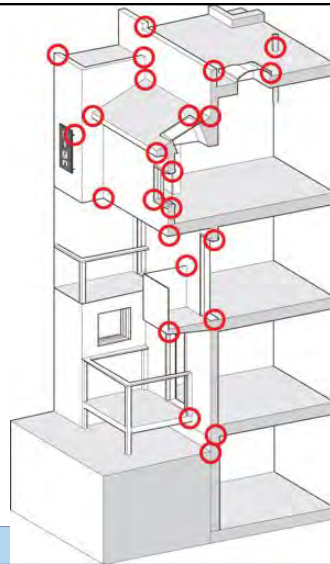
- Same functions as rest of enclosure
  - Support, control, finish
- Windows are often poorly insulated and air leaky
  - Must specify frames, spacers, fills, coatings
- Windows dominate solar gains

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## Enclosure Design: Details

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



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## End of Section

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## Design Checklist & Functions

### Building Enclosure Concept Design Stage Checklist

#### SUPPORT

1. **Support** mechanical loads
  - Sufficient strength and stiffness (from structural engineer)

#### CONTROL

2. **Heat Flow Control** (Temperature and Energy)
  - avoid thermal bridges, reasonable insulation: HVAC energy + capital cost savings
  - control air leakage,
  - excessive glazing = winter discomfort and summer overheating (esp. west glass)
3. **Condensation Control**
  - surface condensation, i.e. thermal bridges, corners, etc.
  - interstitial condensation (summer + winter) by vapour diffusion and air leakage
4. **Air Flow Control**
  - air barrier systems, compartmentalization, convection loops in batts
  - IAQ, control of stack effect, HVAC, and wind-induced air flows, odor, dust

#### 5. Rain Control

- climate, site, building orientation, shape
- deflection, surface drainage, drying, and enclosure rain control strategies

#### 6. Crack/Movement control

- control of cracking and movement are complementary
- consider creep, sag, shrinkage, swelling, both moisture and temperature movement

#### 7. Fire and Smoke Control

- fire resistance rating, flame spread, smoke produced, toxins generated
- special situations, often involved in design decisions (e.g., combustible vs non-combustible)

#### 8. Sound and Vibration Control

- airborne sound reflection, transmission, and impact borne sound transmission
- special situations are sometimes important, always needs some consideration

#### FINISH

9. **Finish**
  - colour, pattern, texture, etc of interior and exterior interfaces
  - architecture and interior designers

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