

John Straube, Ph.D., P.Eng

# Spray Foam

Introduction:  
Building Enclosures



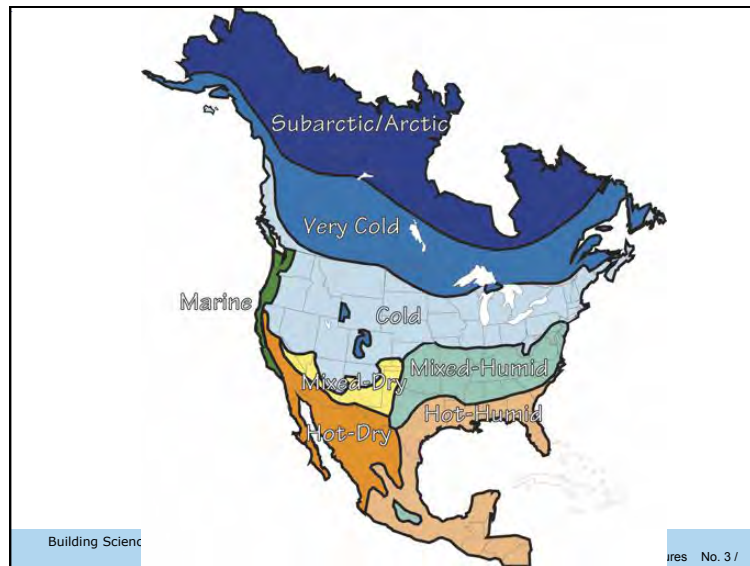
presented by [www.buildingscience.com](http://www.buildingscience.com)

## Course Outline

- Building Science for Spray Foam Industry
  - Applicators, sales, development
- General rules apply
  - Spray foam is not magic
- Unique applications will be discussed
- Pros and Cons
- Climate specific

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## The Need

- The World is Changing. Trends
  - Reliable, durable, comfortable
  - Energy & Green

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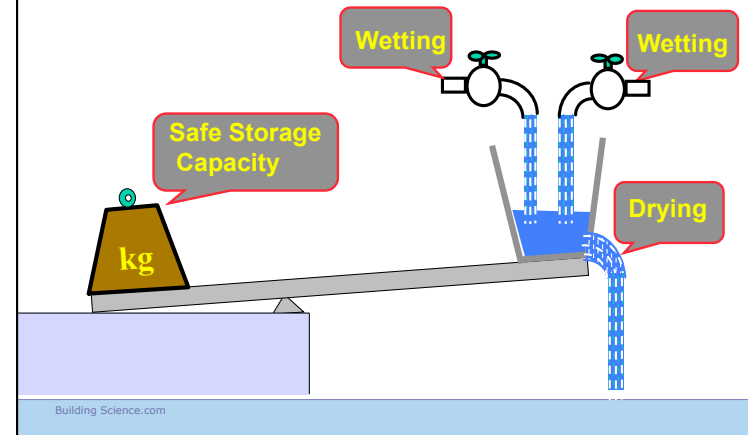
## Pre-WWII Buildings

- 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
- Plaster is the dominant interior finish

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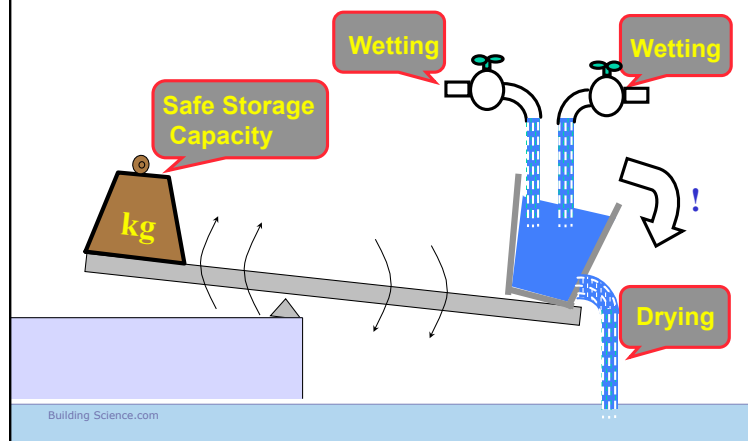
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## Moisture Balance



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## Moisture Balance: Accumulation



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## Five Fundamental Changes

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

## 1. Thermal

- Old buildings used energy leakage to dry materials and assemblies
- Increased airtightness
  - Reduces drying, interior RH increases
- Increased insulation = less drying
  - Colder exterior, colder interior
  - Wider swings

## 2. Permeability

- Low permeance exteriors
  - Metal panels, precast concrete
  - OSB and foam vs skip wood sheathing
- Low permeance interiors
  - Polyethylene, vinyl wall paper
  - Vinyl sheet flooring

## 3. Water/Mold Sensitivity

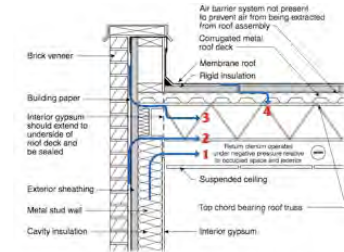
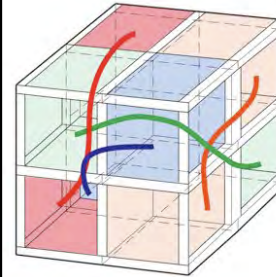
- Moisture= mold growth
- Wood products
  - New growth vs old
  - Processing: plywood, OSB, particle board
  - Paper, Veneers
- Finishes
  - Drywall, ceiling tile

## 4. Hygric Buffer Capacity

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

## 5. Three-D Airflow Networks

- Hollow walls
- Taller buildings



- 1 Air is pulled from exterior wall cavity into return plenum since interior gypsum does not extend to underside of roof deck
- 2 Air is pulled from exterior through gaps in building paper and exterior sheathing
- 3 Air is pulled from exterior through gaps between corrugated metal roof deck and structural steel
- 4 Air is pulled from under roof membrane through gaps in rigid insulation and metal roof deck

## Hollow Buildings



## Five Fundamental Changes

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

## Addressing these changes

- Get back in balance
- Provide better moisture control
  - drainage, airtight, construction control
- Allow diffusion drying of moisture
  - Use vapor barriers with care
- Compartmentalize
  - Air seal within buildings as well

## 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 (Framing, foundation, etc)
  - Enclosure
  - Service Systems (HVAC, power, plumbing)
  - Fabric (furniture, partitions, etc)

## 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)

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

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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 20-35 yrs
  - Sealants 5-25 yrs

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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

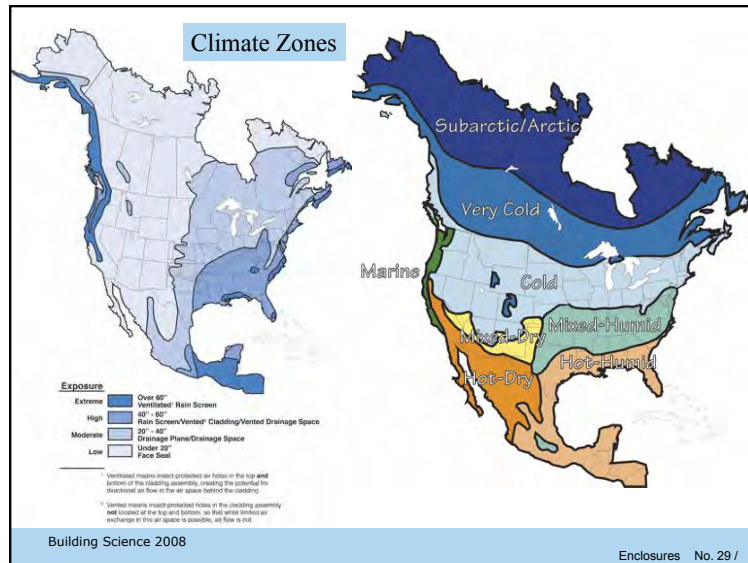
- Design for
  - Climate zone
  - Site
  - Building height, shape, complexity

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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## 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

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## Enclosure Failures

- Problem causes:
  - 1. Material/system does not fill function
  - 2. Functionality not designed for
  - 3. Not built according to design (workmanship)
- Avoidance requires understanding each

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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

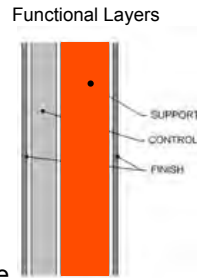
SUPPORT  
CONTROL  
FINISH

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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

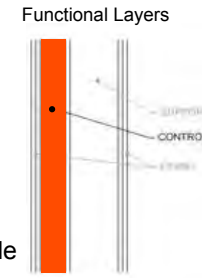


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## Basic Enclosure Functions

- **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

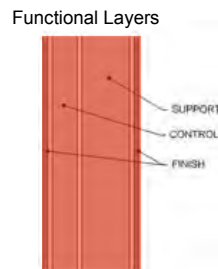


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## Other Control . . .

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

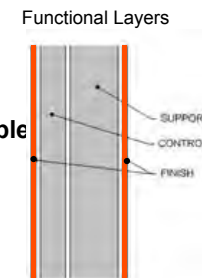


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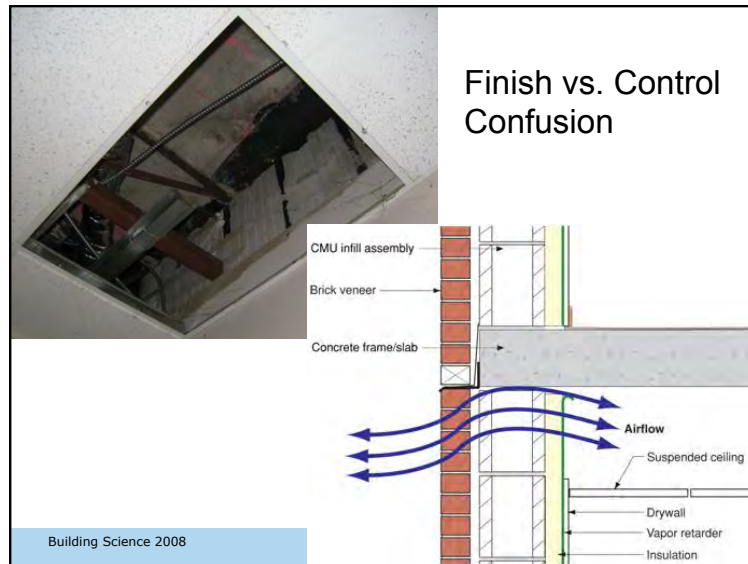
## Basic Enclosure Functions

- **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



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## 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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## History of Control Functions

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



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## Evolution



Commercial

Residential

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## Enclosure Design Principles 1

- Design a **complete** structural load transfer path
  - Structure, windows, ties, etc
  - All loads go to ground
- Respect the site and climate
  - Rain, sun, wind, hill, valley, high rise or low-rise
- **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 (mat'l'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

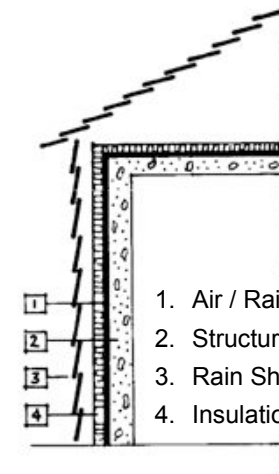
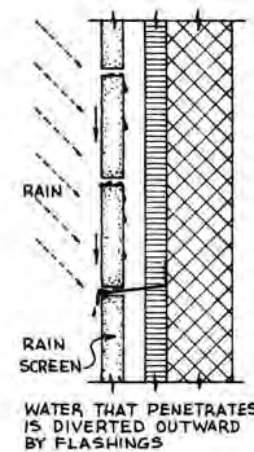


- Structure
- Air-Rain Barrier
- Insulation
  
- Finish

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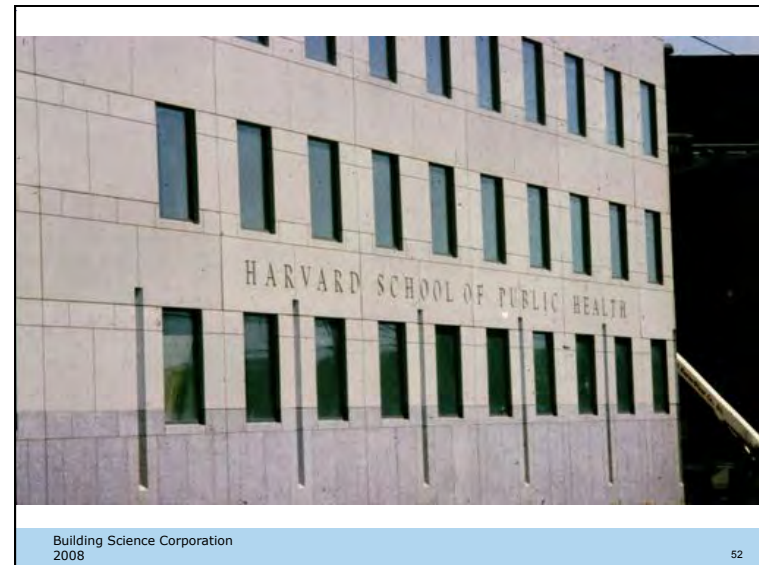
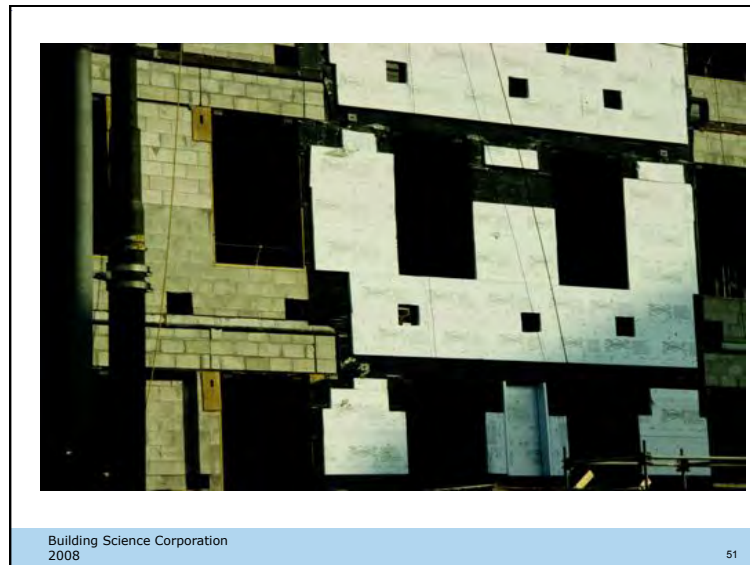
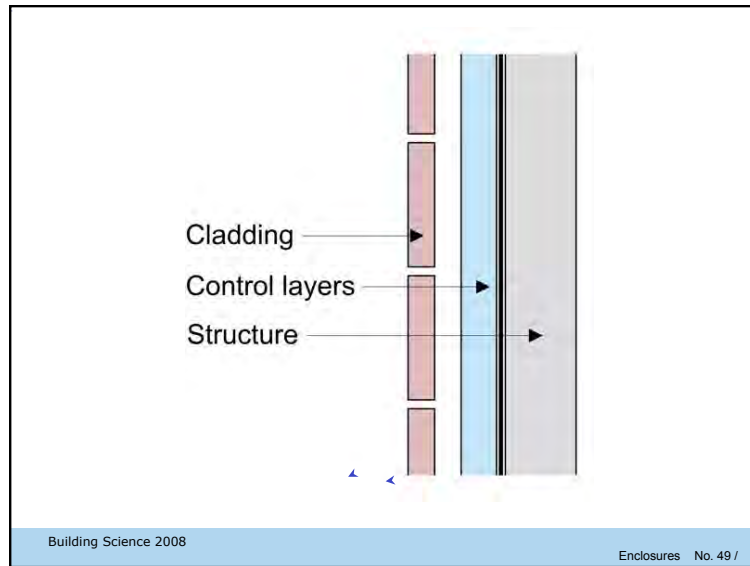
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## Design Information older than I am.



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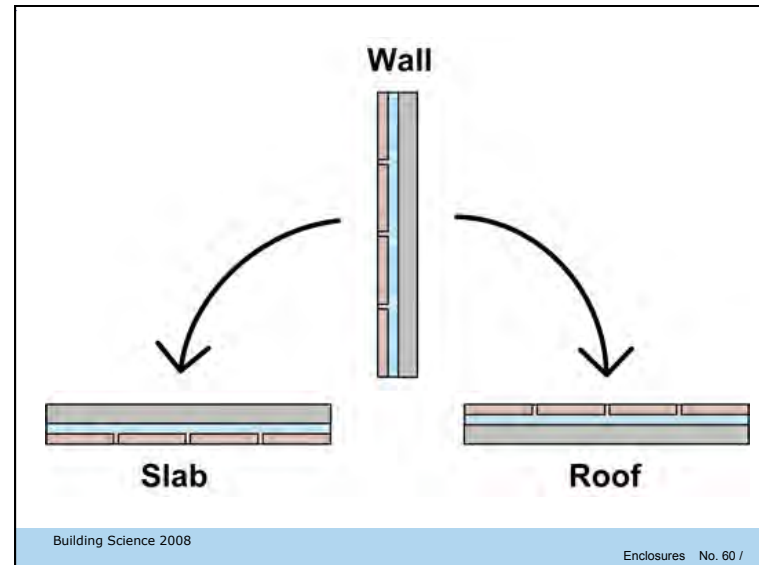
**Four Control Layers**

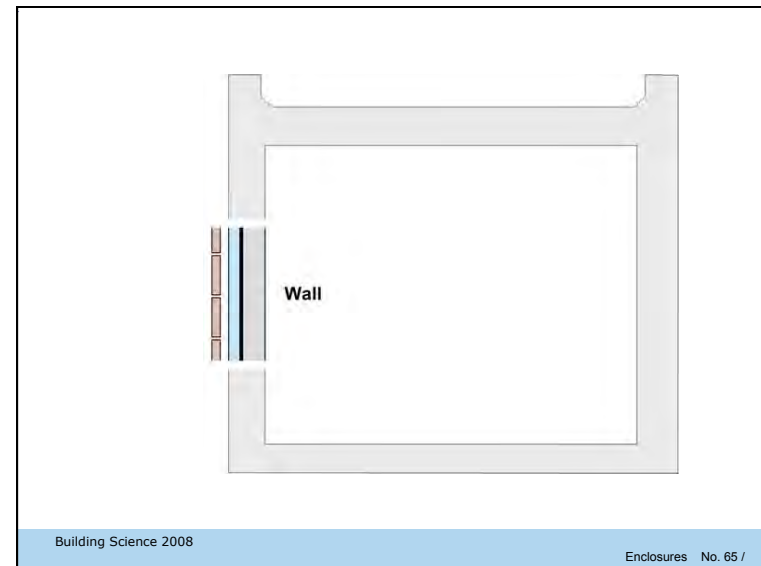
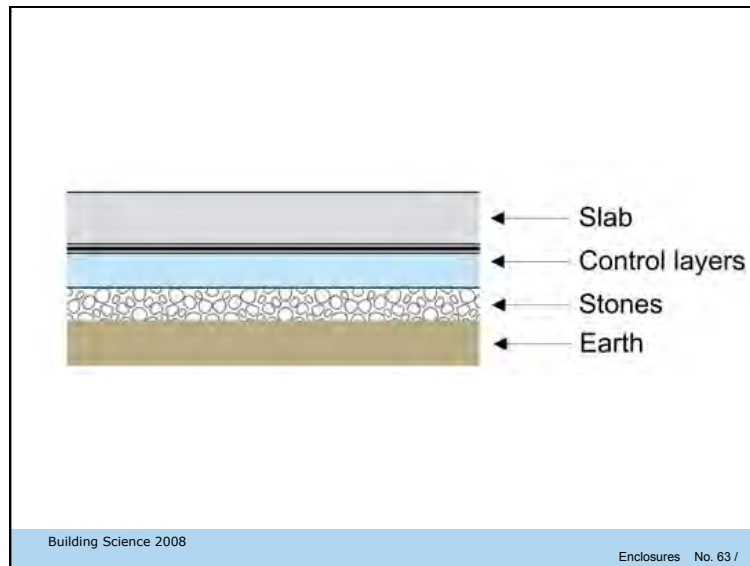
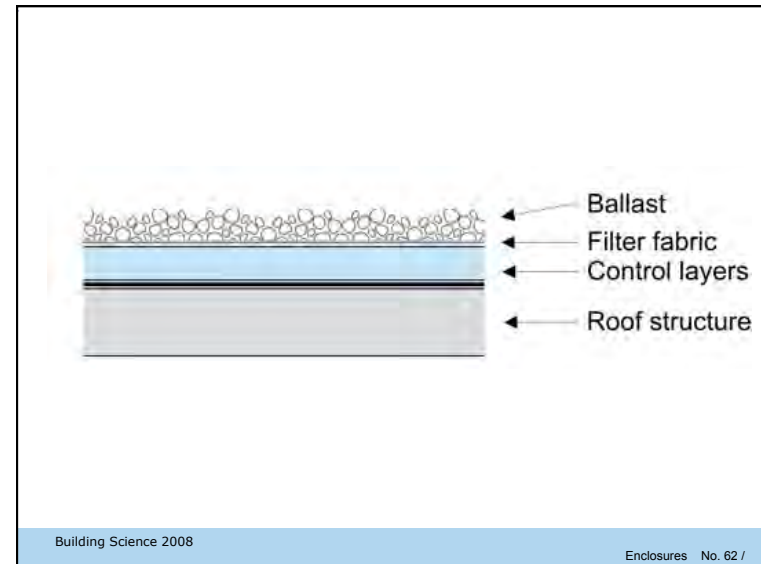
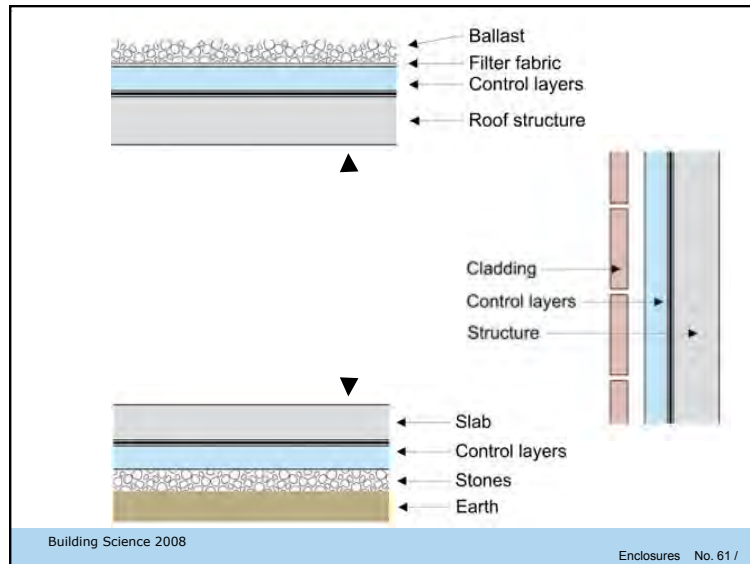
Closed cell Spray foam=

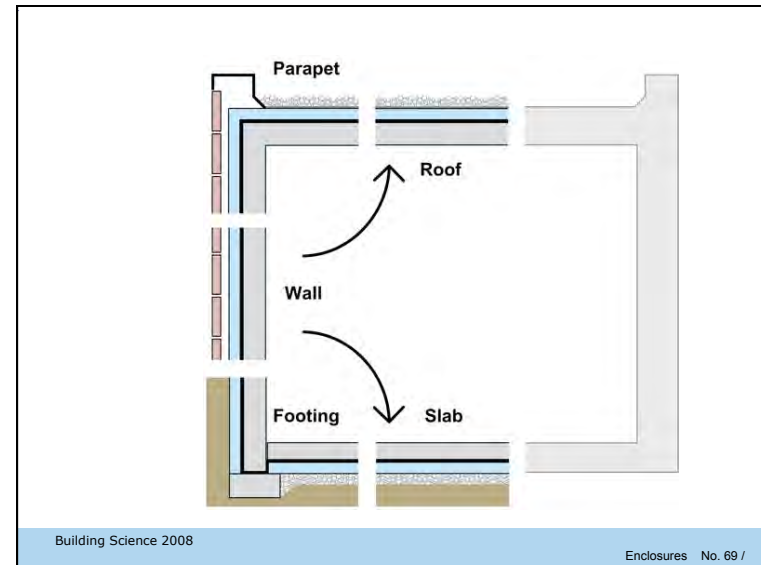
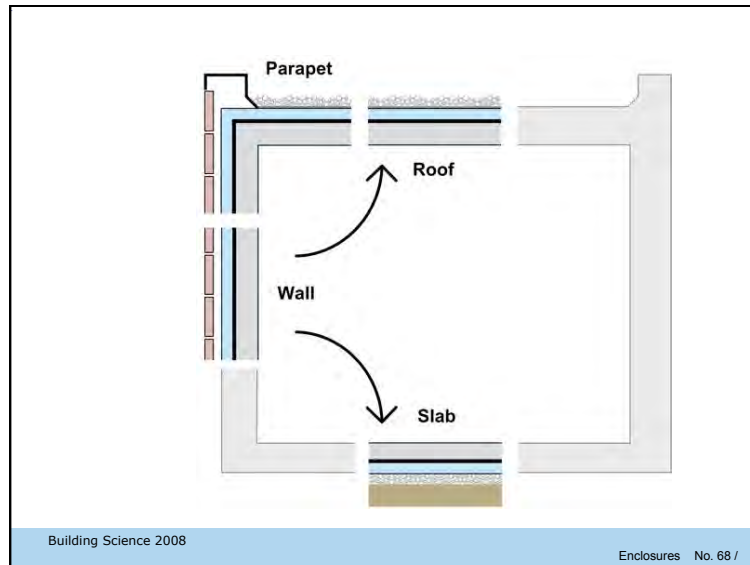
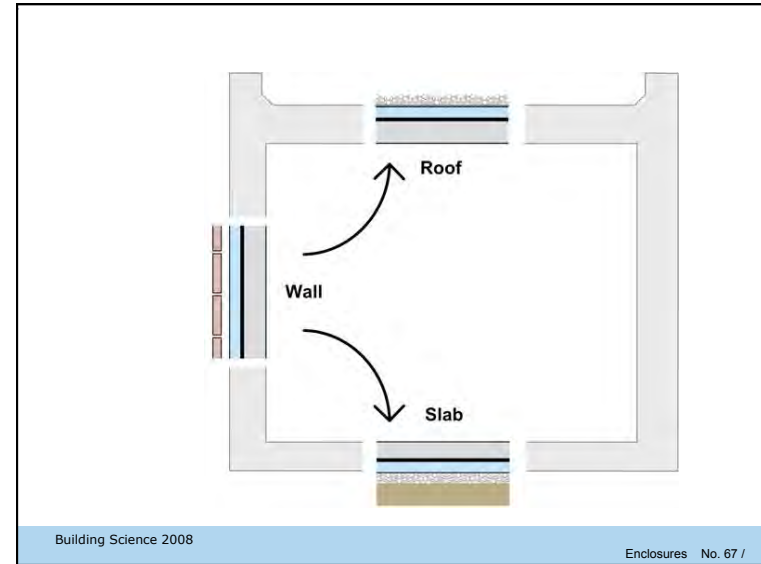
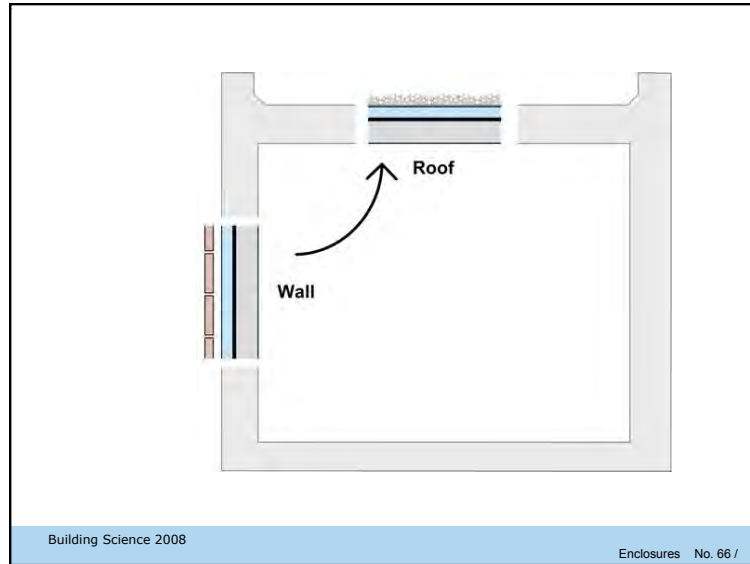
1. air barrier
2. drainage plane
3. Heat flow control
4. vapor control

**Transitions, Continuity, Penetrations**

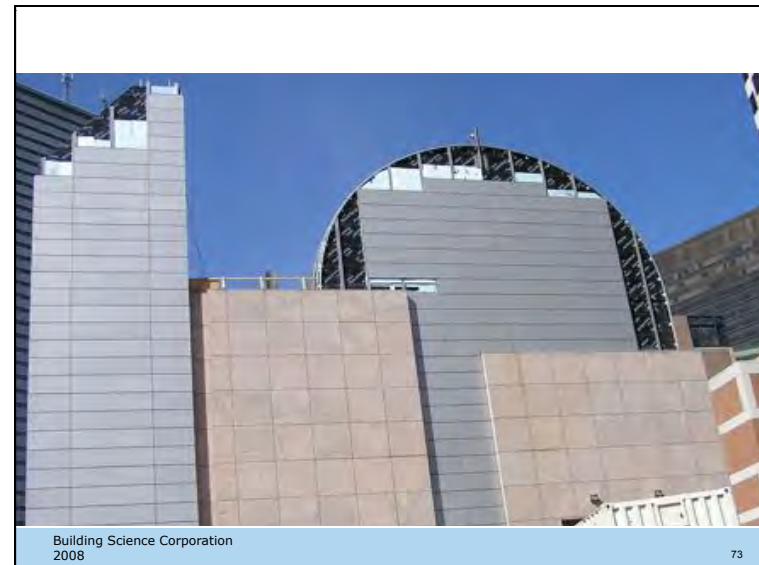
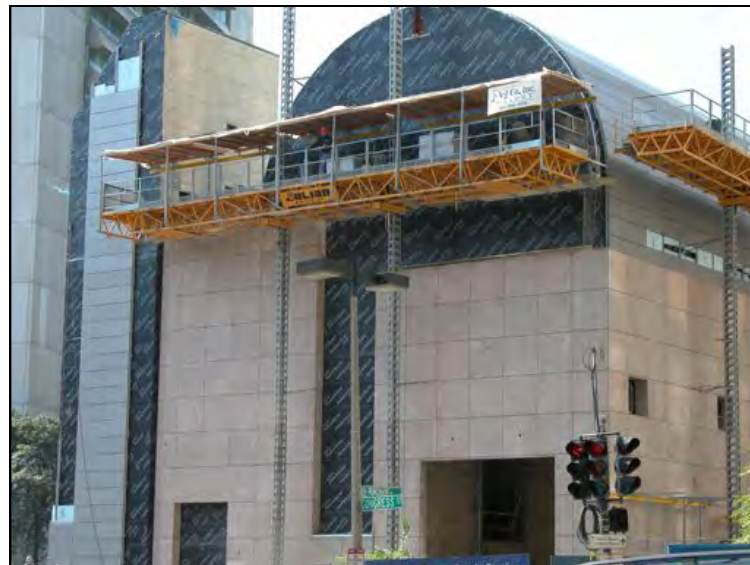
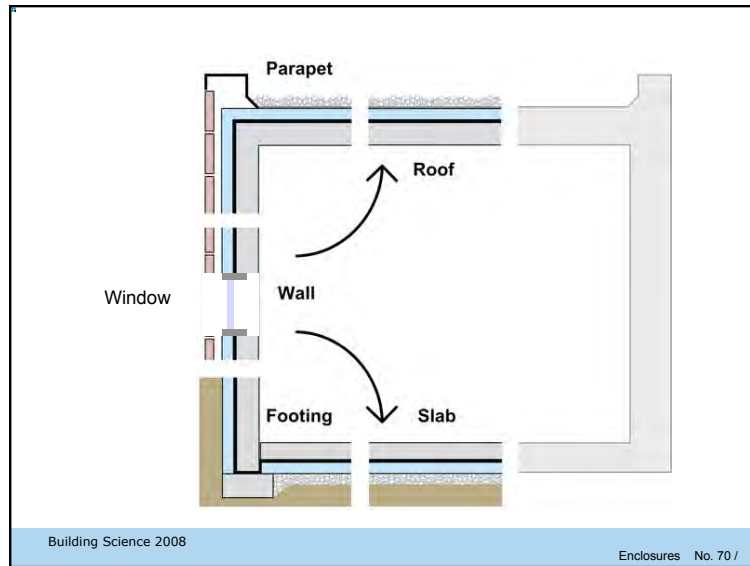
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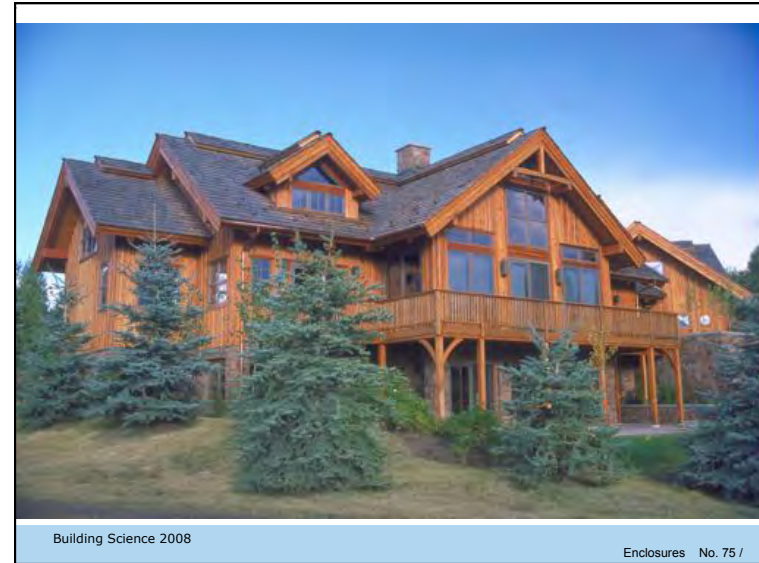
A photograph of a building under construction, showing a different section. The facade is covered in yellow insulation panels. The building is surrounded by trees and other buildings in the background.





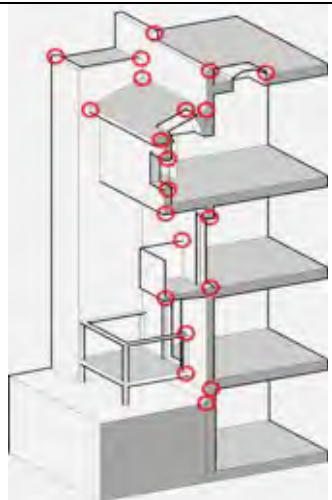






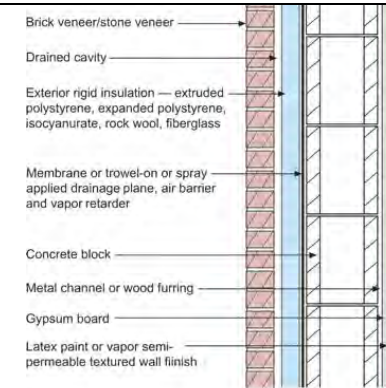
## Enclosure Design: Details

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



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The “Perfect” wall: Higher Performance

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