John Straube, Ph.D., P.Eng

Roxul Building Science

Environmental Separation

presented by 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

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

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

Building Components

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

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

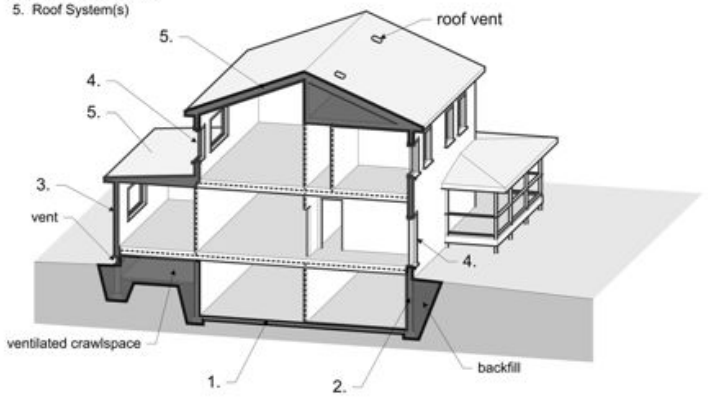
The Enclosure: An Environmental Separator

- 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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Enclosures No. 10 /

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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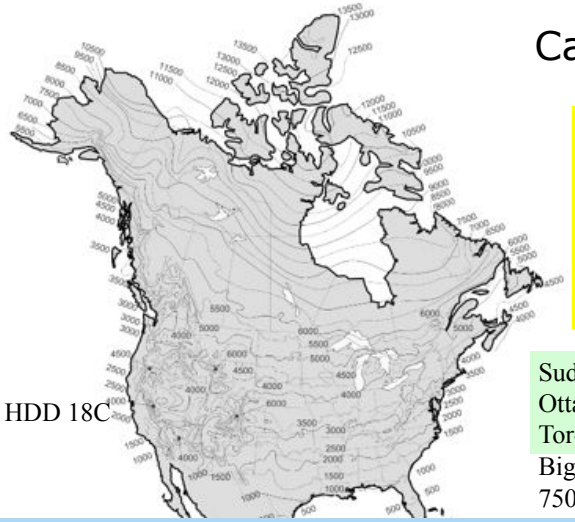
Canada:



HDD 18C

Significant heating demand, especially Prairies and North

Sudbury 5300
Ottawa 4500
Toronto 4000
BigTrout Lake 7500

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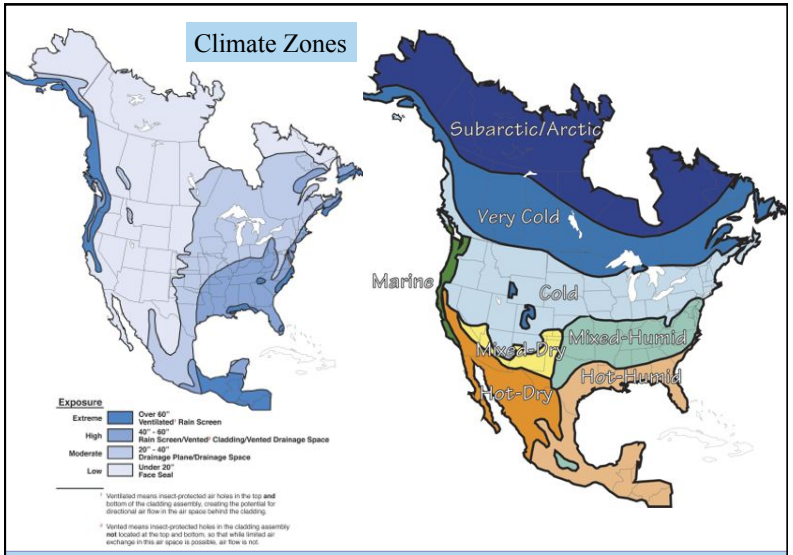

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Enclosures No. 14 /

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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Enclosures No. 15 /

Evolution

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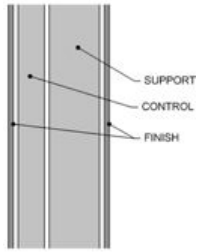
Enclosures No. 16 /

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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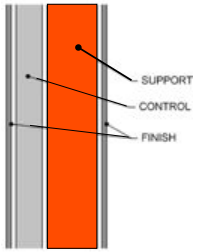
Enclosures No. 17 /

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

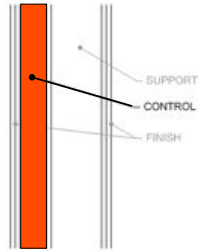
Functional Layers



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

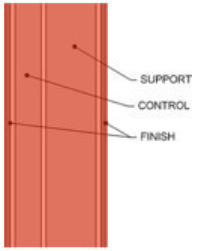
Functional Layers



Other Control Functions . . .

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

Functional Layers



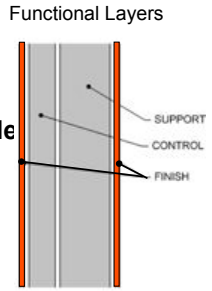
History of Control Functions

- 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



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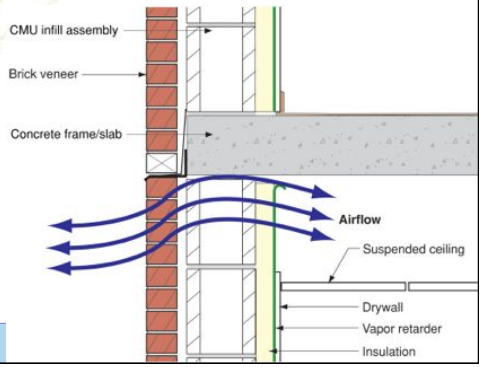
Enclosures No. 22 /

Finish vs. Control Confusion



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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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Enclosures No. 24 /

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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Enclosures No. 25 /

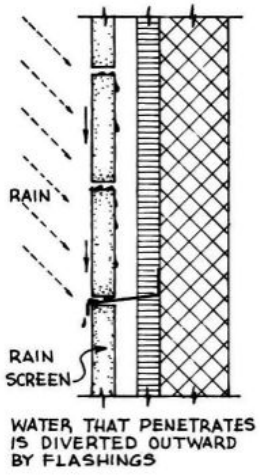
Enclosure Design Principles 2

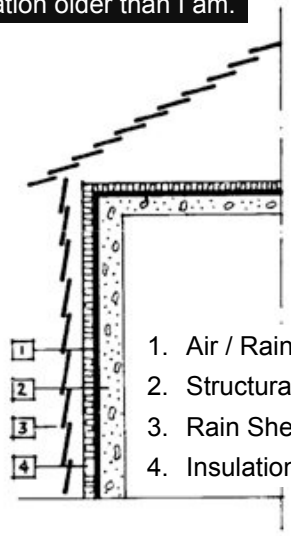
- Provide a continuous plane of insulation
  - Ideally separate structure from enclosure
  - *Avoid thermal bridges*
- Provide a moisture tolerant design
  - Balance wetting, drying, and storage (matl's, climate)
  - Use appropriate levels of vapour control
    - No cold vapor barriers, allow drying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

The Enclosure: Adding the Layers

- Structure
- Air-Rain Barrier
- Insulation
- Finish

Design Information older than I am.





1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation

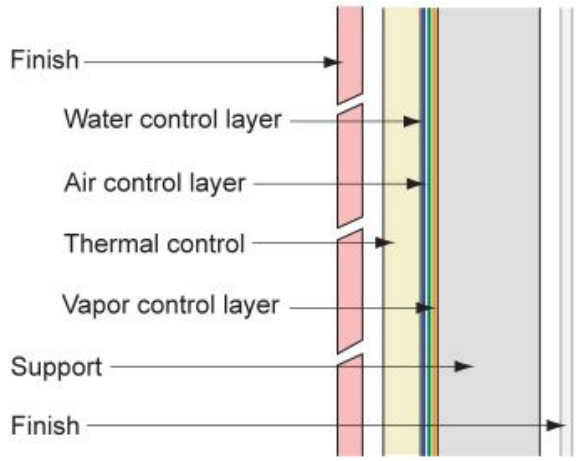
What is a high performance enclosure?

- 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*

High Performance

- No leaks = continuous = no holes

1. Rain
2. Air
3. Thermal



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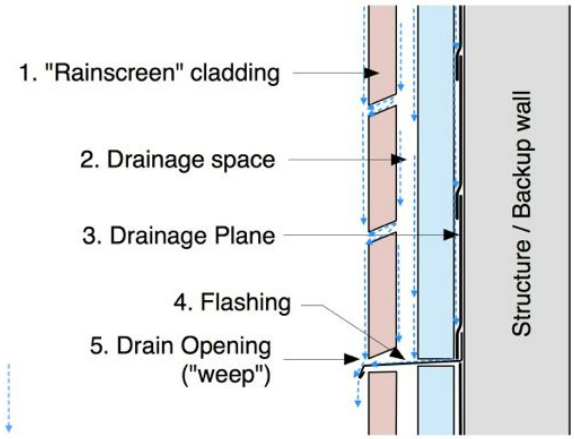
"Rainscreen" or "Drained" System



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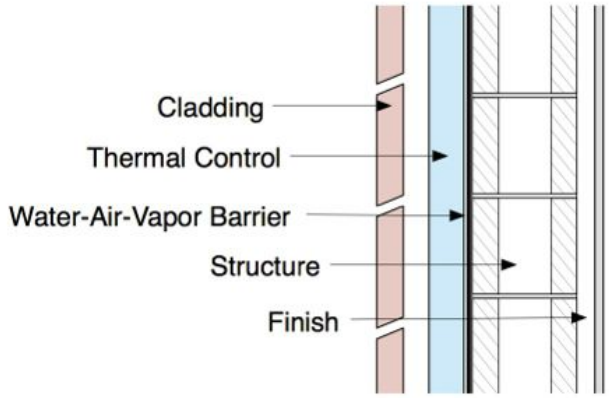

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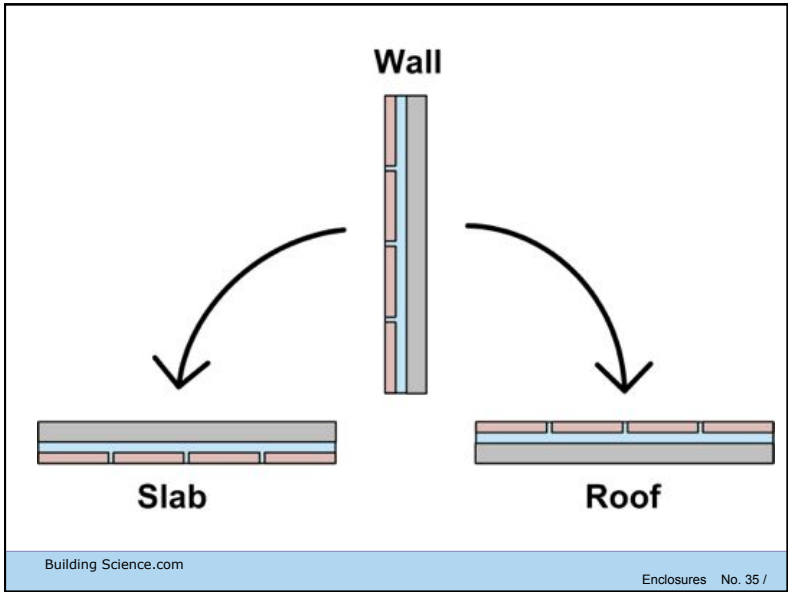
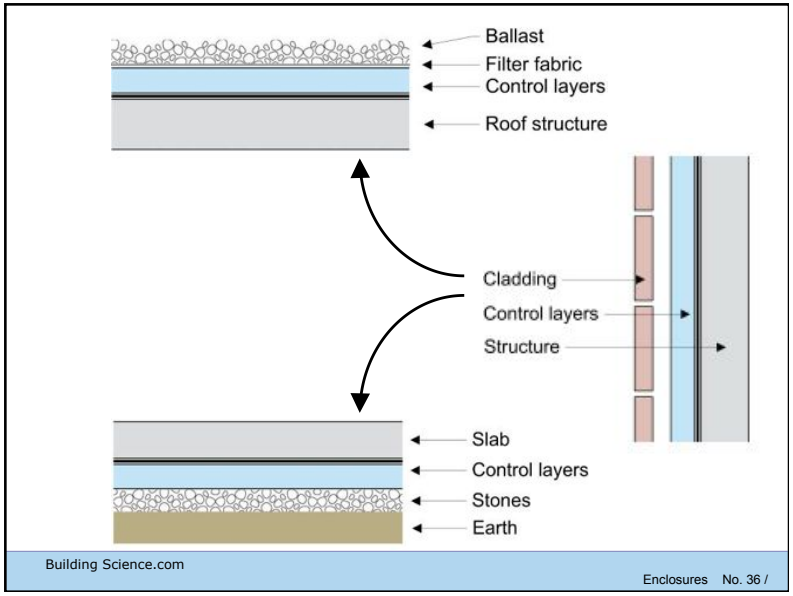
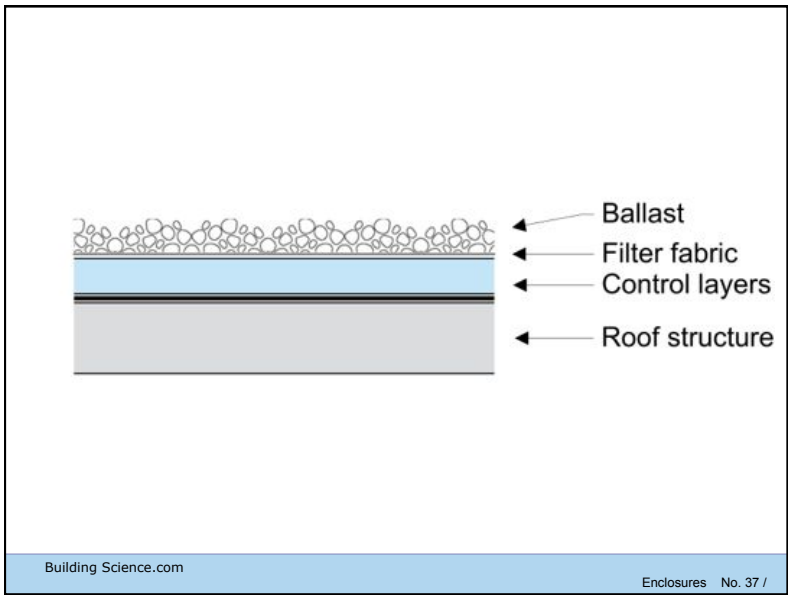
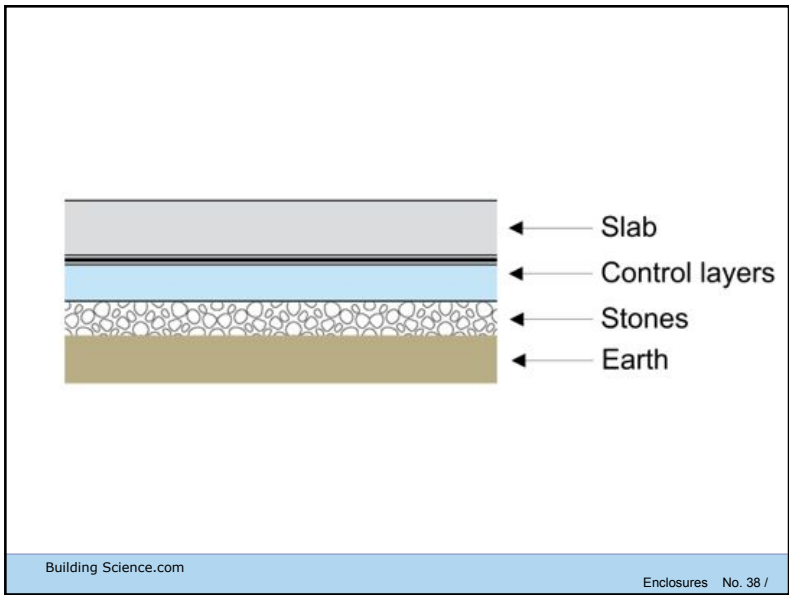
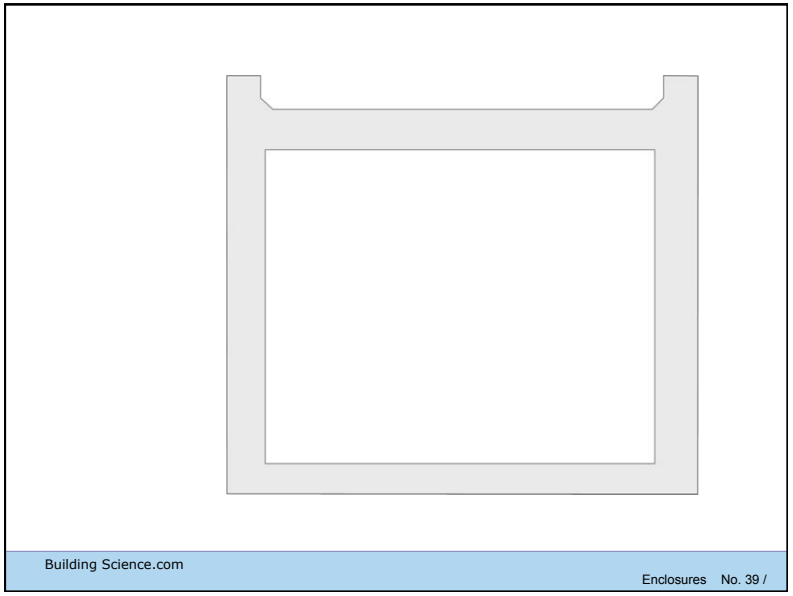
Enclosures No. 34 /


Wall
Slab
Roof
Building Science.com
Enclosures No. 35 /


Ballast
Filter fabric
Control layers
Roof structure
Cladding
Control layers
Structure
Slab
Control layers
Stones
Earth
Building Science.com
Enclosures No. 36 /


Ballast
Filter fabric
Control layers
Roof structure
Building Science.com
Enclosures No. 37 /


Slab
Control layers
Stones
Earth
Building Science.com
Enclosures No. 38 /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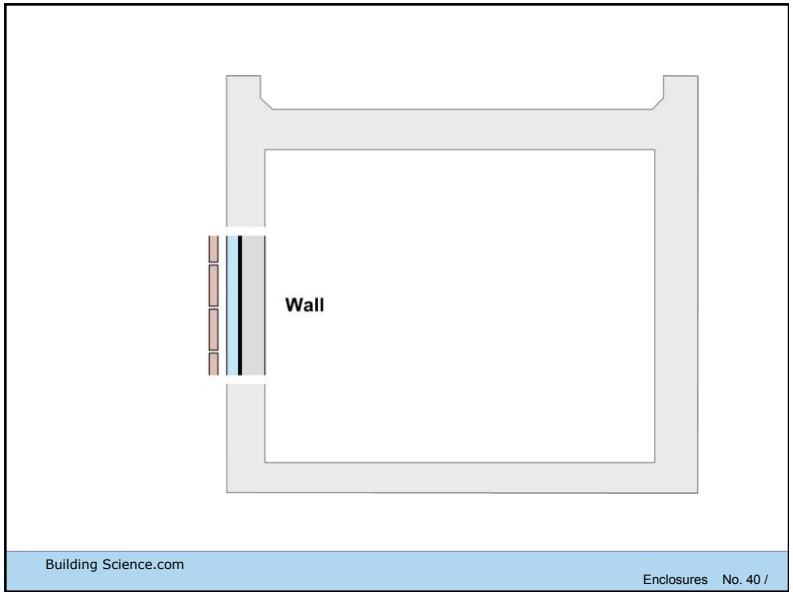
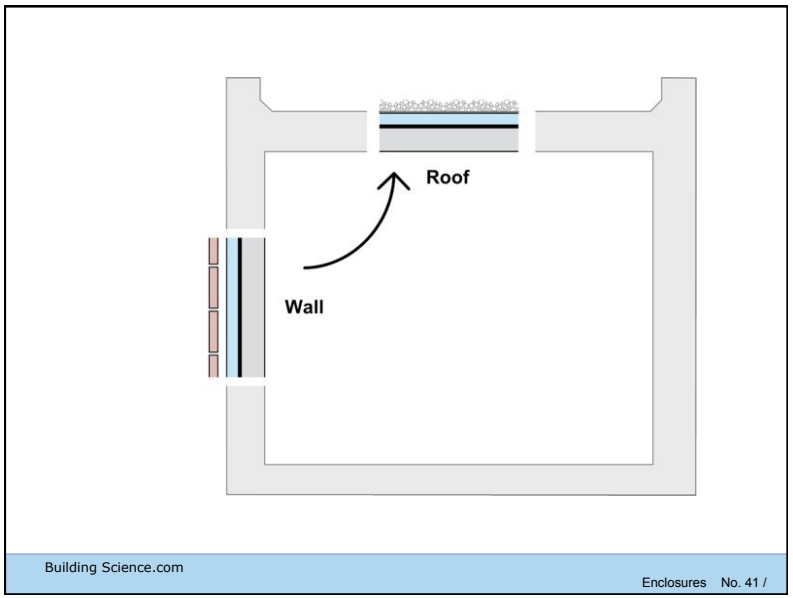
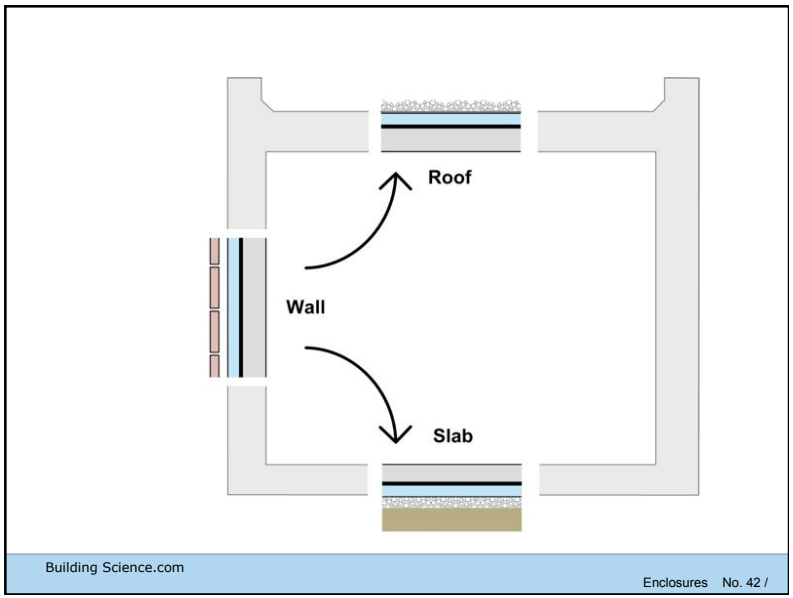
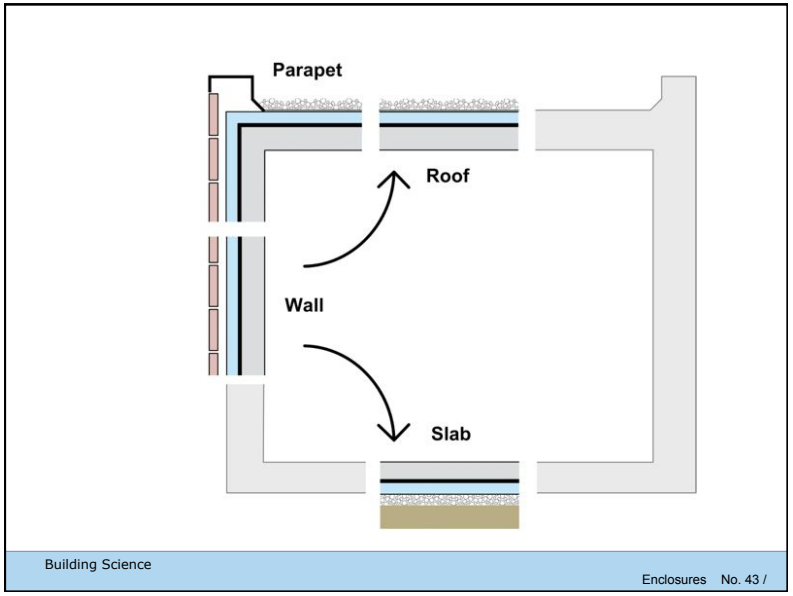
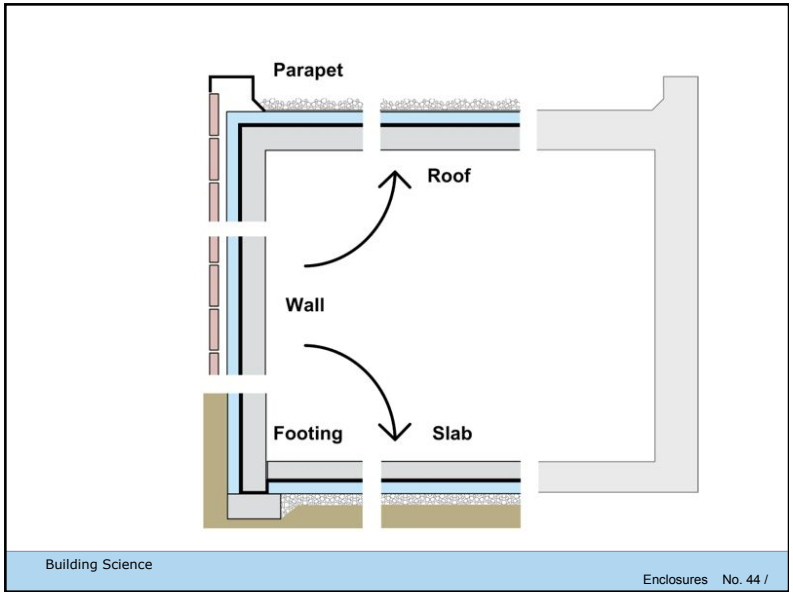
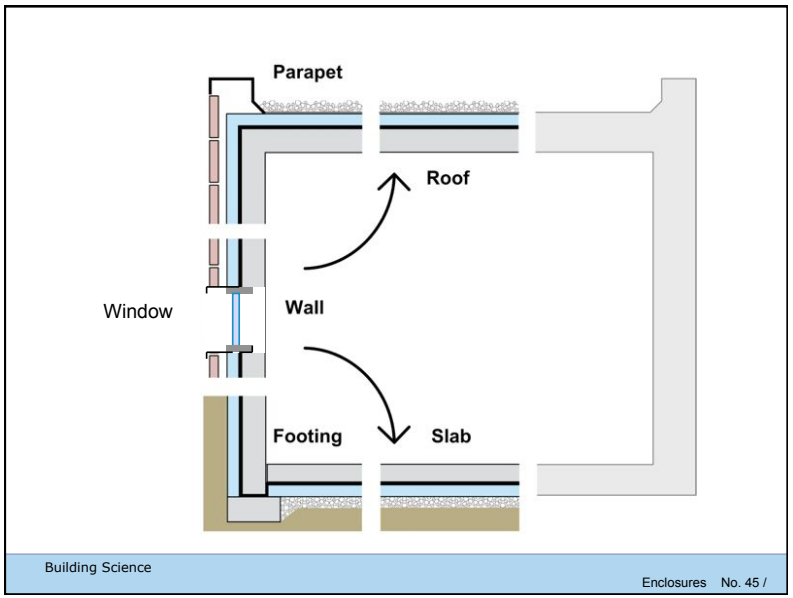

Wall
Building Science.com
Enclosures No. 40 /


Roof
Wall
Building Science.com
Enclosures No. 41 /


Roof
Wall
Slab
Building Science.com
Enclosures No. 42 /

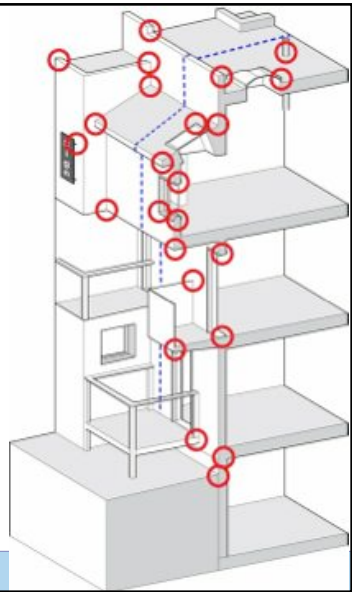

Parapet
Roof
Wall
Slab
Building Science
Enclosures No. 43 /


Parapet
Roof
Wall
Footing
Slab
Building Science
Enclosures No. 44 /


Parapet
Roof
Window
Wall
Footing
Slab
Building Science
Enclosures No. 45 /

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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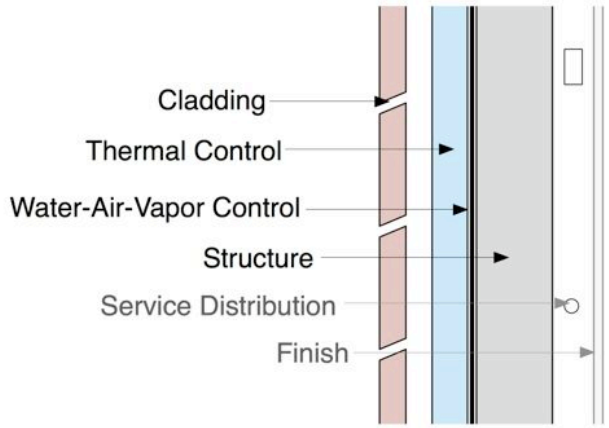

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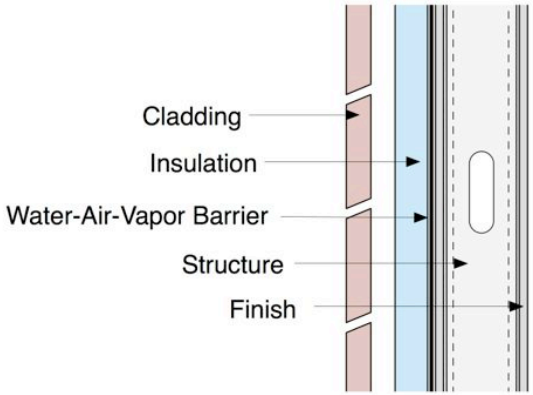

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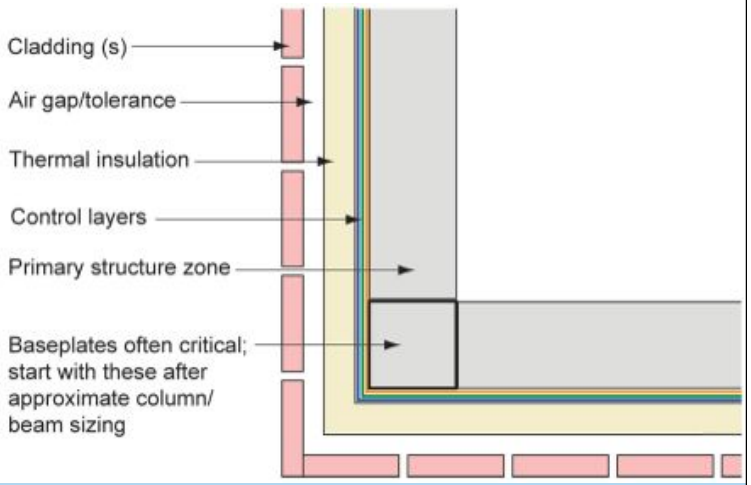
Plan Dimensions



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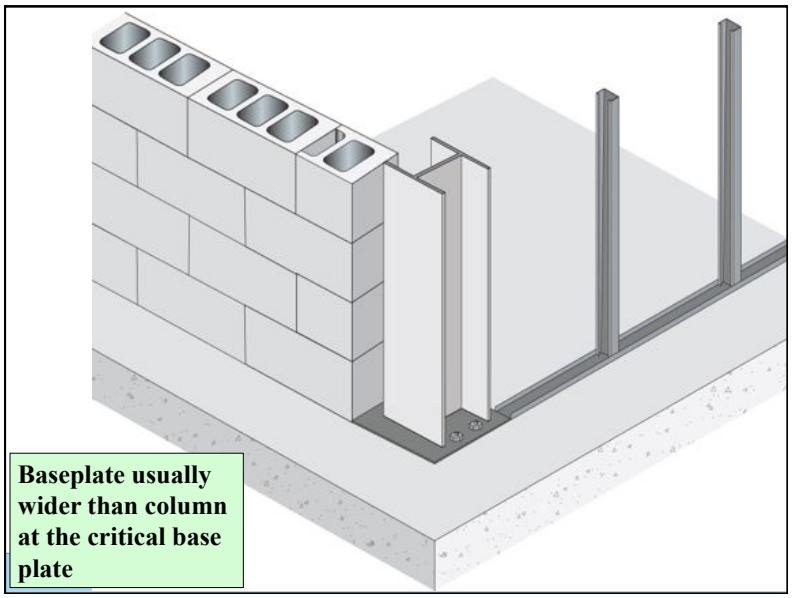
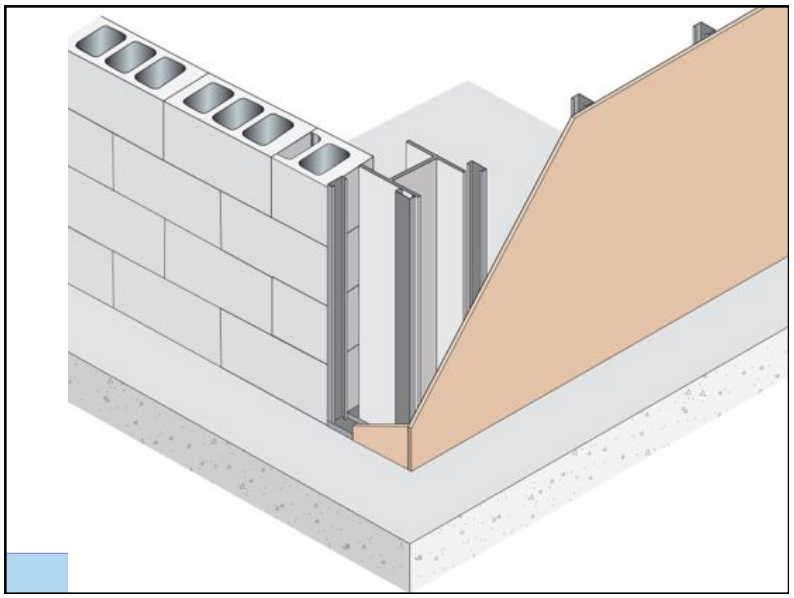
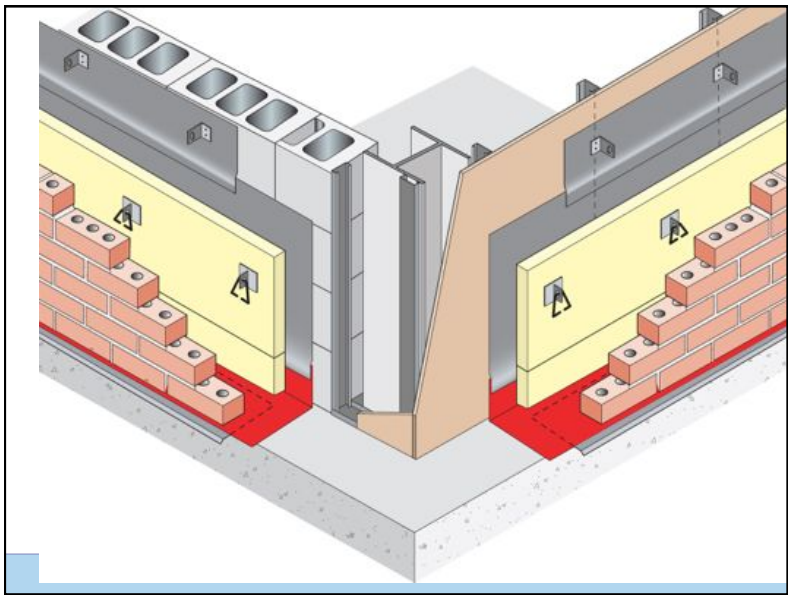
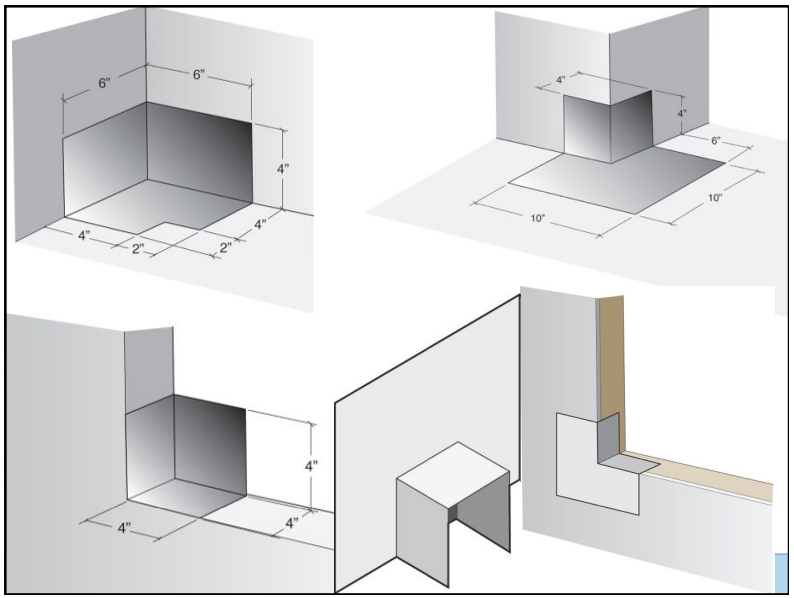

Baseplate usually wider than column at the critical base plate






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

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Building Science 56

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Building Science.com 59

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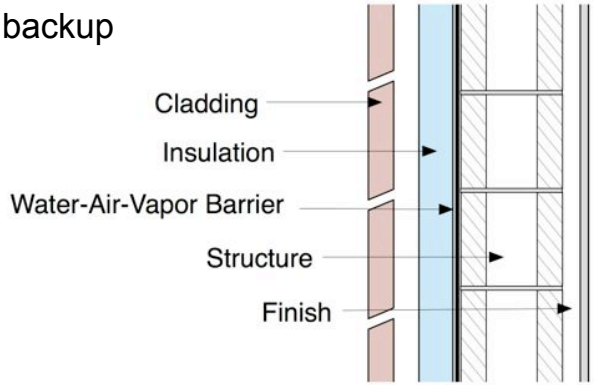
Perfect Wall

- CMU backup



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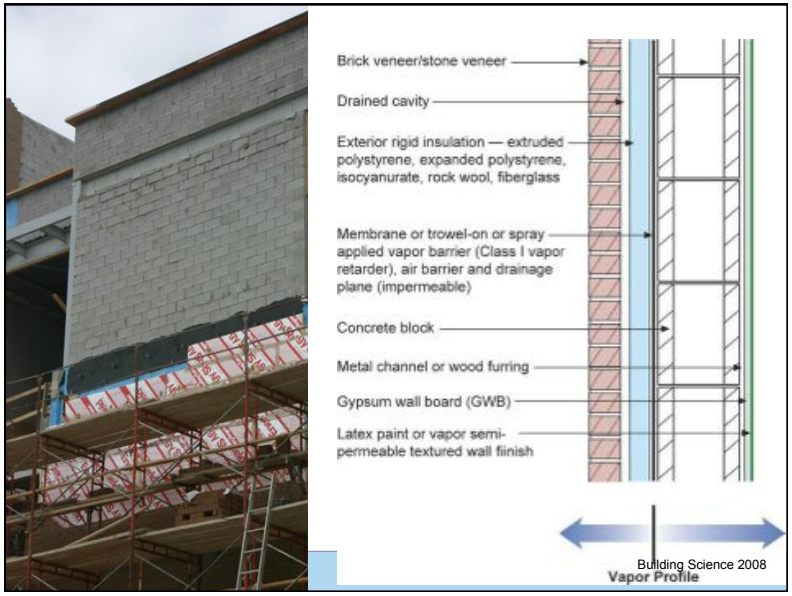

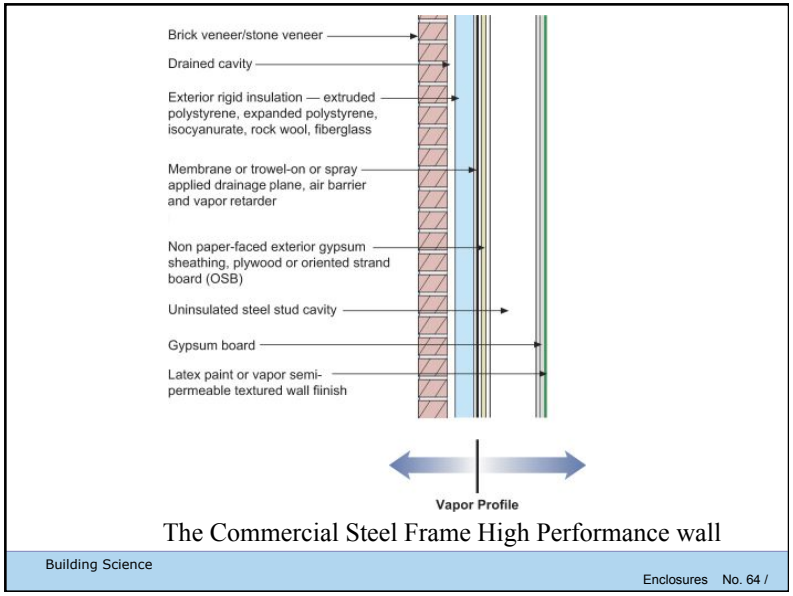

Perfect Wall on Steel stud

Transitions, Continuity, Penetrations

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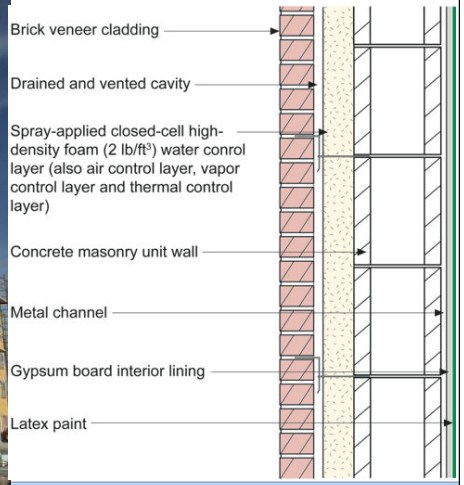
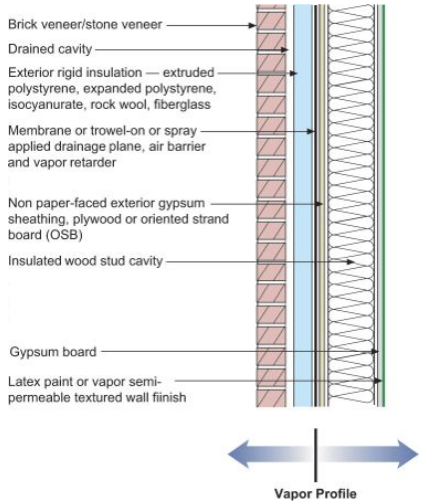
Enclosures No. 65 /

Sprayfoam Control Layer



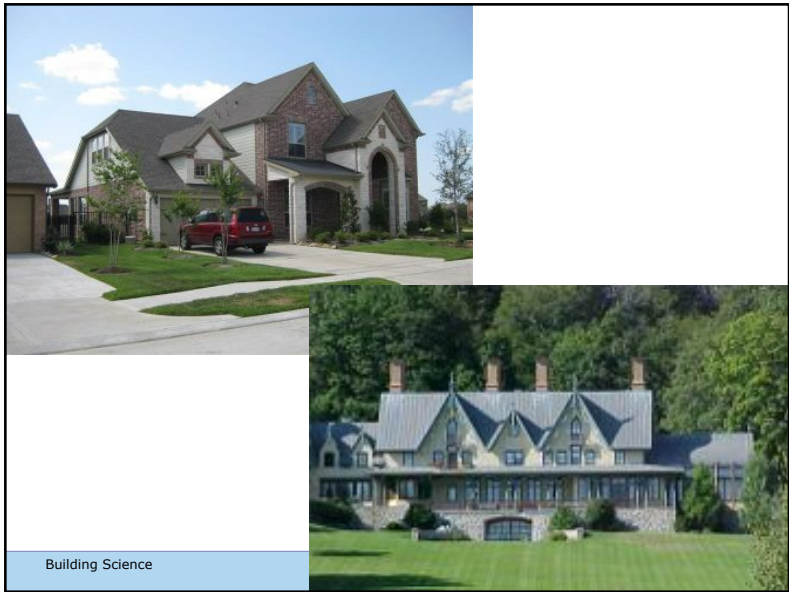
Enclosures No. 66 /



The Compromise Wood Frame High R-value wall

Building Science

Enclosures No. 67 /



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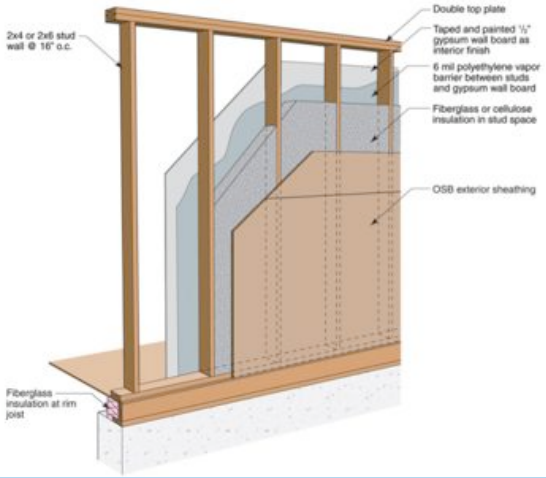
- Discontinuous thermal and air barrier



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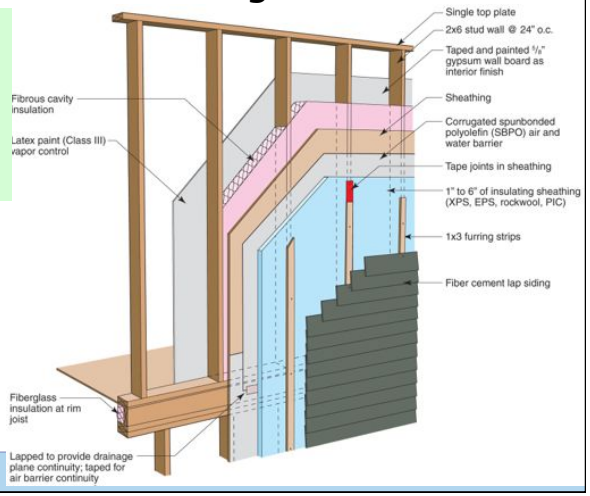
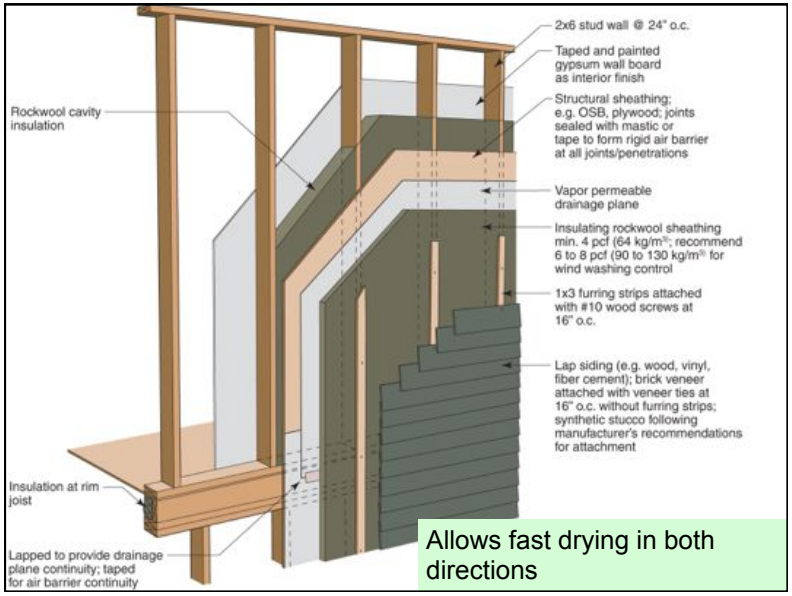
Enclosures No. 69 /

Wood Framed Furring

2x6 w/R5 exterior is a start
2x4 w/R7.5 for higher interior RH
2x6 w/R10-R15 is likely long-term answer

Increasing ratio of Exterior to Cavity insulation reduces risk and improves performance




2x6 stud wall @ 24" o.c.
Taped and painted gypsum wall board as interior finish
Structural sheathing; e.g. OSB, plywood; joints sealed with mastic or tape to form rigid air barrier at all joints/penetrations
Rockwool cavity insulation
Vapor permeable drainage plane
Insulating rockwool sheathing min. 4 pcf (64 kg/m³; recommend 6 to 8 pcf (90 to 130 kg/m³ for wind washing control
1x3 furring strips attached with #10 wood screws at 16" o.c.
Lap siding (e.g. wood, vinyl, fiber cement); brick veneer attached with veneer ties at 16" o.c. without furring strips; synthetic stucco following manufacturer's recommendations for attachment
Insulation at rim joist
Lapped to provide drainage plane continuity; taped for air barrier continuity
Allows fast drying in both directions