Building Enclosures

Dr John Straube
Building Science Corporation
University of Waterloo

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

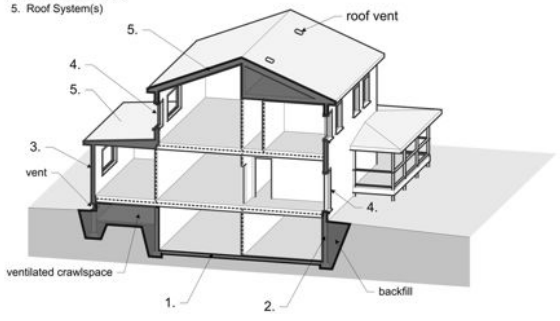
The Enclosure: An Environmental Separator

- 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)

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



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

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…

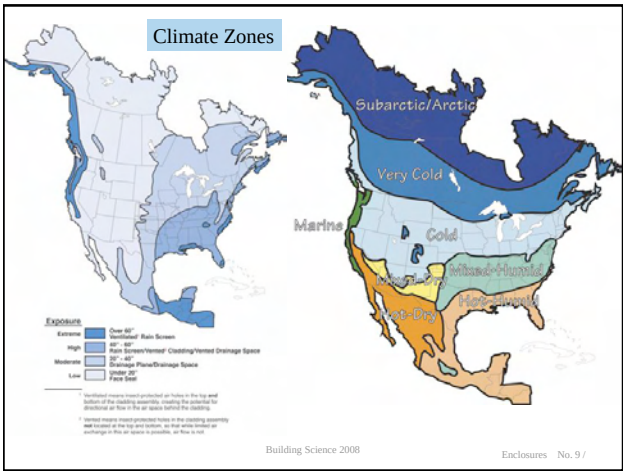
Loads: Climate /

- 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.



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

Mold, Rot, Corrosion, Decay, Recladding

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

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

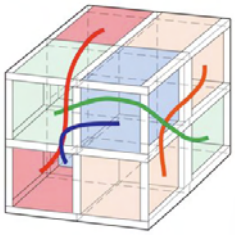
- Moisture= mold growth
- Wood products
  - New growth vs old
  - Processing: plywood, OSB, particle board
  - Paper, Veneers
- Finishes
  - Drywall, ceiling tile

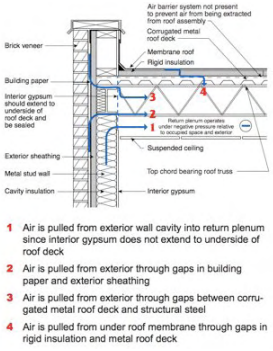
4. Hygric Buffer Capacity

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

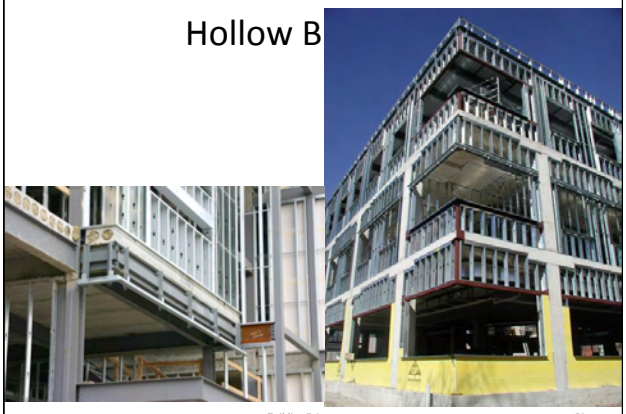
5. Three-D Airflow Networks

- Hollow walls
- Taller buildings





Hollow B



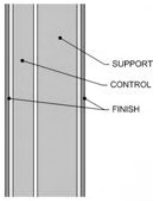
Five Fundamental Changes

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

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

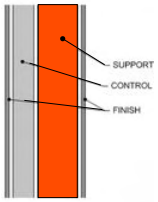
Functional Layers



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

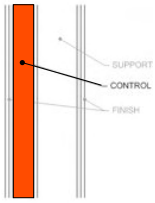
Functional Layers



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

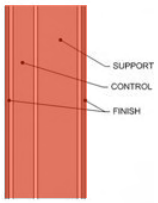
Functional Layers



Other Control . . .

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

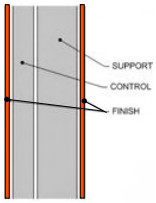
Functional Layers



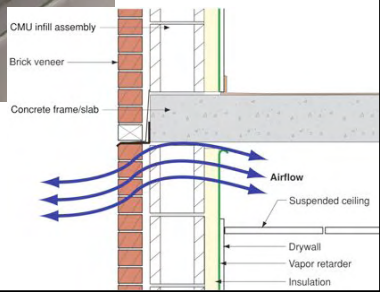
Basic Enclosure Functions

- 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



Finish vs. Control Confusion

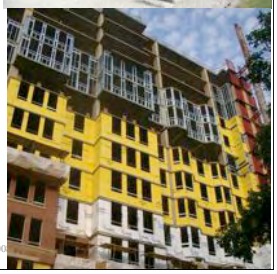


Distribution

- 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 ←

History of Control Functi

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



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

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!

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

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

Continuous Air Barrier

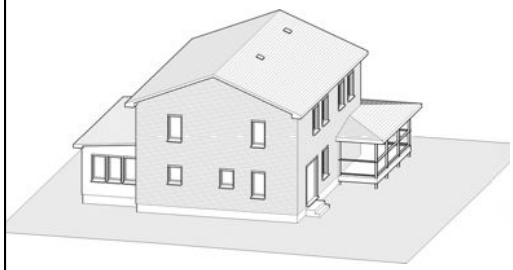
Continuous Insulation

Continuous Rain Control Layers

The Enclosure: Adding the Layers

- Structure
- Air-Rain Barrier
- Insulation
- Finish

Framed Enclosures: Adding the Layers



Structure

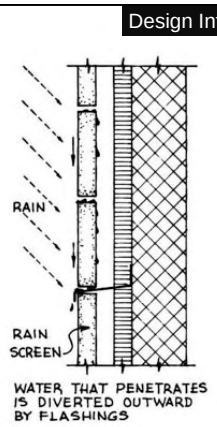
Air Flow Control

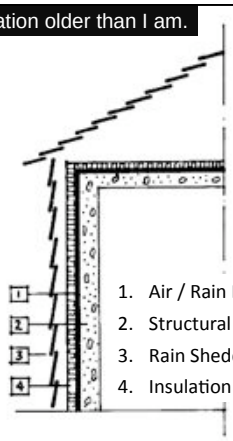
Insulation

Rain Control

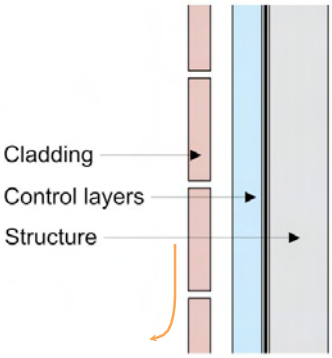
Finish

Design Information older than I am.

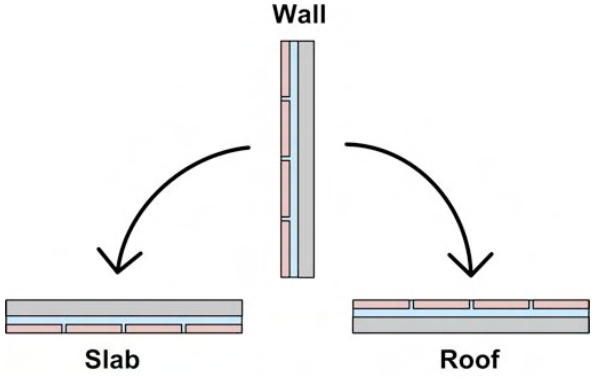


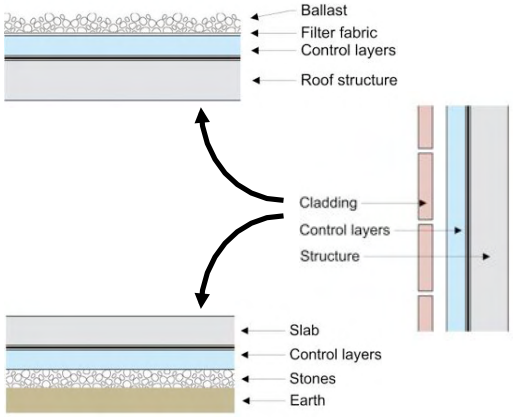


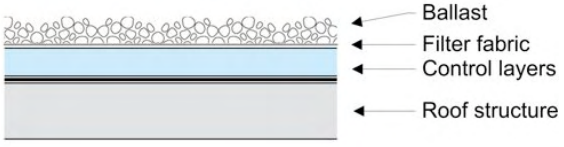
1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation

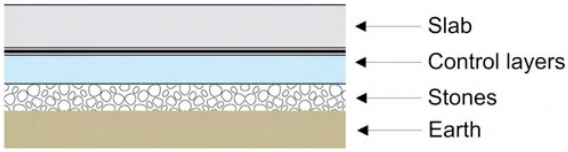


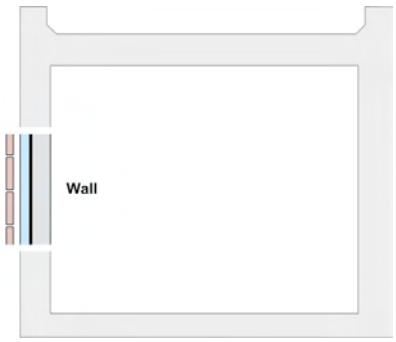
Wall

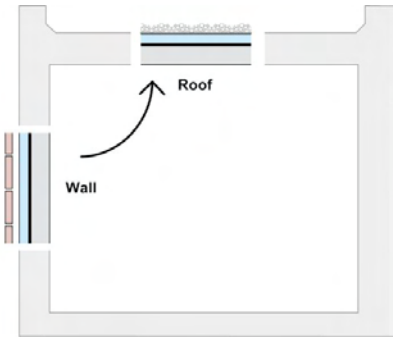


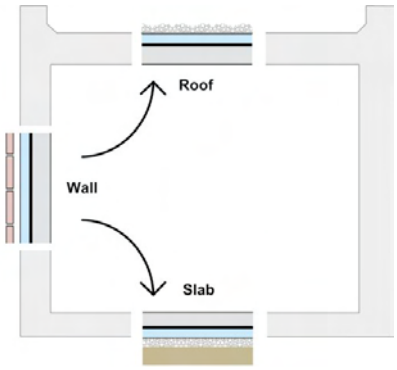


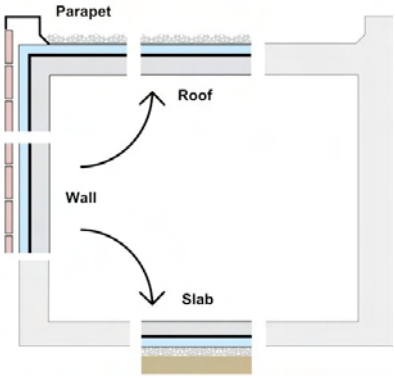


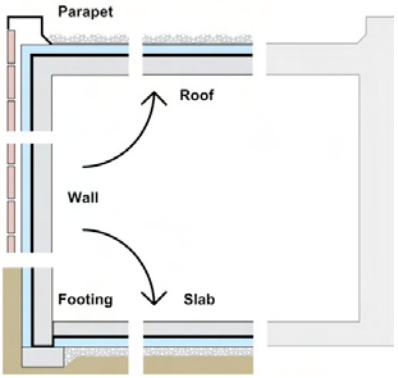


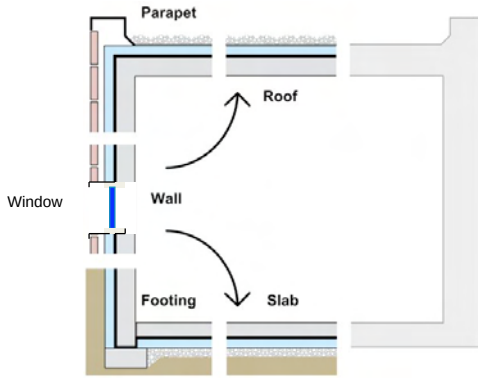

Wall


Roof
Wall

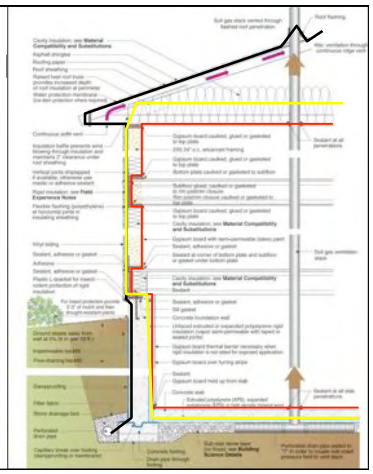

Roof
Wall
Slab


Parapet
Roof
Wall
Slab


Parapet
Roof
Wall
Footing
Slab

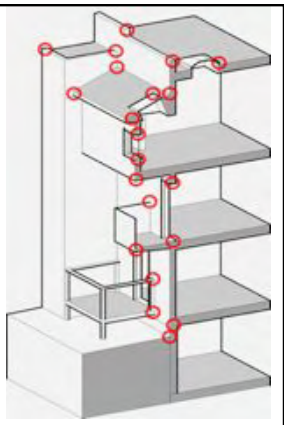


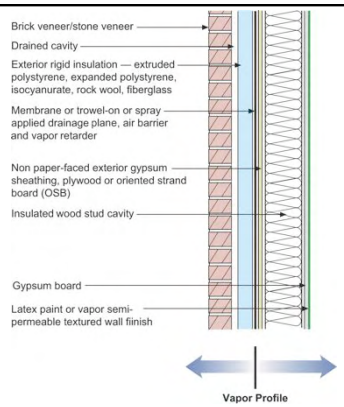
- Rain
- Heat
- Air



Enclosure Design: Details

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



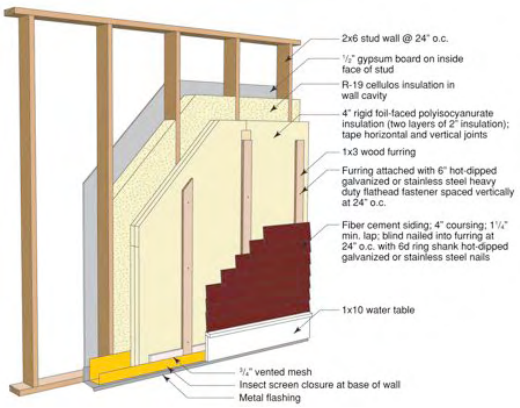


The Wood Frame High R-value wall

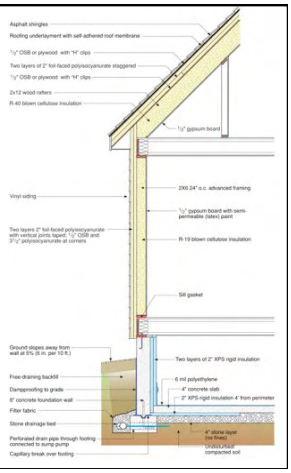
Lowell Habitat for Humanity Bedford, MA
1400 sq. ft. @ $80/sq. ft.

Gas = $50/month @ $1.50 /therm
Electric = $50/month @ $.15/kWh Average = $3.30 per day

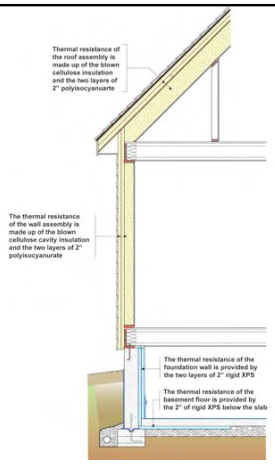
With 4 kW PV and 94 sq. ft. solar hot water $105/sq.ft.
Electric = $0 Gas = $37.50/month Average = $1.25/day



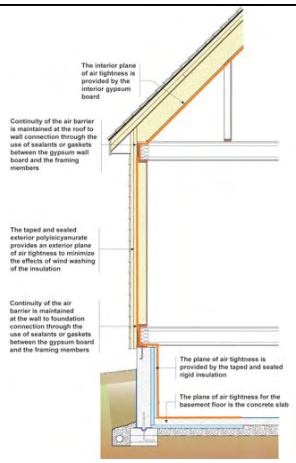
Bedford
Profile with
crawlspace

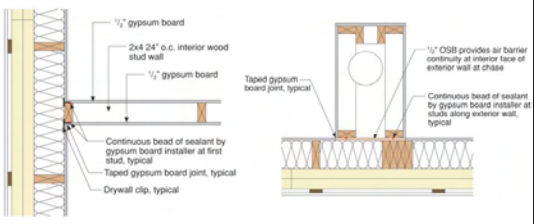


Bedford
Thermal
Insulation
System

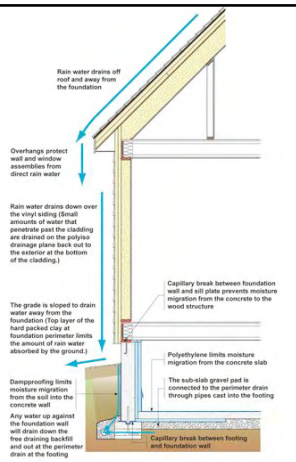


Bedford
Air Flow
Retarder
System

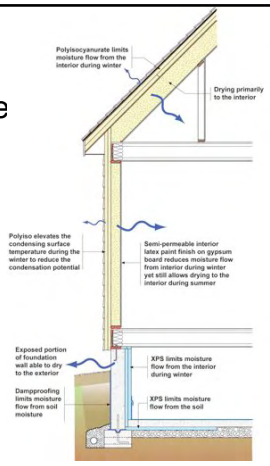




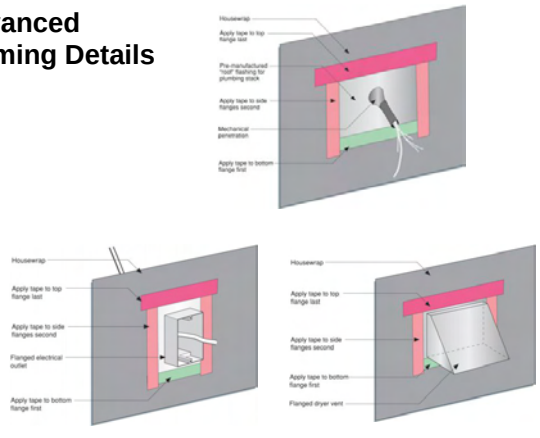
Bedford
Water
Management
System



Bedford
Vapor Retarde
System



Advanced Framing Details



Conclusions