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

Healthy, Durable, Low Energy Buildings:

Fundamentals, techniques, and pitfalls

www.BuildingScience.com

Thermal: High R

Thermal bridges

- Thermal bridges provide shortcut for heat through insulation
- Heat passes through the structural members
- Common offenders
  - Floor and balcony slabs
  - Shear walls
  - Window frames
  - Steel studs

Find the thermal bridge
Building Science 2008
Insulation and Thermal Bridges No. 6/65

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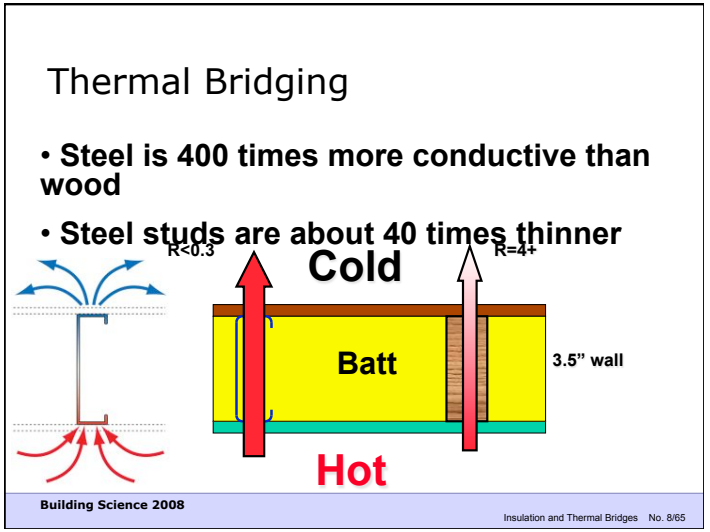
Insulation and Thermal Bridges No. 7/65


Thermal Bridging
• Steel is 400 times more conductive than wood
• Steel studs are about 40 times thinner
R<0.3
Cold
R=4+
Batt
3.5" wall
Hot
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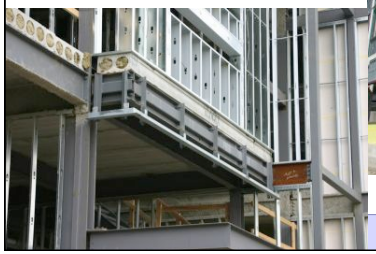
Insulation and Thermal Bridges No. 8/65

Complexity

- Air, thermal continuity



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Adding Insulation Reduces Durability

- Insulating makes in/out face of enclosure cold
  - Gypsum board or OSB in normal walls
- Condensation occurs on cold surface
- Drying occurs slowly when cold
- Ergo... Insulating makes things wetter!
- Air & water vapor moves through fiberglass and cellulose
- Foam stops air and slows vapor

Efficient Enclosures & HVAC

- Airtight buildings require ventilation systems
  - Don't over ventilate. Quality≠Quantity
- Better windows, insulation & lighting
  = Low heat gain
  = dehumidification = less sensible cooling
- Different HVAC systems can now be applied
  - Enthalpy recovery
  - Radiant cooling? DOAS?

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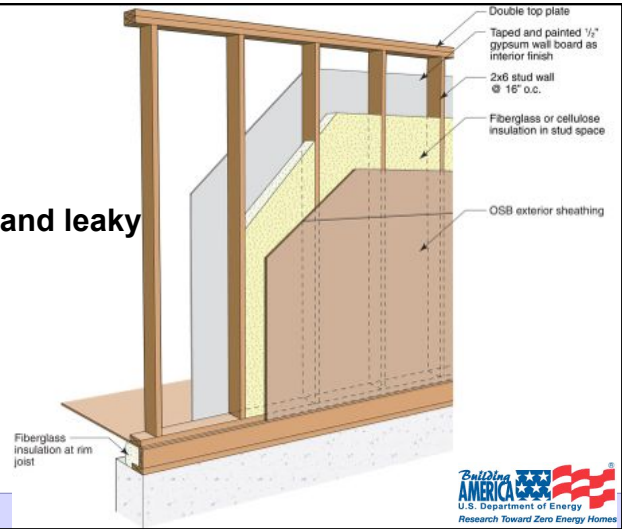
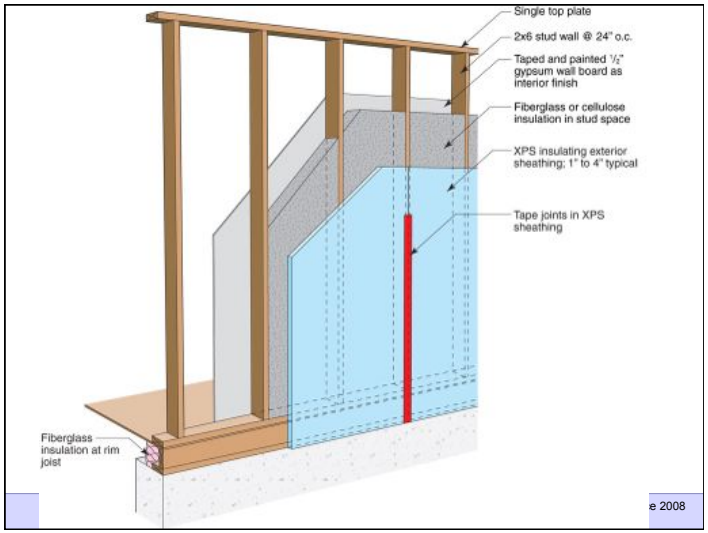
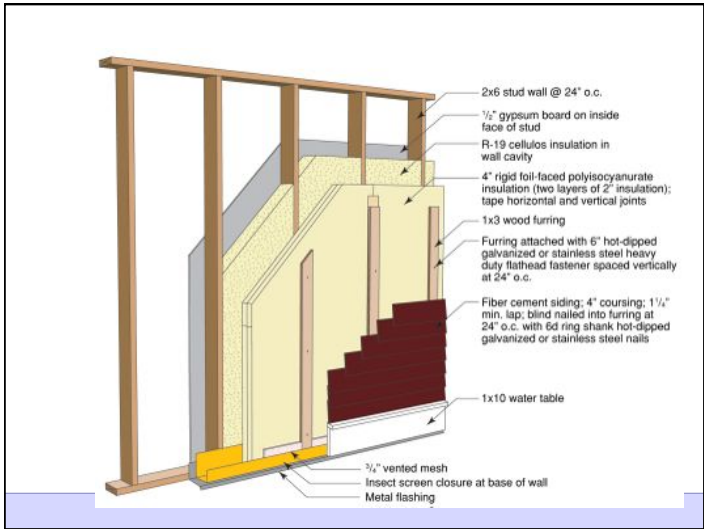
Buildings,Energy, Environment No. 11/84

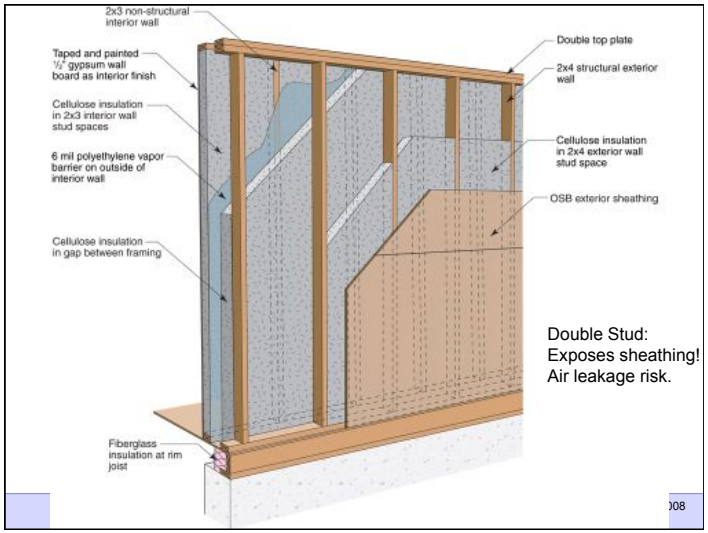
R14 and leaky

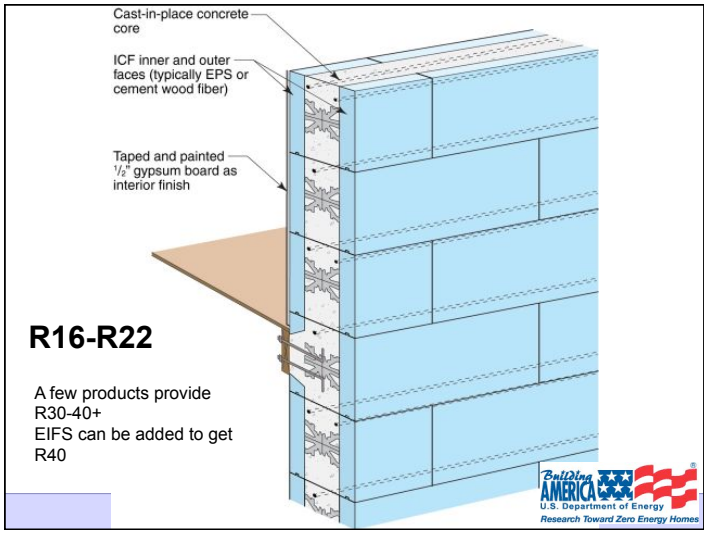



Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Fiberglass or cellulose insulation in stud space
XPS insulating exterior sheathing; 1" to 4" typical
Tape joints in XPS sheathing
Fiberglass insulation at rim joist
e 2008

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity


2x6 stud wall @ 24" o.c.
½" gypsum board on inside face of stud
R-19 cellulos insulation in wall cavity
4" rigid foil-faced polyisocyanurate insulation (two layers of 2" insulation); tape horizontal and vertical joints
1x3 wood furring
Furring attached with 6" hot-dipped galvanized or stainless steel heavy duty flathead fastener spaced vertically at 24" o.c.
Fiber cement siding; 4" coursing; 1¼" min. lap; blind nailed into furring at 24" o.c. with 6d ring shank hot-dipped galvanized or stainless steel nails
1x10 water table
¾" vented mesh
Insect screen closure at base of wall
Metal flashing


2x3 non-structural interior wall
Taped and painted ½" gypsum wall board as interior finish
Cellulose insulation in 2x3 interior wall stud spaces
6 mil polyethylene vapor barrier on outside of interior wall
Cellulose insulation in gap between framing
Fiberglass insulation at rim joist
Double top plate
2x4 structural exterior wall
Cellulose insulation in 2x4 exterior wall stud space
OSB exterior sheathing
Double Stud:
Exposes sheathing!
Air leakage risk.


Cast-in-place concrete core
ICF inner and outer faces (typically EPS or cement wood fiber)
Taped and painted ½" gypsum board as interior finish
R16-R22
A few products provide R30-40+
EIFS can be added to get R40
Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

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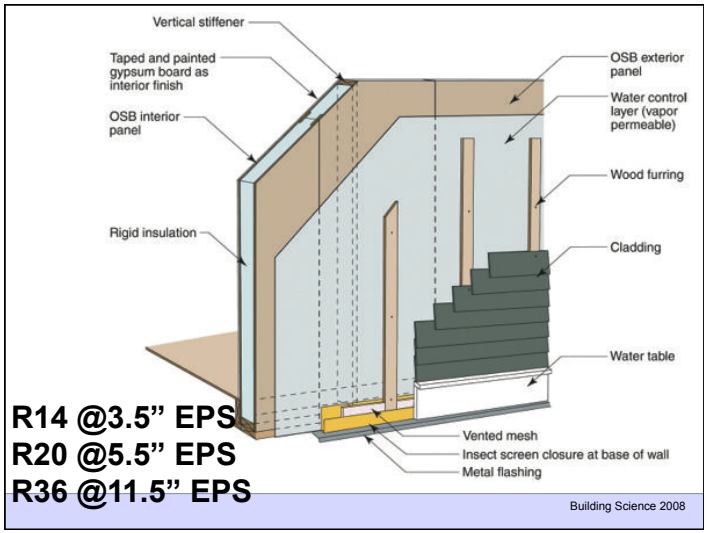

Structural Insulated Panels

- Advantages
  - Superior blanket of insulation
  - if no voids then no convection or windwashing
  - May seal OSB joints for excellent air barrier system
- Therefore, done right = excellent
- Small air leaks at joints in roofs can cause problems
- Don't get them too wet from rain
  - Low perm layers means limited drying

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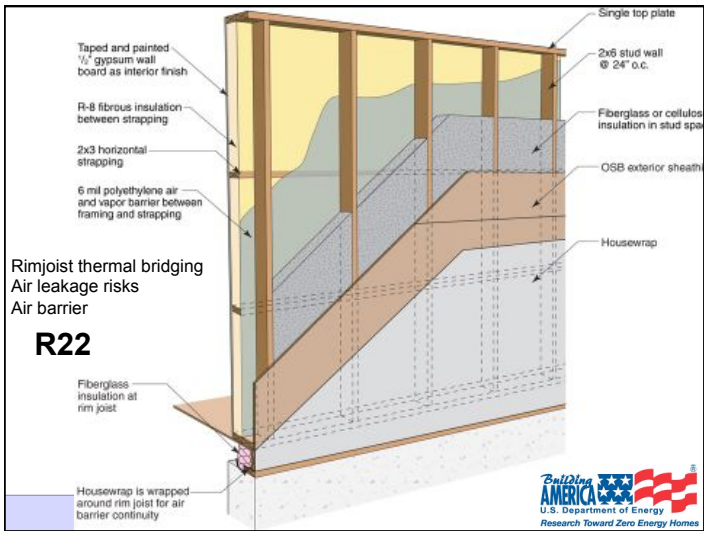

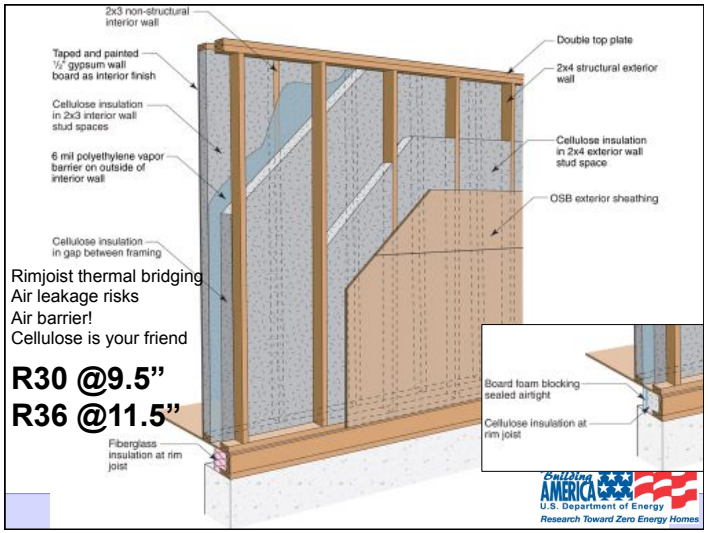
2x3 non-structural interior wall
Taped and painted ½" gypsum wall board as interior finish
Cellulose insulation in 2x3 interior wall stud spaces
6 mil polyethylene vapor barrier on outside of interior wall
Cellulose insulation in gap between framing
Double top plate
2x4 structural exterior wall
Cellulose insulation in 2x4 exterior wall stud space
OSB exterior sheathing
Board foam blocking sealed airtight
Cellulose insulation at rim joist
Fiberglass insulation at rim joist
Rimjoist thermal bridging
Air leakage risks
Air barrier!
Cellulose is your friend
R30 @9.5"
R36 @11.5"
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U.S. Department of Energy
Research Toward Zero Energy Homes

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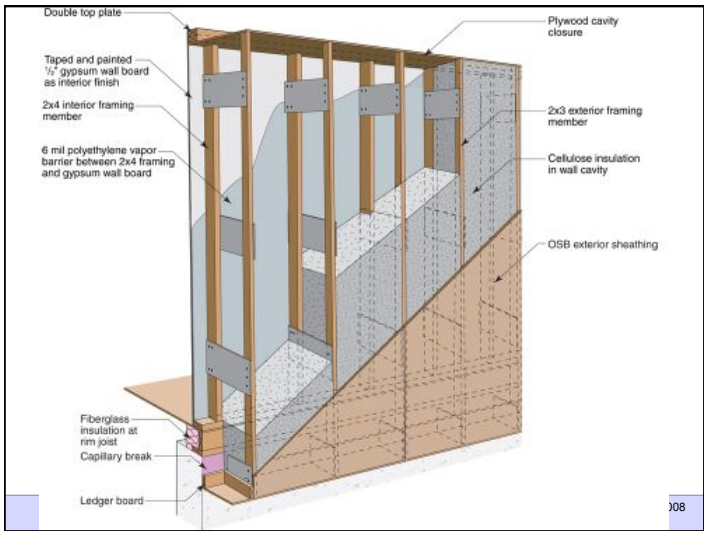
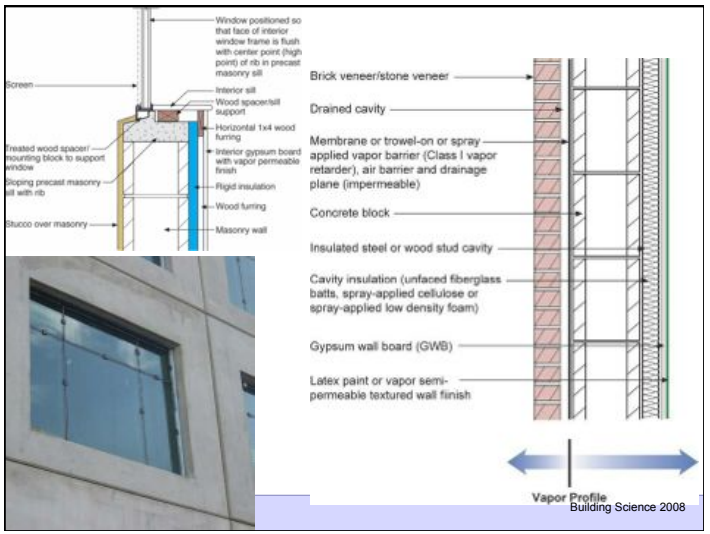

Double top plate
Taped and painted ½" gypsum wall board as interior finish
2x4 interior framing member
6 mil polyethylene vapor barrier between 2x4 framing and gypsum wall board
Plywood cavity closure
2x3 exterior framing member
Cellulose insulation in wall cavity
OSB exterior sheathing
Fiberglass insulation at rim joist
Capillary break
Ledger board


Window positioned so that face of interior window frame is flush with center point (high point) of rib in precast masonry sill
Screen
Interior sill
Wood spacer/sill support
Horizontal 1x4 wood furring
Treated wood spacer/mounting block to support window
Interior gypsum board with vapor permeable finish
Sloping precast masonry sill with rib
Rigid insulation
Wood furring
Stucco over masonry
Masonry wall
Brick veneer/stone veneer
Drained cavity
Membrane or trowel-on or spray applied vapor barrier (Class I vapor retarder), air barrier and drainage plane (impermeable)
Concrete block
Insulated steel or wood stud cavity
Cavity insulation (unfaced fiberglass batts, spray-applied cellulose or spray-applied low density foam)
Gypsum wall board (GWB)
Latex paint or vapor semi-permeable textured wall finish
Vapor Profile
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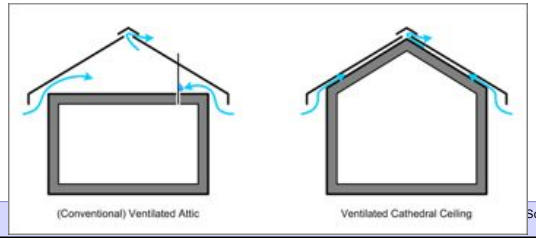
Pitched Roof Types

- Vented Attic
  - Insulation/air barrier at ceiling plane
- Cathedral Ceiling
  - Insulation/air barrier at roof plane



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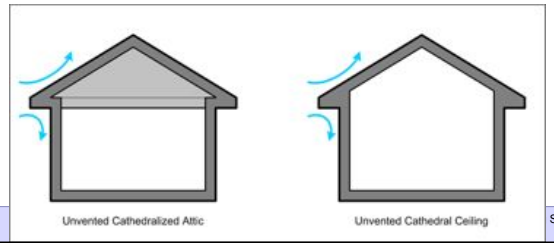
Pitched Roof Types

- Unvented Cathedralized Attic
  - As cathedral but no venting above insulation
- Unvented Cathedral



Science 2008

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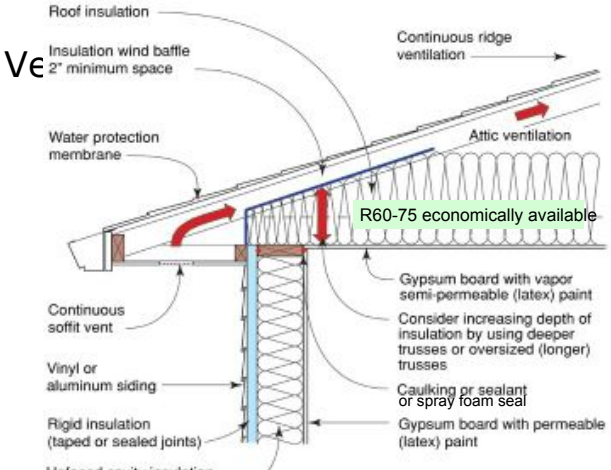

2008

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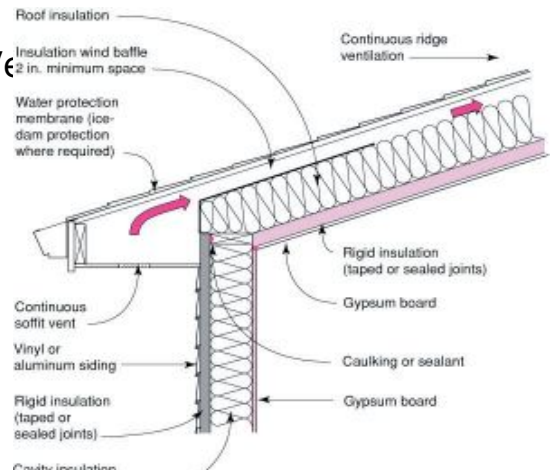

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Unvented Cathedralized Attics

- Move air and insulation control from ceiling plane to roof plane
- Moves HVAC into conditioned space
  - Saves lots of energy, reduce problems with comfort, extends life of equipment
- Avoids wind blown rain, snow, and burning wildfire embers

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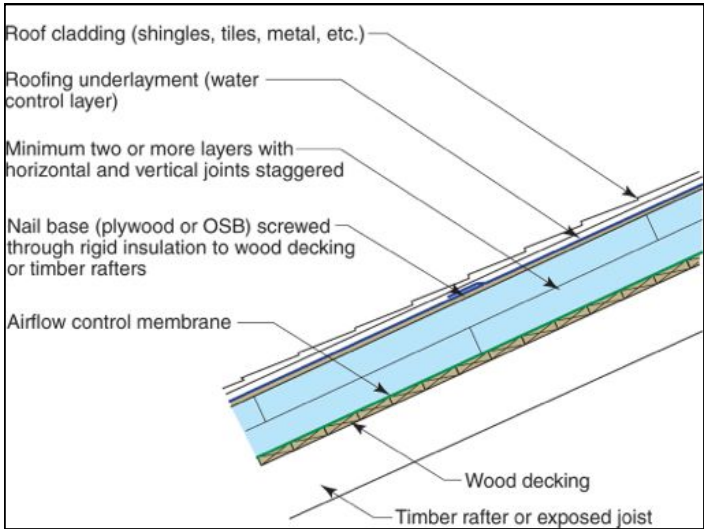
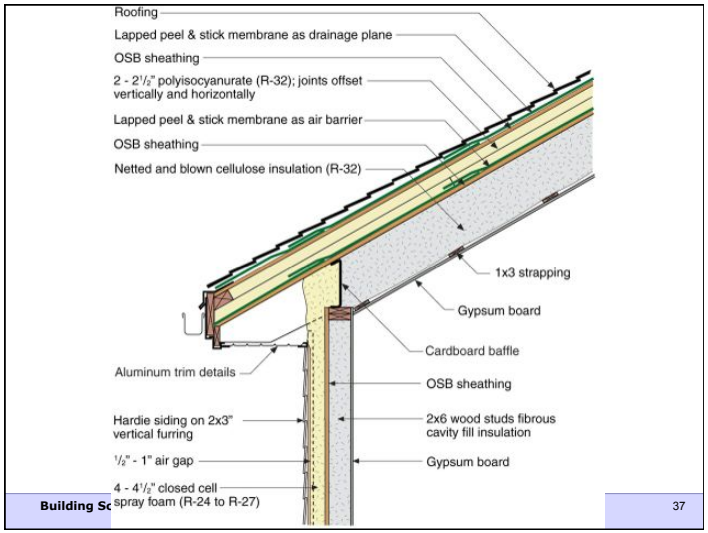
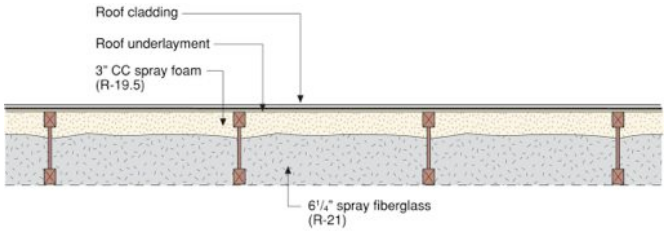




R40+ roof, fire protection



Cold Climate (Zone 5/6) Solution

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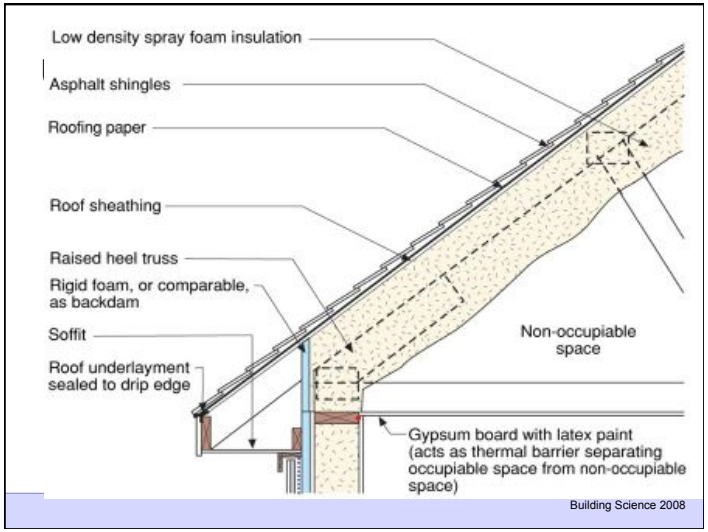

Low-Slope Roofs

- Cover most commercial buildings
- Not flat. Ponding is not acceptable.
- Components
  - Air barrier can be roof membrane
    - Better to install interior
  - Rain barrier is roof membrane
    - Drainage gap is the outdoors
  - Insulation is rigid, usually polyiso

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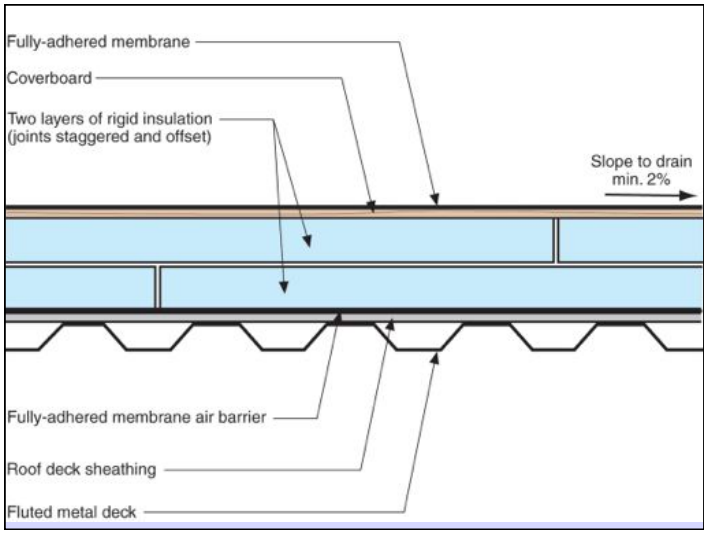
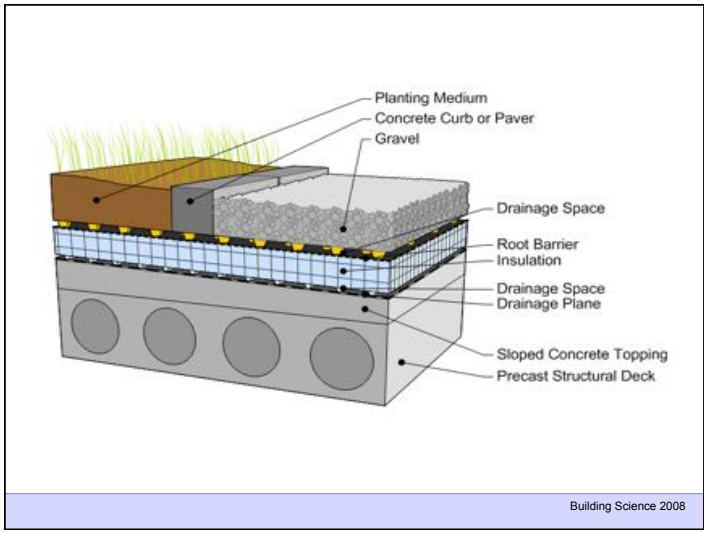

Fully-adhered membrane
Coverboard
Two layers of rigid insulation
(joints staggered and offset)
Slope to drain
min. 2%
Fully-adhered membrane air barrier
Roof deck sheathing
Fluted metal deck


Planting Medium
Concrete Curb or Paver
Gravel
Drainage Space
Root Barrier
Insulation
Drainage Space
Drainage Plane
Sloped Concrete Topping
Precast Structural Deck
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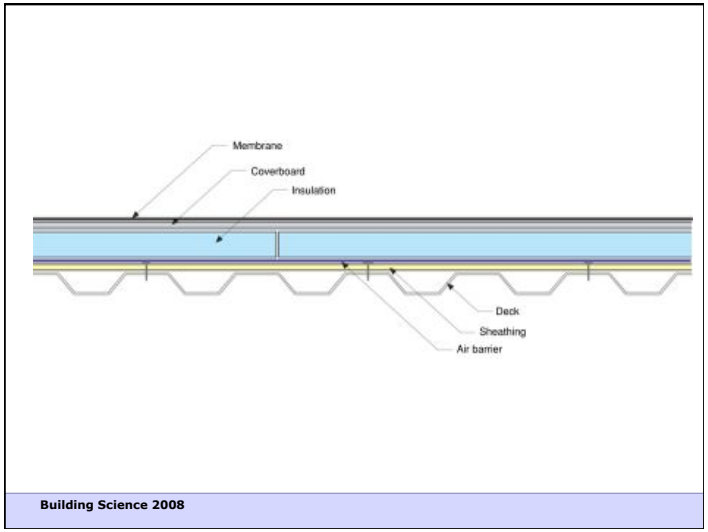
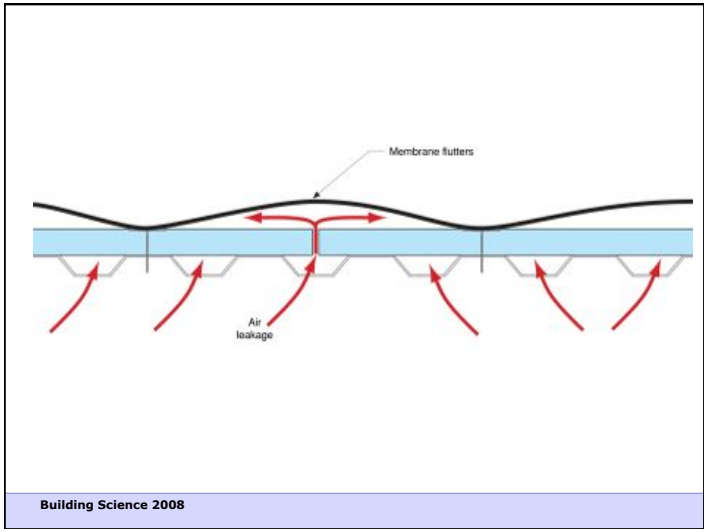

Membrane
Coverboard
Insulation
Deck
Sheathing
Air barrier
Building Science 2008


Membrane flutters
Air
leakage
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Pitched Roofs

- Same physics
- Roof membrane sees less “rain load” and no pooling
  - Hence membranes last longer or can be lower performance

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Basements

- Less extreme temperatures
- But soil is always wet
- Soil has huge thermal mass

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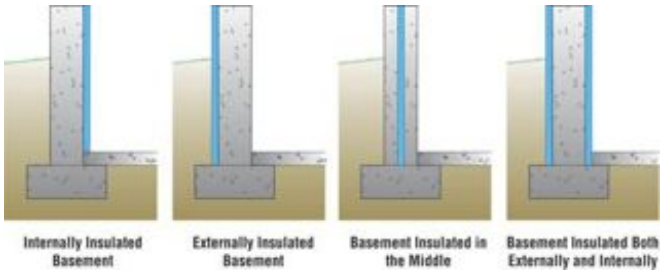
Insulation Location Choices

- Builders like to insulate the interior



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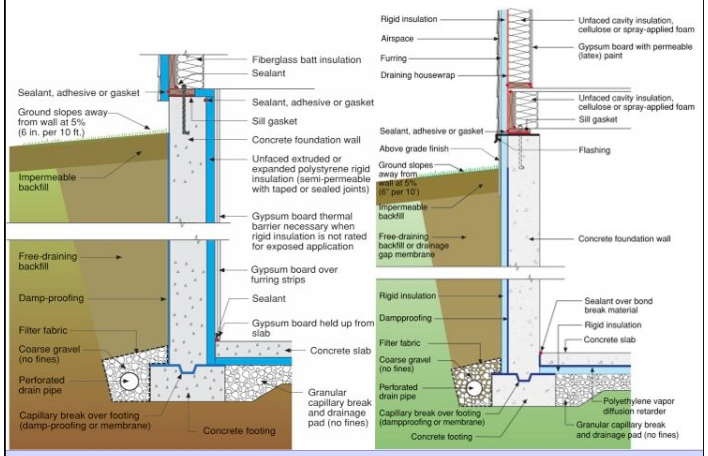

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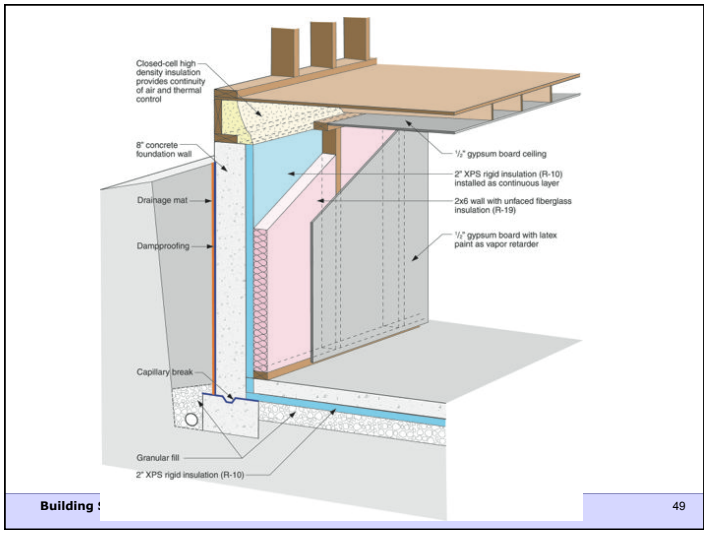
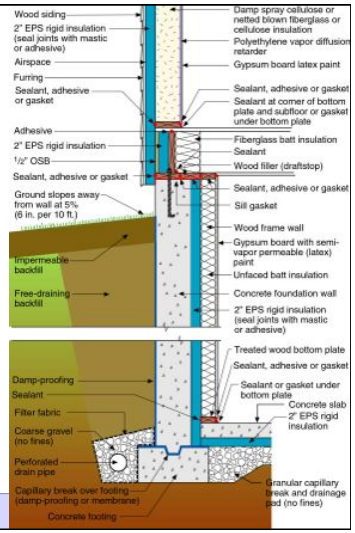
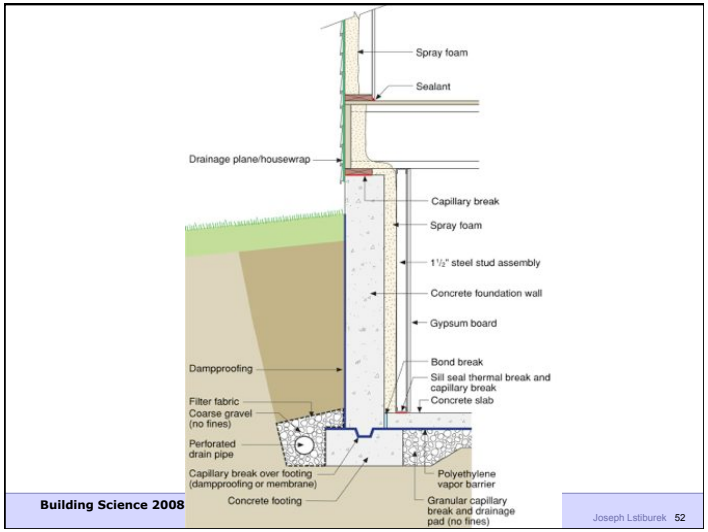


Hybrid

- Add layer of:
  - foam or
  - spray foam

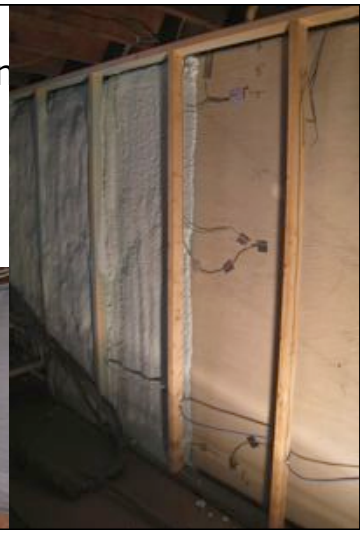
To allow inward drying
• prefer about 1 perm





Spray foam baser

- Open cell
  - Climate specific
- Closed cell



Insulated Concrete Forms (ICF)

- If you afford it, use them –
  - cap break,
  - insulation,
  - vapor retarder,
  - above grade

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Foundations and Basements No. 54/74