Building Science

Adventures In Building Science

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What is a Building?
A Building is an Environmental Separator
- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and rigidity
- Be durable
- Be aesthetically pleasing
- Be economical
Arrhenius Equation
For Every 10 Degree K Rise Activation Energy Doubles

\[ k = A e^{-E_a/(RT)} \]
Damage Functions
Water
Heat
Ultra-violet Radiation
2nd Law of Thermodynamics
Heat Flow Is From Warm To Cold
Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less
Air Flow Is From A Higher Pressure to a Lower Pressure
Gravity Acts Down
Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer
Cladding

Control layers

Structure
Control layer

Control layer

Roof structure
Wall
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

Concrete block

Metal channel or wood furring

Gypsum board

Latex paint or vapor semi-permeable textured wall finish

Vapor Profile
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)

Uninsulated steel stud cavity

Gypsum board

Latex paint or vapor semi-permeable textured wall finish

Vapor Profile
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 steel or wood stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall finish

Vapor Profile
Brick veneer/stone veneer

Drained and vented cavity

Thermal control layer - exterior rigid insulation - rock wool or fiberglass

Membrane or trowel-on or spray applied or liquid applied water control layer and air control layer

Concrete block

Metal channel or wood furring

Gypsum board

Latex paint or vapor semi-permeable textured wall finish

Figure 2a

Vapor Profile
Figure 2b

Vapor Profile

- Brick veneer/stone veneer
- Drained and vented cavity
- Thermal control layer - exterior rigid insulation - rock wool or fiberglass
- Membrane or trowel-on or spray applied or liquid applied water control layer and air control layer
- Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
- Uninsulated steel stud cavity
- Gypsum board
- Latex paint or vapor semi-permeable textured wall finish
Figure 2c

Vapor Profile

- Brick veneer/stone veneer
- Drained and vented cavity
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- Membrane or trowel-on or spray applied or liquid applied water control layer and air control layer
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- Insulated wood stud cavity
- Gypsum board
- Latex paint or vapor semi-permeable textured wall finish
Commercial Enclosure: Simple Layers

- Structure
- Rain/Air/Vapor
- Insulation
- Finish
Hydrostatic pressure

Hydrostatic pressure
Pascals  mph

- 50 Pa = 20 mph
- 100 Pa = 30 mph
- 150 Pa = 35 mph
- 250 Pa = 45 mph
- 500 Pa = 65 mph
- 1,000 Pa = 90 mph

Wind Speed (mph) vs. Stagnation Pressure (Pa)
Air Leakage
Supply air into occupied zone returns to AHU by passing through deliberately porous dropped ceiling or through return grilles installed in dropped ceiling.

Air handling unit extracts air from dropped ceiling, conditions it and injects it into the occupied zones via supply ductwork.

Dropped ceiling depressurized by air handling units extracting air from dropped ceiling.
- Parapet flashing
- Fully-adhered water control membrane
- Tapered rigid insulation
- Air control layer transition membrane
- Fiberglass batt insulation
- Water, air and vapor control membrane; preferably fully-adhered
- Peel and stick transition membrane; air and water control
- Cant
- Wood blocking
- Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
- Fully adhered roof membrane
- Two (2) layers insulation; joints staggered horizontally and vertically
- Metal deck
- Air control membrane
- Light gauge steel framing (installed slightly proud of I-beam)
- Backer rod fills gap
- Peel and stick transition membrane; air and water control
- Water, air and vapor control membrane; preferably fully-adhered
- Open web steel joist
- Deflection track allows space for sheathing to move
Parapet flashing

Fully-adhered water control membrane

Tapered rigid insulation

Air control layer transition membrane

Fiberglass batt insulation

Water, air and vapor control membrane; preferably fully-adhered

Peel and stick transition membrane; air and water control

Cant

Wood blocking

Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet

Fully adhered roof membrane

Two (2) layers insulation; joints staggered horizontally and vertically

Metal deck

Air control membrane

Light gauge steel framing (installed slightly proud of I-beam)

Backer rod fills gap

Open web steel joist

Deflection track allows space for sheathing to move

Water, air and vapor control membrane; preferably fully-adhered
Building Science Corporation

Joseph Lstiburek 106
Cant
Engineered wood blocking
Fully adhered roof membrane
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Two (2) layers insulation; joints staggered horizontally and vertically
Peel and stick transition membrane; air and water control
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Fully-adhered water, air and vapor control membrane
Light gauge steel framing (installed slightly proud of I-beam)
Deflection track allows space for sheathing to move
Metal deck
Air control membrane
Open web steel joist
Cant

Fully adhered roof membrane
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet

Two (2) layers insulation; joints staggered horizontally and vertically

Peel and stick transition membrane; air and water control

Fiberglass batt insulation

Backer rod fills gap

Peel and stick transition membrane; air and water control

Fully-adhered water, air and vapor control membrane

Light gauge steel framing (installed slightly proud of I-beam)

Deflection track allows space for sheathing to move

Metal deck
Air control membrane

Open web steel joist
Houses With Vented Attics Suck
Houses With Vented Attics Suck
Not all the Time.....but......
Outside

0°F

Dewpoint
(50% RH, 70°F)

70°F

Location of condensation and frost

Exterior sheathing

Inside
Simple linearized energy-temperature relation for water
From Straube & Burnett, 2005
The inside face of the exterior sheathing is the condensing surface of interest.

Wood-based siding
Building paper
Exterior sheathing
R-19 cavity insulation in wood frame wall
Gypsum board with any paint or wall covering

The graph shows the mean monthly outdoor temperature and the dew point temperature at different relative humidities (R.H.) for each month. The potential for condensation is indicated by the shaded area below the dew point curve.
The inside face of the insulating sheathing is the condensing surface of interest.

- Wood-based siding
- R-7.5 rigid insulation
- R-13 cavity insulation in wood frame wall
- Gypsum board with any paint or wall covering

Graph showing:
- Insulation/sheathing interface temperature (R-7.5 sheathing, R-13 cavity insulation as shown in adjacent drawing)
- Mean monthly outdoor temperature
- Potential for condensation
- Dew point temp. at 35% R.H., 70°F
Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.
Shingles
Roofing paper
R-19 batt insulation installed with wire stays or twine or netted cellulose
R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)
\(\frac{3}{8}\)" sheathing over rigid insulation
Roof sheathing
Sealant
Rigid insulation notched around roof trusses and sealed
Vinyl or aluminum siding
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint
Underside of roof sheathing is typically the “first” condensing surface
Building paper drainage plane
The inside face of the roof sheathing forming the cavity is the first condensing surface.

OSB or plywood nail base for shingles

R-30 unfaced batt ceiling insulation compressed to fit within 2x8 rafters or damp spray cellulose or "netted" dry blown cellulose or fiberglass

R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)

Rigid insulation notched around roof rafters and sealed

Vinyl or aluminum siding

Rigid insulation (taped, shiplapped or sealed joints)

Unfaced batt insulation

OSB or plywood roof sheathing

Gypsum board ceiling with semi-vapor permeable (latex) paint

Caulking or sealant

Gypsum board with semi-vapor permeable (latex) paint

Sealant
Roofing tile

Roofing paper

Netted cellulose insulation or batt insulation installed with wire stays or twine

Roof sheathing

Underside of roof sheathing is typically the “first” condensing surface

Stucco

Unfaced batt insulation

Rigid insulation

Gypsum board with vapor semi-permeable (latex) paint

Building paper drainage plane
18" wide membrane strip under parapet folded down over exterior rigid insulation
Coping wedge
OSB
Rubber roofing membrane
Rigid insulation
Air barrier membrane (membrane roofing in very cold and cold climates; house-wraps, building paper in all other climates)

Metal cap
OSB sheathing
Scupper
Sealant
Rigid insulation
OSB
Cavity insulation
Sealant
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane

Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Cavity insulation
Metal cap
18" wide membrane strip under parapet folded down over exterior OSB
Coping wedge
OSB
Rubber roofing membrane
OSB sheathing
Scupper
Two layers OSB
High density spray foam insulation
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
Gypsum board with semi-permeable (latex) paint
Cavity insulation
Sealant, adhesive or gasket at top plate
Caulking or sealant
Cavity insulation
1" HD spray foam

2x6 top chord

OSB/plywood sheathing

Drainage plane

Spray fibreglass; 8" nominal

Gypsum board

2x6 frame wall

4 1/2" cellulose or spray fibreglass

1" HD spray foam
Low density spray foam insulation

Asphalt shingles

Roofing paper

Roof sheathing

Raised heel truss
Rigid foam, or comparable, as backdam

Soffit
Roof underlayment sealed to drip edge

Non-occupiable space

Gypsum board with latex paint (acts as thermal barrier separating occupiable space from non-occupiable space)
Map of DOE's Proposed Climate Zones

- Marine (C)
- Dry (B)
- Moist (A)

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands.

March 24, 2003
Conditioned Attics Not Unvented Attics
Step 1
- Remove strip of OSB from each side of ridge

Step 2
- Create air seal with strip of vapor open membrane (tape seams)
- Vapor open membrane sheet sealed to OSB with acrylic caulk sealant
- Hold vapor open membrane sheet in place with metal strapping

Step 3
- Construct wood ridge vent with 2x2 furring
Continuous exterior insulation
Cladding
Rodent protection for continuous rigid insulation

For insect protection provide 3'-0" of mulch and then drought-resistant plants

Ground slopes away from wall at 5% (6 in. per 10 ft.)

Dampproofing

Granular capillary break and drainage pad (no fines)
Rigid insulation as bond break material
Concrete foundation wall
Concrete footing below frost depth
Capillary break
Continuous exterior insulation

Cladding

Rodent protection for continuous rigid insulation

For insect protection provide 3'-0" of mulch and then drought-resistant plants

Ground slopes away from wall at 5% (6 in. per 10 ft.)

Dampproofing

Concrete foundation wall

Cavity insulation

Gypsum board

Sealant, adhesive or gasket

Sill gasket

Mastic membrane strip

Polyethylene

Concrete slab

Geotextile (filter fabric)

Granular capillary break and drainage pad (no fines)

Rigid insulation as bond break material

Concrete footing below frost depth

Capillary break
Continuous exterior insulation

Cladding

Rodent protection for continuous rigid insulation

Cellular PVC protection board

For insect protection provide 3'-0" of mulch and then drought-resistant plants

Ground slopes away from wall at 5% (6 in. per 10 ft.)

Rigid insulation

Cavity insulation

Gypsum board

Flashing set in mastic sealed to slab

Sealant, adhesive or gasket

Sill gasket

4" concrete slab

4" granular capillary break and drainage pad (no fines)

Concrete grade beam

Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break
Continuous exterior insulation
Cladding
Rodent protection for continuous rigid insulation
Cellular PVC protection board

For insect protection provide 3'-0" of mulch and then drought-resistant plants

Ground slopes away from wall at 5% (6 in. per 10 ft.)
Dampproofing
Rigid insulation

4" concrete slab
4" granular capillary break and drainage pad (no fines)
Concrete grade beam
Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break
Building wrap
Sealant, adhesive or gasket (typ.)
2x4 Capillary break
Rodent protection for continuous rigid insulation

For insect protection provide 3'-0" of mulch and then drought-resistant plants

Ground slopes away from wall at 5% (6 in. per 10 ft.)

T&G subfloor
1½” rigid insulation
Plate under load bearing walls only

Polyethylene
Building wrap

Sealant, adhesive or gasket (typ.)

2x4 Capillary break

Rodent protection for continuous rigid insulation

For insect protection provide 3'-0" of mulch and then drought-resistant plants

Polyethylene

T&G subfloor

1½" rigid insulation

Plate under load bearing walls only

Ground slopes away from wall at 5% (6 in. per 10 ft.)
For insect protection provide 3'-0" of mulch and then drought-resistant plants.

Ground slopes away from wall at 5% (6 in. per 10 ft.).
For insect protection provide 3'-0" of mulch and then drought-resistant plants.

Ground slopes away from wall at 5% (6 in. per 10 ft.)
Rockwool

1x3 furring @ 24” o.c.
#10 screws @ 16” o.c. vertically
Result: 20 psf cladding weight with < 2/100” deflection
Second layer of z-bars should be installed perpendicular to the first layer; orientation of the two layers will depend on the requirements of the cladding attachment system.

First layer of z-bars embedded in the insulation layer; should the first layer be installed horizontally, the exterior leg should be turned down to promote drainage to the exterior.