Expansion of Conditioned Space

- Conditioned space boundaries moving towards exterior surfaces of building
- Garage isolated from house by air barrier/pressure boundary
- Garage ventilated and conditioned independently of rest of conditioned spaces
Mechanisms of Flow

• Liquid Gravitational Hydrostatic Pressure
  Capillary Suction Pressure
  Osmosis Solute Concentration

• Vapor Diffusion Vapor Pressure
  Convective Air Pressure
Roof overhang screens wall (deflects rain)

Site grading slopes ground away from building over entire perimeter
- Keep rain water away from the foundation perimeter
- Do not place sand layer over polyethylene vapor diffusion retarder under concrete slab
- Where vinyl flooring is installed over slabs, a low water-to-cement (w/c) ratio (≤ 0.45 or less is recommended) to reduce water content in the concrete; alternatively, the slab should be allowed to dry (less than 0.3 grams/24 hrs/ft²) prior to flooring installation
Rain water falling on roof is collected in gutters

Overhang protects the ground around the foundation from getting saturated

Flash roof into gutter

Down spouts carry rainwater from the roof away from the foundation

Capillary break under plate

Ground slopes away from the foundation

Conditioned space

Polyethylene ground cover acting as both an air barrier and a vapor barrier

Interior grade of crawlspace higher than surrounding grade

- Keep rain water away from the foundation perimeter
- If the interior crawlspace is lower than the exterior grade, a sub-grade perimeter footing drain is necessary as in a basement foundation
- The crawlspace is conditioned space; it is part of the "interior" of the building and should be heated, cooled and ventilated as part of the building’s heating, cooling and ventilating strategy
Rain water falling on roof is collected in gutters.

Overhang protects the ground around the foundation from getting saturated.

Flash roof into gutter.

Down spouts carry rainwater from the roof away from the foundation.

Ground slopes away from the foundation.

Concrete foundation wall.

Groundwater flow is downward (not horizontal) under the influence of gravity to the perimeter drainage system.

Impermeable top layer of backfill (clay cap) prevents ground adjacent to foundation from getting saturated.

Free-draining backfill (or drainage board).

Filter fabric above and below drain pipe.

Coarse gravel (no fines).

Perforated drain pipe located below floor slab level (piped to sump or daylight).

Pipe connection through footing connects exterior perimeter drain to granular drainage pad under basement slab.

- Keep rainwater away from the foundation perimeter.
- Drain groundwater away in sub-grade perimeter footing drains before it gets to the foundation wall.
Roof flashing
Vent stack
Sealant at all slab penetrations
Concrete slab
Polyethylene vapor barrier
Granular drainage pad (no fines)
Perforated drain pipe added to "T" in order to couple sub-slab pressure field to vent stack
Roof flashing

Vent stack

Polyethylene vapor barrier

Sealant at all penetrations in air barrier

Concrete slab

Perforated drain pipe added to "T" in order to couple sub-slab pressure field to vent stack
Concrete Porch Slab with Housewrap

- Exterior sheathing
- Housewrap, WRB or building paper
- Waterproof membrane
- Sealant
- Tar paper as bond break
- Concrete porch
- Treated mudsill
- Band joist
- Subfloor
- Wood stud wall
- Foundation wall
- 4” stone pad (no fines)
- Undisturbed/compacted earth
Concrete Porch Slab with Insulating Sheathing

- Wood stud wall
- Subfloor
- Band joist
- Treated mudsill
- Foundation wall
- Exterior finish
- 1” insulating sheathing
- Waterproof membrane
- Tar paper as bond break
- Sealant
- Concrete porch
- 4” stone pad (no fines)
- Undisturbed/compacted earth
Control joint at steps in foundation wall
Control joints at corners
Control joints are sealed with flexible sealant at the exterior prior to backfilling
Control joints at window openings

Sealant
Sealant

Diagonally cut 2 x 2's in forms provide goose neck joint
Saw cut joint
Garage foundation
(Isolated from basement
foundation for frost
heave protection)

Bond break material

Perimeter drain pipe around
exterior of garage foundation

See Figure 4.4
Isolation joint
between garage foundation and
basement foundation

The diamond shaped joints may
be omitted if column footings are below
floor level and the column is wrapped
with two layers of sheathing membrane
or joint filler to break the bond

Concrete foundation wall
control joints

Slab control joints

Exterior insulation can act as garage
corner joint isolation joint

Column isolation joints

Column

Sump (airtight cover)

Bond break between slab
and foundation wall at slab
perimeter

Through footing pipes
connect granular drainage
pad under slab to
perimeter drain pipe

Perimeter drain pipe connected
to sump
Internally Insulated Basement

Externally Insulated Basement

Basement Insulated in the Middle

Basement Insulated Both Externally and Internally
Structure of house on foundation must be shifted outward to compensate for thickness of exterior insulation.

Protection layer/system
Calculating capillary rise

\[ h = \frac{2 \sigma \cos \theta}{g \rho r} \]

\[ P_{\text{cap}} \]

\[ 2r \]

\[ P_0 \]

\[ \Delta z \]

\[ \frac{2 \sigma \cos \theta}{r} \]

ambient pressure

Pressure

\[ g \rho \Delta z \]
Capillary rise versus diameter
Capillary Flow

Siding laps
Continuous fillet bead of urethane sealant between 2” XPS bond break and foundation wall
Continuous fillet bead of urethane sealant between 2” XPS bond break and concrete slab
2” XPS bond break
4” concrete slab with welded wire mesh placed at mid-depth
6 mil polyethylene vapor barrier
2” XPS rigid foam slab insulation
Embedded hydronic tubing

Free-draining backfill
Liquid-applied capillary break (must dry tack-free) applied on top of footing prior to placing/casting concrete foundation wall
Keyway
Filter fabric placed under perimeter drain and wrapped around gravel
Coarse gravel (no fines)
4” PVC pipe through bottom of footing connecting interior and exterior gravel beds
4” perforated perimeter drain

4” gravel pad (no fines)
Filter fabric
Undisturbed native soil or engineered fill as determined by soil conditions
Continuous concrete footing 2’-0” wide and 10’ deep
Sealant, adhesive or gasket (typ.)

$\frac{3}{8}''$ fibercement

Drainage plane

Sill gasket (capillary break)
Vapor semi-permeable assembly allows moisture to pass in a slow, controlled manner.

- Plywood subfloor
- Top-side epoxy coating
- Extruded polystyrene; unfaced, no polypropylene or foil facing
- 1x4 furring (16" o.c.)
- Concrete slab
Vapor pressure on top of slab and under slab equalizes, thereby stopping capillary transfer of water and soluble mineral salts (moisture content in airspace and under slab remains the same; i.e. "wet")

Damp ground
(no capillary break, no polyethylene ground cover)

Existing slab

Dimpled plastic sheet membrane
(air tight and gas tight)

Air space

Rigid insulation (extruded polystyrene — unfaced, no polypropylene or foil facers)

3/4" plywood (T&G — narrow edges "biscuit" joined)

Carpet or wood floor (avoid vinyl flooring as vinyl flooring does not breathe)
Rigid extruded polystyrene
Polymer based (PB) stucco
Plastic L-bracket for insect/rodent protection of rigid insulation
Weep screed/capillary break/termite shield for stucco rendering over polyethylene

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.)

Granular capillary break and drainage pad (no fines)
Rigid insulation as bond break material
Concrete foundation wall
Concrete footing below frost depth
Latex paint (vapor permeable, but water repellent)

Polyethylene "skirt" attached to form; remains in place after form is removed

Capillary break (polyethylene strip) extending under grade beam and upwards to grade
Plain
Scratch Back
Hollow or Scratch Back
Continuous exterior insulation

Cladding

Rodent protection for continuous rigid insulation

Cavity insulation

Gypsum board

Sealant, adhesive or gasket

Sill gasket

Masticed membrane strip

Polyethylene

Concrete slab

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

Cavity insulation

Gypsum board

Sealant, adhesive or gasket

Sill gasket

Masticed membrane strip

Polyethylene

Concrete slab

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
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

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
Building wrap
Sealant, adhesive or gasket (typ.)
2×4
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
1 1/2″ 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

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

T&G subfloor
1 1/2" rigid insulation
Plate under load bearing walls only

Polyethylene
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.).

Building wrap
Sealant, adhesive or gasket (typ.)
2x4
Capillary break

T&G subfloor
1 1/2" rigid insulation
Plate under load bearing walls only

Polyethylene
Building wrap

Sealant, adhesive or gasket (typ.)

2x4

Capillary break

T&G subfloor

1 1/2” rigid insulation

Plate under load bearing walls only

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.)
From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.
Frost Line
Capillarity + Salt = Osmosis

- Mineral salts carried in solution by capillary water
- When water evaporates from a surface the salts left behind form crystals in process called efflorescence
- When water evaporated beneath a surface the salts crystallize within the pore structure of the material in called sub-efflorescence
- The salt crystallization causes expansive forces that can exceed the cohesive strength of the material leading to spalling
1. **Evaporation**

   Water with salt in solution travels in porous material via capillary flow to surface where evaporation occurs.

2. **Salt is left behind as water evaporates; process leads to an ever-increasing concentration of salt as evaporation continues.**

3. **Water rushes to dilute concentration of salt leading to potentially huge hydrostatic pressures.**

4. **“Spalling”**

   Surface breaks apart and flakes when hydrostatic pressure due to "osmosis" exceeds cohesive strength of material.
Diffusion + Capillarity + Osmosis = Problem

- Diffusion Vapor Pressure: 3 to 5 psi
- Capillary Pressure: 300 to 500 psi
- Osmosis Pressure: 3,000 to 5,000 psi
Mortar “eaten” away as drying happens from within the mortar matrix

Salts left behind on surface in the form of crystals ("efflorescence")

Evaporation from surface film of water

Capillary flow of salts in solution
Lime mortar “eaten” away over time “sacrificing” itself to protect brick and masonry units

Evaporation from thick lime-based mortar rendering

Capillary flow of salts in solution
16 Million Gallons are Pumped Out of the Tunnels Each Year....