

# Foundations

## Issue

Building foundations are vulnerable to moisture problems for a number of reasons, including:

- Water from rain and from plumbing leaks is drawn by gravity to foundations, which are exposed to surface water, rain-soaked soil and, possibly, high water tables.
- Water may condense on foundation materials during warm weather because the materials are cooler than the outdoor air.
- Crawl spaces and basements are holes in the ground and have more extensive contact with soil than slab-on-grade foundations.
- Many moisture problems can be avoided by properly designing the foundation. Moisture problems associated with improperly designed foundations can be difficult and expensive to identify and fix, can create the potential for health problems resulting from mold growth, and can be a liability for building owners.

## Goals

**Foundation Design Goal 1:** Design the foundation to prevent rainwater and groundwater incursions.

**Foundation Design Goal 2:** Avoid condensation on slab-on-grade foundations, in crawl spaces and in basement foundations.

## Guidance

**Foundation Design Goal 1:** Design the foundation to prevent rainwater and groundwater incursions.

**Guidance 1:** Plan the surrounding slope to divert water away from the building. This guidance applies to slab-on-grade foundations, crawl spaces and basements.

- Specify a 5 percent—6 inches per 10 feet—slope to the finish grade away from the foundation to

control the surface flow of water, or meet a more stringent local building code requirement. Applying this slope to a distance of 6 to 10 feet from the foundation generally is acceptable.

- Reduce water infiltration into the soil surrounding the building using a barrier at or slightly beneath the surface (e.g., a cap of silty-clay soil or subsurface drainage landscape membrane). Care must be taken to prevent the roots of plants in this zone from penetrating the barrier.
- Design the foundation and surrounding grade so there is a minimum of 8 inches of exposed foundation after the final grading.

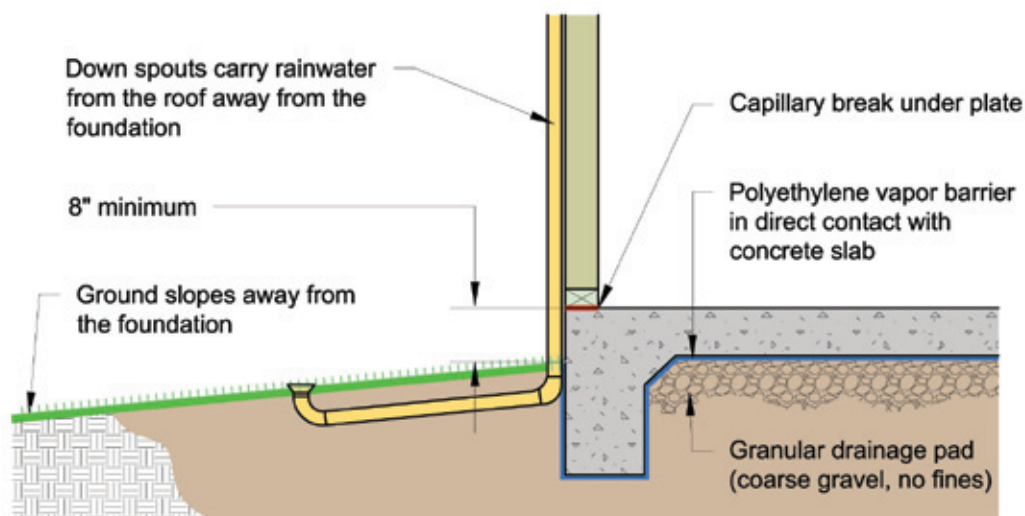
**Guidance 2:** Design below-grade drainage systems to divert water away from the foundation and specify capillary breaks to keep water from wicking through the foundation to moisture-sensitive materials (e.g., wooden framing and paper-covered gypsum board).

## Slab-On-Grade Liquid Water Control (See Figure 2-2)

Below-grade perimeter drainage is not required for concrete slab-on-grade foundations when the surrounding finish grade is sloped as specified in Guidance 1, the slab is elevated at least 8 inches above finished grade, and the design includes appropriate capillary breaks. Incorporate a capillary break between:

- The foundation and the above-grade wall (e.g., a layer of polyethylene foam sill seal, metal or rubber flashing, or a damp-proof masonry course between the concrete foundation and the wood or steel framed walls or the concrete or masonry walls).
- The earth and the floor slab (e.g., a layer of coarse aggregate with no fines, a plastic or rubber membrane, or a layer of plastic foam insulation placed beneath the slab). NOTE: While coarse stone will provide a capillary break, a vapor barrier directly beneath the slab is required to manage water vapor migration.
- The earth and below-grade portion of the perimeter stem wall or thickened edge slab (e.g., damp-proof coating or a water-proof membrane placed on the thickened edge slab or stem wall).

Figure 2-2 Illustration of Ground Water Control for Slab Foundations



- Keep rain water away from the foundation perimeter
- Do not place sand layer over polyethylene vapor barrier 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/24hrs/ft<sup>2</sup>) prior to flooring installation

If there is a joint between the slab's perimeter edge and a stem wall, a capillary break may be needed between the edge of the slab and the perimeter wall to prevent water wicking from the perimeter wall into the slab.

If the roof slopes to eaves without gutters, protect the bottom of the above-grade portion of the wall against rain splash (e.g., raise the foundation wall and slab out of the ground 18 inches or more, or construct the wall with robust drainage and drain plane protection).

### Crawl Space and Basement Liquid Water Control (See Figures 2-3 and 2-4)

- Design the basement or crawlspace so that the interior floor grade is above the 100-year flood level and the local water table.
- Specify a curtain of free-draining material (e.g., sand and gravel, coarse aggregate with no fines, or a synthetic drainage mat) around the outside of the foundation between the unexcavated earth and the basement wall.
- Specify a drainage collection and disposal system to be located below the top of the footing or the bottom of the slab floor (e.g., perforated exterior footing drain pipe surrounded by coarse aggregate with no fines and filter fabric, drained to a preferred disposal option such as daylight or a sump pump).
- Locate the top of the pipe at or below the bottom of the finished slab regardless of the location of the pipe with respect to the footing.
- Specify filter fabric to prevent fine soils from clogging the curtain drain and the footing drain system.
- Incorporate a capillary break between:
  - The top of the foundation wall and the first-floor framing system (e.g., a layer of polystyrene sill seal, metal or rubber flashing, or a masonry damp-proof course between the concrete foundation and the wood, steel, or concrete floor structure).
  - The earth and the basement floor slab (e.g., a layer of coarse aggregate with no fines, a plastic or rubber membrane, or a layer of styrene foam insulation placed beneath the slab).
  - The free-draining perimeter fill and the below-grade portion of the basement wall (e.g., a damp-proof coating or a water-proof membrane placed on the outside of the basement wall).

NOTE: A plastic or elastomeric membrane can be used in place of a concrete slab to form a capillary break and prevent evaporation from the soil into the crawl space. A concrete slab has the advantages of being more durable and of blocking the entry of burrowing rodents. Membranes are less expensive and easier to install.

- Design a capillary break between the top of the footings and foundation walls (e.g., painted-on coating).
- Specify a drain in the foundation floor that leads to an approved disposal site.
- Include in the plan:
  - Assumptions about maximum rainfall or snowmelt.
  - Drainage surface areas including shapes, slopes, superstructures or other obstructions.
  - Estimated water flows.
  - The location and capacities of all sub-grade drainage features (e.g., drain lines, discharge locations, man-holes, access pits).

**Foundation Design Goal 2:** Avoid condensation on slab-on-grade foundations, in crawl spaces or in basement foundations.

### Slab-on-Grade Condensation

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- Insulate slab-on-grade foundations (e.g., install extruded styrene foam board beneath the slab) to keep the floor from sweating during warm, humid weather.
- Provide perimeter and sub-slab insulation to meet the International Energy Conservation Code.
- Provide a vapor retarder sheet directly under the concrete floor slab to prevent water vapor from infiltrating the floor system. Vapor retarders should meet the requirements of ASTM specification E 1745 Class A, B or C.

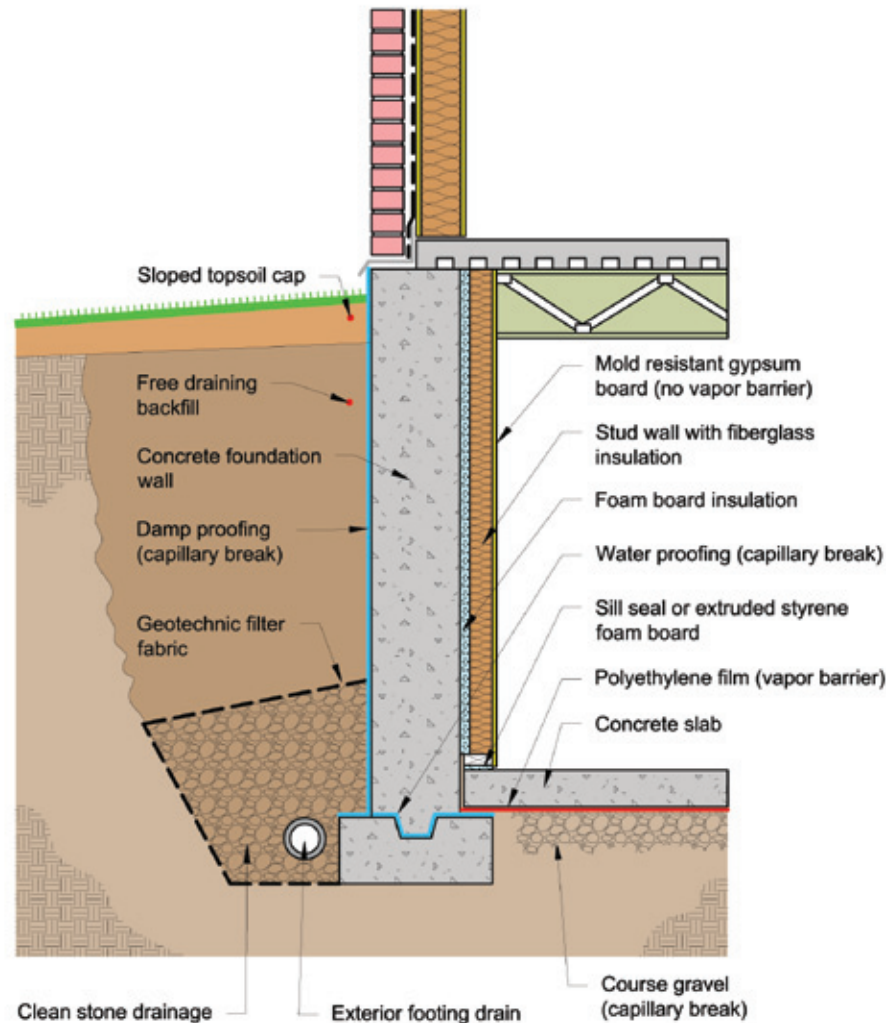
### Basement Condensation Control (See Figure 2-3)

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- Specify insulation for the above- and below-grade basement walls to meet the ASHRAE Standard 90.1 requirements. NOTE: Do not insulate basement ceilings.

- Provide a vapor retarder sheet directly under the concrete floor slab to prevent water vapor infiltration through the floor system. Vapor retarders should meet requirements of ASTM specification E 1745 Class A, B or C.
- Mechanical equipment can be located in basements that have insulated walls. Specify air-sealing details to provide a continuous air barrier from the above-grade wall down the foundation wall and ending in the center of the basement floor. Use the pen test (See Appendix A) to trace the continuity of the air barrier. NOTE: The air barrier for the foundation is a part of the whole building air barrier system.
- Specify a whole building air leakage rate when tested at 75 Pascal pressure difference in accordance with ASTM E779-10 *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* or ASTM E1827-96(2007) *Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*. For example, the U.S. Army Corps of Engineers now requires a maximum air leakage rate of 0.25 cubic feet per minute at 75 Pascal pressure difference.
- When insulating on the outside of foundation walls:
  - Specify insulating materials that can tolerate exposure to the earth. Extruded styrene and high-density expanded styrene foam boards, closed-cell spray polyurethane foam insulation, and fiberglass or mineral wool insulating drainage panels have been successfully used to insulate outside surfaces of foundation walls.
  - Extend the insulation from the top of the footing to the top of the sub-floor.
  - Specify protective covering for the above-grade portions of exterior insulation (e.g., stucco on stainless steel lath).
- When insulating on the inside of foundation walls:
  - Specify a layer of foam board or closed-cell spray polyurethane foam insulation against the interior side of the basement wall to keep warm humid air away from the cool foundation.
  - Specify an insulating value for the foam layer high enough to meet the ASHRAE Standard 90.1 requirements, or specify a combination of foam insulation and, on the foundation wall, moisture-tolerant insulation in the wall cavity (e.g., fiberglass or mineral wool). The combination of foam and fiberglass insulation meets the required R-value, prevents condensation and allows the assembly to dry to the interior (See Figure 2-3).

Figure 2-3 Illustration of Basement Foundation Showing Drainage and Damp Proofing Only



- Specify appropriate fire protection for the interior insulation system (e.g., fire-rated gypsum board).
- Design the entire system so that wooden and paper-based materials do not touch concrete (e.g., isolate them with a spacer, such as closed-cell foam board, spray polyurethane foam or polyethylene foam, which provides a capillary break).
- Do not use any materials inboard of the insulating layer that have a permeability rating of less than two perms. Materials that have a perm value of one by the dry cup method and a perm value higher than two by the wet cup method may be used. For example, do not use vapor-impermeable vinyl wallpaper on insulated basement walls.
- Provide details showing how the insulation layer on the inside of the foundation provides continuity with the upper floor wall insulation.
- Use air conditioning or dehumidifiers to reduce basement humidity during warm, humid seasons.

### Crawl Space Condensation Control

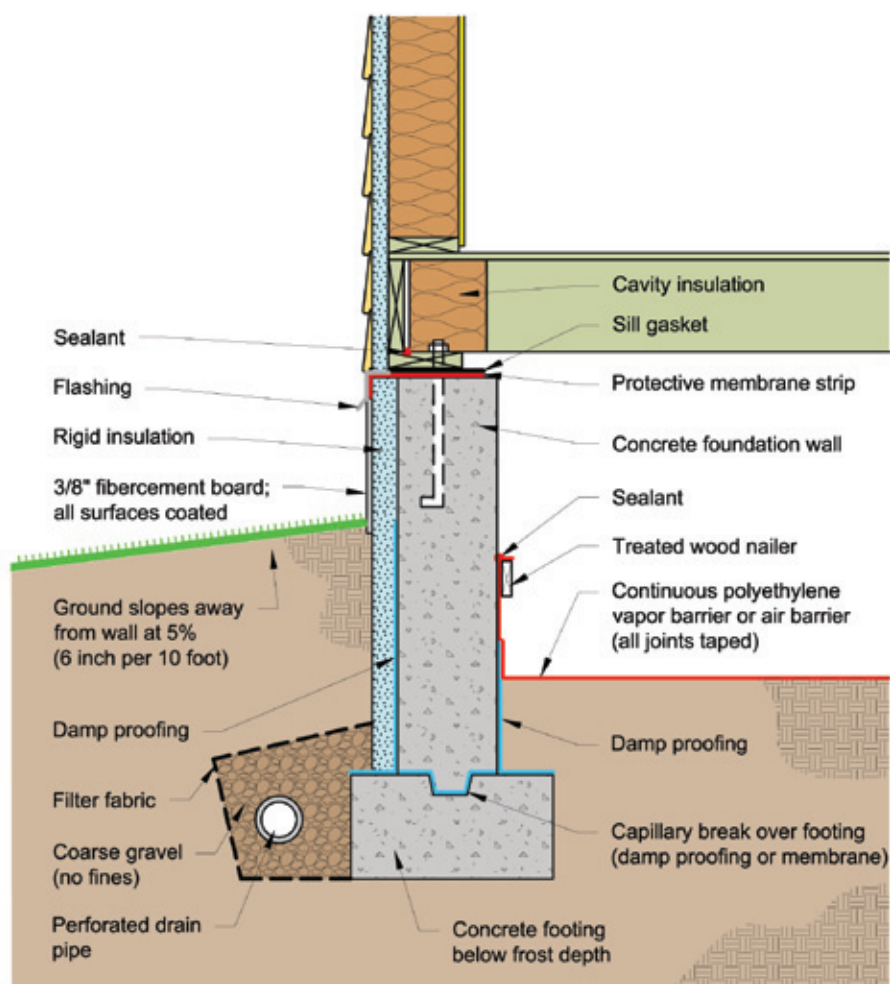
- Crawl space foundations may be vented to the outdoors or air sealed.
- The specifications for non-vented crawl spaces are the same as for basements, with one exception: a plastic or elastomeric membrane can be used instead of a concrete slab to form a capillary break and prevent evaporation from the soil into the crawl space. Concrete slabs are more durable, provide a solid floor for the contractor to work from, and block the entry of burrowing rodents; however, membranes are less expensive and easier to install. Sealed crawlspaces must be ventilated in accordance with International Building Code 1203.3.22012 (See Figure 2-4).

- For vented crawl spaces:
  - Specify one or more layers of insulation in the floor system between the crawl space and the first floor to achieve the insulation levels required by ASHRAE Standard 90.1. NOTE: Mechanical equipment cannot be located in vented crawlspaces. Specify air-sealing details to provide a continuous air barrier from the above-grade wall across the floor between the crawl space and the first floor. Use the pen test (See Appendix A) to trace the continuity of the air barrier. NOTE: The air barrier for the foundation is part of the whole building air barrier system.
  - Specify a whole building air leakage rate when tested at 75 Pascal pressure difference in accordance with ASTM E779-10 Standard Test Methods for Determining Air Leakage Rate by Fan Pressurization or ASTM E1827-96(2007)

Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door. For example, the U.S. Army Corps of Engineers requires a maximum air leakage rate of 0.25 cubic feet per minute at 75 Pascal pressure difference.

- A plastic or elastomeric membrane can be used instead of a concrete slab to form a capillary break and prevent evaporation from the soil into the crawl space. Concrete slabs are more durable, provide a solid floor for the contractor to work from, and block the entry of burrowing rodents; however, membranes are less expensive and easier to install.
- Provide screened vents to meet the International Building Code requirements for ventilated crawl spaces (Section 1203.3.1).

Figure 2-4 Components of an Unvented Crawl Space Foundation



Source: Conditioned Crawl Space Performance, Construction and Codes, Building Science Corporation (<http://www.buildingscience.com/documents/bareports/ba-0401-conditioned-crawl-space-construction-performance-and-codes>). Accessed November 6, 2013.

## Verification of Foundation Design

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- Write a description detailing how the foundation system manages rain and surface and sub-surface water. This typically would be located in the basis-of-design document.
- Provide details of sub-surface drainage systems in construction documents.
- Use the pen test (See Appendix A) to verify elements of the drainage system and the continuity of the capillary break from the intersection of the foundation with the first floor walls, around the foundation wall footing, to the center of the foundation.
- Provide two-dimensional sectional drawings where two materials that form the rainwater control come together and three-dimensional drawings where three or more elements of the rain protection system come together.
- Provide a list of critical details and an inspection schedule for the drainage and capillary break elements of the foundation that identifies the sequence of inspections, the parties responsible for the inspections, and the required documentation of the inspection results.
- Provide a list of inspection and maintenance requirements for the foundation drainage system.
- Write a description detailing how the foundation system manages water vapor during cooling and heating modes, as applicable. Prepare drawings and specifications that detail water vapor migration control and the permeability and insulating values for all materials.
- Provide two-dimensional sections where two materials that form the air barrier, insulation layer and water vapor control intersect. Provide three-dimensional drawings where three or more elements of the air barrier, insulation layer and water vapor control intersect.
- Specify a fan pressurization test in design specification documents to assess the entire building enclosure using ASTM E779-10 *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. Or ASTM E1827-96(2007) *Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*.
  - Specify when the test should be conducted in relation to the completeness of the air barrier system.
  - Identify the appropriate testing party.
  - Specify how the results should be documented, judged and accepted or rejected.
  - Specify the remedies if the building fails the test.
- Specify quality assurance programs for the installation of the hygrothermal control elements of the enclosure. Provide a list of critical details and an inspection schedule for the air barrier, insulation layer and water-vapor-control elements of the foundation. Specify the sequence of inspections, the parties responsible for the inspections and the required documentation of the inspection results.
- Provide a list of inspection and maintenance requirements for the interior finishes if they are critical to water vapor control. For example, if water vapor control depends on a vapor-permeable interior finish, low-perm vinyl wall coverings and paints should be avoided during renovations. Pictures, blackboards and mirrors should be spaced off the wall.
- Specify, in the control guide for the building operators, the maximum dew point levels allowed in the interior of basements and crawlspaces.