TechNote

Rain & Groundwater Management: Reducing the Risk of Water Intrusion & Damage

Introduction

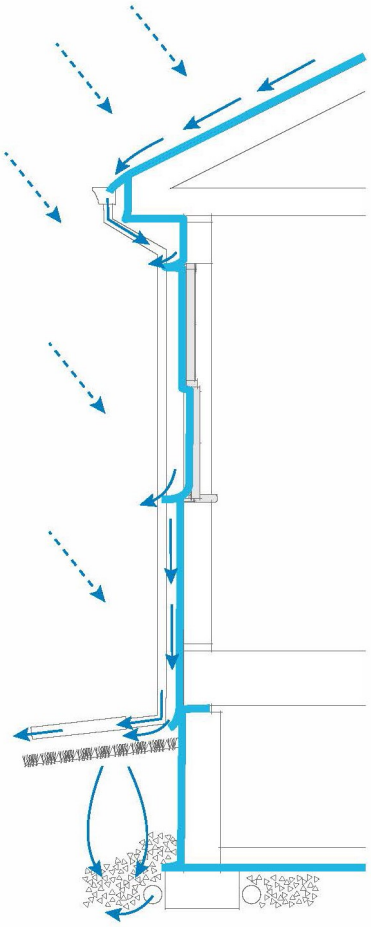
Despite significant advances in design and construction practices, water intrusion remains one of the most common causes of building repair. Water intrusion can lead to mold, decay, and poor indoor air quality, and affect the durability of the home [1]. Water entering a basement or crawl space can contribute to moisture problems in above grade areas due to increased relative humidity. Even minor omissions during design or construction can lead to significant water damage. Building codes establish minimum requirements for moisture control but don't always provide sufficient implementation details.

Objective

This TechNote provides an overview of essential water management measures and building code provisions that builders should consider to minimize the risks of water intrusion. The focus is on rain and groundwater control practices for foundation and above-grade wall construction. Water vapor migration through building assemblies and corresponding potential moisture problems is the subject of a future TechNote.

Solution

The fundamental principle of water management is that exterior water must be provided with a path from the roof to the foundation to drain down and away from the building. Proper drainage and flashing are key to control rain and groundwater intrusion (see Graphic 1).



Graphic 1. Example continuous water control layer (indicated by solid blue line) and water draining down and away from the building (solid blue arrows) [2].

Building Science Terminology

Moisture migration: the movement of moisture (liquid water or water vapor) through the building enclosure. There are four primary modes of moisture migration:

- *Bulk moisture* – the movement of water into and through buildings.
- *Capillary action* – the wicking of water through porous materials or small cracks.
- *Air leakage* – the transport of water vapor carried within moving air.
- *Vapor diffusion* – the migration of water vapor through permeable materials.

Hydrostatic pressure: horizontal pressure against the foundation due to groundwater forces.

Control Layers: the four principal hygrothermal (moisture and heat) control layers of a building enclosure are the water, air, water vapor, and heat control layers [3]. All four layers affect the moisture performance of a building enclosure.

Water-Resistive Barrier (WRB): The primary purpose of the WRB is to protect the wall assembly from bulk water (e.g., wind-driven rain) that breaches the cladding system. The WRB must minimize water intrusion and allow drainage – the WRB is the **drainage plane** of the wall. The WRB is generally located behind the siding or cladding, but can be on the wall exterior for face-sealed assemblies (e.g., stucco on solid masonry wall). An air gap between the WRB and cladding enables drainage and ventilation. To be effective, the WRB must be continuous (lapped or sealed) and properly integrated with flashing.

Common WRB products, such as #15 asphalt felt, Grade D building paper, and most house wraps, are vapor-permeable to allow moisture within the wall assembly to dry to the exterior but can still shed bulk water that reaches the WRB. Rigid foam insulation and other membrane products installed as a WRB can be less permeable or impermeable. Additionally, the WRB can serve as an air barrier to help reduce air infiltration.

PREPARED BY Home Innovation RESEARCH LABS

SEPTEMBER 2014

Building Code

The International Residential Code (IRC) establishes minimum moisture control measures for foundations, walls, and roofs. Applicable sections from the 2015 IRC are indicated below (in parentheses) next to the corresponding water management measures.

Foundations — Design Considerations & Best Construction Practices

Site drainage. Site grading directs surface water away from the foundation. Building codes require a minimum final grade of 5% (6 in. drop within the first 10 ft), or sufficient drains or swales to provide drainage away from the foundation, and a 2% grade (1/4 in. drop per ft) for impervious surfaces (patio slabs, walks, driveways) within 10 ft of the foundation (IRC R401.3). Roof drainage (e.g., gutters and downspouts) is required to direct water at least 5 ft away from the foundation where soil is known to be "expansive or collapsible" (IRC R801.3).

Foundation drainage. Drainage is required to direct groundwater away from foundations for basements and crawl spaces with floors below exterior grade, unless the foundation is supported on well-drained soils such as gravel or gravel and sand mixtures (Soil Group I per Table R405.1). Drainage tiles, gravel or crushed stone drains, perforated pipe, or other approved systems must be installed at or below the area to be protected (e.g., next to the footing to protect a basement floor) and discharge by gravity or mechanical means into an approved drainage system. Perforated pipe must be placed on 2 in. of gravel and covered with at least 6 in. of gravel. The pipe or the gravel must be covered with an approved filter membrane except where otherwise recommended by the drain manufacturer (R405.1). Window wells should be connected to the foundation drainage system (IRC R310.2.3.2).

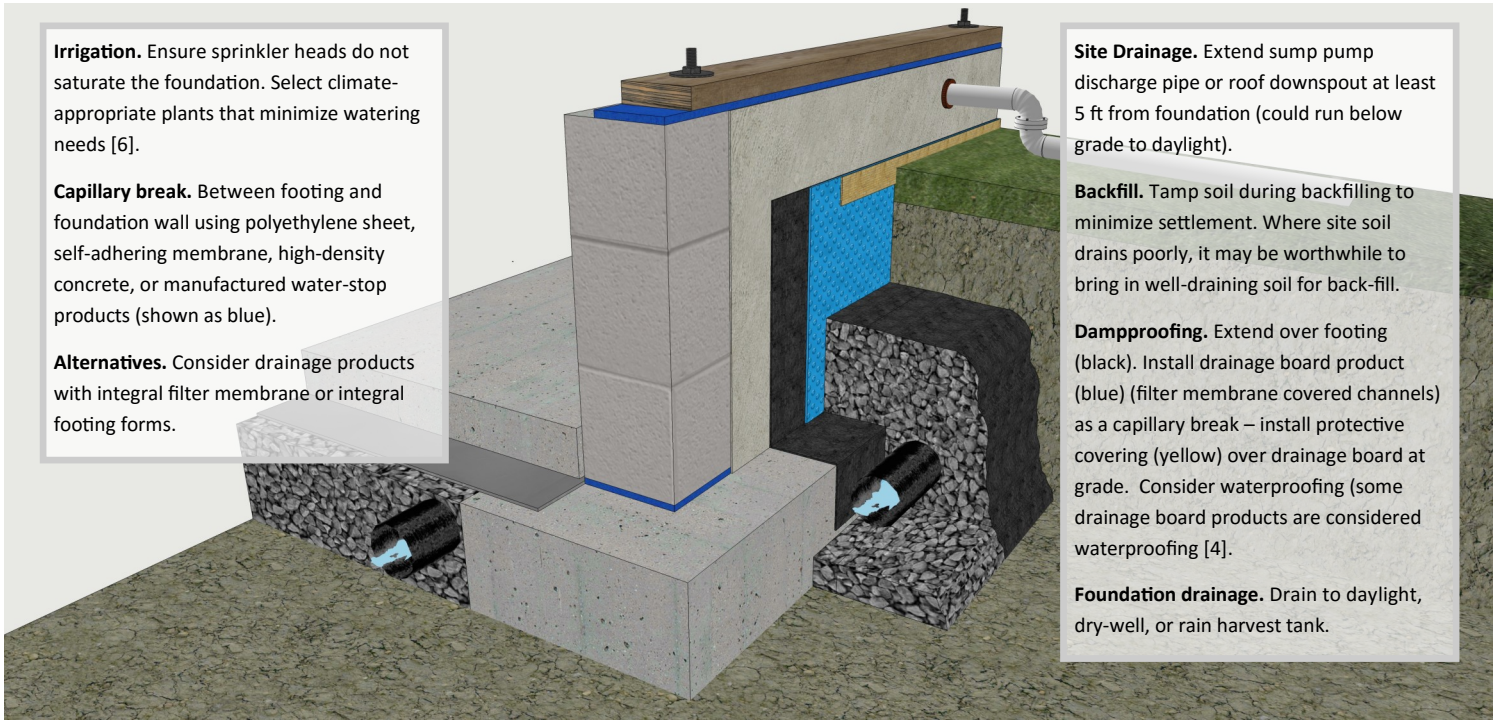
Waterproofing and Dampproofing. Damp-proofing protects foundations from absorbing ground moisture by capillary action and is not intended to resist moisture intrusion due to hydrostatic pressure. Building codes typically require dampproofing for basements and crawl spaces where the floor is below exterior grade (IRC R406). Waterproofing is generally required where hydrostatic pressure exists due to a high water table or poorly draining backfill (IRC R406.2) [4].

Capillary Break. A product or assembly that prevents water intrusion by capillary action. Generally required where wood framing meets a concrete or masonry foundation (e.g., a membrane product below the sill plate at foundations) (IRC R317) and at concrete slabs below grade (the gravel base is the capillary break, and the typical 6-mil polyethylene is the vapor retarder) (IRC R506).

Protection of wood. Wood siding, sheathing, and wall framing generally require a minimum ground clearance of 6 in. to protect the wood against decay (IRC R317.1).

Flood hazard areas. Crawl spaces are permitted in flood hazard areas if the finished grade of the crawl space is equal to or higher than the outside finished grade on at least one side, or for crawl space construction that meets FEMA Technical Bulletin TB-11 requirements (IRC R408.7) [5].

Graphic 2: Foundations - Best Practices



Water-resistive barrier. The water-resistive barrier (WRB) provides a drainage plane to protect the wall assembly from liquid water. Building codes require a WRB behind the exterior veneer, except for concrete/masonry walls or other wall assemblies which have been demonstrated through testing to resist wind-driven rain (IRC R703.1). The IRC specifies #15 asphalt felt, complying with ASTM D226 for Type 1 felt, as the default specification for a WRB, but allows for "other approved WRB" products, and requires installing the WRB horizontally with the upper layer lapped over the lower layer (shingle-fashion) not less than 2 in., and lapped at vertical joints not less than 6 in., continuously to the top of walls (IRC R703.2). House wraps, Grade D building paper (specified in IRC R703.7.3 for stucco applications), and sheathing and tape system products (e.g., ZIP System™) are common approved substitutes for #15 asphalt felt. Rigid foam and fully adhered sheet or liquid membrane products installed as a WRB may be approved substitutes as well [8].

Flashing. Flashing is installed to prevent water intrusion at a joint, opening or penetration, change in material, or as part of a WRB system. Flashing must be installed shingle-fashion and extend to the surface of the exterior wall finish, except for window and door openings where the flashing may extend only to the WRB. **Flashing is required:** at windows and doors, where masonry construction meets frame or stucco walls, under and at ends of copings and sills, above projecting wood trim, where porches, decks or stairs meet wood-frame walls or floors, at wall and roof intersections (IRC R903.2 describes a kick-out type flashing), and at built-in gutters (IRC R703.4).

Cladding. WRB and flashing details can vary by cladding type (see Table 1, page 4). An air gap between, or integral to, the WRB and cladding enables drainage and ventilation for drying. Absorptive claddings that can store water, such as stucco, manufactured stone veneer, and brick, require an air space or drainage assembly separating the cladding and WRB [7]. For vinyl siding, the air gap is integral to the product profile. The air gap is also referred to as a drainage gap, air space, or rain screen. Building codes address drainage requirements for many cladding types (IRC R703.5 through R703.17).

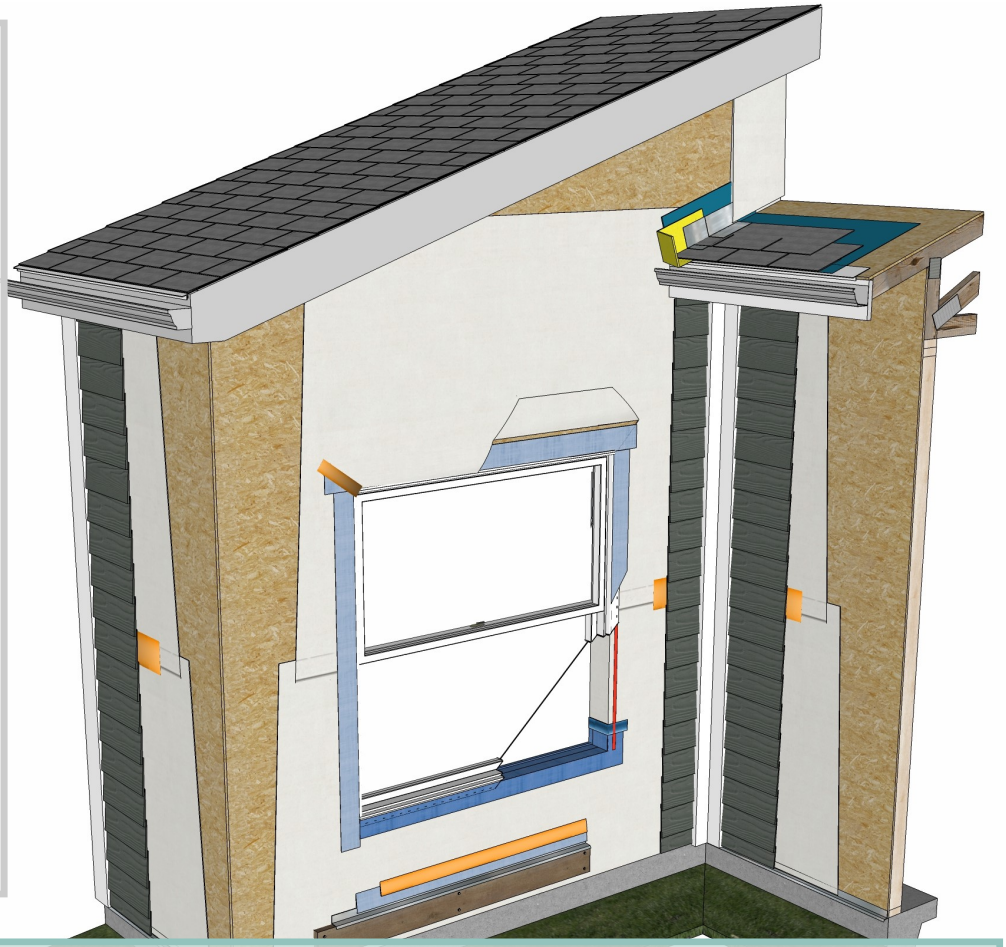
Graphic 3: Walls - Best Practices

Weather-resistive barrier (WRB)

- Ensure proper overlaps – manufacturers commonly require more than code minimum.
- Tape seams as required, particularly if WRB is installed as an air barrier.
- Consider "drainable" WRB/house wrap products with built-in spacers or vertical channels to improve drainage - even where not required (e.g., fiber-cement lap siding).
- Ensure the WRB is integrated with all flashing to maintain an effective wall drainage plane.

Flashing

- Windows and doors: follow manufacturer instructions for installation sequence; consider rigid pan flashing products.
- Install flashing at the bottom of exterior frame walls at the foundation, and lap the WRB over the flashing attachment plate.
- Install flashing at all wall penetrations (e.g., vent hoods, electrical boxes, and other utilities).
- Install flashing at ledger boards and architectural elements (maintain the drainage plane behind architectural elements as needed, e.g., trim around doors).
- Roof-wall intersections: install kick-out diverter flashing; consider pre-made products to reduce the risk of leakage.



Continuous insulation

Products such as rigid foam (e.g., extruded polystyrene) can be installed before the WRB, over the WRB, or as the WRB (without house wrap). Where installed as the WRB:

- At windows, add counter flashing adhesive tape above the head flashing.
- At wall-roof intersections, install counter flashing over apron flashing or step flashing, and builder tape over the counter flashing.
- Seams must be flashed/sealed to maintain the drainage plane. Consider z-flashing at horizontal seams.

Continuous insulation may require different details at windows and doors to accommodate any additional insulation thickness.

Table 1: 2015 IRC drainage details for common cladding types (alternatives or best practices are shown in parentheses)

Cladding Type	Drainage Details
Wood lap siding, IRC R703.5	**Drainage Gap.** Per manufacturer instructions (vertical furring strips recommended)
	WRB. #15 asphalt felt or approved equivalent (e.g., house wrap or Grade D building paper)
	Flashing at Foundation. Per manufacturer instructions (recommended)
Wood shakes and shingles, IRC R703.6	**Drainage Gap.** Not required over wood-based sheathing and WRB, but furring strips required over nonwood sheathing; horizontal furring strips where used must be 1x3 or 1x4; where the WRB is nonpermeable furring strips shall be placed first vertically and then horizontally (furring strips or drainable WRB product recommended in all cases)
	WRB. #15 asphalt felt or approved equivalent (e.g., house wrap or Grade D building paper)
	Flashing at Foundation. Not specified (recommended)
Exterior plaster, IRC R703.7 (stucco or Portland cement plaster)	**Drainage Gap.** Between WRB layers, or approved WRB assembly
	WRB. Where applied over wood sheathing: 2 layers of Grade D paper or equivalent, each layer installed independently so each layer provides a continuous plane, and any flashing to the WRB is directed between layers; or 1 layer 60 minute Grade D paper or equivalent separated from the stucco by a non-water-absorbing layer or drainage space.
	Flashing at Foundation. Weep screed to allow drainage at or below the foundation plate line on exterior stud walls; 4 in. minimum above earth, 2 in. above paved surface; WRB lapped over the weep screed attachment flange.
Anchored stone and masonry veneer, IRC R703.8 (e.g., brick)	**Drainage Gap.** 1 in. minimum
	WRB. #15 asphalt felt or approved equivalent (e.g., house wrap or Grade D building paper)
	Flashing at Foundation. Flashing beneath the first course above grade; Weep-holes immediately above flashing to allow drainage to the exterior of the cladding – minimum 3/16 in. diameter, maximum spacing 33 in. on-center.
Fiber cement lap siding, IRC R703.10	**Drainage Gap.** Not specified (furring strips or drainable WRB product recommended)
	WRB. #15 asphalt felt or approved equivalent (e.g., house wrap or Grade D building paper)
	Flashing at Foundation. Not specified (recommended)
Vinyl siding, IRC R703.11	**Drainage Gap.** Not specified (drainable WRB product recommended)
	WRB. #15 asphalt felt or approved equivalent (e.g., house wrap or Grade D building paper)
	Flashing at Foundation. Not specified (recommended)
Adhered masonry veneer, IRC R703.12	**Drainage Gap.** See WRB, below
	WRB. Shall comply with stucco requirements of R703.7 and requirements in Sections 12.1 and 12.3 of Building Code Requirements and Specifications for Masonry Structures (TMS402/ACI530/ASCE5)
	Flashing at Foundation. On exterior stud walls: adhered masonry veneer shall be installed with a minimum clearance of 4 in. above earth, 2 in. above paved surface, or 1/2 in. above walk with shared foundation; screed or flashing must extend at least 1 in. below the foundation plate; WRB must lap over attachment flange of screed or flashing.
Insulated vinyl, IRC R703.13	**Drainage Gap.** Per manufacturer instructions (drainable WRB recommended)
	WRB. #15 asphalt felt or approved equivalent (e.g., house wrap or Grade D building paper), or per manufacturer instructions
	Flashing at Foundation. Per manufacturer instructions (recommended)

Recommendations for Assuring Consistent Quality of Moisture Control Measures

Design Phase

- Review the building plans to ensure that rain and groundwater have a continuous path, from the roof to the foundation, to drain down and away from the house.
- Show all drainage and flashing details and installation sequences on plans, specifications, and scopes of work for trades.
- Don't rely on caulks or sealants as a substitute for proper flashing.
- Select and install all products in accordance with manufacturer's installation instructions, local building codes, and specifications established by the licensed design professional.

Construction phase

- Inspect all drainage and flashing components for continuity during installation.
- Minimize moisture accumulation during construction as practical, and ensure assemblies are dry before enclosed [6].

Homeowners

- Ensure gutters are cleaned as needed, downspouts direct water away from the foundation, irrigation sprinklers do not saturate the ground near the house, and landscaping does not trap water against the foundation.

Notes and Resources

[1] *Durability by Design: A Guide for Residential Builders and Designers*. Washington, D.C.: U.S. Department of Housing and Urban Development (HUD) (Prepared by NAHB Research Center, May 2002).

[2] For information on the control layer "pen test" concept see: *Moisture Control Guidance for Building Design, Construction, and Maintenance*. Washington, D.C.: U.S. Environmental Protection Agency (December 2013).

[3] For more discussion of control layers, see: *Owens Corning Residential Complete™ Wall Systems: Builder's Guide*. Somerville, MA: Building Science Press.

[4] *Six State-of-the-Art Systems for Waterproofing, Damp-proofing Basement Walls*. Washington, D.C.: National Association of Home Builders (8/6/2013).

[5] *FEMA Technical Bulletin TB-11: Crawlspace Construction for Buildings Located in Special Flood Hazard Areas.* (2001; updated 02/28/2014).

[6] 2012 *ICC 700 National Green Building Standard™.* Washington D.C.: National Association of Home Builders.

[7] *Improving Drainage and Drying Features in Certain Conditions: Rain Screen Designs for Absorptive Claddings*. Washington, D.C.: National Association of Home Builders (2008).

[8] The International Code Council Evaluation Service (ICC-ES) has tested and approved several products as water-resistive barriers.

Other resources:

- *EnergyStar Certified Homes, Version 3 (Rev. 07) Water Management System Builder Checklist*. Washington, D.C.: U.S. Environmental Protection Agency.
- *Indoor airPLUS Construction Specifications, Version 1 (Rev. 02).* (November 2013).
- *The JLC Guide to Moisture Control: Practical Details for Durable Buildings*. The Journal of Light Construction (2007).