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Moisture Control in Buildings: Putting Building Science in Green Building

I am continually surprised by how little emphasis the green building movement places on building science. As we examine the many priorities of green building—from land-use planning to energy efficiency, material selection, and indoor air quality—the basic science of how we design and build structures to ensure long life and healthy indoor environments should be at (or near) the top of the list.

Excess moisture is at the center of many problems relating to durability and indoor air quality—not just in homes but in all types of buildings in a wide range of climates. If we build structures that won't rot or support mold growth, we will both increase the longevity of those buildings and reduce the health risks of living in them.

This article examines the physics of moisture in buildings and addresses design and construction strategies for (a) keeping buildings dry and (b) allowing those buildings to dry out if they do get wet. While the emphasis and examples are largely focused on houses, most of the ideas apply more broadly.

Moisture 101

Moisture exists in three commonly known forms or *phases*: liquid, gas (vapor), and solid (ice), along with an additional *adsorbed* state that is somewhat between liquid and vapor in characteristics. All these forms come into play in buildings, though it is liquid water that results in most of the problems. With water vapor, the greatest concern is that it will condense into liquid water on a surface.

Roof overhangs, gutters, and downspouts help to prevent rainwater intrusion into buildings. Shown here is the Ladybird Johnson Wildflower Center in Austin, Texas, which also has an extensive rainwater harvesting system.

Common sources of moisture in buildings are listed in the sidebar below.

The movement of moisture from one place to another is governed by physical forces. The principal forces affecting moisture flow are listed below, with brief explanations.

• **Gravity.** Rain falls to earth; water runs down roofs and walls.

• **Capillarity.** Water can be pulled through thin air spaces or pores through a process called capillarity. Capillarity occurs because intermolecular forces cause water to stick to itself (surface tension) and to many other materials. (These same intermolecular forces allow water to cling to the bottom of a joist, running along horizontally until a gap is reached where the water accumulates into a drop large enough that gravity becomes the dominant force.) Capillarity is a powerful force—strong enough to raise water hundreds of feet into the air (counteracting gravity) in tall trees. This is the primary mechanism of moisture movement through porous materials, such as concrete floor slabs and wood siding.

• **Convection.** Airflow can carry moisture in both liquid and vapor forms. This movement occurs through air pressure differences. Wind blows rain into the walls of buildings, for example, and forced or passive airflow carries water vapor (humidity) with it.

• **Diffusion.** Water vapor can diffuse through permeable materials. This process is driven by partial pressure (vapor pressure) differences across the material. Vapor pressure as a driving force is confusing. In any mixture of gases, such as air, each separate gas has its own concentration or *vapor pressure*. If the vapor pressure of a gas in one area is greater than in another area, those vapor pressures will try to equalize through the movement of gas molecules from one air mass to the other. This is why it's very difficult to keep part of a building dry through air-conditioning if other parts of the building operate at ambient humidity levels. (Experts once thought diffusion was the primary mechanism through which moisture got into wall cavities, and we installed poly vapor retarders to block that diffusion; they now believe that airflow—convection—is a much greater source of such moisture migration.)

• **Temperature differential.** Moisture is known to move from hot to cold within a material. When brick siding gets soaked from rain, for example, and then the sun heats the outside of the brick, moisture in the brick is driven through the wall to the interior. Although the mechanism is not fully understood, it involves phase-change, according to physicist and building scientist Terry Brennan, of Camroden Associates in Westmoreland, New York. "As liquid water is warmed, the evaporation rate goes up rapidly. The vapor pressure goes up rapidly as well because the number of water molecules in the gas state has gone up." The net result of this is that a great deal of moisture can be driven through a porous siding or roofing material.

These various mechanisms of moisture movement interact in complex ways in buildings. Capillarity may deliver water through a concrete slab, for example. That water then evaporates (it might never even appear as liquid water or dampness) and is distributed throughout the building via convection and vapor pressure differences.

Integral to the moisture dynamics in a building is the issue of relative humidity and the phase change between liquid and vapor. Humidity is a measure of the moisture content of air—the concentration of water-vapor molecules in a particular air mass. Usually, we refer to *relative humidity* (RH), which is the amount of water vapor in the air, as a fraction of the total moisture that air could contain. "I think of RH as the fraction of the way we are between totally dry and condensation," says Brennan. The amount of water vapor a given volume can hold is dependent on temperature—more water vapor can exist in a space if it is warm than if it is cold. As a mass of air and water vapor is cooled, the relative humidity increases, until the mass reaches 100% RH, when liquid water condenses out (changes phase from gas to liquid). This point is known as the *dew point*.

This process has a huge bearing on moisture problems in buildings. If warm indoor air flows into the wall cavity through cracks in the drywall during cold weather, for example, that air mass may cool enough to reach the dew point within the wall cavity. When this occurs, the insulation in the wall cavity or the inner surface of the exterior sheathing gets wet—and that can cause big problems.

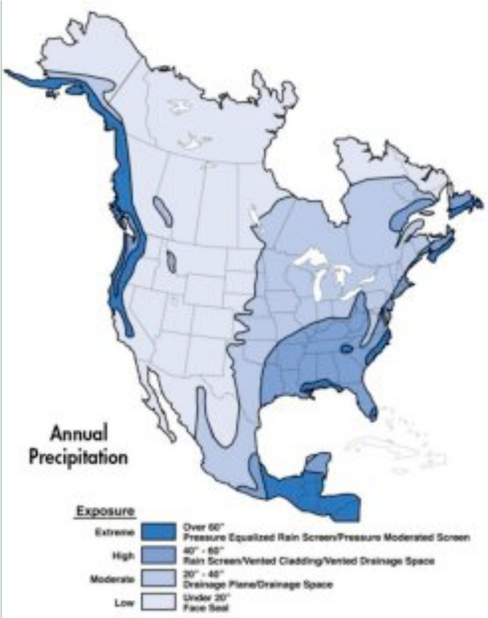
Moisture storage capacity is also very important. Some materials can absorb and release large quantities of water. Both wood and masonry materials have large moisture-storage capacity; metals, plastics, and many of today's panel products have low moisture-storage capacity. "Wood is a fantastic material because it's a hygric buffer," says Joseph Lstiburek, principal of Westford, Massachusetts-based Building Science Corporation. While the moisture content of wood is typically 3–8% (by weight), that moisture content can safely increase to 15%, he says. In other words, wood can safely store up to 10% of its weight in water—between 50 and 100 gallons (190–380 l) for a typical house.

Brennan notes that the moisture dynamics of wood are climate dependent. "For northern climates, the moisture content of wooden materials in houses with ordinary vapor loads and ventilation rates cycles between 5–10% in winter and 12–18% in summer," he says. In milder climates, wood doesn't dry out as much, according to Brennan, and 10–15% is a typical minimum. However, excursions above this level can safely occur. "Wood can safely store moisture up to even 30% moisture content if it only has to do it for a few days," says Brennan.

Because of this dynamic moisture-storage capacity, Lstiburek argues that wood-framed walls can be superior to steel-framed walls. The wood framing helps to regulate moisture in buildings.

Risks of Moisture in Buildings

Excess moisture in buildings is bad. Decay of wood and other cellulosic materials is dependent on moisture and temperature. With moisture content in framing lumber over about 20% (28% according to some experts) and typical room temperatures, decay is possible. There are



North America divided into four zones based on annual precipitation, with suggested cladding system approach for each zone.

actually two issues, according to Lstiburek: we may see mold growth on surfaces with moisture content as low as 16%, but decay fungi that grow *within* wood require higher moisture content (a minimum of 20% to 28%, depending on which expert you ask). Keep in mind that the fungal spores that cause both surface mold and decay are ubiquitous and can become established whenever the right conditions present themselves.

The duration of high-moisture events, as well as the substrates, influences whether mold will grow. Thesis research conducted by Susan Doll, at the Harvard School of Public Health, found that liquid water on oriented strand board (OSB) and plywood produced mold in just three and six days, respectively. Without liquid water but sitting in chambers at 95% RH, it took 24 days for mold to become established on OSB and 42 days on plywood. Below 85% RH, mold did not appear at all during a 60-day test period. Brennan speculates that the difference between OSB and plywood has to do with the fact that each wood strand in OSB is surrounded by a fairly impermeable layer of glue. "You're reaching a higher moisture content at the surface of the OSB quicker," he believes.

In addition to causing wood decay, moisture can corrode—and eventually destroy—steel structural members and fasteners. Steel does not have to be wet to begin rusting. Corrosion can occur whenever the relative humidity is above 70–80%, according to Lstiburek, though corrosion problems worsen when pipes or fasteners actually become wet through condensation, leaks, and so forth. In coastal areas with high salt content in the air, the humidity threshold for corrosion drops for reasons that are not fully understood.

Keeping humidity levels within an acceptable range is an important strategy both for ensuring a long life for buildings —longer-lasting buildings are greener buildings—and for ensuring health of the occupants. While differences of opinion exist as to the optimal indoor humidity range, a consensus seems to be emerging that the relative humidity should not be lower than about 25% (to prevent dry eyes and throats, shrinking of wood flooring, and static electricity problems on carpeting) or higher than about 60% in the center of a room. The 60% level is intended to keep the relative humidity from exceeding 70% at *surfaces*, such as walls and floors, according to Lstiburek. The relative humidity near surfaces is typically higher than it is in the center of a room. When the relative humidity at surfaces is above 70%, mold growth can occur.

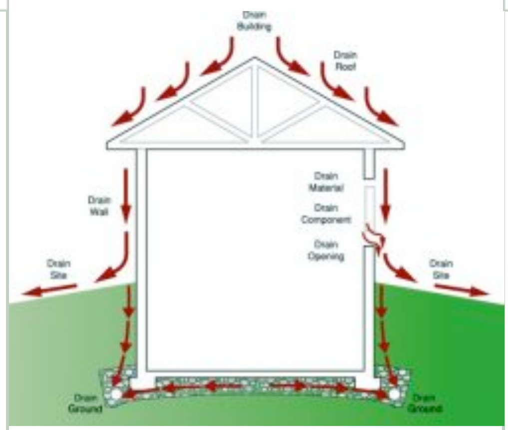
When the RH is high (say 95%), a surface has to be only a few degrees cooler than the air for condensation to occur, according to Brennan, and for mold growth to follow within a few days. At 70% RH, you need a surface temperature that is 11°F (6°C) cooler for condensation to occur, and at 50% RH, the surface temperature needs to be 20°F (11°C) cooler for condensation to occur. Just as significant, things dry out more slowly when the humidity level is high. At 75°F (24°C) and 70% RH, over 600 lbs (270 kg) of water will evaporate from 1,000 ft^2 (90 m^2) of water surface in a day; at 95% RH, the evaporation drops to less than 100 lbs (45 kg) per day. Thus, at higher relative humidity levels in a building, even a fairly small source of liquid water can become a big problem.

Controlling Moisture in Buildings

A multipronged approach is required for dealing effectively with moisture in buildings. Broad strategies include the following: keeping water out, avoiding (or managing) plumbing leaks, avoiding condensation inside the building or within the building envelope, controlling the entry of humid outside air, controlling indoor sources of humidity, designing building assemblies to dry out, providing mechanical ventilation, and providing mechanical dehumidification. Each of these broad strategies is described below, followed by a more detailed checklist of specific recommendations relating to keeping water out and designing building assemblies that can dry out.

Keeping water out

A key priority in avoiding moisture problems in buildings is preventing rainwater and groundwater from entering the building. “Drain, drain, drain,” is the mantra echoed by building scientists Brennan and Lstiburek. Keeping rainwater out necessitates quality flashing details at all window and door openings, roof penetrations, and roof-wall intersections. Specialized flashing systems, including pan flashing and formable flashing, are illustrated in the figures on pages 16 and 17. Less obvious but also very important is the need for drainage planes in walls to prevent water from getting through siding and sheathing. Building Science Corporation has developed a convenient annual precipitation map of North America keyed to drainage requirements in wall assemblies. Capillary breaks are also needed to keep groundwater from moving through foundation walls and floor slabs. Rainwater can be kept away from the building walls with overhangs, properly installed gutters and downspouts, and an adequately sloped ground surface around the building. Detailed strategies for keeping water out of buildings are provided in the checklist sidebar.



Any surfaces of the building envelope that might encounter liquid water must be designed to drain that water away.

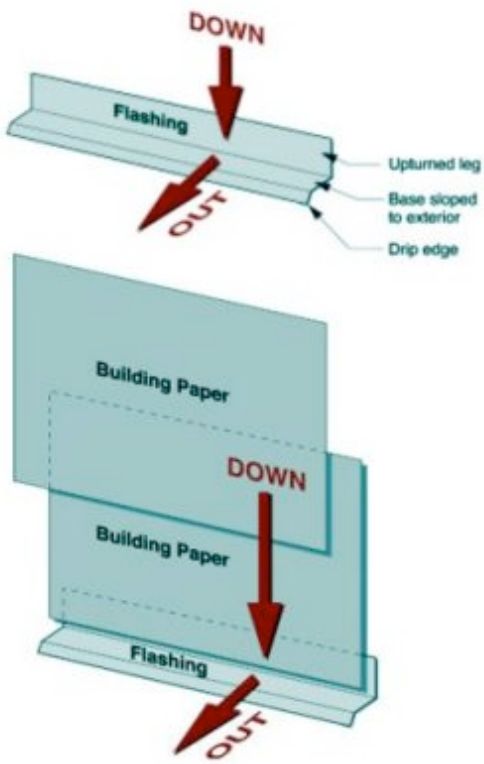
Avoiding moisture problems from plumbing leaks

Consider it a given that, sooner or later, leaks will develop in most plumbing systems. In fact, Lstiburek considers plumbing leaks to be “more significant than any other factor” in causing moisture problems in buildings. Based on his company’s experience, he estimates that one-third of all houses develop plumbing leaks within the first five years! These leaks should be planned for in the design and construction of buildings. Most building science experts recommend installing all plumbing in interior rather than exterior walls. Brennan even suggests leaving pipes fully exposed to provide full access—as he sometimes sees in older buildings.

When pipes are installed in interior walls, leaks are more likely to be noticed and fixed quickly—before mold, decay, and other moisture-related damage occurs. To reduce damage, minimize use of standard drywall and other porous materials in locations where leaking pipes or appliances are most likely (bathrooms and kitchen walls with sinks, dishwashers, and refrigerators). In place of standard drywall, use one of the recently introduced mold-resistant drywall products (U.S. Gypsum’s Humitek™ or Georgia Pacific’s DensArmor™), monolithic (non-paper-faced) drywall, such as USG’s Fiberock™, or—where leaks and other moisture problems are most likely—cement board. If standard drywall must be used, at least raise the drywall panels a few inches off the floor and cover the space with baseboard (taking care not to compromise the airtightness of the wall). If practical, install clothes washers and water heaters in spaces with floor drains or in watertight pans, and provide clearly visible shut-off valves. (When floor drains empty into a building’s sewer line, provision should be made to keep the trap filled with water to prevent the entry of sewer gases into the building; specialized trickle-flow products that do this are commonly used in commercial buildings but not [yet] as often in houses.) Flooring in spaces prone to leakage should be water resistant, such as tile. Avoid carpeting in these locations.

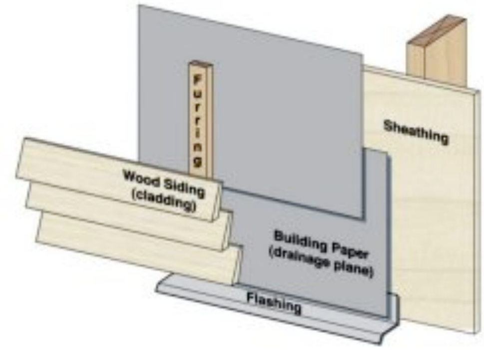
Avoiding condensation

Condensation can occur in buildings whenever an indoor surface temperature drops below the dew point of the indoor air (which depends on the humidity). In cold climates, condensation is common on poorly insulated window glazings, on non-thermally broken window frames, and when uninsulated concrete walls or steel framing results in a thermal bridge to the outdoors. Condensation can also occur in warmer months when humidity is high and cold-water pipes are significantly cooler than the air temperature. When such condensation is severe, water can accumulate and cause mold or decay. Risk of condensation can be reduced or eliminated through careful attention to energy-efficient building practices (high-performance glazings, proper wall insulation, insulative sheathing on steel framing, foundation and slab insulation, etc.) and by insulating *all* water pipes (see *EBN* Vol. 11, No. 10).



Lapping the materials properly and ensuring that surfaces are sloped to drain are essential in an effective drainage plane.

Controlling humidity



An example of a rain-screen assembly that provides a high level of protection from rain penetration.

High humidity in buildings can come from either indoor or outdoor sources. The concern is typically much greater in summer months, when outdoor humidity levels are high. While experts used to recommend ventilating unheated basements during the summer months, most now discourage that practice in humid climates (even though codes may still require it), because the ventilation *introduces* more moisture than it removes. Building science expert Don Gatley, of Gatley and Associates in Atlanta, Georgia, says that for outdoor ventilation to dry a building out, the outdoor dew point must be 55°F (13°C) or lower.

Preventing the entry of humid outside air involves creating a tight building, installing a poly vapor retarder on the ground in crawl spaces, and avoiding conditions that will depressurize the building. The most common *interior* sources of humidity—showering and cooking—are best dealt with through spot ventilation at the source (see below). Avoid storing firewood indoors, venting clothes dryers indoors, and using unvented gas heaters—the last because unvented heaters produce significant quantities of water vapor as well as other combustion products).

Designing building envelopes to dry out

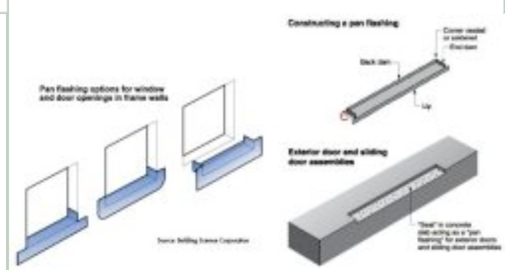
Because we can't always succeed in keeping moisture out of our buildings and building assemblies, the second line of defense should be to design our structures to dry out. Think of this as an insurance policy. Some strategies for improving a building's drying potential have ancillary benefits, such as longer life for paint. How you should design a building envelope to dry out depends on the climate. Experts used to say that you should always put the vapor retarder on the warm side (on the interior in cold climates and on the exterior in warm climates), but Lstiburek now argues that in most climates the envelope should have some drying potential in both directions —because moisture-driving forces change dramatically throughout the year. Only in the very coldest climates does Lstiburek still recommend interior vapor retarders.

CertainTeed has begun marketing MemBrain™, developed by a German subsidiary of CertainTeed's parent company, Saint-Gobain. This so-called "smart" air/vapor barrier, made from 2-mil nylon, becomes more permeable as the humidity increases, moving from below 1 perm at 50% RH to 36 perms at 95% RH—57 to 2070 ng/(s·m^2·Pa). This product should permit the use of an air/vapor

CertainTeed's new MemBrain™ is a "smart" air barrier and vapor retarder that becomes more permeable as the humidity increases.

barrier on the inside of walls even in climates where drying to the interior should be possible some of the time. It may even be effective as an exterior housewrap product in hot, humid climates. Specific recommendations for designing building envelopes to dry out are provided in the checklist on page 15.

Providing mechanical ventilation



Mechanical ventilation should always be part of the moisture-control strategy for buildings. Spot ventilation at locations where a lot of moisture is generated—kitchen ranges and bathrooms—is the first priority. Beyond that, whole-building, continuous mechanical ventilation—even in homes—is recommended in most climates. The proposed ASHRAE 62.2 residential ventilation standard has just been approved by a key committee at ASHRAE and is awaiting publication—despite strong opposition by the National Association of Home Builders and the Gas Appliance Manufacturers Association. This standard, for those municipalities that adopt it, would require continuous mechanical ventilation rated at 7.5 cubic feet per minute (cfm) per occupant plus 1 cfm for every 100 ft^2 of usable floor area—3.5 liters per second (l/s) plus 0.5 l/s for every 9 m^2. Homes in hot, dry climates and most of California would be exempt, under the assumption that windows could provide effective ventilation.

Providing dehumidification

As a last resort in the control of moisture, mechanical dehumidification can be used. As noted above, experts recommend that indoor RH levels should be kept below 60%, and there may be conditions in which this cannot be achieved without some form of dehumidification. Generally, dehumidification is needed only if a space is cooled by air-conditioning or earth contact. Unfortunately, most air conditioners do not dehumidify well, especially if the need for sensible cooling is small, which is often the case in energy-efficient buildings.

Fortunately, wood, concrete, and some other building materials help to regulate humidity by absorbing moisture when the air is humid and releasing moisture when the air is dry—so some excursions above the 60% limit are acceptable. This enables a building to operate with cycling humidity—higher in the summer, lower in the winter, but generally within the 25–60% range. When dehumidification is required, a high-efficiency dehumidifier or a high-efficiency air conditioner with a high moisture-removal rating should be used.

Final Thoughts

By making use of today's best building science, we can not only design and construct buildings that will last well over a century but also greatly reduce the risk of moisture-related health problems, including exposure to molds and other allergens. To apply building science, we have to address the interactions among components in a building—looking to manufacturers for solutions at the level of their individual product isn't enough. There is rarely anyone filling the role of building scientist on design teams today. It is up to architects to either learn enough to play that role, or hire consultants who can work through every detail of the envelope and mechanical and plumbing systems with them.

– Alex Wilson

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Excellent resources are available on the Web site, including *Read This Before You Design, Build or Renovate.*

Sidebar: Common Sources of Moisture In Buildings

Sources of Liquid Water

Precipitation: Rain and other forms of precipitation are the most significant sources of water in many homes—though the entry might not be direct.

Groundwater: In areas with high water tables, groundwater entry into buildings can be a huge problem. Note that groundwater (a "rising water table") is often incorrectly blamed when rain saturates the soil around a foundation faster than that water can drain away.

Leaking pipes: Leaking pipes are surprisingly prevalent in buildings and a leading source of moisture problems. Building science expert Joe Lstiburek, of Building Science Corporation, believes leaking pipes to be the single largest source of moisture problems in houses.

Cleaning and other maintenance: Poor cleaning practices can leave carpeting, upholstery, and other surfaces too wet to adequately dry out before moisture-related problems occur.

Condensation: While not truly a moisture source, condensation of water from humid (or even not-so-humid) air can produce liquid water on windows, exterior walls, foundation walls, and other surfaces that are significantly cooler than most surfaces in a building. Condensation can occur when there is a small temperature difference but high humidity, and it can occur when there is fairly low humidity but a large temperature difference (a surface being much colder than the surrounding air).

Sources of Water Vapor

Moist air from outdoors: Depending on the location and the season, the entry of moist outdoor air into buildings can be a very large source of moisture. Humid air entry is greatest in the summer.

Soil moisture: If a building operates under negative pressure, moist air from the ground can be brought into a building through the foundation walls and floor slab. According to building science expert Terry Brennan, of Camroden Associates, soil air can be a significant moisture source/problem either when the ground around a building is particularly porous so that soil air accounts for a large fraction (10-20%) of total ventilation, or when soil air is able to infiltrate a cavity between a foundation wall and an inner finished wall.

Vaporization of liquid water: Any wet materials that dry out or water that evaporates indoors will contribute water vapor to the building. Rainwater entering crawl spaces and basements is the most common source of this evaporative water vapor.

Showers: Atomized hot water from showers can contribute large quantities of water vapor.

Cooking: Nearly all cooking activities, but especially boiling water, contribute significant amounts of water vapor.

Dishwashing: Dishwashers release water vapor into the kitchen during their drying cycle. Hand washing of dishes also releases water vapor as they dry.

Cleaning and other maintenance: Many cleaning activities involve wetting surfaces, which releases water vapor into the air through evaporation.

Respiration: People (and their pets) release substantial quantities of water vapor through their breathing. A typical adult exhales water vapor at a rate of 1 pound per day (450 g/day) when resting, 2.8 pounds per day (1.3 kg/day) standing, 4.5 pounds per day (2 kg/day) doing light work, and 7 pounds per day (3.2 kg/day) doing moderate work.

Unvented combustion: Unvented (vent-free) gas heaters and "fireplaces" produce significant quantities of water vapor as one of the two primary combustion products (see EBN Vol. 5, No. 3). Gas ranges and ovens introduce smaller amounts of water vapor.

New building materials: Building materials can be large sources of water vapor—particularly concrete, joint compound, paint, wet-spray cellulose insulation, framing lumber, and any materials that got wet on the job site. Improper storage of building materials on the job site is a surprisingly large source of mold problems in buildings (see EBN Vol. 11, No. 5).

Checklist: Checklist: Design Strategies for Moisture Control

Keeping Water Out

Provide proper flashing on all windows and doors: All components should be layered so that water is shed down and outward. There are numerous ways to flash windows—flashing can be installed before or after housewrap or building felt "drainage plane," specialized formable flashing can be used at the sill, and special measures are required with masonry walls and when rigid foam provides the drainage plane (see illustration, as well as the EEBA Water Management Guide review in book review department).

Provide a rain screen behind siding: To facilitate drying of siding and to provide a capillary break between the siding and the sheathing, most experts now recommend rain screen detailing in wetter climates (see map). This can be provided with vertical strapping (minimum $^3/_8$", 9.5 mm thick); a specialized rain screen product, such as Benjamin Obdyke's Home Slicker™; or, with brick siding, a bottom-draining air space behind the brick facing.

Seal wood and fiber-cement siding: Porous siding materials should be sealed on all sides. Pre-priming is recommended prior to installation, with multiple coats as needed, especially on end-grain. Sealed siding will not absorb moisture, thereby reducing moisture migration driven by solar heat.

Provide a capillary break above footing: Paint the top of the footing with a dampproofing coating or install an impermeable layer before installing the foundation wall to block the upward migration of soil moisture.

Provide drainage layer and poly vapor retarder under concrete slab: Before pouring a concrete floor slab, install a minimum 4" (100 mm) layer of crushed stone (no fines) and a poly vapor retarder. The concrete should be poured right on top of the poly; without a layer of sand between the poly and slab.

Provide perimeter drainage at footing: Install crushed stone (no fines) and perforated drain pipe around the footing. The drainage pipe should be slightly pitched but extend neither below the bottom of the footing nor above the top of the footing. Sections of plastic pipe should extend through the footing every 6 to 12 feet (2–4 m) to drain the space under the slab. Wrap the layer of crushed stone with geotextile filter fabric to keep fines out.

Paint outside of foundation wall with dampproofing layer: A durable dampproofing should be painted on the outside of the foundation wall. Several layers are suggested, with the minimum thickness depending on the material (follow manufacturer's recommendations).

Install free-draining layer next to foundation wall: Install a specialized drainage layer (free-draining insulation, kinked nylon mesh, corrugated plastic, etc.) against the foundation wall, or backfill against the wall with crushed stone, or do both. When using a layer of crushed stone, protect it with a geotextile filter fabric to keep fines out.

Slope ground away from building and provide impermeable cap: The ground should slope away from a building at a minimum pitch of 5% (6" per 10', 5 cm per m). Provide a low-permeability (high-clay-content) soil cap extending 6 feet (1.8 m) from the building to reduce infiltration and direct surface runoff away from the structure.

Provide a roof overhang to keep rainwater away from building: The longer the roof overhang, the greater the protection of the house. A minimum 24" (600 mm) overhang is recommended in most climates; 36" (900 mm) is preferable. Porch roofs and awnings also drain water away.

Provide self-sealing ice and water barrier on roof: To protect against water penetration if ice dams occur in cold climates, install a self-sealing protective layer (e.g., Grace Ice & Water Shield®) under roofing.

Install gutters and downspouts: Install durable gutters and downspouts to direct rainwater away from the building.

Use screening to keep leaves and other debris out of downspouts, and instruct building owners to keep gutters and downspouts clean. At the bottom of downspouts, water should be channeled as far from the building as possible. Do not connect downspouts to footing drains.

Designing Building Assemblies to Dry Out

In most climates, provide drying potential to both interior and exterior: Building Science Corporation now recommends that in all but the coldest climates, above-ground walls should be designed to dry to both the exterior and interior. This means avoiding a poly air/vapor retarder and using permeable or semipermeable layers in the wall system.

In the coldest climates, install poly vapor retarder on interior: BSC recommends that polyethylene vapor retarders should be used only in the coldest climates. In such climates (over 8,000°F [3,400°C] heating degree days), install a poly vapor retarder on the interior wall, under the drywall. The vapor retarder should be carefully sealed at all overlaps, edges, and penetrations. This arrangement will allow the wall cavity to dry to the exterior only.

Design basements to dry to interior: In all climates, basement walls should be designed to dry to the interior. Insulation should be permeable or semipermeable, such as expanded polystyrene (EPS) or fiberglass with a moisture-resistant gypsum board product, such as Fiberock® or HumiTech™, and vapor-permeable latex paint on the interior.

Provide vented rain screen on exterior walls: In climates with more than 40” (1 m) of rain per year, BSC recommends an exterior wall detail with a minimum $^{3}/_{8}$” (9.5 mm) air space behind the siding, with screened vents at top and bottom. This rain screen detail both provides a capillary break and allows drying to the exterior. In climates with fewer than 40” (1 m) of rain per year, this vented rain screen may not be necessary. See map, page 13.

Use plywood rather than OSB to aid in drying: Recent research shows that while both plywood and OSB have low permeability when dry, plywood becomes significantly more permeable than OSB when moisture content rises; this will aid drying to the exterior. With a fully vented rain screen detail, using OSB should be satisfactory.

Consider perforating sheathing: The June 2003 issue of Energy Design Update reported on Canadian research demonstrating the effectiveness of drilling 3” (75 mm) holes through the exterior sheathing at the top and bottom of stud bays. Some builders drill lots of smaller holes through the sheathing to aid in drying.

Provide a vented roof assembly: In all climates, a vented roof assembly will assist in drying and is generally recommended. In cold climates, a vented roof also helps to prevent ice dams by keeping the roof surface cold. Full-length soffit and ridge vents are the preferred venting strategy. Keep roof geometry simple to aid in venting. Unvented (hot) roofs can be successful, but only with great care in the construction; avoid this approach unless working with an expert.

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