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Water and moisture can come from a variety of places and be a problem for multiple parts of a building. Controlling where moisture does and doesn't go is critical to the successful performance of a building and achieved by focusing on products and systems with the right capabilities. Pictured is 60 Holborn Viaduct located in London.

Integrated Approaches to Control Moisture in Buildings

High-performance products integral with other systems can create better results

Sponsored by Inpro, Xypex Chemical Corporation, and ZIP System® R-sheathing

By Peter J. Arsenault, FAIA, NCARB, LEED AP

Moisture in buildings is probably one of the most investigated, discussed, reviewed, and researched challenges in building design and construction. There are good reasons for this. Consider the Building Assessment Survey and Evaluation (BASE) study that was conducted by the US Environmental Protection Agency (EPA) in the 1990s. It found that among the randomly selected public and private office buildings studied across all 10 climate zones in the United States, 85 percent had been damaged by water at some point, and 45 percent had leaks at the time data was collected. That data indicates that most buildings are likely to experience some form of impact from unwanted or excessive moisture accumulation. Those conditions can lead to serious problems, such as the degradation, deterioration, or even failure of building materials, development of mold and mildew, and possible risks to human health and safety. Repairing any of these conditions after the building is constructed and occupied typically involves opening up construction assemblies, which is disruptive, time-consuming, and costly. Hence, it is no wonder that there is great interest in understanding how moisture can be controlled in buildings at the outset to avoid any or all of these potential problems and risks.

The Whole Building Design Guide (WBDG), a program of the National Institute of Building Sciences, provides some of the best, objective, state-of-the-art thinking on this topic. It identifies three main causes of moisture movement, namely, water impingement or leakage (as in a roof, wall, or floor system), movement of moist air (through gaps or openings in roofs, walls, or floors), and vapor diffusion through materials that can

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Learning Objectives

After reading this article, you should be able to:

1. Identify and recognize the significance of water and moisture penetration in a building based on its effects on materials and people.
2. Assess the means available to provide waterproofing of concrete for foundations and other building systems.
3. Explain the importance of continuity of water-resistant barriers in wood-framed construction and integrated approaches to achieve it.
4. Determine how to specify expansion joints and covers that are integrated into construction assemblies with attention to water and moisture control.

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One Hyde Park, designed by Rogers Stirk Harbour + Partners, is tagged as 'the most luxurious address in London.' Crystalline concrete was selected for this project as a waterproofing and protection solution for the three-level basement slab and wall areas, attenuation tanks, podium slab, and penthouse roofs. It was also used for the traditionally cast and post-tensioned concrete, while also being utilized as a remedial solution for areas adjacent to the existing structure.

occur slowly over time but saturate and damage materials nonetheless. The WBDG points out that solutions cover the gamut of design and construction activities, stating, "Preventive and remedial measures include rainwater-tight detail design; prevention of uncontrolled air movement; reduction of indoor air moisture content; reduction of water vapor diffusion into walls and roofs; selection of building materials with appropriate water transmission characteristics; and proper field workmanship quality control." Listed all together, that may sound like a tall order, but in essence, it means that everyone involved in a building project has a role to play in managing moisture in buildings, starting with the design team.

In this course, we will look at three specific areas that are common to buildings, namely concrete foundations, wood-framed enclosures, and expansion joints. Each of these areas will be looked at for their general and specific issues related to moisture management, with some example solutions noted for each.

CONCRETE FOUNDATION WATERPROOFING

Foundations are necessarily in contact with the earth, which is known as a source of water infiltration into buildings. There are certainly some site-engineering approaches for draining water away from a foundation or adding drainage systems around the outside of a building, and their use is common. However, it is also common to provide some type of waterproofing system to keep any water from passing through the concrete. However, achieving that can be challenging since the formation of cured concrete produces a myriad of air gaps, holes, pores, capillary tracts, and other internal voids. Further, concrete shrinks in size as it cures, although if it is cured properly, that shrinkage can be kept to a minimum. Nonetheless, visible cracks or much less-visible microcracks can occur. The end result is that while concrete may appear strong and impenetrable on the surface, it actually ends up quite porous due to the variety of openings and voids inherent within it. This porosity means that water can penetrate into and even through a concrete structure, causing water seepage that is usually not desirable.

Over time, the inherent water permeability limitations of concrete may get more pronounced in several ways. First, any exposed surface can be physically damaged due to physical force, abuse, weather, etc. Such physical damage can cause the surface of the concrete to crack or break, exposing the inner aggregate and creating a rough surface that is vulnerable to moisture absorption and further deterioration. Secondly, the permeable nature of concrete can allow not only water but also soluble chemicals to penetrate into the foundation and cause deterioration of the concrete or corrosion on any metal components embedded in the concrete. This can include reinforcing steel, anchors, sleeves, post supports, angles, or any other metal that is used with concrete structures.

Surface treatments: In any of these conditions, concrete deterioration fueled by moisture can produce aesthetic, functional, or structural problems if not treated properly or prevented. To overcome these issues, there are several approaches. A common one is to use a surface coating to waterproof the concrete, thus keeping not just water out but chemicals and other harmful substances too. This approach is based on applying a protective coating either in liquid or sheet form over the concrete. Either one has an inherent limitation, however, in that they are not integral to the concrete but rather an applied layer on top of it. This means their success is entirely dependent on the workmanship of the installation and ultimately the full adhesion to the concrete surface to prevent it from separating and peeling off. This can be a particular challenge in locations where the concrete shape is irregular or where different sections meet and the coating needs to conform to multiple underlying shapes.

Admixtures: A different approach to waterproofing concrete is the use of specific chemical admixtures to make the waterproofing completely integral to the concrete itself. Admixtures, in general, have been used for decades to improve the performance of concrete in a variety of ways. Their first widespread use was to extend the temperature range that concrete could be poured without fear of freezing. They also became common to improve the workability of concrete through plasticizers that allowed less water in the mix while still retaining adequate slump (formability). Building on this proven success, some specific admixtures have been developed for waterproofing concrete that are based on filling and sealing all pores, small cracks, and openings with solid crystallized material. Referred to as crystalline technology or crystalline concrete, it has achieved some impressive results.

Crystalline concrete: In essence, crystalline technology takes advantage of the natural and porous characteristics of concrete. When a cement particle hydrates, the reaction between water and the cement causes it to become a hard, solid, rocklike mass. The reaction also generates chemical by-products that lie dormant in the concrete. Crystalline technology adds another set of chemicals to the mixture. With water as the catalyst, specific chemical admixtures are used that react with the natural by-products of cement hydration (calcium hydroxide, mineral salts, mineral oxides, and un-hydrated and partially hydrated cement particles). When these two groups, the by-products of cement hydration, and the crystalline chemicals are brought together in the presence of moisture, a chemical reaction occurs. This reaction forms a nonsoluble crystal that grows to form a web-like crystalline structure within the interconnected pores and other voids in concrete. In this way, the crystalline structure becomes a permanent, integral part of the concrete itself. Because it is nonsoluble, it fills the voids, cracks, capillaries, pores, and other openings to make the concrete impermeable, thus preventing the ingress of water and other liquids even under strong hydrostatic pressure. That means it also protects against liquid-borne chemicals that can deteriorate concrete or corrode steel reinforcing, even in harsh, aggressive environments or under high hydrostatic pressures.

Integral crystalline technology products are manufactured in the form of a dry powder compound consisting of portland cement, very fine treated silica sand, and selected chemicals. It is the chemicals that react with the by-products of cement hydration to produce the nonsoluble crystalline formation. Specific formulations are produced for application either as a coating material, concrete admixture, or dry shake product applied to the wet concrete and troweled in. It can be incorporated into a structure as it is being constructed or later on in the life cycle as a maintenance material that will further enhance its durability. As such, crystalline concrete is a viable method for waterproofing building foundations that can be used as a stand-alone system or as part of an integrated waterproofing system incorporating surface membranes. Crystalline waterproofing can reduce costs, accelerate construction schedules, and be used where other waterproofing methods or assemblies are difficult or impractical.

WOOD-FRAMED MOISTURE PROTECTION

Designing and constructing wood-framed buildings commonly involves several different trades working on the roof and wall systems. As we have already noted, these are places where water- and air-borne moisture can infiltrate a building and cause damage. This is the reason that building codes like the International Building Code (IBC) and the International Residential Code (IRC) require a water-resistant barrier (WRB) on the exterior side of wood sheathing. Achieving that is commonly done with a field-applied material, such as rolls of housewrap or spray, on material over the exterior sheathing. This approach necessarily relies on the skills and capabilities of the installers to achieve a truly continuous, water-resistant solution.

Integrated engineered-wood sheathing: In recent years, alternative products have emerged to address the need for a WRB layer that can be consistent and reliable with less susceptibility to variable labor and field conditions. Referred to as integrated engineered-wood sheathing systems, these products are used as structural sheathing in single-family, multifamily, and light-commercial Type 5 construction projects for non-fire-rated roof decks and exterior walls assemblies. They also have additional properties that have been shown to reduce the risk of moisture damage in several ways. First, and perhaps most significantly, a WRB layer is manufactured (not laminated) in the factory onto the exterior surface of these engineered wood panels. This eliminates the need for designers to specify a separate layer and gives construction crews one less thing to install. Second, integrated engineered-wood sheathing effectively addresses the seams between sheets with a high-performance tape that creates full contiuity of the WRB. Third, states like Oregon or elsewhere are requiring rainscreens or enhanced drainage planes behind the final cladding (siding, masonry, etc.). In response, these products have been tested per the applicable ASTM standards and shown to meet the code definition of an enhanced drainage plane with 90 percent drainage efficiency. Finally, due to the integrated engineering aspect of these products, they not only provide full WRB protection, but they also qualify as an air barrier to keep out unwanted air infiltration. This air-barrier quality means that it helps prevent airborne moisture from penetrating into a construction assembly too.

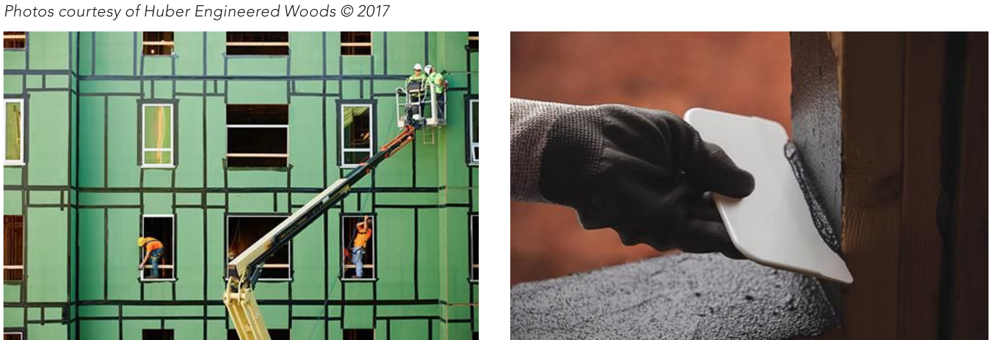
In order to achieve the needed full protection and continuity of a WRB and air barrier, proper taping and flashing is needed around window and door openings, penetrations, and junctions of different assemblies (wall/roof, wall/foundation, etc.) This can be accomplished in one of two ways:

Tape and flashing products: High-performance tape products that are made from an advanced composite acrylic provide superior adhesion, aggressive bonding, and resistance to ultraviolet (UV) light exposure. Some of these tapes are especially formulated for use with integrated engineered-wood sheathing for full compatibility and should be specified as a coordinated system. Such specialty tape can use a pressure-activated formula with a specific viscoelasticity that provides the right balance to form an ionic bond with the WRB layer. Such tape can also be manufactured and specified with four distinct layers including slip resistance (since it's used in roof applications), UV protection, a bonding layer, and eight mils of acrylic adhesive.

In addition to sealing the joints of integrated sheathing panels, this tape can be used as flashing to cover the exposed framing and face of the sheathing on window and door heads, jambs, and sills to create a continuous protective layer that seals out water and air around these openings. Such flashing tape is commonly available in 4- and 6-inch widths in both a straight flashing formulation and a stretchable version. The stretchable tape is also available in 10-inch widths to provide the appropriate coverage in a single installation over the full depth and perimeter of the openings as opposed to piecing multiple tape segments together. The fully flashed opening is then ready to receive a window or door unit, which may then be further counter flashed over or around integral flanges using the same flashing tape. In either case, the tape is pressure rolled into place using handheld rollers to assure a complete and uniform bonding. If stretchable tape is used, it is particularly well suited to irregular-shaped window openings or even curved/rounded openings.

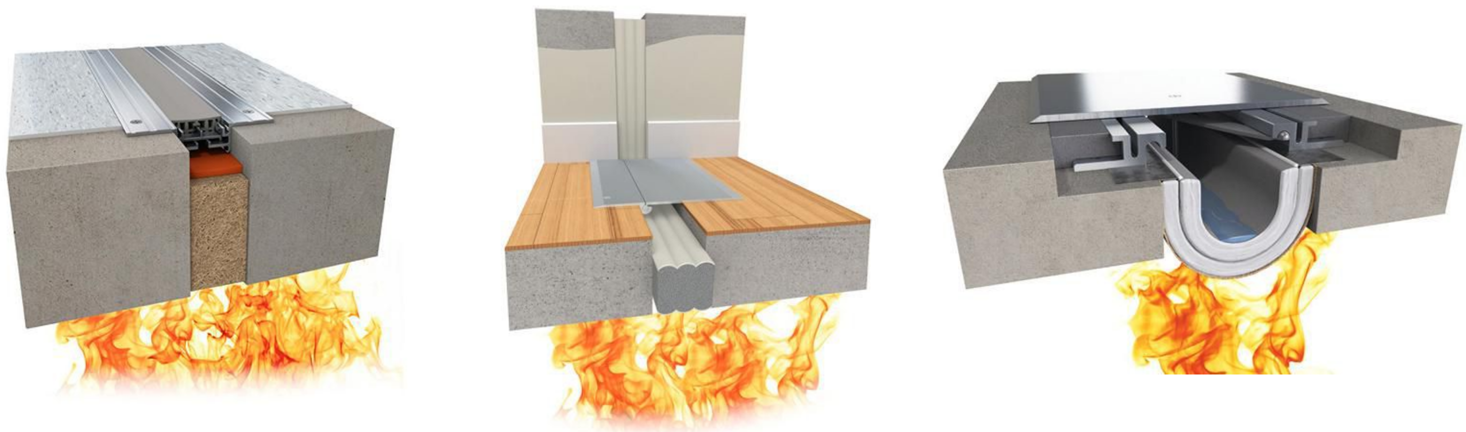
Liquid flashing products: Much like other liquid waterproofing products, liquid flashing formulated for integrated engineered-wood sheathing can be applied to create a continuous, seamless condition around windows, doors, and other openings. It is also particularly well suited to variable surface conditions, such as wood to masonry transitions (i.e., wall to foundation), round, curved architectural details, or parapet walls. It is common for products like these to be hand-applied using a towel or a brush onto a surface, such as sheathing, framing, metals, etc. Once applied, it is intended to dry to a complete and continuous water- and air-proof seal around all portions of the condition being flashed. Since it is usually the thickness of the application that is important for quality control, applicators likely need to be trained in the installation of these flashing products, and on-site quality control becomes very important. Such liquid flashing products can also be stronger and higher rated than some tape systems, making them particularly suitable for upper stories in multifamily buildings subject to higher wind ratings.

Photos courtesy of Huber Engineered Woods © 2017



Integrated engineered-wood sheathing provides a continuous defense against water in wood-framed construction when paired with self-adhering tape and liquid flashing.

Images courtesy of Inpro



Three common types of expansion joint systems that can resist both water and fire include compression systems with mineral wool (left), waterproof, fire-rated foams (center), and waterproof fire blankets (right).

Part of the effectiveness of liquid flashing is that it can be applied with optimal viscosity to flow easily into irregular shapes and surfaces, such as recessed windows, corners, roof valleys around chimneys, and pipe penetrations. Typically, such flashing can be weather resistant and tack free in as little as 20–40 minutes. Even better, since it is available in a moisture-curing formula, the liquid flashing membrane can bond and cure in otherwise unfriendly site conditions, including wet weather and damp substrates. At least one is backed by a 180-day exposure guarantee, meaning that if it remains uncovered for up to six months, it will still perform. In the end, it is usually the architect's preference whether to use liquid-applied flashings or other systems, but the versatility and durability of these products cannot be ignored, particularly for long-term solutions on larger and taller buildings.

KEEPING EXPANSION JOINTS WEATHER TIGHT

Architectural expansion joints are often necessary, predetermined gaps in structures that are designed to absorb environmental movement in buildings. When done right, they tend to be integrated with their construction such that they blend in with a design and almost disappear. Hence, it is easy to overlook the fact that they can be a potential source of water and moisture infiltration and damage. That infiltration could be problematic for the expansion joint itself, or it could cause problems for other building materials or occupants too. Either way, when using expansion joints that need to cut across exterior surfaces, their ability to resist water needs to be factored in along with the other requirements for the joints.

At the most basic level, expansion joints are a necessary component that must be engineered to handle movement between adjacent structural sections or components. Filling the resulting gap with an appropriate material that can expand and contract along with the building is the essence of expansion joint filler and cover design. The details of both the material used and its connection to the adjacent surfaces are what manufacturers of these systems focus on to assure that successful products and applications are possible. For example, when a joint filler and cover are used for floors, high durability is needed to withstand pedestrian traffic, push carts, scissor lifts, etc. Similarly, when it comes to acting as a moisture barrier, a continuous, sealable connection is needed to prevent water infiltration. This may include a means to help channel rainwater away from the joint and toward predetermined drainage points. Either way, the system needs to prevent water infiltration, which could do damage to the filler and cover system first and then go on to damage other areas of the building.

Water and moisture control are particularly important if the expansion joint is in a fire-rated assembly since the joint filler and cover will need to be fire rated as well. The apparent paradox of providing an intentional break in the structure to allow for normal expansion and contraction while still maintaining a fire rating is addressed by providing an expansion joint fire barrier that is tested for performance. However, since these fire barriers become worthless if they are wet, preventing water from entering a fire barrier is also critical to life safety. In that regard, choosing a supplier for expansion joint systems and fire barriers that are truly effective cannot be overstressed.

With all of the above in mind, there are three common types of barrier expansion joint systems that can be considered. The suitability of each for a particular project condition will depend on the size of the joint or gap as well as the conditions which the joint are subjected to.

Compression systems are typically for 4-inch and smaller expansion gap widths. These products are commonly comprised of mineral wool strips held in place through compression. These are topped with sealant to secure the barrier in place and protect it from water infiltration. For fire rated versions, fire lab testing of compression systems is typically done for both concrete and drywall conditions.

Foam seals are suitable for 6- to 8-inch and smaller gaps and conditions where abuse is not likely. In certain applications, the use of foam seals in expansion joints provides a solid seal against the elements, providing both thermal and moisture protection. Open-cell foams provide some breathability and are best in vertical applications, allowing any moisture that becomes trapped in a wall cavity to wick out. Closed-cell foams are watertight and block water from entering—whether in liquid or vapor form. This is the best application for horizontal runs where water could penetrate and pool where it is not wanted.

▶ Continues at ce.architecturalrecord.com

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PRODUCT REVIEW

Integrated Approaches to Control Moisture in Buildings

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Xypex Crystalline Concrete Waterproofing

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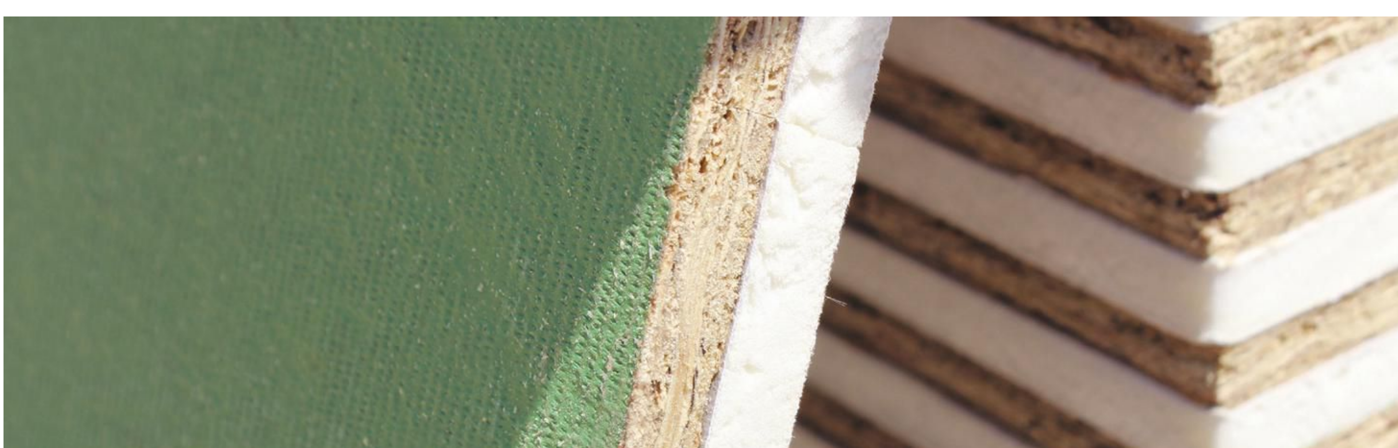
ZIP System® R-sheathing



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All-in-One Insulated Sheathing Panel

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