

A HOUSE OF BRICK:

Water Repellents and Elastomeric Coatings

By Wei Lam and Jonas Hawk

When the third little pig built his famous house of brick, he had only wind resistance in mind. The well-known children's tale leaves out any mention of whether our wise little friend specified a water repellent or elastomeric coating for his masonry project. Obviously, he made a well-informed decision, because, as we all know, he lived happily ever after.

Today, the problems resulting from construction defects and water penetration are at the forefront of issues faced by the industry. Water-repellent and coating applications are frequently recommended for masonry walls without adequate consideration of the issues that will make the application a success or failure. Failures are frequently attributed to accumulation of moisture behind the masonry once a treatment has been applied. A sound decision whether to include these products in new or existing construction should be based on an understanding of the substrate

properties, available product classes, and the potential risks of an inappropriate selection or application.

Building envelope (BE) professionals in today's construction industry are frequently the source that architects, owners, and contractors turn to for answers on these products. BE professionals, in turn, encounter an increasingly complex array of

products and information when it comes to masonry wall construction and moisture management. Countless commercial water-repellent and waterproofing products for masonry have been introduced in the past 30 years. The products include those with formulations and physical properties that vary widely, though they are frequently classified in similar groups. The specifica-

tion and use of these products are debated, and much has been written about proper selection. While many projects may benefit from the application of a properly selected repellent or waterproofing material, there are cases when these products may exacerbate existing problems or create new ones.

Wetting, Storage, and Drying of Masonry

While a detailed discussion of moisture storage and transport mechanisms in porous materials reaches beyond the scope of this article, these concepts are central to understanding how coatings and penetrating sealers affect these functions. Masonry used for exterior cladding applications may include clay brick, natural

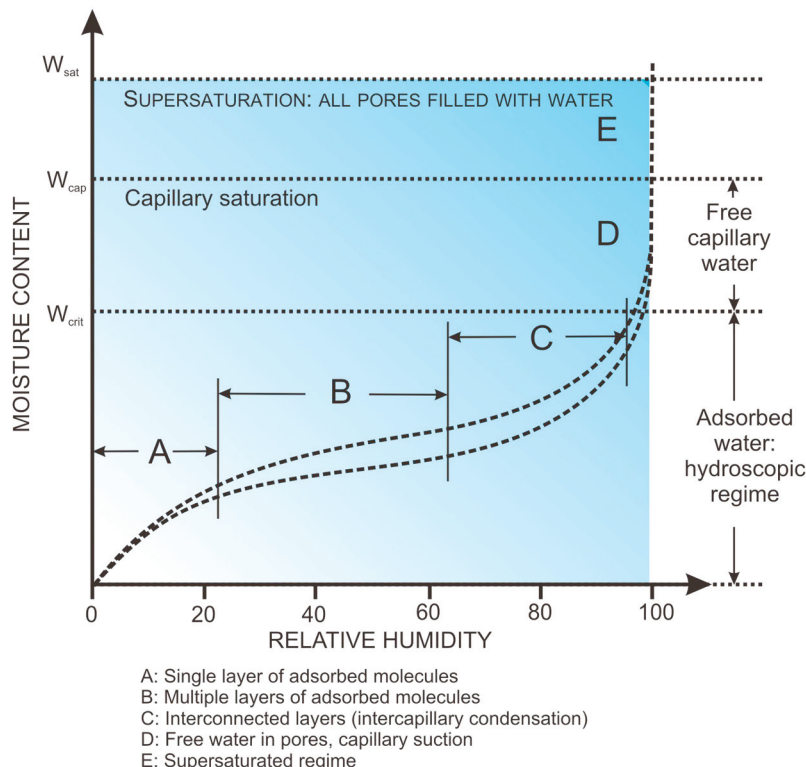


Figure 1: Moisture storage function (Straube et al. 2003).

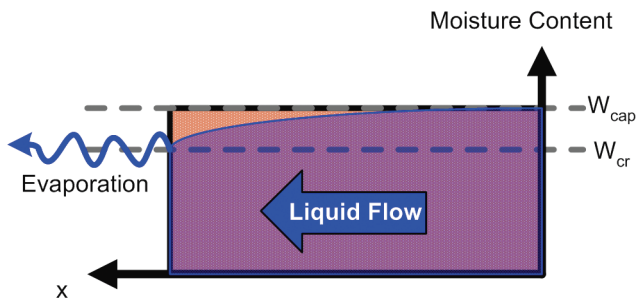


Figure 2a: Stage I drying (Roppel 2003).

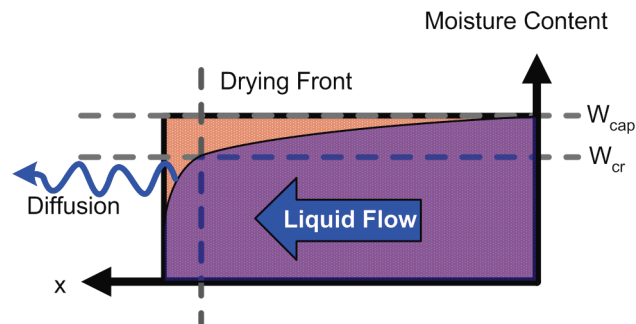


Figure 2b: Stage II drying (Roppel 2003).

stone, cast stone, concrete masonry units (CMU), architectural precast, or exposed cast-in-place concrete. While varying in degree, all of these materials are considered porous and have internal surface areas that are able to store and transport considerable amounts of moisture within their pore structures.

Storage

Most masonry types may be considered hygroscopic, meaning they have moderate affinity to attract and adsorb water vapor. Moisture exists in an adsorbed phase (adsorbate) when water vapor molecules are attracted to a surface by polar forces. Hygroscopic materials attract water vapor in this way until they reach a dynamic equilibrium and water content that varies with material properties, temperature, and relative humidity. As the relative humidity approaches 100%, water molecules begin to interconnect, and masonry materials begin to store water by capillary condensation, surface tension, and containment. Plotting moisture content versus the relative humidity results in sorption isotherm diagrams.

Over the years, several scholars have further defined regimes in these diagrams to differentiate mechanisms and phases of stored moisture. This includes the definition of water contents associated with critical saturation (W_{crit}), capillary saturation (W_{cap}), and supersaturation (W_{sat}). See Figure

1. [Straube *et al.*, 2003].
Transport

Moisture is transported through a porous material in the same phases as moisture storage: as adsorbate, vapor, or liquid. The forces driving each phase into a porous material are different. Adsorbed water relies on mass concentration gradients at the pore walls. Vapor is driven by differentials in vapor pressure. Liquid water transport can be governed by gravity, wind, hydrostatic, and capillary forces.

The primary wetting mechanism of masonry is capillary attraction from contact with liquid water. Rainwater, condensation, and groundwater are the primary sources of water available for capillary suction. Other wetting mechanisms include capillary condensation and absorption of vapor molecules. Water repellents and waterproof coatings will both decrease the potential from capillary suction and, depending on their formulation, may also act against other mechanisms of wetting.¹

Moisture is removed from hygroscopic materials through drainage, evaporation, and desorption. Oversaturated materials will drain by gravity until the capillary saturation moisture content is reached. The remaining moisture is removed by evaporation and desorption, which results in two distinct drying stages. Figure 2 illustrates

these stages. In the first stage, liquid water will flow by capillary conduction to the surface to replace the evaporated moisture. In the second stage, unsaturated flow and desorption begin once the material is no longer saturated. The rate of free water evaporation (Stage I) is usually much higher than the rate of desorption (Stage II) [Hall *et al.*, 1984]. Stage II drying occurs at a slower rate for two reasons:

1. Resistance of vapor flow occurs between the exterior surface and the drying front.
2. The vapor pressure gradient is less at the drying front compared to evaporation at the exterior surface.

The location at which liquid water ceases its flow in the material is called the drying front. When porous materials are treated with hydrophobic materials such as penetrating sealers, the drying front starts at the penetration depth of the sealer because liquid flow to the surface is interrupted. Therefore, the penetration depth of the sealer will influence the drying rate of the porous material because drying will start at this depth and occur at the Stage II drying rate as seen in Figure 3. When impregnated porous materials are near saturation, the drying rate can be much lower compared to the drying rate of untreated masonry near saturation.

Water Repellents And Elastomeric Coatings

While there continue to be debates and a lack of consensus when it comes to the terminology and nomenclature used to describe specific water-repellent and waterproofing treatments, a useful way to consider the range of products has been proposed by Mailvaganam and Straube. The classification is based on the surface interaction

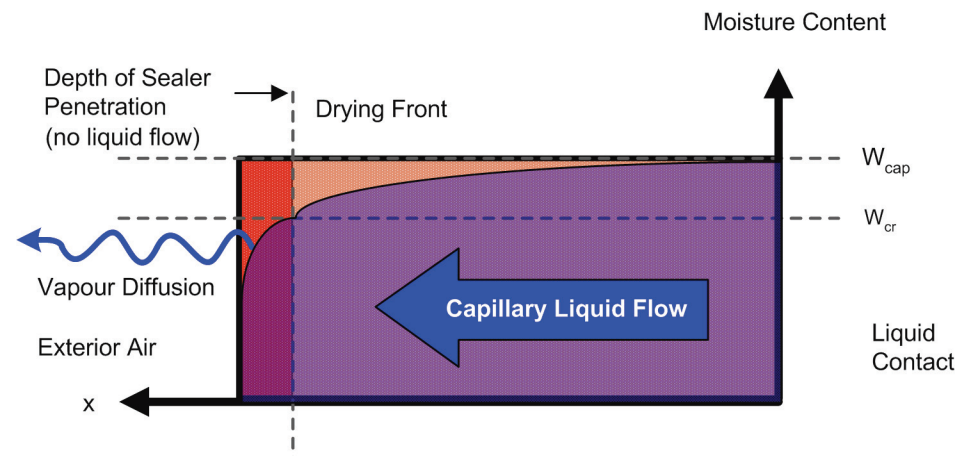


Figure 3: Drying of impregnated masonry [Roppel 2003].

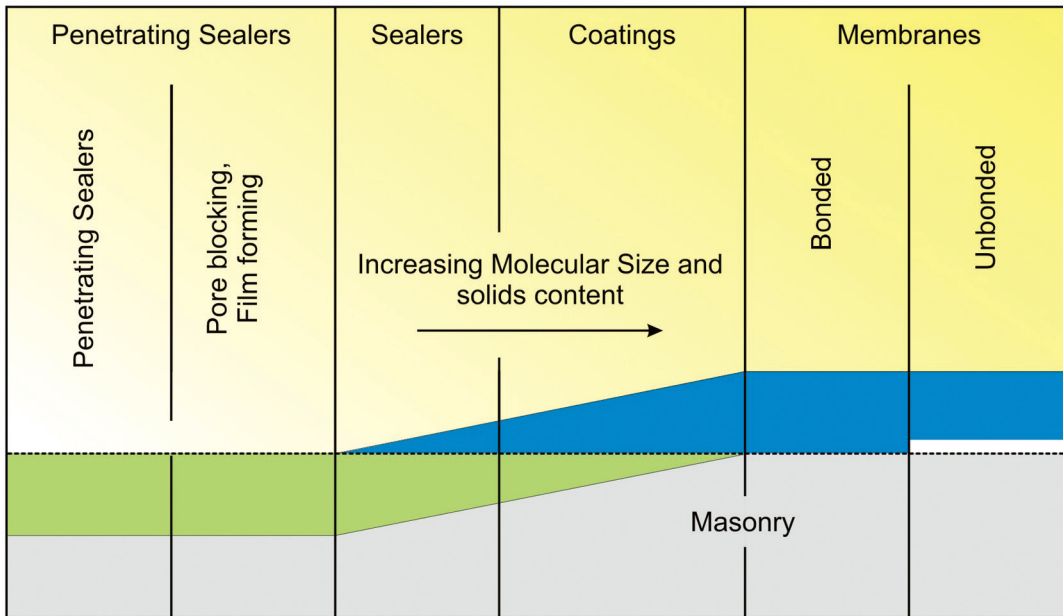


Figure 4: Waterproofing treatment types (adapted from Straube, 1997, and Mailvaganam, 1992).

and thickness of the treatment as illustrated in Figure 4. Most products considered for above-grade masonry wall treatments can be classified in the range between penetrating sealers and coatings. An important consideration with this classification is that the same generic product may behave in fundamentally different ways, depending on formulation and surface conditions. Industry has consolidated these products into three major classes: water repellents, elastomeric coatings, and cementitious coatings.

Water Repellents

Most water repellents in today's construction market are formulated to slightly penetrate the surface of the masonry and to have little effect on the appearance of the surface. While formulated to penetrate, some products may leave a very thin clear or semi-opaque film, depending on formulation and substrate properties. Small molecular size, low viscosity, and high solvent content improve penetration into the masonry pore structure. Modern water-repellent treatments will be more vapor-permeable (breathable) than elastomeric coatings or waterproof membranes. However, any repellent will have some limiting effect on the vapor transmission compared to an untreated surface. Water repellents that do not exhibit good vapor permeance have contributed to substantial failures. The vast majority of available water-repellent products for above-grade masonry walls are formulated from modified silanes, siloxanes, and blends of these suspended in

water or solvent-based carriers. Other products include silicates and methyl siliconates, though these are less frequently used due to their tendency to cause undesirable staining or discoloration of surfaces.

Smaller molecular size allows silanes to

and result in ineffective application.

While similar to silanes, siloxanes have a larger molecular size. This quality inhibits their ability to penetrate masonry surfaces. Siloxanes react with moisture in the substrate, but, unlike silanes, do not require a

penetrate deeper than siloxane molecules. Silanes react with moisture in the substrate, aided by the alkalinity of the substrate. In carbonated concrete and other neutral masonry materials such as clay brick, a primer or integral catalyst may be required. The relatively volatile nature of silanes requires a percentage of solids of 40% or greater in most formulations to account for evaporative losses that occur before the catalysts take effect. If environmental conditions evaporate moisture and solvent carriers prematurely, the effectiveness of silane-based products may be affected. Exposure to rainfall shortly after application may also result in leaching of silanes

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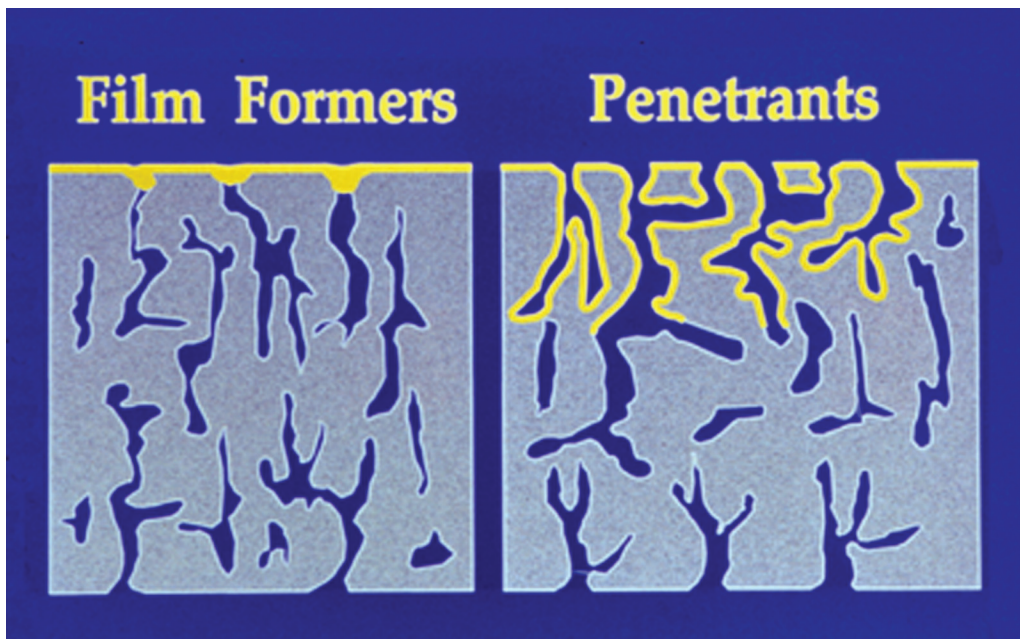


Figure 5: Film formers vs. penetrants (Graphic courtesy of Prosoco).

high pH to catalyze. This makes them well suited for neutral masonry such as brick or carbonated concrete. Because they are less volatile and create less of a concern with evaporation, siloxanes are provided in formulations ranging from 10 percent to 15

percent solids. Siloxanes are frequently blended with silanes to take advantage of the unique properties of each. This can be seen in blends specifically formulated for clay brick, in which the silane reacts with lime in the mortar and the siloxane pene-

trates the pore structure of the brick. Because siloxanes readily react with silica, they form a strong bond with glass, and proper care should be taken to mask areas of application.

Elastomeric Coatings

Properly applied elastomeric coatings become well bonded to the masonry surface, usually by a combination of penetration into the pore structure, mechanical keying, and – to a lesser degree – intermolecular attraction. The majority of available elastomeric coatings for use on above-grade masonry walls are formulated from acrylics, polymer-based cementitious products, or silicones. The breathability of these products varies greatly but is generally less than that of penetrating water repellents. Because coatings

are exposed on the surface of the masonry, they are subject to deterioration by UV rays and other environmental conditions.

Acrylics form a film on the surface of the masonry and generally have moderate ability to bridge smaller cracks that form after



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the coating has been applied. With a smaller molecular size, acrylic polymers permit good penetration with low-solids formulations. High-solids formulations result in surface coatings. Acrylics may significantly limit the vapor permeance of masonry, especially when coatings become thicker.

Silicone-based elastomeric coatings typically offer exceptional crack-bridging qualities while limiting vapor permeance. Silicone molecules (the largest when compared to silanes and siloxanes), have the least penetration into masonry pore structure. Penetration of the silicone molecule is a function of the solvent used. Bonding of silicone elastomerics to masonry is primarily through mechanical keying and intermolecular forces. Silicone resin coatings are not compatible with other types of polymer coatings and require recoating in like kind.

Cementitious Coatings

Polymer-based or modified cementitious products are specified to replace traditional parging or mortars. They can offer improved strength, water repellency, adhesion, and density over normal materials. The application of a cementitious coating can drastically change the appearance of masonry walls, giving them the appearance of Portland cement plaster (stucco). These products can be applied in thin layers but are more susceptible to cracking, given their limited elastomeric properties. Cementitious coatings offer greater vapor permeance than most elastomeric coatings.

Figure 6: Faulty flashing leads to moisture accumulation and permanent freeze/thaw damage at roof interface.



What Can Go Wrong

Water repellents and elastomeric coatings can significantly reduce the amount of wetting that masonry walls experience. However, these products may also be considered for reasons other than their ability to limit wetting and resulting deterioration. These include: change of appearance, graffiti and dirt resistance, and consolidation of deteriorating materials. Regardless of the purpose, they will also limit the drying rates of masonry, potentially allowing water to accumulate behind the surface and accelerate moisture-related problems.

Many failures associated with penetrating water repellents and elastomeric coatings can be linked to a disregard for the other sources of wetting not mitigated by the application of these products. Faulty

application of flashings, obstructed drainage paths, excessive air exfiltration (warm interior air escaping and condensing on the back of masonry), building geometry, poorly formed masonry joints, and improperly located irrigation are a few examples of other sources of moisture that should be considered. Frequently, one or more of these conditions comprise greater sources of water penetration than the porous masonry surfaces.

In cold climates, moisture accumulation can lead to accelerated freeze/thaw deterioration. Freeze/thaw can result in severe cracking and spalling of brick masonry. Theories of freeze/thaw damage are debated, but there is general agreement that inclusion of water repellents may only exacerbate the problem in northern climates.



Figure 7: Freeze/thaw brick and parge coating failure.

In warm and mixed climates, accumulation of moisture and the differences in vapor permeance between masonry and coatings can lead to adhesion failures caused by osmotic blistering and evaporation of water below the coating. Maintaining a balance between wetting and drying of masonry is critical for long-term performance.

The development of efflorescence on a masonry wall commonly leads owners and builders to consider water repellents. Efflorescence is caused when water-soluble salts are carried through masonry and deposited on the surface. Unless the source of water penetration is addressed, addition of a water repellent may force the salts to be deposited below the surface of the brick as water evaporates. This condition, known as subflorescence, can cause brick to spall.

When drying is prevented from occurring on the exterior side of a masonry wall, moisture may become trapped within those walls lacking properly installed vapor retarders. In humid climates, this scenario can quickly turn into one involving mold and mildew.

Selection Considerations

- Identify masonry materials and verify selection of treatment with the manufacturer. Brick, stone, CMU, glass fiber reinforced concrete (GFRC), and architectural precast all have unique properties that will react differently to similar treatments. Manufacturers may



Figure 8: Workers remove sealer blush from a Southern California office building. Sealer blush results from using film-forming sealers on masonry. As water tries to evaporate out of the masonry, it is blocked by the film former. Eventually, the escaping water vapor breaks the sealer bond in spots. Where the sealer has debonded, more water from rain or other sources soaks in, leading to further debonding and more widespread sealer blush. The condition, as shown here, is correctable only by removing the failed coating, which can be expensive. (Photo courtesy of Prosoco.)

offer testing of substrates with various products to determine effectiveness of application and staining potential.

- Before committing to masonry waterproofing treatments, review all possible sources of moisture into the masonry, and determine first if they can be mitigated. Consider whether

any wall properties will contribute to a negative imbalance in the wetting and drying of the masonry if a treatment is applied. Select the most breathable treatment that provides the desired level of water repellency.

- Specify products that come pre-diluted to prevent field batching that may result in improper dilution and



Figure 9: Efflorescence from rainwater penetration can quickly mar a beautiful new masonry façade. (Photo courtesy of Prosoco.)



Figure 10: Single-wythe CMU: Interior view of integrally waterproofed CMU block and mortar. The head joints were not properly consolidated and did not prevent the passage of water during high wind events.

use of contaminated water.

- Local and federal environmental codes regarding volatile organic compounds (VOCs) have become much more stringent in the past decade. Verify with the manufacturer that selected treatments are in compliance with local environmental requirements.
- When reactive repellents are specified (i.e., silanes), evaluate carbonation of the substrate to ensure that the application does not require a separate primer or catalyst. Ensure that the surfaces are clean and compatible with the materials to be applied.
- Formulations of water repellents vary among manufacturers. Products with similar percentages of solids may provide significantly different performance and final appearance. When substitutions are made, ensure that manufacturers verify that their products meet all of the physical and chemical properties of the specified materials.
- Consider the climatic conditions recommended by the coating manufacturer. Typically, temperatures between 40°F and 100°F are required. Application on windy days should be

avoided when possible.

- Study related performance standards for materials. These include ASTM specifications and test standards for key physical properties. Knowledge of field evaluation methods is also helpful. RILEM/MAT tube testing and localized permeability testing provide comparative data on wetting through treated versus untreated masonry. Various methods for coating adhesion evaluation are also available.
- Utilize manufacturers' technical support services and local technical representatives. Some manufacturers offer project-specific material and compatibility testing. Local technical representatives may have more firsthand knowledge of what has worked and what has failed in a given market.

Summary

A new client recently stated that his approach to water-repellent applications in the past followed the age-old saying, "When in doubt, leave it out." As building envelope professionals, our recommendations should be based on a careful consideration of the specific project conditions and available materials. In many cases, any doubt about

ROOF KNOWLEDGE ASSESSMENT

Test your knowledge with the following questions developed by Donald E. Bush Jr., RRC.

1. **When designing or reviewing a design of a commercial building, which part of the building envelope must be considered?**
2. **When considering moisture control requirements for non-vented spaces, must an approved vapor retarder be provided?**
3. **When considering moisture control requirements for non-vented spaces, are there any exceptions regarding the application of an approved vapor retarder?**
4. **The maximum solar heat gain coefficient (SHGC) and the thermal transmittance (U-factor) of window assemblies and glass doors located in the building envelope shall be based on the window projection factor. What is the window projection factor?**

Answers on page 32

ROOF KNOWLEDGE ASSESSMENT

Answers to questions from page 31:


1. Walls, roof assemblies, floors, glazing, and slabs on grade that are part of the building envelope for buildings where the window and glazed door area is not greater than 50% of the gross area of the above-grade walls. Buildings with more glazing shall meet the applicable provisions of ASHRAE/IESNA 90.1.
2. All framed walls, floors, and ceilings not vented to allow for moisture to escape shall be provided with an approved vapor retarder having a permeance rating of 1 perm or less. The vapor retarder shall be installed on the warm-in-winter side of the insulation.
3. Exception 1: Buildings located in Climate Zones 1 through 3.
Exception 2: In construction where moisture or its freezing will not damage the materials.
Exception 3: Where other approved means to avoid condensation in unventilated, framed wall, floor, roof, and ceiling cavities are provided.
4. The window projection factor shall be determined by the equation:

$$PF = A/B$$
, where:
 PF = Projection factor (decimal)
 A = Distance measured horizontally from the furthest continuous extremity of any overhang, eave, or permanently attached shading device to the vertical surface of the glazing.
 B = Distance measured vertically from the bottom of the glazing to the underside of the overhang, eave, or permanently attached shading device.

Where different windows or glass doors have different PF values, they shall each be evaluated separately, or an area-weighted PF value shall be calculated and used for all windows and glass doors.

Reference: *International Energy Conservation Code*

the suitability of repellent or coating applications can be addressed by analysis of the associated risks and benefits. The amount of information and products offered can make this a daunting task. By gaining a better understanding of moisture transport and storage theory in masonry, available product classes, and the associated risks of inappropriate selection and application, the consultant is in a position to make an informed recommendation for the client.

While there are several factors that can result in failed applications of repellents and coatings, accumulation of moisture behind the masonry is one that can result in long-term permanent damage to the façade and structure. When used, water repellents and coatings should be selected to minimize this risk and maintain an appropriate balance between wetting and drying. 

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¹ Roppel, 2003

² Straube, 1997

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