STANDARDIZED PERFORMANCE METRICS FOR SELF-ADHERED FLASHING PRODUCTS USED FOR THE INSTALLATION OF WINDOWS AND DOORS

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Introduction

Moisture intrusion behind walls, roofs, and other areas that can trap water is a source of significant damage to buildings, including mold formation and structure rot. While there are many recognized sources of moisture intrusion in buildings, one of the most critical is the interface between the wall and openings in the wall, such as fenestration products (windows and doors). Figure 1 gives examples of the types of damage that can occur to buildings around window openings if improperly installed or flashed. A report by RDH Building Engineering Limited in Canada studied the occurrence of leakage for a wide variety of window types and assemblies, considering six potential leakage paths for water intrusion [1]. Although water leakage was found to some extent in all of the leakage paths, the “through window to wall interface to adjacent wall assembly” was the most prevalent leakage path for all types of windows tested and had a high risk of consequential damage to the building. Improper use of flashing and the over-reliance on building sealants were consistently noted as key contributing effects in this report. Another report by the Partnership of Advancing Technology in Housing (PATH), which publishes the Durability by Design Guideline, noted that “most leakage problems are related to improper or insufficient flashing details or the absence of flashing” [2]. The PATH report also noted that “caulks and sealants are generally not a suitable substitute for flashing”.

Figure 1: Examples of building damage due to improper flashing and installation. The figure on the left shows damage that occurs behind the building façade, while the picture on the right shows damage at the interior sill of the window.

It is thus recognized that a durable seal at the window-wall interface is essential to assist in the prevention of damaging moisture intrusion in buildings and that building sealants alone cannot adequately perform this task. While mechanically-attached flashing materials have traditionally been used in tandem with building sealants to deflect moisture away from and provide a moisture seal at the window-wall interface, self-adhering flashing products are often utilized to combine these properties into one product. When applied properly, self-adhering flashing products have been shown to be highly effective in protecting the window-wall interface for various window shapes and designs [3, 4].

The self-adhering products serve as a bridge between the flange or mounting fin of a fenestration product and the water resistive barrier (WRB). Self-adhering flashing products are defined in AAMA 711-13 as “flexible facing materials coated completely or partially on at least one side with an adhesive material and which do not depend on mechanical fasteners for permanent attachment” [5]. The definition goes on to state, “They are used to bridge the joint (gap) between fenestration framing members and the adjacent water resistive barriers or sealed drainage plane material. The purpose of flashing is to drain water away from the fenestration product to the exterior”. Whereas a building sealant is designed to seal a 1-2 cm gap, the self-adhering flashing provides a much wider seal that is backed by a durable topsheet designed to maintain the seal integrity against building and joint movement and external exposure. Builders are now broadly utilizing these products due to their numerous advantages, which include ease of installation, robust water seal around the interface, and durability against environmental exposure and building joint movement. Numerous self-adhered flashing products are available in the market based on various adhesive technology, including the traditional bitumen / modified bitumen, butyl rubber, copolymer elastomers, and acrylics. Some products feature an extendable topsheet to flash around non-linear and three-dimensional shapes, such as round-top windows and sill pans.

The self-adhering flashing products are thus characterized primarily by 1) the type of topsheet used, which can be various polymer films, nonwoven material, and/or extendable material for specialty applications, and 2) the type of adhesive backing. Most products also contain a release liner, since the adhesive is very aggressive and would be difficult to unroll without this feature. The self-adhering flashing products are typically produced through lamination of the topsheet and a pressure sensitive adhesive, and both components contribute significantly to the performance attributes.

The topsheet provides the strength, tear resistance, durability, and flexibility (in some cases conformability) required for this demanding application. It is essential that the topsheet have sufficient durability to UV exposure, since the products are often exposed for several weeks or months after application and before the installation of the building façade, as well as thermal durability to withstand the thermal cycling that will occur both behind the façade and on the window flange. In addition, the topsheet must be flexible enough to conform around irregular shapes, maintain the integrity of the seal against building and joint movement, maintain physical integrity against thermal exposure, and, in some cases, be extendable to seal seamlessly on three-dimensional shapes such as the formation of sill pan flashing.

The pressure sensitive adhesive backing is also a critical defining parameter in characterizing the end-use performance of the flashing product. Current offerings are categorized into main adhesive classifications: 1) rubber modified-asphalt / bitumen adhesives and 2) polybutene / polyisobutylene based "butyl" adhesives, 3) block copolymer based hot melt adhesives, and 4) acrylic adhesive coatings. These adhesive systems are a blend of many components, including the base rubber, tackifiers, waxes, and other functional or non-functional fillers, that control the end-use properties of the adhesives. The right components, as well as proper mixing technology, are critical to achieve performance attributes desired. More details on the chemical attributes of the pressure sensitive adhesive systems can be found in a number of other sources [6-9].

Several studies have compared the performance attributes of modified-asphalt based self-adhering flashing products to butyl based systems [10, 11]. These studies have examined material durability and adhesion performance after exposure to UV light, accelerated heat aging, and adhesion performance to various substrates under various conditions (temperature, surface cleanliness, and moisture conditions) and have provided several important differentiating conclusions as to the self-adhering flashing systems. Another study provides a thorough evaluation of comparative performance attributes and application considerations [12].

To summarize, it is essential for the end-user to consider the application conditions (surface, temperature, cleanliness) and the service life conditions (heat exposure, thermal cycles, and building movement) when selecting a self-adhering flashing system. A key challenge for the self-adhering flashing products lies in the fact that while most industrial adhesives are applied in a controlled manufacturing environment, the self-adhering flashing products used in the building industry are applied in an external environment with all possible conditions, including temperature ranges, surface moisture, and a high degree of contamination (this is a construction site!). Thus, setting minimum performance attributes for these products is critical, which has been accomplished by the AAMA 711 standard.

Types of Flashing Products – Comparison of AAMA Standards

While the application of self-adhering flashing products is becoming widespread, there are several important considerations that must be addressed to achieve the full benefits. For instance, since these products are often installed in non-ideal environmental conditions, proper installation and surface conditions are essential to their successful use. To ensure minimum performance attributes are met for the application, industry standards are developed to establish material requirements. In the following sections, these considerations will be categorized into the following key elements: 1) types of self-adhering flashings, 2) performance attributes, based industry standards, and 3) installation methodologies unique to self-adhering flashing products.

Flashing products used for the installation of windows & doors generally fall into three main categories: 1) mechanically attached flashings, 2) self-adhered flashings and 3) liquid-applied flashing. Each of these categories of flashing can be used effectively to prevent moisture intrusion, as long as they are properly utilized for their intended application and exposures. To help ensure this proper use, the American Architectural Manufacturers Association (AAMA) has developed a series of material standards for the three main categories of flashing products. The first standard, AAMA 711-13, "Voluntary Specification for Self-Adhering Flashing Used for

Installation of Exterior Wall Fenestration Products", specifically addresses the self-adhering flashing products that are the primary subject of this paper [5]. The AAMA Flashing committee then published a similar material standard for mechanically attached flashing products, AAMA 712-14, "Voluntary Specification of Mechanically Attached Flexible Flashing" [13]. A third standard to address the emerging liquid-applied flashing products, AAMA 714-15, "Voluntary Specification for Liquid Applied Flashing Used to Create a Water Resistive Seal Around Exterior Openings in Buildings" [14], was then developed. Table 1 provides a summary of these three distinct categories of flashing products used for building penetrations and windows & doors, including key defining features and challenges. In addition, all three of these standards are now referenced in the International Code Council (ICC), both in the residentially focused International Residential Code (IRC) and commercial building focus International Building Code (IBC). The initial Code reference for each document is indicated on the table.

Table 1 – Summary of AAMA Flashing Standards

Flashing Type	**Mechanically Applied (Nail-On Flashing)**	**Self-Adhering Flashing (Peel-and-stick)**	**Liquid Applied Flashing**
Applicable Standard	AAMA 712-14	AAMA 711-13 (currently under revision)	AAMA 714-15 (currently under revision)
Minimum Width	9" (23 cm)	2" (5 cm) past the critical interface/ 4" (10 cm) minimum	None
Code Reference IRC 703.4	Since 2015	Since 2009 (2018 IBC)	Since 2015 (2018 IBC)
Key Features	Water deflection from interface / water seal when used with sealant	Provides both deflection and seal at interface / seals through fasteners & penetrations	Ultimate conformity for difficult geometries (recessed windows / bump outs…), adhesion to CMU, vapor permeable products
Key Challenges	Penetrations not sealed, reliance on gunnable sealant	Reliable adhesion to various substrates and unfavorable conditions	Bridging gaps / uneven interfaces, direct applied stucco adhesion

Standardized Performance Attributes for Self-Adhering Flashing Products

AAMA 711 is the first consensus document to characterize self-adhering flashing products, specifying several physical property requirements, which will be examined in more detail in this section. This standard specifies nine property elements, with test method and minimum requirements noted, for self-adhering flashing products in building openings. These properties and minimum accepted values are listed in Table 2. The ICC Evaluation Services adopted these properties for self-adhered flashing products in the "Acceptance Criteria for Flexible Flashing Materials," AC-148 [15]. This section will review the basis and special considerations for material property attributes for self-adhering flashings, using Table 2 as a guideline. This AAMA standard also contains sections defining acceptable installation conditions and setting minimum dimensions such as flashing width, which is currently defined as "two inches (50 mm) past the critical interface, or at least four inches (100 mm) overall". The 'critical interface' is defined in detail in the AAMA 711-13 standard.

TABLE 2: Property Requirements for Self-Adhering Flashing as per AAMA 711-13

Section / Property	Minimum Acceptable	Comments
5.1 Tensile Strength	2.9 lbf/in	Low threshold, just enough to bridge gaps
5.2 Sealability through Fasteners	Pass @ 1.5" H20	Under revision to remove ASTM D1970 reference Key differentiation from mechanical flashing.
5.3 Peel Adhesion	1.5 lbf/in, Room Temp after 24 hr dwell time	Four substrates specified: OSB, Vinyl, Aluminum & Plywood - 4"width corresponds to 6 lbf bond
5.4 UV Aging	Pass 5.3 after UV per ASTM G154 or G155	Min adhesion & note visual change, corresponds to 60 days exposure
5.5 Elevated Temp Exposure	Pass 5.3 after 7-day exposure @ 3 Levels: 50, 65, and 80 C	Min adhesion & no curl back / visual change, differentiates butyls & bitumen products
5.6 Thermal Cycling	Pass 5.3 after 10 cycles -40 to 50 °C	Min adhesion & no curl back / visual change
5.7 Cold Temperature Pliability	Pass mandrel test @ -18 °C	Ensure no cracking of adhesive at low temperature
5.8 Adhesion after Water Immersion	Pass 5.3 after soaking 7 days	Adhered to aluminum substrate
5.9 Peel Resistance	No curl back after aging	Measure of dimensional stability of flashing lap onto itself

AAMA 711 Section 5.1, Tensile Strength: As noted in the previous section, self-adhering flashing topsheets can be made from a wide variety of materials. These include polymer films, nonwoven sheets, and elastomeric films. Since various materials can be used, three different test methods are specified in the AAMA 711 standard so that the appropriate method is utilized for a given material, as listed in Table 2. A minimum tensile strength is specified so that the product has adequate strength to support the adhesive seal across the building joint and against movements in that joint without fracturing the seal. Given that the product is fully adhered to the substrate, the minimum requirement for tensile strength is relatively low.

AAMA 711 Section 5.2, Sealability around Fasteners and Nails: Nail sealability is a key differentiating attribute for self-adhering flashing products, compared to non-adhered membrane products. The ability to 'self heal' around penetrations through the flashing, such as nails, staples, and other fasteners found at building sites, contributes significant value to protect against water intrusion through fasteners used for siding, window trim, and other attachments at or near the window-wall interface. The AAMA 711 Standard specifies two different test methods for nail sealability: 1) a modification of ASTM D1970, Section 7.9 (note that the AAMA Flashing Committee is currently working on a revision to remove the reference to ASTM D1970 and make it a stand-alone method) and 2) a modification of ASTM E331/E547 for water resistance.

The modified ASTM D1970 test is a horizontal water column test. The height of the water column is specified at 31 mm (1.2 inches) of water to simulate 50 mph wind driven rain. This is a realistic exposure for a material that will be either behind a façade, in the case of head and jamb flashings, or at the sill of a window, in the case of sill pans. A passing criterion is no water leakage under the substrate around the fastener after 25 thermal cycles. As for the suitability of this test, the D1970 test has the advantage of being a lab scale test that is easy and inexpensive to run, but the flashing products are typically not in a horizontal state unless they are used in the sill pan, in which case a penetration through the flashing (nail / fastener / staple) is not recommended. The alternative method for sealability around nails is a modified wall test, as per ASTM E331/E547. This is a vertical test with three fasteners through the flashing substrate, as shown in a series of schematics in the AAMA 711 Standard. This test better simulates the vertical application of self-adhering flashing at the heads and jambs of the windows, but requires a more complex setup that involves a test lab with a spray rack. Thus, there are advantages to both methods and either is acceptable to meet the specifications of this Standard.

AAMA 711 Section 5.3 Peel Adhesion: Peel adhesion is a quantitative measure of the bond between the self-adhering flashing and the substrate, which is also an indirect measure of the quality of the resulting watertight seal. Thus, this is the most critical physical property measurement to ensure adequate moisture seal performance. Peel adhesion in this application is also subject to several special challenges.

In typical industrial sealant and adhesive applications, the conditions of the substrate surface and exterior environment are specified and tightly controlled. This is essential to achieve reproducible results and a reliable bond between substrates. In the case of self-adhering flashings, this type of substrate and condition control is not possible. First, the products are applied on widely varying substrates: these include vinyl flanges of windows (which can be of various compositions), water resistive barriers (which can range from polymeric films, nonwoven substrates to asphalt impregnated building paper), or the exterior sheathing of the building, which is the largest source of variation. Building sheathing can include Oriented Strand Board (OSB), which itself is a highly variable substrate, plywood, fiberglass coated gypsum board, poured concrete or concrete block, metal frame, and various other fibrous or film coated materials.

While the substrate type is highly variable, the other main source of variability lies with the environmental and surface conditions in application. Self-adhering flashing products are applied in an exterior environment that is exposed to a continuous source of contamination and debris –

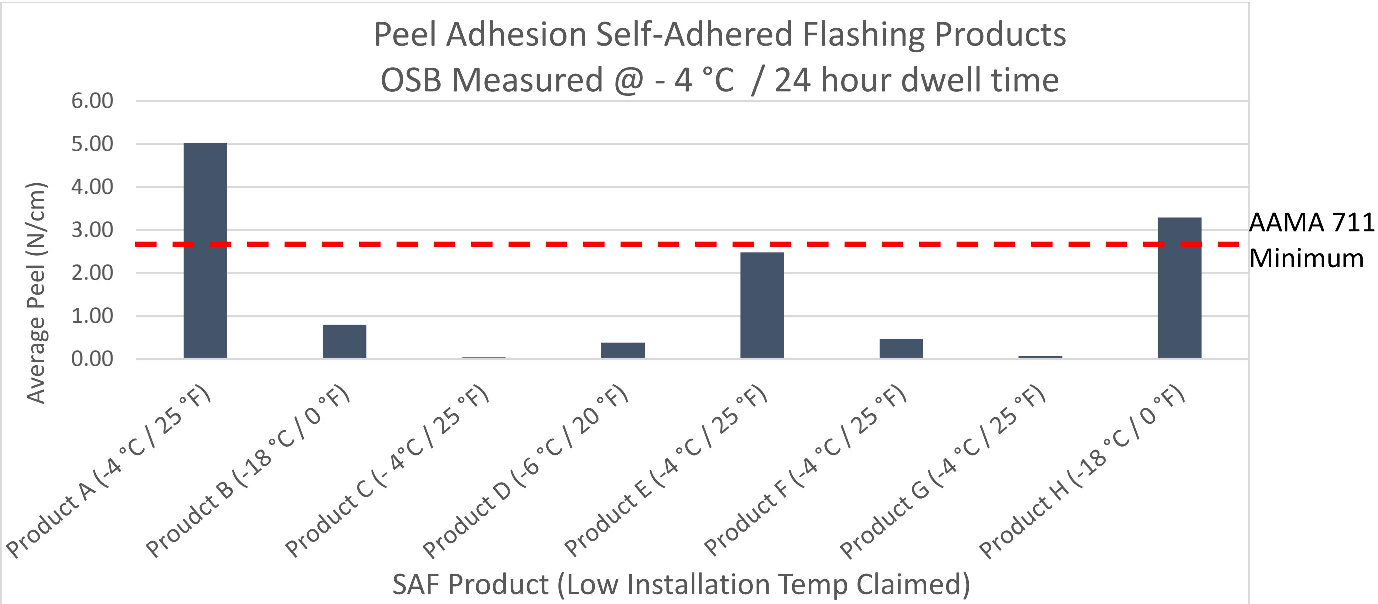
it is a building site! In addition, the external exposure includes a full range of environmental conditions: wet, dry, hot, and cold are all expected states. Thus, substrate variability, surface contamination, and a full range of environmental conditions make the application of self-adhering flashing products a unique challenge to achieve a reliable, watertight seal over the joint between the fenestration and the wall. However, installers and flashing manufacturers have learned to overcome, or at least work around, these issues such that they are being successfully utilized in a high portion of building sites.

Another challenge is to quantify minimum 'acceptable' adhesion for the end-use needs. This minimum acceptable adhesion must be adequate to hold the self-adhering flashing product in place through the expected life of the building, as well as enable a watertight seal over the joint / building interface. The AAMA 711 Standard, Section 5.3, has established 2.6 N/cm (1.5 lb/in) as the minimum peel adhesion force, as measured by ASTM D3330, method F for a 90º peel between the flashing and the substrate. Conditions specified are 23º C & 50% RH, with a 24 hour dwell time. The AAMA 711 Standard specifies five substrates to which the product must meet this minimum peel adhesion value at room temperature conditions, which are: oriented strand board (smooth side), aluminum, vinyl, plywood, and the self-adhering flashing facing material (to account for adequate adhesion of laps). Self-adhering flashing products that are able to meet the minimum peel strength requirement on these substrates, as well as after exposures noted below, without the aid of a primer, are categorized as Type A Products. Those that require the use of a primer to meet these requirements are classified as Type B Products.

Substrate surface integrity is a key source of variability and low adhesion failure with self-adhering products. When an inadequate bond is often realized, it is the substrate surface that fails, due to the unbonded surface where the components that make up the surface (fibers, wood chips, fiberglass, etc) pull away from the substrate, rather than the pressure sensitive adhesive on the flashing product. This is especially the case with the loosely bonded surface found on oriented strand board, where wood chips are pressed together to various degrees of bond, and fibrous sheathing material such as fiberglass coated gypsum board. The mode of failure with these types of substrates is the delamination at the substrate surface. With substrates where the surface is loosely bonded, it is essential that these surfaces are adhesively bonded, through the use of a primer or other spray adhesive application, in order to achieve adequate bond strength with self-adhering flashing products.

Low Temperature Application: As noted above, the actual external application environment will vary widely from the ideal conditions specified in ASTM D3330. Another key concern is the lowest acceptable installation temperature for the self-adhered flashing product, which is defined in Section 6.7 as the low temperature where the minimum adequate peel adhesion (2.6 N/cm or 1.5 lb/in) is achieved. Low temperature adhesion is a primary application concern and represents the most challenging environment for the self-adhering flashing. Minimum temperature application is typically reported by Flashing Manufacturers as an indication of the adhesion performance –several report temperatures below 0 ºC, some even as low as -18 ºC, but not all these (actually only a few) products actually meet the minimum peel adhesion requirements at this temperature.

Table 3 – Peel Adhesion of Self-Adhered Flashing Products at Low Installation Temperature Claimed



AAMA 711 Section 5.4, Accelerated UV Aging: Self-adhering flashing products are installed during the installation of the window, which can occur several weeks or months before the exterior façade is installed. Thus, the products must have sufficient UV stability to prevent deterioration of the topsheet as well as the pressure sensitive adhesive before being covered and protected from UV radiation. It is important that these products are not exposed indefinitely to exterior light unless specifically noted by the manufacturer.

The UV aging performance of polymeric materials can be simulated using an accelerated UV aging test, of which there are several versions with different light sources and exposure schemes. The AAMA 711 Standard specifies either ASTM G154, UVA cycle 1, for 336 hours, or ASTM G155, modified cycle 1, for 504 hours. The effect of long-term UV exposure on various types of self-adhering flashing products was studied in more detail and is documented [10]. This study utilized accelerated UV aging techniques and showed a dramatic difference in the performance of various commercially available self-adhering flashing products, particularly in terms to their adhesive classification (butyl- based or modified-asphalt / bitumen based). After UV aging, the products are tested for peel adhesion per AAMA 711 Section 5.3 and any visual alteration is noted.

AAMA 711 Section 5.5, Exposure to Elevated Temperature – Thermal History: Self-adhering flashing products are exposed continuously to thermal cycling due to external exposure throughout the life of their use. These products typically are attached to the window flange and bridge the interfacial gap with the wall, so it is essential that the products maintain their integrity throughout the extremes of the thermal cycles. Temperatures behind siding that gets direct sunlight, as well as on flanges with can be made of metal (typically aluminum) or vinyl, or even reflected sunlight off the neighboring buildings, can build up excessive heat behind the sidings. The photograph below in Figure 2 was taken on an 80º F (26.5º C) day in Sacramento, California, where the surface temperature on grey colored wood siding was measured to be 170º F (76.7º C). It can be easily imagined that on hotter days, or on metal surfaces that received direct or reflected sunlight, the temperatures can easily exceed 80º C.

Figure 2: Surface Temperature on a 26.5 °C (80º F) day in Sacramento, California

While these extreme temperature exposures may last only a few hours in a given day, the products used behind these surfaces will see this exposure many times over their useful life, resulting in an accumulated thermal affect.

The effect of the thermal exposure to various types of commercially available self-adhering flashing products was studied in detail [11]. This study showed significant differential performance of the self-adhering flashings, depending primarily on the adhesive system utilized, where the butyl-based systems were more thermally stable than modified-asphalt / bitumen-based materials.

Thus, it is important that the correct self-adhering flashing products are selected based on the thermal exposure expected. To this end, the AAMA-711 standard has specified three levels of heat exposure that can categorize the products differentially into acceptable thermal exposure ranges: : Level 1 at 50º C (122º F), Level 2 at 65º C (149º F) and Level 3 at 80º C (176º F). As detailed in reference [12], not all commercially available self-adhering flashing products are able to withstand the Level 3 heat exposure, particularly those that feature a rubber modified-asphalt / bitumen adhesive system, as they are prone to losing integrity, causing the topsheet to curl back. The performance criterion in AAMA 711 is that the products maintain minimum peel adhesion to a given surface after exposure for 7 days at the select temperature above, along with no change (pull back) in original appearance. It is thus important to consider the heat exposure expected when selecting a self-adhering flashing product to ensure durability throughout the expected life of the installation.

AAMA 711 Section 5.6, Thermal Cycling: In addition to high temperature exposure, the self-adhering flashing products will be subject to temperature cycles in use. Thus, while a self-adhering flashing product may be exposed to temperatures above 80º C, as per the above discussion, they may also be exposed to extremely low temperatures, such as -40º C. The adhesive systems for self-adhering flashing products are a blend of many components, as noted previously, including the base rubber, tackifiers, waxes, and other fillers. The adhesives are processed to ensure the correct morphology for the functional performance of the adhesive, but it is possible that this morphology may be disrupted at severe temperature exposure, causing phase separation and a shift in performance. As a result, the AAMA-711 standard requires thermal 'shock' cycling between -40º C and 50º C for 25 cycles, followed by peel adhesion testing to assure that minimum performance is maintained. This will ensure that the adhesive system will not undergo unexpected modification in morphology or physical form through expected thermal cycles in end-use.

AAMA 711 Section 5.7, Cold Temperature Pliability: As discussed in the previous section, the self-adhering flashing products may be exposed to extreme low temperatures as well as high temperatures. In order to perform as a sealing material, the self-adhering flashing products must maintain ductile pliability and, in particular, must not form cracks or exhibit brittle failure. Thus, the AAMA 711 standard requires a cold temperature pliability test at -18º C (0º F), which can be done as per the bend tests described in the various ASTM methods noted in the AAMA 711 standard.

AAMA 711 Section 5.8, Adhesion after Water Immersion: Self-adhering flashing products must maintain their watertight seal behind building facades, which are known to have only limited ability to hold water back. Thus, it is expected that the self-adhering flashing products will see extensive moisture exposure during the end-use life of these products. In fact, self-adhering flashing products can also be used at the sill below the fenestration product as sill pan flashing, in which case the products are in a horizontal position and may experience exposure to standing water for a period of time. The AAMA 711 standard thus requires that the self-adhering flashing products maintain integrity and minimum peel adhesion after 7-day immersion in tap water.

This test is specified to be performed on an aluminum substrate, such that the substrate itself is not affected by the water immersion (as OSB or other wood-based sheathings would be). However, in reality these substrates will be bonded to OSB substrates during installation in wet conditions, so adhesion performance to wet surfaces is critical. The effect of moisture on the peel adhesion of various commercially available self-adhering flashing products was studied in more detail [10,11]. In one of these studies [11], the effect of dusty surfaces was examined as well.

AAMA 711 Section 5.9, Peel Resistance: Self-adhering flashing products are typically installed in lap fashion, lapping one product over the other, in order to create a proper shingle for water management. Thus, it is essential that the adhesive form a stable bond to the topsheet surface. AAMA 711 Section 5.9 specifies a small assembly test (per Annex 2) to test the self-adhering products lapped onto themselves, noting any 'curl back' or bond release from the topsheet. This test is performed at the same elevated temperatures described in AAMA 711 Section 5.5, for the sake of consistency.

SUMMARY AND CONCLUSIONS

The correct application of flashing around windows and doors is critical to building performance and represents an important end-use application for pressure sensitive tape materials. This application involves many challenges to achieve successful, long-term performance. To help characterize the end-use requirements for this application, The American Architectural Manufacturer's Association (AAMA) has developed voluntary specifications for three distinct types of flashing materials used in this application, including the AAMA 711 standard for self-adhering, pressure-sensitive tapes. The AAMA flashing standards detail several end-use application properties and durability specifications necessary to meet the criteria, such as adhesion to common building substrates, sealability through fasteners, and adhesion durability after exposure to UV aging, high temperature, and thermal cycling. The Standards have been adopted into the International Building Codes, and as such, currently provide the best reflection of the material requirements necessary for successful, long-term performance.

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