WINDOW AND DOOR DESIGN AND INSTALLATION GUIDE

INTERACTIVE RESOURCES
Architects & Engineers

June 13, 2011

Contents

INTRODUCTION

Techniques for installation of "punched"[1] windows and doors have been evolving continually over the last two decades. For many years, the accepted standard involved four strips of flexible flashing integrated with a nailing fin and the water resistive barrier (WRB) at the window perimeter. This concept was easy to understand and implement because the window fins, the flashings and the WRB were typically all in the same plane. It is amazing, however, that so many designers and builders were still able to get it wrong.

Up until the 1990s, flexible flashings were typically made of laminated kraft paper treated with asphalt. Chronic exposure to water often resulted in disintegration and resulting structural damage. The introduction of plastic, rubber and modified bitumen flexible flashings, mostly of the "peel and stick" (self-adhesive) variety in the decade of the 1990's improved durability vastly.

Then came the trend toward windows that are recessed from the outermost wall plane, driven either by developers and architects looking for a certain aesthetic or imposed by regulatory design review organizations. At first, self-adhering flexible flashings appeared to offer a solution to conquering the multi-plane configurations required to perimeter flash recessed windows. But few construction workers had the skill or patience required for a successful installation, and fish mouths, wrinkles and adhesion problems on dirty, damp or chemically treated surfaces compromised the effectiveness. If that didn't do the job, a lather would drive dozens of nails or staples through the sill flashing before application of cement plaster.

Then in 2002 came SB 800, California's new answer to construction defects. The law gave contractors a "right to repair" prior to a homeowner initiating litigation, but it also set clear standards and warranties for performance of building components. Recent changes to the *International Residential Code* require window manufacturers to provide installation instructions with each window. Because of the transience of contractors, the difficulties in obtaining contractors' insurance, insurance exclusions for mold, and the rising cost of water damage and mold claims, window manufacturers are increasingly being targeted by litigants as the "deep pockets" in lawsuits that often have dozens of defendants.

Where window manufacturers once avoided installation advice, they have now reluctantly embraced it, concluding that they have to provide it to protect themselves, and in the future, conform to building codes.

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[1] Punched refers to an individual window or door in a wall as opposed to a "storefront" or "curtain wall" system.

Many of the leading window and door manufacturers have gone from a dearth of installation information to a plethora. Unfortunately, most of it is complex, hard to read, difficult to understand and overly optimistic that a construction worker will implement it – particularly if it is not translated into Spanish or some other language.

Similarly, many manufacturers of WRBs and self adhered flashings have developed detailed instructions for using their products in conjunction with doors and windows.

Most instructions cover only a few typical installation conditions. Few deal with recessed windows. Some assume that the WRB is house wrap and not building paper or felt, although building paper (asphalt saturated kraft paper) and, to a lesser degree, asphalt saturated felt, continue to predominate in the west. The procedure for flashing a window with a house wrap WRB is substantially different from that using building paper or felt. There are stacked and ganged windows that require special care, as do cladding systems such as one-coat stucco and EIFS.

In the simple old days, nailing fins were integral to the window and provided a waterproof appendage. Today, some are loosely attached or even field-applied and designed to fold back during shipping, making the waterproofing of that joint, as well as a corner insert, another complicating field challenge.

Then there is the architect. If the building is a custom home, the architect may know what window manufacturer will be used and can at least obtain window details and installation instructions to start from. If it is a public building or merchant built housing, the window specifications will either be generic or will anticipate more than one potential manufacturer. The architect will have to provide generic installation details and subsequently find some way of reconciling those with the instructions of a specific manufacturer after the product is chosen. What architect or contractor would deviate from a manufacturer’s instructions and risk compromising a warranty or inviting responsibility in case of a failure – even if there really is a better way of doing it?

Ultimately, the installation procedures and materials may have to conform to the following:

- Window and door manufacturer’s installation instructions
- Architect’s design

- Instructions of manufacturer's of water restive barrier and flexible flashings
- Requirement of a quality control agency, for example Quality Built

These multiple parties may have conflicting requirements that have to be resolved to preserve warranties and manage risks of future failures. We have found the best way to do this is to schedule a prototype installation for each window or door type and each installation type. Attending would be the architect, the window or door installer (subcontractor), a technical representative of the window and door manufacturer, the project superintendent and the quality control agency, if there is one. All conflicts are worked out, and a report with photos and/or graphic is prepared for review and approval by all. This becomes the standard for the installation of all other windows and doors.

Often, the prototype installation is followed by a water test conducted pursuant to ASTM E1105 to confirm that the installation has been successful and will perform at the specified water resistance test pressure. If there are failures, they can be diagnosed and the causes corrected before installation of the remaining windows or doors proceeds.

CODE REQUIREMENTS

The 2010 *California Residential Code*, Section 612.1 states:

R612.1 General. This section prescribes performance and construction requirements for exterior window systems installed in wall. Windows and doors shall be installed and flashed in accordance with the manufacturers written installation instructions. Window and door openings shall be flashed in accordance with Section R703.8. Written installation instructions shall be provided by fenestration manufacturer for each window and door.

R703.8 Flashing. Approved corrosion-resistant flashing shall be applied shingle-fashion in a manner to prevent entry of water into the wall cavity or penetration of water to the building structural framing components. Self-adhered membranes used as flashing shall comply with AAMA 711. The flashing shall extend to the surface of the exterior wall finish. Approved corrosion resistant flashings shall be installed at all of the following locations:

1. Exterior window and door openings. Flashing at exterior window and door openings shall extend to the surface of the exterior wall finish or to the water-resistive barrier for subsequent drainage.

The 2010 *California Building Code*, Section 1405.4 states:

1405.4 Flashing. Flashing shall be installed in such a manner so as to prevent moisture from entering the wall or redirect it to the exterior. Flashing shall be installed at the perimeters of exterior door and window assemblies…

INDUSTRY STANDARDS

Selection of a Performance Rating

The current industry standard for performance rating of windows and doors is *Standard/Specification for Windows, Doors and Skylights*, AAMA/WDMA/CSA 101/I.S.2/A440.[2] This standard has been published by AAMA, in conjunction with other related industry organizations, in various versions since the 1940s. This standard includes test requirements for determining the performance grade, including water penetration resistance, of windows based on the wind design pressure of a building and its exterior envelope. Windows are typically specified by performance class and are required to have an AAMA approved label showing the performance class. Design pressures are calculated using formulas in building codes that take into consideration the location, height, contextual geography and configuration of a building.

In AAMA/WDMA/CSA 101/I.S.2/A440, the *water resistance test pressure* is a minimum of 15% of the design pressure, but not less than 2.86 PSF, for Residential (R), Light Commercial (LC), Commercial (C) and Heavy Commercial (HC) windows. For Architectural (AW) windows in institutional and high-rise buildings, the *water resistance test pressure* is a minimum of 20% of the design pressure. Water resistance test pressures are determined by manufacturer laboratory testing using ASTM E 547, *Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Difference*, and/or ASTM E 331, *Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference*.

Selection of a performance class of window should at least be based on the structural wind loads required by the building codes. For water penetration resistance, higher performance classes may be selected if experience or data for micro-climatic conditions of wind-blown rain indicate a higher resistance is needed, or if the building owner desires a higher safety factor.

Field testing of the water resistance of windows is typically performed by ASTM E-1105, *Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference*, which is essentially the same set up as ASTM E 547 and ASTM E 331, except it is intended to be performed *in situ* rather than in a laboratory.

The installation of the window in the surrounding wall can also be tested by ASTM E 1105. It is reasonable to expect that the wall assembly adjacent to a window, including cladding, flashings

[2] American Architectural Manufacturers Association, 1827 Walden Office Square, Suite 550, Schaumburg, IL 60171, 847/303-5664, fax 847/303-5774, www.aamanet.org

and WRB should perform at least to the level of the window, assuming the window has been appropriately selected for performance at the building location.

Some confusion and controversy has developed around the field testing procedures because AAMA 502, *Voluntary Specification for Field Testing of Windows and Sliding Glass Doors*, appears to recognize a performance level lower than that specified for a new window:

> **4.9** Water penetration resistance tests shall be conducted at a static test pressure equal to 2/3 (0.667) of the test pressure specified for the applicable product designation in ANSI/AAMA/NWWDA 101/I.S.2. For example, a product rated as H-C50 shall be field tested at a pressure differential of 0.667 x 360 Pa (7.50 psf) = 240 Pa (5.00 psf).

However, the passage goes on to say:

> ***NOTE:*** *The specifier is permitted to increase the field water penetration resistance test pressure to the value specified for the project, however, this shall be stipulated in Paragraph 3 of the Short Form Field Testing Specification.*

In this case, the specifier, means the person responsible for ordering or conducting the test. Some believe this is a self-serving attempt by the window industry to justify a 1/3 reduction in performance expectations between factory and installation to account for damage during transit and installation as well as component degradation. We believe there is no reason to expect lower performance in the field than in the laboratory for a relatively new window. Over time, however, degradation in components such as seals, may be expected to result in some decline in performance. A fundamental flaw in the window design or installation should not, however, be acceptable. A window specified new with an inappropriately low or marginal performance grade may fail as its components degrade over time.

Following is an example of how a required performance level would be calculated:

> The document AAMA/WDMA/CSA 101/I.S.2/A440-08 NAFS North American Fenestration Standard/Specification for Windows, Doors and Skylights includes information about selection of performance levels for windows and doors.
>
> The first step is calculating the Design Pressure using ASCE 7.05. For this project, using current California Building Code 20010 requirements:
>
> > Wind Speed = 85 mph
> >
> > Roof Angle = 20^{o}

Wall Area "A" P_{s30} = 15.9 psf
Use Exposure D (unobstructed areas – top of hill)
Mean roof height = 24' +/- Use 25'
$\lambda = 1.61$
Importance factor
I = 1.0
$P_s = \lambda$ Kzt I P_{s30}
= 1.61 (1.0) (15.9)
= 25.6 λKzt

Figure 6.4
$Kzt = (1 + k_1 K_2 K_3)^2$
$H/L_n = 0.5$ (max) 2H for L_n
2-D ridge
$K_1 = 0.7$ $H/L_n = 0.5$
$K_2 = 0.33$ $x/L_n = 1.00$
$K_3 = 0.55$ $z/L_n = .25$

$Kzt = (1 + (7.2)(.33)(.55))^2 = 1.28$
P_s = 25.6 (1,28) = 32.8 psf Use 33 psf

For Design Pressure (DP) of 33, Water Resistance Test Pressure = (33) (.15) = 4.95
Select a window and door product with a Performance Grade 40

Installation Standards

Useful industry standards for installation include:

- E2112 – *Standard Practice for Installation of Exterior Windows, Doors and Skylights*
- E2266 – *Standard Guide for Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion*

A general summary of design and construction techniques windows and doors can be found in ASTM E2266 - *Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion*.

14. Windows, Doors and Similar Wall Penetrations
14.1 *Products*:
14.1.1 *Windows and Doors*:
14.1.1.1 Select for exposure and performance as recommended in the AAMA Window Selection Guide.
14.1.1.2 Aluminum, vinyl (PVC) and wood windows and glass doors should conform to ANSI/AAMA/WDMA 101/I.S 2/NAFS – 03, and each assembly should bear a label, verified by a third party agency, certifying that the product has been tested for performance class and grade. Water penetration testing of window products is usually accomplished using Test Method E 331 and Test Method E 547.
14.1.1.3 For water-repellant (non-pressure treated) millwork require products meeting the requirements of NWWDA
I.S. 4.

14.1.2 *Flashings*:
14.1.2.1 Numerous types of flashing materials are available.
Refer to Practice E 2112 (Appendix XI) for a discussion of door and window flashing materials.
14.2 *Design and Construction*:
14.2.1 Refer to Practice E 2112, which provides detailed guidance for installation of doors with integral mounting flanges and several types of windows. Practice E 2112 includes instructions for integration of doors and windows with the weather-resistive barrier. The AAMA IM-TM InstallationMasters Training Manual provides guidance on installation from the perspective of training window installers.
14.2.2 Installation of doors without integral mounting flanges is not specifically addressed in Practice E 2112. Practice
E 2112 does, however, include applicable design principles, such as the use of pan flashings and methods used for
integrating the weather-resistive barrier with windows that do not have integral mounting flanges.
14.2.3 Exterior doors that are not performance-rated should be installed in recesses or under canopies where they will be protected from wind-driven rain. Alternatively, the installed door assembly may be tested according to Test Method E 1105 at a minimum pressure of 140 Pa (2.86 psf).

E2112 – *Standard Practice for Installation of Exterior Windows, Doors and Skylights* is a voluminous document that covers a wide range of window installation wisdom, including a discussion of pan flashings (5.16) and flashings (5.17).

Pan Flashings

To complicate things even more, there is a tectonic shift going on in the window industry and among the experts who design, consult and litigate about windows. The big news is that ALL WINDOWS LEAK! There are actually two kinds of windows, they say, “those that leak from the beginning and those that leak later.” The one possible exception seems to be vinyl windows with heat welded corners. Aluminum windows typically have sealed joints that can fail from factory defects, shipping damage, job-site damage or installation damage. Aluminum and vinyl clad wood windows still have to depend on wood joints that shrink and swell over the years through the action of heat and moisture. Vinyl windows may have strong corner joints, but a high coefficient of thermal expansion leaves the perimeter subject to excessive water intrusion that requires unique solutions. All windows suffer a decline in water resistance over the years through normal use or abuse and the deterioration of seals and weatherstripping.

> My colleagues and I conducted a survey of over 3,500 vinyl windows that were less than two years old — factory manufactured, precision engineered. We found that 20% of them had already begun to leak. So if you build a house with 20 vinyl windows, the odds are that 4 will leak right away (others will leak later). Which 4 windows do you want leaking into the wall? None of them, of course. So we have to assume that every window leaks and build accordingly. But what is the common practice?[3]

[3]Joseph Lstiburek, “Water Managed Wall Systems,” *Journal of Light Construction* (March 2003)

To mitigate this new revelation, experts and window manufacturers are moving toward universal advocacy of pan flashings that will, theoretically, collect any water from minor leaks and direct it away from sensitive construction components. Sill pans were incorporated into ASTM E2112, *Installation of Exterior Windows, Doors and Skylights*. The currently prevalent design strategy keeps incidental water on the outside of the WRB, but not necessarily on the outside of the wall. Even with this type of sill pan, a significant leak could overwhelm the system and result in damage.

Two publications during the time period 2002-2003 have been widely referenced as reflecting the thinking among window manufacturers and building envelope consultants who design, consult and litigate about windows.

From *Water Penetration Resistance of Windows*:

> One of the key components of this focus is the provision of some redundancy in water penetration control through the installation of subsill drainage.[4]
>
> Subsill drainage should be provided for all windows except those that are located in a "no exposure" environment."[5]

Despite Lstiburek's experience, I have heard other experts say that vinyl windows can't leak because the corners are heat welded. However, a high coefficient of thermal expansion leaves the perimeter subject to excessive water intrusion that requires unique solutions, and damage or installation errors are just as likely as with any other material. Aluminum windows typically have sealed joints that can fail from factory defects, shipping damage, job-site damage or installation damage. Aluminum and vinyl clad wood windows still have to depend on wood joints that shrink and swell over the years through the action of heat and moisture. All windows suffer a decline in water resistance over the years through normal use or abuse and the deterioration of seals and weatherstripping.

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[4] Water Penetration Resistance of Windows – Study of Manufacturing, Building Design, Installation and Maintenance Factors (Vancouver, BC: RDH Building Engineering Limited, sponsored by Canada Mortgage and Housing Corporation, Homeowner Protection Office and British Columbia Housing Management Commission, December 12, 2003, Executive Summary)

[5] Water Penetration Resistance of Windows, Conclusions

Figure 1

Ridges on PVC 3window fins can interfere with adhesion of self-adhered flashings and provide a path for water to penetrate inside of the flashing system.

To mitigate this growing consensus, experts and window manufacturers are moving toward universal advocacy of pan flashings that will, theoretically, collect any water from minor leaks and direct it away from sensitive construction components.

One of the key components of this focus is the provision of some redundancy in water penetration control through the installation of subsill drainage.[6]

There are two organizations that provide what could be termed industry standards for window installation, the American Society for Testing and Materials (ASTM) and American Architectural Manufacturers Association (AAMA).

Pan Flashing in ASTM E2112-07 Standard Practice for Installation of Exterior Windows, Doors and Skylights

ASTM assigned the subject of window installation to Task Group E06.55.11, originally chaired by the late Barry G. Hardman of National Building Science Corp. Task Group E06.55.11 is the author of ASTM E2112-07, *Standard Practice for Installation of Exterior Windows, Doors and Skylights*. The Task Group has some 50 members that represent window manufacturers, manufacturers of

[6] Water Penetration Resistance of Windows – Study of Manufacturing, Building Design, Installation and Maintenance Factors (Vancouver, BC: RDH Building Engineering Limited, sponsored by Canada Mortgage and Housing Corporation, Homeowner Protection Office and British Columbia Housing Management Commission, December 12, 2003, executive summary)

window installation accessories such as sealants and flashing materials, window industry organizations, and a number of building envelope consultants, including architects and engineers.

Window manufacturers who typically attended Task Group E06.55.11 meetings during the drafting of ASTM E2112 included Jeld-Wen (Budd Beatty, Mike Westfall, Chad Elbert), WinDoor, Inc. (Heath Cobb), MI Windows and Doors (Bill Emley), Anderson Windows (Steve Johnson), Marvin Windows (Tom Stoll, Jim Krahm), Pella Corporation (Cordell Burton), MW Windows (Travis Arthur, Wayne Breighner) and Kawneer Company (Mike Mitchell, Donnie Hunter)

Industry organizations included AWDI (John Jervis, S. Erling), WDMA (Rick Perry), AAMA (Larry Livermore, John Lewis)

ASTM E2112-07 defines pan flashing and recommends its use "under all windows and doors, except where wall construction details incorporating fenestration drainage systems are provided by the building designer, or where wall construction details are specifically provided by fenestration manufacturers' installation instructions."

> 3.2.91 *pan flashing*, *n*—a type of flashing used at the base of rough opening to divert incidental water to the exterior or to the exterior surface of a concealed WRB. NOTE 3—Pan flashings have upturned legs at the interior edge and ends of the rough opening to form a three-sided *pan*. They are intended to collect and drain water toward the exterior, including water that may enter through the window unit (for example, between the jambs and sill) or around the window (between the rough opening and the fenestration). The pan flashing must be integrated with other flashings and the window assembly to capture water that may otherwise penetrate to the sill framing and allow it to freely drain to the exterior. The window, flashings, and pan are to be sealed in a manner that reliably inhibits air and moisture flow to the interior.
>
> 5.16.3 *Use of Pan Flashings*—This practice recommends that pan flashings be used under all windows and doors, except where wall construction details incorporating fenestration drainage systems are provided by the building designer, or where wall construction details are specifically provided by fenestration manufacturers' installation instructions. Where used, pan flashings shall be integrated with the wall's weather resistive barrier in shingle-lap fashion (see Fig 5). The pan flashing shall be continuously sealed to the weather-resistive barrier. NOTE 16—Pan flashings may not be applicable for certain installations, for example, surface barrier systems, window receptors, pre-existing

ASTM defers to the manufacturer in case of conflict:

> 1.5 This practice provides minimum requirements that will help to accomplish the installation of fenestration products in an effective manner. Actual conditions in buildings vary greatly and, in some cases, substantial additional precautions may be required. In the event that the manufacturer's installation instructions provided with the product conflict with requirements of

this practice, the manufacturer's instructions shall prevail. This practice is not intended to limit or exclude other new procedures that may refine or further improve the effectiveness of fenestration installation.

AAMA FMA/AAMA 100-07 Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction

AAMA FMA/AAMA 100-07 *Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction* is the latest AAMA publication, and it embraces sill pans, but like the ASTM document, it also defers to manufacturers:

> PAN FLASHING (a.k.a. sill pan): A type of flashing used at the base of rough opening to divert water to the exterior or to the exterior surface of a concealed WRB. Pan flashings have upturned legs at the rear interior edge (back dam) and right and left sides (end dam) to form a three-sided pan that has the front open for drainage. They are intended to collect and drain water toward the exterior, including water that may enter through the window unit or around the window (between the rough opening and the fenestration).
>
> *NOTE 1: The pan flashing must be integrated with other flashings and the window assembly to capture water that may otherwise penetrate to the sill framing and allow it to freely drain to the exterior. For this reason, sill pans shall not be sloped to the interior. The window, flashings, and pan flashing must be sealed in a manner that reliably inhibits air and moisture flow to the interior.*
>
> Pan flashings can be made from self-adhering flashing or from rigid or semi-rigid material, such as a metal or semi-rigid polymer.
>
> 5.16.3 *Use of Pan Flashings*—This practice recommends that pan flashings be used under all windows and doors, except where wall construction details incorporating fenestration drainage systems are provided by the building designer, or where wall construction details are specifically provided by fenestration manufacturers' installation instructions. Where used, pan flashings shall be integrated with the wall's weather resistive barrier in shingle-lap fashion (see Fig 5). The pan flashing shall be continuously sealed to the weather-resistive barrier. NOTE 16—Pan flashings may not be applicable for certain installations, for example, surface barrier systems, window receptors, pre-existing

AAMA defers to the manufacturer in case of conflict:

> 1.5 This standard practice provides minimum requirements for window installation based on current best practices. Actual conditions in buildings may vary. In cases were variations occur, the installer shall consult with the window manufacturer or registered design professional. If this standard conflicts with the manufacturer's instructions, the manufacturer's instructions shall take precedence.

These Instructions represent an acceptable installation method. Other methods may be acceptable. Determining the acceptability of alternate installation methods is the sole responsibility of the installer, contractor or architect.[7]

Final Report Laboratory and Field Evaluation Of Pan Flashing/Sill Protection and Water Resistive Barriers

A 2006 study by U.S. Department of Housing and Urban Development concluded:

> The risk of water intrusion can be reduced by using durable pan flashing/sill protection products, in conjunction with other water management techniques.
>
> Many such products have come on the market in the last few years, providing a wide range of materials and cost levels.
>
> The pan flashing system evaluated in this study demonstrated successful performance in all three modes:
>
> • Small-scale pan flashing evaluation: all mockups in this series have remained watertight, although sensors have recorded some minor fluctuations in moisture readings.
>
> • Full-scale window/wall chamber evaluation: to date, no water intrusion has been observed within any portion of the full-scale window/wall chamber.
>
> • Field investigations: the pan flashing/sill protection assemblies used in the field evaluations have performed satisfactorily over several months of exposure to indoor/outdoor conditions.
>
> 3. The first cost of pan flashing/sill protection installation is worthy of consideration given the potential costs of structural damage, mold growth, remediation work, and litigation**.** An estimated average first cost for a home with 15 windows is $150 for materials and $175 for labor, for a total of $325, or $21.67 per window.[8]

EPA Technical Guidance to the Indoor airPLUS Construction Specifications

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[7] Residential New Construction, Vinyl Window, Installation Instructions (Excludes Storm Windows) (Phillips Products, Lit-1601, 8/04, Rev C)

[8] *Final Report Laboratory and Field Evaluation Of Pan Flashing/Sill Protection and Water Resistive Barriers*, April 2006, Prepared by: Williams Building Diagnostics, Inc. 945 Tennis Avenue Maple Glen, PA 19002 Under Subcontract to: NAHB Research Center, Inc. 400 Prince George's Blvd. Upper Marlboro, MD 20774-8731 (http://www.toolbase.org/PDF/CaseStudies/PanFlashingReport.pdf)

> The first flashing (pan flashing) is applied over the rough sill framing; its drainage performance will be improved if a piece of beveled siding is placed underneath it to aid the drainage of any water that collects in the "pan" where the window unit rests.[9]

An example of a window manufacturer's instruction showing a pan flashing is Figure 1 from Jeld-Wen. The pan is a proprietary product provided by Jeld-Wen. For more information, see http://www.jeld-wen.com/resources/installation.cfm.

Window Manufacturers

Milgard Windows and Doors

The only installation instructions provided by Milgard are referenced to AAMA 2400-02: *Standard Practice for Installation of Windows and Doors with a Mounting Flange in Stud Frame Construction*. This standard was originally developed in 1995 by the now defunct California Association of Window Manufacturers (CAWM). In a recent window exercise at a San Francisco Bay Area project, Dan McAndrew of Milgard DanMcAndrew@milgard.com) took no exception to the use of a sill pan with a vinyl window. To an inquiry about Milgard's position on pan flashings, McAndrew responded,

Milgard has a "new SmartCase™ system" that "installs a durable structural frame sill pan that allows installation of finish stucco, siding and trim before windows arrive. It absorbs any construction-related bumps and protects windows from possible damage. After interior paint is applied and decorative exterior trim is installed, the final windows then are placed in the frame." I am trying to get graphics for it.

AMSCO Windows

Like Milgard, AMSCO does not recommend pan flashings but does not object to them being used. See http://www.amscowindows.com/pdfs/installation_instructions.pdf for installation instructions.

Jeld-Wen

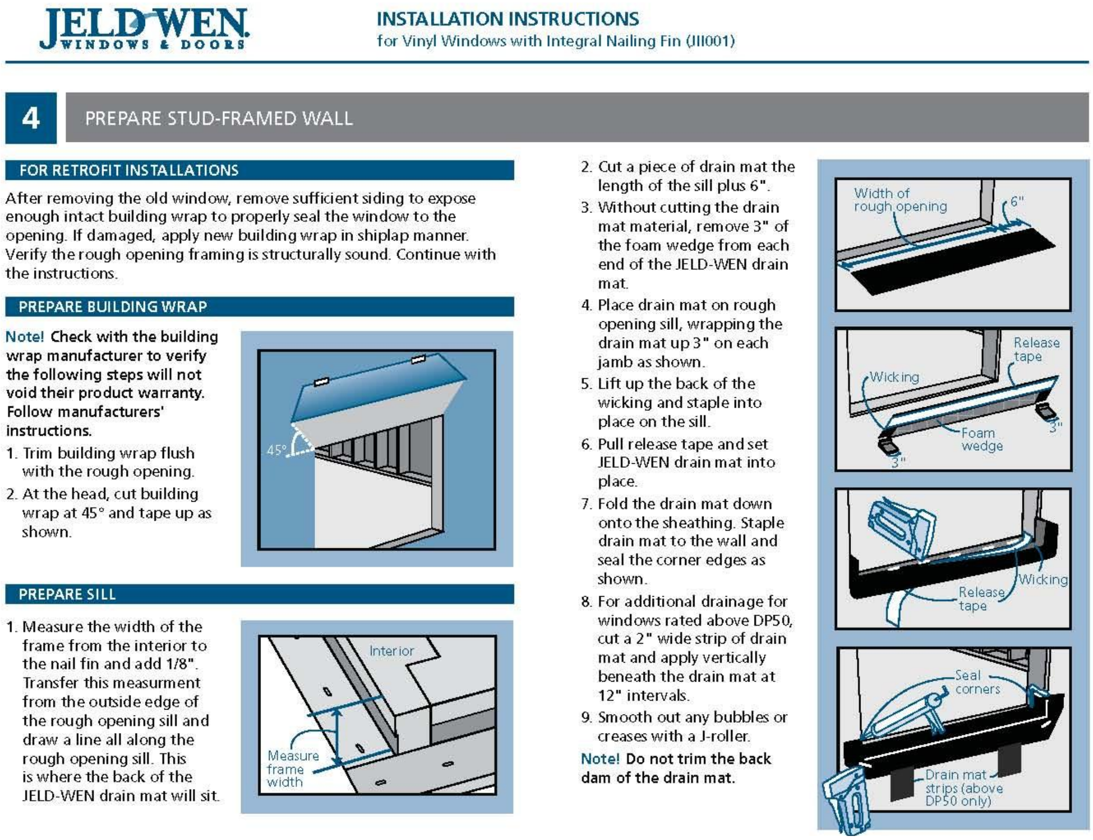
Jeld-Wen provides a proprietary sill pan that incorporates a drain mat that is an integral part of its window installation. See http://c2456372.r72.cf0.rackcdn.com/JII001.pdf.

Other Sill Pan Articles and Manufacturers

- http://www.finehomebuilding.com/PDF/Free/021197054.pdf

[9] http://www.epa.gov/indoorairplus/technical/moisture/1_6.html

- http://www.carlisle-ccw.com/Doco/brochureEzpan.pdf
- http://suresill.com/home.html
- http://www.weatheroutflashing.com/products-double-buck-window-and-door-corner-sill-pan-flashing-with-back-rib-black.htm
- http://www.buildingscience.com/documents/information-sheets/pan-flashing-for-exterior-wall-openings/files/bscinfo_302_window_flashing.pdf
- http://www.epa.gov/indoorairplus/technical/moisture/1_6.html
- http://www.everclearwindows.com/cgi-bin/Everclear-Forum/YaBB.pl?num=1233096617
- http://www.jamsill.com/
- http://www.youtube.com/watch?v=zeVByDIlqLA
- http://www.buildingscience.com/documents/information-sheets/pan-flashing-for-exterior-wall-openings?topic=doctypes/information-sheets
- http://www.polyguardproducts.com/products/architectural/datasheets/Flexible%20Pan%20Flashing%20data%20sheet.pdf
- http://www.constructorservicesinc.com/SillPanflashing.htm
- http://www.weatheroutflashing.com/products-4-9-16-window-and-door-corner-sill-pan-flashing-with-back-dam-brown.htm
- http://www.dunlapsupply.com/items.asp?Cc=SILL
- http://www.rci-online.org/interface/2010-04-bateman.pdf



JELD-WEN WINDOWS & DOORS

INSTALLATION INSTRUCTIONS
for Vinyl Windows with Integral Nailing Fin (JII001)

4 PREPARE STUD-FRAMED WALL

FOR RETROFIT INSTALLATIONS

After removing the old window, remove sufficient siding to expose enough intact building wrap to properly seal the window to the opening. If damaged, apply new building wrap in shiplap manner. Verify the rough opening framing is structurally sound. Continue with the instructions.

PREPARE BUILDING WRAP

Note! **Check with the building wrap manufacturer to verify the following steps will not void their product warranty. Follow manufacturers' instructions.**

1. Trim building wrap flush with the rough opening.
2. At the head, cut building wrap at 45° and tape up as shown.

PREPARE SILL

1. Measure the width of the frame from the interior to the nail fin and add 1/8". Transfer this measurment from the outside edge of the rough opening sill and draw a line all along the rough opening sill. This is where the back of the JELD-WEN drain mat will sit.

2. Cut a piece of drain mat the length of the sill plus 6".
3. Without cutting the drain mat material, remove 3" of the foam wedge from each end of the JELD-WEN drain mat.
4. Place drain mat on rough opening sill, wrapping the drain mat up 3" on each jamb as shown.
5. Lift up the back of the wicking and staple into place on the sill.
6. Pull release tape and set JELD-WEN drain mat into place.
7. Fold the drain mat down onto the sheathing. Staple drain mat to the wall and seal the corner edges as shown.
8. For additional drainage for windows rated above DP50, cut a 2" wide strip of drain mat and apply vertically beneath the drain mat at 12" intervals.
9. Smooth out any bubbles or creases with a J-roller.

Note! **Do not trim the back dam of the drain mat.**

Figure 2 – *Jeld-Wen*
Installation Instructions for Vinyl Windows with Integral Nailing Fin (JII001)

Marvin also shows a proprietary sill pan (Figure 3). See http://www.marvin.com/windows-and-doors/installation-instructions. for more information.

Figure 3- Marvin Clad Ultimate Double Hung and Single Hung

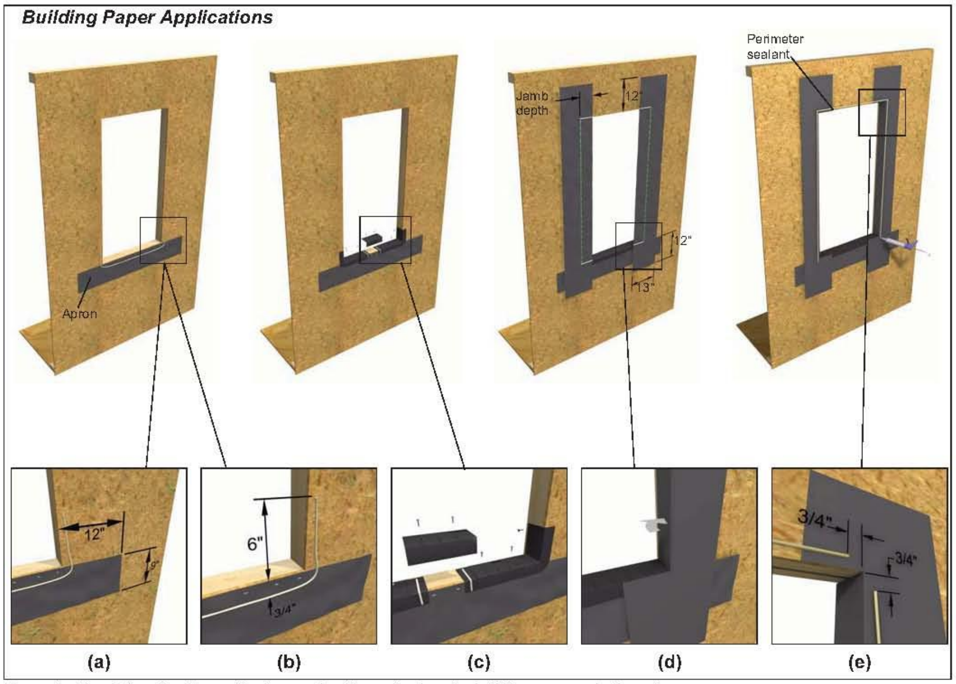


Figure 4 Rough Opening Preparation for construction methods using building paper and sill panning.

1. Make an "apron" by cutting a 9" (229) wide strip of Grade D building paper approximately 24" (610) longer than the window rough opening width. Center the apron even with the bottom of the RO and staple along the top edge only. See figure 4a.
2. Run a bead of sealant approximately 3/4" (19) from the edge of the opening. Start the bead about 6" (152) up from the sill (or the height of the sill panning). See figure 4b.
3. Install sill panning following manufacturer's instructions. See figure 4c.
4. Cut a 13" (330) piece of Grade D building paper 24" (610) longer than the RO height (adjust width for jamb depth). Tack the pieces in place, overlapping the RO by as much as the jamb depth. Use a utility knife to cut the paper even at the head jamb and sill. Fold jamb flaps to the interior and tack in place. See figure 4d.
5. Starting in 3/4" from the side, apply a 1/4" to 3/8" bead of sealant 1/2"-3/4" across the top of the RO stopping 3/4" in from the end. Apply sealant down both sides of the window opening in the same manner. Do not apply sealant across the RO bottom. See figure 4e.

Marvin SillGuard™

Installation Instructions

The instructions on the following pages will show how to install Marvin SillGuard for windows in new residential applications using two methods of integrating the weather resistive barrier with the product. These methods are based on those found in ASTM E2112-01. **Method A involves installing the window AFTER the weather resistive barrier has been installed. Method B involves installing the window BEFORE the weather resistive barrier has been installed. Method B is also appropriate for installations where building paper will be used.**

This product is intended for use with all Marvin products except Bow and Bays, Tilt Pacs, Insert Applications, and all doors.

As always, follow local codes and the window manufacturer's installation instructions.

CAUTION: It is recommended that you add 1/4" (6) to the rough opening height when using a rigid sill pan product such as SillGuard.

MARVIN Windows and Doors

Built around you.

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19972112

Although pans can be theoretically constructed solely of self adhering flexible flashing material, it is extremely difficult. Recessed windows exacerbate the challenge. One way of simplifying the process is to use a preformed sheet metal or plastic pan or use preformed corners joined by self adhering flexible flashing material. Sheet metal can be fabricated to size locally, and several plastic products are available commercially.

One such product, *Jambsill Guard*, has been around for a decade and is intended primarily for doors (Figure 3).

Figure 4 - *Jambsill Guard*
(for more information, see http://www.jambsill.com/products.asp?what=jg)

I favor sheet metal, since it can be prefabricated to conform to whatever configuration is required. The best approach is to fabricate two pices that can be snugged into the framing corners and than lapped and sealed in the center.

RECESSED WINDOWS

Recessed windows in frame construction are a special challenge. Not only do they require a pan flashing under the window unit, but they also shpould have a pan covering the exterior sill area – typically over the WRB and under the cladding. This means that four multiplane corner transitions are needed – two for the window pan and two for the sill pan. The window pan needs to lap over and be sealed to the sill pan. It is possible to leave the exterior sill pan on a recssed window exposed, but typically, it is overed with a finish such as stucco.

Stucco on horizontal surfaces is vulnerable to water penetration at cracks and joints, so the sill pan and the WRB below it needs to be robust. Avoid penetration of the sill pan by fasteners. Stucco lath can be formed over the sill pan using expanded metal lath fasted only at vertical surfaces instead of wire lath.

Figure 5
Decay in framing below a recessed window sill due to inadequate protection of the framing by flashing

Figure 6
Exterior sill flashing of a recessed window using self-adhered flexible flashing. Multiple layers are required to fashion corners, resulting in wrinkles and fishmouths. Voids behind inside corners are vulnerable to puncture

The soffit also needs special attention, particularly when the clading is stucco. Although the building codes have required weep screeds at the base of stucco-clad walls for years (see *California Building Code* 2512.1.2 there is no explicit code requirement for exactly the same condition that a wall-soffit interface. Without a weeping function at a wall-soffit, any water penetrating the stucco above a soffit will be trapped above the soffit where it can penetrate vulnerable joints and laps in the WRB.

The Appendix to ASTM C926,*Application for Portland Cement Plaster*, includes the following:

> A2.2.3 Where vertical and horizontal exterior plaster surfaces meet, both surfaces shall be terminated with casing beads with the vertical surface extending at least 1⁄4 in. (6 mm) below the intersecting horizontal plastered surface, thus providing a drip edge. The casing bead for the horizontal surface shall be terminated not less than 1⁄4 in. from the back of the vertical surface to provide drainage.

The best solution is a combination drip and weep screed commonly available from manufacturers of stucco trim and accessories. Failure to use a drip-weep at soffits, even the small soffit formed by a recessed window can result in massive damage. Some type of weep-dripfunction is recommended where materials other than stucco are used for cladding.

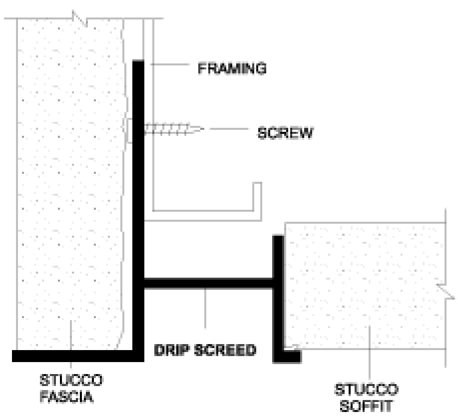

Figure 7
Typical soffit weep-drip screed of extruded aluminum

Figure 8
Damage at recessed window head resulting from lack of a soffit weep-drip screed

Figure 9 (Left)
Damage at recessed window head resulting from lack of a soffit weep-drip screed

FLEXIBLE FLASHING MATERIALS

Self adhering waterproofing membranes, such as W.R. Grace *Bituthene, Vycor* and *Polyguard* have been used as penetration flashings, sub-flashings for copings, and similar applications for years. They are flexible, elastomeric (which makes them self-healing), adhesive and unaffected by water. They typically have a foil or plastic backing to protect the adhesive and come rolled with a release paper that is removed just prior to application.

Figure 10
Example of a self-adhering flexible flashing product, Fortifiber "Fortiflash"

Today, there are dozens of products generically known as self-adhering flexible flashings, or self-adhering flashings (SAF). A comprehensive survey appeared in the June, 2001, edition of *Journal of Light Construction*.[10] These products are a quantum leap above the old paper-based products widely used into the 1990s, but they are not a panacea, and they have their own challenges. Also, not every flexible flashing is created equal.

Unless some fatal flaw turns up with self-adhered materials, the non-adhesive flashings are rarely used but still available. One application example is *Moistop neXT* used under a sill flashing to keep it from adhering to the sheathing (so the WRB can be tucked up behind it). In addition, there may be cold weather applications where adhesives will not stick and non-adhesive flashings may be the only alternative.

There are no industry standards for self adhering flashings, although the ICC Evaluation Service has an Acceptance Criteria (AC148) for Flashing Materials that is used as criteria for accepting a number of proprietary products (http://www.icc-es.org/Criteria/pdf_files/AC148_for_use_with_Legacy_Codes_and_2006_earlier_I-Codes.pdf). Evaluation Reports on specific products can be searched at http://www.icc-es.org/evaluation_reports.

Polymers

There appear to be differences among SAF products based on the waterproofing and adhesive polymer used. The two prevailing polymers are rubberized asphalt and butyl. There is some

[10] Martin Holladay. Choosing Flexible Flashings" *Journal of Light Construction* (Williston, VT: Journal of Light Construction, June 2001)

indication that rubberized asphalt tends to creep or run more in hot environments or when left exposed for more than a limited time, which may adversely affect long term adhesion.

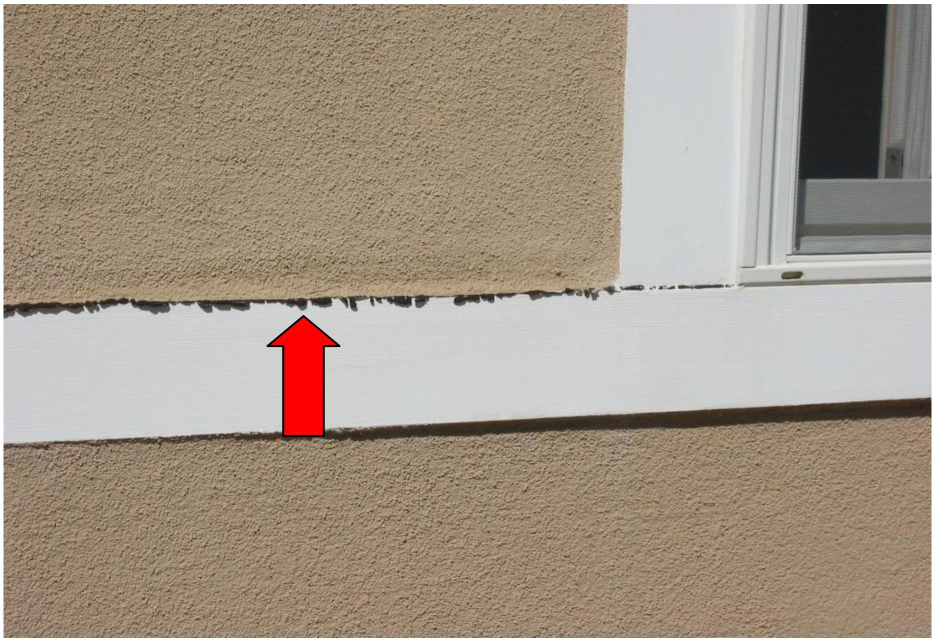

Figure 11
Adhesive polymer from a self-adhering flexible flashing flowing out of a joint between wood trim and stucco

Will butyl adhesives stick to weather resistive barriers? This has not been resolved "The jury is still out on whether butyl tapes should be allowed contact with asphalt felt. "If you are talking about 15-pound felt, there is not a lot of asphalt, because felts are relatively dry," says Winzeler. "You'll probably have fewer issues with compatibility than with roofing cement. But until you test, you can't be sure." Theresa Weston, a chemical engineer at DuPont, recently opined that DuPont's butyl tape, FlexWrap, is compatible with asphalt felt.

Rubberized asphalt is incompatible with some types of flexible vinyl, especially vinyl flashings that come in a roll. It doesn't appear to have any compatibility problems with hard vinyl, like the vinyl used for window fins. Watch out for staining. Rubberized asphalt, like other asphalt products, can stain some materials, especially vinyl. According to Bob Sims, customer service manager at Bakor, such staining, called plasticizer migration, occurs when oils in the asphalt dissolve plasticizers in the vinyl. Since rubberized-asphalt flashings shouldn't be left exposed, staining is generally not a problem. The siding or other material used to cover the flashing usually hides any stains."[11]

Exposed Surface

If the material is not going to be covered with cladding soon after installation, a foil surface SAF seems to be a good idea.

[11] Martin Holladay. Choosing Flexible Flashings" *Journal of Light Construction* (Williston, VT: Journal of Light Construction, June 2001)

Thickness

Some SAF and window manufacturers believe that thinner flexible flashings result in better workmanship and that lesser build-up of thickness can result in fewer problems integrating flashings with windows and door frames as well as claddings.

Workmanship - General

Workmanship may be the most important factor of all, particularly for recessed openings. Wrinkles, fishmouths and lack of sufficient pressure to achieve good adhesion are serious problems.

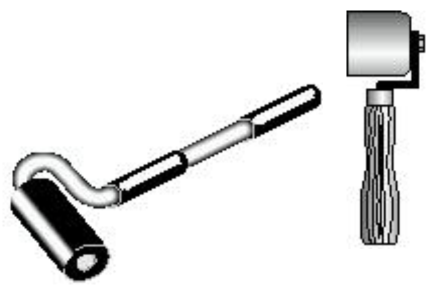

Figure 12
Roller tools made for plastic laminate and wallpaper can be used to apply pressure to flexible flashings to avoid wrinkles ad achieve good adhesion. These are available from:
Beno J. Gundlach Company
211 North 21st Street • PO Box 544 •

The illustration above shows two of several types of rollers available that can be used to install self-adhering flexible flashings. Some product manufacturers require the use of rollers for installation. Hand pressure, alone, is generally not sufficient to provide maximum adhesion and avoid wrinkles. Workers assigned to installation of flexible flashings should have good manual dexterity and be trained to do proper, high quality installations.

> Hand pressure or roller? Many, but not all, manufacturers recommend that their flexible flashing should be installed with a steel or hard-rubber J-roller — the same type of roller used for gluing plastic laminate countertops. Many manufacturers' reps admit that this recommendation is widely ignored, but doing so carries some risk: When it comes to priming and using a roller, the bottom line is that builders who deviate from a manufacturer's recommendations can't expect any support from the manufacturer if something goes wrong.[12]

There may eventually be standards for bonding, adhesion, allowable fishmouths, wrinkles and air voids, but these are still in the developmental stage. For adhesion, ASTM D D3330 *Test Method for Peel Adhesion of Pressure-Sensitive Tapes,* or ASTM D903 *Test Method for Peel or Stripping Strength of Adhesive Bonds*, can be used in a laboratory setting, but field use may be difficult. Flashing manufacturers often publish adhesion information. For example, Fortifiber provides lap adhesion properties of its 25 mil and 40 mil "Fortiflash, as 9.3 lbf/in and 10 lbf/in, respectively. There are no known qualitative industry standards for installation workmanship.

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[12] Martin Holladay. Choosing Flexible Flashings" *Journal of Light Construction* (Williston, VT: Journal of Light Construction, June 2001)

It may not be reasonable to expect a level of workmanship in the field that can successfully flash recessed windows and doors. I have yet to see a level of workmanship that, in my opinion, is fully acceptable. Without a history of performance, however, it is impossible to tell how critical this will be.

Products Without Flashing Fins

Some products without waterproof installation fins require flexible flashings to be adhered to frames, which involves careful workmanship to result in an effective and permanent seal. Most conventional aluminum windows are still shipped with continuous perimeter fins intended for both installation and waterproof connections to flashing. Some manufacturers of vinyl clad wood and vinyl windows incorporate fins that are intended predominantly for installation and are not attached to the window frame with a waterproof joint. Pella is an example. Self-adhered flexible flashings have to be rolled onto the fins at a 90 degree angle to achieve a waterproof connection. Workmanship and adhesion are challenges.

Minimum width of flexible flashings at opening perimeters

Traditionally, 9 inches has been the industry standard recommended minimum, and this is incorporated into ASTM E2112. There is no reliable data from which to draw conclusions about the optimum or minimum width of flashings. Sometimes, lesser width flashings are extended in effective width by adding additional strips. Some professionals have voiced concerns that excessively wide flashings create an area with a vapor retarder and could have an adverse impact on a wall’s ability to pass water vapor, resulting in condensation problems.

Primers

Based on tests described in an unpublished paper, primers recommended by flashing manufacturers can significantly increase adhesion.[13]

Sealant

Setting door and windows fins be set in sealant over flexible flashings may be a good idea because of the difficulty in achieving a complete and permanent seal with the flashing adhesive, this makes the continuity of the fin-to-flashing joint virtually certain, and this is a critical area of exposure because of the relatively high possibility of some water intrusion occurring through the joint between the window frame and the cladding/trim. For installations without a double application of flexible flashings, this would be even more critical.

Integration with Water Resistive Barriers

Traditionally, non-adhesive flexible flashings have not been sealed to WRB’s. There is no body of evidence that suggests this has been a contributing factor in typical failures. After all, WRB roll products are required by code to be lapped only 6 inches at ends and 2 inches top and bottom. However, flashings around openings may be expected to have more exposure to water

[13] Zima, A. D., Weston, T. A., and Haygood, R., “Comparison of Butyl Versus Modified Asphalt Window Flashing Adhesives,” Durability of Building and Construction Sealants and Adhesives, ASTM STP 1453, A. T. Wolf, Ed., ASTM International, West Conshocken, PA 2004

than WRB's under the field of cladding. Some window manufacturers (Pella) require a sealed connection between the flexible flashing and the WRB.

Sill Weeping

Traditionally, finned aluminum windows have been sealed all around. It was presumed that no water would pass through the plane of the WRB, fins and flashings. With clad wood windows, particularly, there seems to be a movement toward creating a sill pan that can weep. This is separate from the integral weeps in the window product that are intended to weep to the outside of the cladding. Pella, for example, provides instructions on how to create a partial sill pan from flexible flashing material and instructs that it not be sealed to the sill fin so that any water intruding past the plane of the WRB would, theoretically, drop down to the sill pan and weep out under the sill fin and into the plane of the WRB.

Application to Sheathing

Is there any reason that flexible flashings should adhere to sheathing other than temporarily until the cladding is applied? In other words, does the flexible flashing/sheathing bond play any role in the water resistance of the system? Other than providing temporary positioning and serving to keep the flashing system in place, a bond between a flexible flashing and sheathing appears to have no other role – certainly not a waterproofing role.

Typically and traditionally, for installation in conjunction with organic felt and paper-based WRB products, flexible flashings are applied to sheathing prior to the installation of the WRB. For non paper-based (polymer products), such as housewraps, are installed first, and flexible flashings installed on top, with a slit made in the WRB above the head that the flashing can be inserted shingle-style. No data is available to substantiate the advantage of one method over the other.

Layering

Are two layers of flexible flashings better than one? If so, should they "sandwich" the WRB, go under it, or over it? Or does it make any difference? We are aware of no test data that can provide a conclusion. Because of potential adhesion failures, two layers would appear to provide a higher factor of safety than one layer.

RECOMMENDATIONS

So, how does an owner, contractor or developer and his architect cope with all this? Here are my suggestions:

1. Details have to be drawn. If you don't know which brand of window will be used, take your best guess. Obtain that manufacturer's installation details, usually available on the Internet.
2. Determine the key differences, if any, between the standard installation instructions and the specific project. This may include recesssed windows, different WRBs, or custom stacking and mulling configurations. Contact the manufacturer's technical representative for assistance or advice.
3. Prepare full scale head, jamb and sill details for all typical opening conditions. Anything less than full scale will not be comprehesible because of the interfacing and lapping of multiple layers of WRBs and flexible flashings. Use diagrams, if necessary to show installation sequences.
4. The manufacturer's instructions will refer to primers, sealants, drain screens, flexible flashings, foams and other accessories only generically. Find out from the window manufacturer what specific brands and products are compatible and acceptable. Typically, a manufacturer will have tested the installation sucesssully with specific accessory products. If that information is unanvailable, a one-part urethane sealant conforming to ASTM C920 is probably the best bet where sealant is called for. Because of dust and dampness on surfaces, a primer recommended by the flexible flashing manufacturer is always good insurance.
5. If a different window than that detailed is used, it may be necessary to revise all the installation details for consistency.
6. Whether or not the manufacturer recommends a sill pan, it should be included in the design. The sill fin should not be sealed to the flexible flashing and WRB so that any leaks into the assembly can eventually drain out on the outside of the WRB.
7. When the first window is ready for installation, convene a pre-installation meeting and field demonstration of a prototype attended by at least the architect, the window installer and the job superintendent to work out any bugs and agree on the final procedure. If at all possible, a technical representative from the window manufacturer should be present. Some one should take photos and make notes for distribution and review, perhaps with sketches if necessary.

EXHIBIT 1 – ASTM E2112 STANDARD PRACTICE FOR INSTALLATION OF EXTERIOR WINDOWS, DOORS AND SKYLIGHTS

EXHIBIT 2 - E2266 – STANDARD GUIDE FOR DESIGN AND CONSTRUCTION OF LOW-RISE FRAME BUILDING WALL SYSTEMS TO RESIST WATER INTRUSION