Interim Report:

# Study of the water resistance performance of the exterior envelope relating to fenestration during minimal high winds

Project #: P0108029

Submitted to:

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## Introduction

This interim report is a deliverable from Project #P0108029 regarding the water penetration performance of fenestrations in the exterior envelope of buildings during minimal high wind events and presented to the Florida Building Commission in support of working group on hurricane Irma exterior envelope damage reports. The objective of this project is address water leakage due to wind-driven rain on residential structures in hurricanes.

## Scope of work

- Provide support to Workgroup deliberations and discussions
- Review existing literature on water leakage through residential building envelopes by University of Florida, Florida International University, Florida Institute of Technology and others.
    - Summarize the recommendations and conclusions
    - Determine which if any recommendations are included in the Building Code.
    - Provide input to Workgroup regarding benefits and costs of modifying wind-driven rain test standards
- Review forensic reports water damage to units as provided to us by the Workgroup Chair
    - Analyze the dataset of units – age, story height, orientation etc.
    - Estimate peak wind speed and other meteorological data to estimate rain loading and wind loading on windows

## Work Completed to Date

A literature review compilation of references in the current Florida Building Code, ASTM international and Fenestration Manufacturers Association (FMA), existing studies on water penetration through residential building envelopes, to identify recommendations and conclusions was carry out.

Additionally, the work was presented to the workgroup in Jacksonville in February 18th, 2019 (link of the presentation: https://www.dropbox.com/s/nurmbop9tji41kd/UF-Prevatt-Water%20Intrusion%20Workgroup-18Feb2019rev.pptx?dl=0 ). A brief summary of the content of the presentation for the Florida Building Commission and the outline of the presentation are presented below.

## Presentation Highlights

In section 1, Florida Building Code (2007) provisions were reviewed, specifically for chapter 6, chapter 7 and chapter 8 related to Wall construction, Wall recovery and Roof assemblies, respectively.

In section 2, an extensive review of Standard Practice for Installation of Exterior Windows, Doors and Skylights (ASTM E2112-07) was carry out. Specifically were analyzed different ways of application of the Weather-Resistive Barrier (WRB). Method A, Method A1, Method B and Method B1 were compared and it was found that the same installation features were considered but sequence of window and flashing installation are different. Additionally, FMA/AAMA 100-12 and FMA/AAMA 200-12 for wood systems and masonry systems, respectively, were analyzed. In the case of FMA/AAMA 200-12 the major emphasis is focused on sealing the surrounding area of the window's masonry opening to restrict the water from penetrating at the window opening and/or around of the window frame. A comparison between ASTM E2112-07 and FMA/AAMA standards shows that FMA/AAMA standards require that the window rough opening must be drainable through sill pan flashing under the fenestration unit and that is necessary to install a perimeter air seal between window frame and rough opening at or near interior edge of the window frame. Moreover, FMA/AAMA standards provide more information for the installation steps as well as illustrations.

In section 3 of the presentation a literature review of existing studies on water penetration through residential building envelopes performed by University of

Florida, Florida International University and Florida Institute of Technology, and others was carry out as part of the objectives to complete.

**Katsaros et al.** (Katsaros, J. D., and Carll, C. G., 2009. "Extreme Exposure Fenestration Installations—The Florida Challenge." *Journal of ASTM International*, 6(5), 1-17) investigated the construction of 1$^{st}$ floor surface barrier CMU walls & 2$^{nd}$ floor membrane-drainage in wood walls. Main observations of this work are:

- The sill pan flashing suggested by FMA/AAMA 100 and 200 were found to be effective to reduce water penetration which was not observed between the pan and the window bottom flange (where there was not a continuous seal).
- Leaks were observed in areas where adhesion between the window frame and the sill pan was not sufficient.
- A "whole wall" approach to water management appears necessary due to observed water seepage through the internal portion of the block at unsealed area, but not at in the sealed area.

**Salzano et al.** (Salzano, C. T., Masters, F. J., and Katsaros, J. D., 2010. "Water penetration resistance of residential window installation options for hurricane-prone areas." *Building and Environment*, 45(6), 1373-1388) investigated water penetration resistance of current window installation options of single-family houses. Main observations of this work are:

- Contrary to the water barrier method, the drainage method installations did not perform well on the concrete masonry unit wall specimens tested due to discontinuity between the water shedding surface and the exterior moisture barrier of the window-wall system.
- Windows installed into the wood frame walls, both water barrier and drainage installation methods provided sufficient water penetration resistance due to adequate continuity of the critical barriers.
- Low expansion foam seals prevent leakage for pressures up to 4788 Pa (100 psf), but only if the excess of foam is not trimmed.

- In fact, if the excessive foam is trimmed, it does not present any water resistance.
- Selecting an appropriate sealant is paramount to water penetration performance found to work the best.

**Lopez et al.** (Lopez, C., Masters, F. J., and Bolton, S., 2011. "Water penetration resistance of residential window and wall systems subjected to steady and unsteady wind loading." *Building and Environment*, 46(7), 1329-1342) investigated the diagnostic ability of standard static & cyclic water penetration tests and quantified water ingress rates of operable, sliding windows under wind tunnel derived wind load time-history. Main observations of this work are:

- Compression sealed windows are better performers than sliding sealed windows (greater water leakage in sliders)
- Water leaks occurs through the window/wall interface
- Water tightness of interface joints is crucial for good water tightness of the window system.
- A differential pressure of 600 Pa or more window/wall systems exhibit first sign of leaks in dynamic environment
- Rapid pulse test loads caused formation of more leakage paths than the static pressure test.
- Sill dam height is critical in reducing rate of water leaks into the interior of building. The sash-to-sill and sash-to-jamb interfaces only partially sheds water;
- Water penetrates or fills the air void underneath the sash and rises in proportion to the exterior pressure
- Substantial leakage (1 liter/min) will occurs once the mean pressure exceeds the hydraulic pressure required to raise a column of water up to the vertical distance between the bottom of the sash and the top of the sill dam

Finally**, Beers & Smith** (Beers, P. E., and Smith, W. D., 1998. "Repair Methods for Common Water Leaks at Operable Windows and Sliding Glass

Doors." Water Leakage through Building Facades, ASTM International) investigated water leakage through building facades, specifically repair methods for common water leaks at operable windows and sliding glass doors. Experimental setups and results as well as important observations of each one of the papers are presented in section 3 of the presentation. The main conclusion of this work is:

- A series of tests and repairs is necessary before a successful method is found, test method of ASTM E1105 is recommended.

In section 4, ASTM (i.e. Modified AAMA 501.1, D226/D226M—17, ASTM E331 - 00(2016) and ASTM STP 1314) and industry Standard Tests (i.e. Probe Method for moisture and Infrared Thermography from RJF Environmental Consulting Services, Inc) for water intrusion and leakage were briefly reviewed.

In section 5 the field data provided by Daniel L. Lavrich show some features of buildings affected by Hurricane Irma in 2017. Field data contains the date of construction, the total units and inspected units, the height of the buildings and the zip codes. In addition, a zip code map with the locations of the buildings and a comparison between State of Florida’s Design Wind Speed map vs Irma Wind speeds is shown to highlight the fact of Florida’s Design wind speeds are larger than those caused by Hurricane Irma in 2017. Is important to notice that a preliminary analysis of water damaged units is presented due to the data analysis has not been developed yet.

In Section 6 Florida Public Hurricane Loss Model (FPHLM), administered by FIU and supported by several Florida Universities, is described for mid/high rise buildings. This model permit asses hurricane wind risk and predict insured losses for residential properties by developing damage functions and vulnerability curves. Finally, an outline for FPHLM with workgroup to estimate the benefit/cost ratios of possible mitigation measures is shown.

## Presentation Outline

1. Florida Building Code (Provisions)
    - 1.1 Florida Building Code Chapter 6. Wall construction
    - 1.2 Florida Building Code Chapter 7. Wall covering
    - 1.3 Florida Building Code Chapter 9 Roof Assemblies

2. ASTM and FMA review (Normative vs Standard Practice)
    - 2.1 ASTM E2112-07: Standard Practice for Installation of Exterior Windows, Doors and Skylights. Weather-Resistive Barrier (WRB) Applied after the Window Installation—Flashing Applied Over the Face of the Mounting Flange (Method A)
    - 2.2 ASTM E2112-07: Standard Practice for Installation of Exterior Windows, Doors and Skylights. Weather-Resistive Barrier (WRB) Applied Prior to the Window Installation—Flashing Applied Over the Face of the Mounting Flange (Method A1)
    - 2.3 ASTM E2112-07: Standard Practice for Installation of Exterior Windows, Doors and Skylights. Weather-Resistive Barrier (WRB) Applied After to the Window Installation—Flashing Applied Behind the Face of the Mounting Flange (Method B)
    - 2.4 ASTM E2112-07: Standard Practice for Installation of Exterior Windows, Doors and Skylights. Weather-Resistive Barrier (WRB) Applied After to the Window Installation—Flashing Applied Behind the Face of the Mounting Flange (Method B1)
    - 2.5 Comparison of ASTM E2112-07 Methods
    - 2.6 – 2.10 Fenestration Manufacturers Association FMA/AAMA 100-12 Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction for Extreme Wind/Water Conditions.
    - 2.11 – 2.14 Fenestration Manufacturers Association FMA/AAMA 200-12 Standard Practice for the Installation of Windows with Frontal

Flanges for Surface Barrier Masonry Construction for Extreme Wind/Water Conditions.

2.15 Comparison ASTM E2112 vs. FMA Standards.

3. Water Penetration Through Residential Building Envelopes (Previous Research)

    3.1 – 3.4 Katsaros, J. D., and Carll, C. G. (2009). "Extreme Exposure Fenestration Installations—The Florida Challenge." *Journal of ASTM International*, 6(5), 1-17

    3.5 – 3.9 Salzano, C. T., Masters, F. J., and Katsaros, J. D. (2010). "Water penetration resistance of residential window installation options for hurricane-prone areas." *Building and Environment*, 45(6), 1373-1388.

    3.10 – 3.14 Lopez, C., Masters, F. J., and Bolton, S. (2011). "Water penetration resistance of residential window and wall systems subjected to steady and unsteady wind loading." *Building and Environment*, 46(7), 1329-1342.

    3.15 Beers, P. E., and Smith, W. D. (1998). "Repair Methods for Common Water Leaks at Operable Windows and Sliding Glass Doors." Water Leakage through Building Facades, *ASTM International*.

4. ASTM and industry Standard Tests

    4.2 Modified AAMA 501.1

    4.3 D226/D226M—17

    4.4 ASTM E331 - 00(2016)

    4.5 ASTM STP 1314

    4.6 Probe Method for moisture

    4.7 Infrared Thermography

5. Data analysis (not developed yet)

   5.1 Buildings and numbers of units experiencing water intrusion issues with little or no wind damage.

   5.2 Location of the buildings (Zip codes)

   5.3 Design Wind Speed

   5.4 State of Florida's Design Wind Speed vs. Irma Winds Category II (3-sec. gust)

   5.5 Preliminary Analysis of Water Damaged Units

6. Florida Public Hurricane Loss Model

   6.1 -6.13 Florida Public Hurricane Loss Model: Characterization, Vulnerability Model of mid/high-rise buildings (MHRB), and Plan of action.