Final Report:

Water Resistance Performance of Exterior Building Envelope and Fenestration During Minimally High Wind Events in Hurricane Irma

Project #: P0108029

Submitted to:

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DISCLAIMER

Executive Summary

The Workgroup assembled to address a critical concern regarding water leakage into high-rise buildings during Hurricane Irma. Hurricane Irma made landfall on xx/x/2017 in the Florida Keys and then on the west coast of Florida near to Marco Island. This was a minimal mainland hurricane event in Florida but its path and size of the rain bands produced elevated winds and heavy rains over the Florida peninsula from south to north. Irma was forecast to make landfall near to the east coast which would have created far more damaging winds in the Miami-Dade areas.

This report gathered information on the performance of building envelope systems in high-rise structures during Hurricane Irma. With limited forensic data on from engineering inspections of some 15 buildings, there was evidence that water leakage occurred during the Hurricane Irma resulting in $12.9 million dollars in damage to condominium and apartment units. Of the three buildings constructed post Florida 2002 Building code, the total losses were $3.3 million dollars. While the information presented is fairly limited, the research team found other engineering reports that water leakage may have been extensive. The Research Team developed a data collection form to capture generic data on the buildings in a non-identifiable manner and the form is included in Appendix should this be required for future events. In some statements engineers claim that the rate of water leakage through fenestrations may have increased since Hurricane Irma due to hidden damage and defects in the fenestration.

The report presents a summary of previously conducted research studies that demonstrated holistic water testing procedures for building envelope systems in Florida construction. It was clear many times leakage occurs at or around windows and doors, at or around the building envelope systems as well as through the windows and at the interfaces of these systems.

In addition, a study with the Florida Public Hurricane Loss Model, investigated the possible impact of fenestration defects on insured losses. The study shows that defects in fenestrations could have a substantial effect on insured losses for low intensity events like Irma in South-East Florida, in terms of overall percentage of the losses, and the analysis does not report significant differences between pre- and post-2002 buildings. However, the analyses do not capture the magnitude of the absolute loss as reported for some 15 buildings in this report. This suggests that hurricane catastrophe models like the FPHLM might need to be recalibrated to give a truer projection of the magnitude of this problem.

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1 Introduction

This final 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.

1.1 Objective and Motivation

Following Hurricane Irma (2017), Mr. Daniel L. Lavrich, P.E. conducted forensic surveys of over 3,309 condo/apt units in 15 buildings 33xxx zip code. It was observed that water intrusion damage through/around fenestration occurred, although Irma's wind speed was much lower than design wind speed (170 mph) for the area. In general, the objective of this project is address water leakage due to wind-driven rain on residential structures in hurricanes.

1.2 Previous Research

Daniel L. Lavrich, P.E. collected documentation on the water leakage due to wind-driven rain, called Database of Water-Damaged Buildings that occurred to several structures in Florida during hurricane Irma, including the building location, age of structure, and components of the building envelope systems, amount of and cause of water leakage.

Several projects completed in the past by University of Florida and others developed empirical models for water penetration a leakage due to wind-driven. More recently, those studies have led to the development of vulnerability models, which essentially draw a relationship between wind speed, rain intensities, building façade construction and the extent of water leaks. The Florida Public Hurricane Loss model administered by FIU and supported by several Florida universities can make this information available.

Current research has estimated where water distribution within a building might occur, given specific interior components. The field data from Mr. Lavrich could provide the necessary calibration and validation for more realistic loss models leading to improvements in loss predicts on regional or state-wide building portfolios.

1.3 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 Daniel L. Lavrich, P.E.
    - 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
- Recommendation for future studies

2 Literature Review for Water Penetration

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.

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.

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.

2.1 Florida Building Code

2.1.1 Chapter 6: Wall Construction Requirement

R607.1: Sills

Water emulsion coating > 3mm.

R609.2: Performance

Design Wind Loads for windows and doors table R 301.2.2(2).

R609.3: Testing and labeling

Exterior windows and sliding doors requirements.
AAMA/WDMA/CSA101/I.S.2/A440 or TAS 202 (HVHZ shall comply with TAS 202 and ASTME1300).

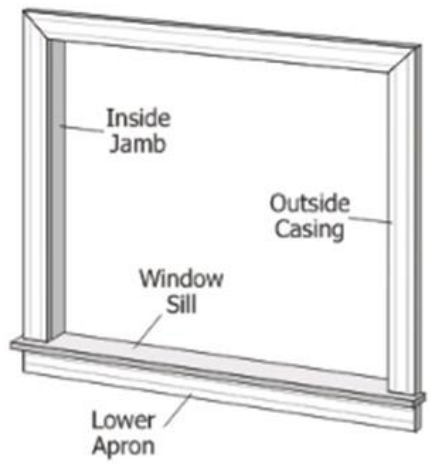


Figure 1. Windows component sketch

2.1.2 Chapter 7: Wall Covering Requirement

R703.1.1: Water resistance

- No water accumulation in the exterior envelope.
- Water resistant barrier behind exterior veneer.

R703.2 & R703.7.3: Water-resistant barrier

One layer of No.15 asphalt felt, free from holes and breaks, complying with ASTM-D226 for type 1 felt.

R703.4 Flashing

- All exterior fenestration products shall be sealed at the juncture with the building wall with a sealant complying with AAMA 800 or ASTM C 920 Class 25 Grades NS.
- Flashing at exterior window and door openings shall extend to the surface of the exterior wall finish or to the water-resistive barrier complying with Section 703.2 for subsequent drainage.

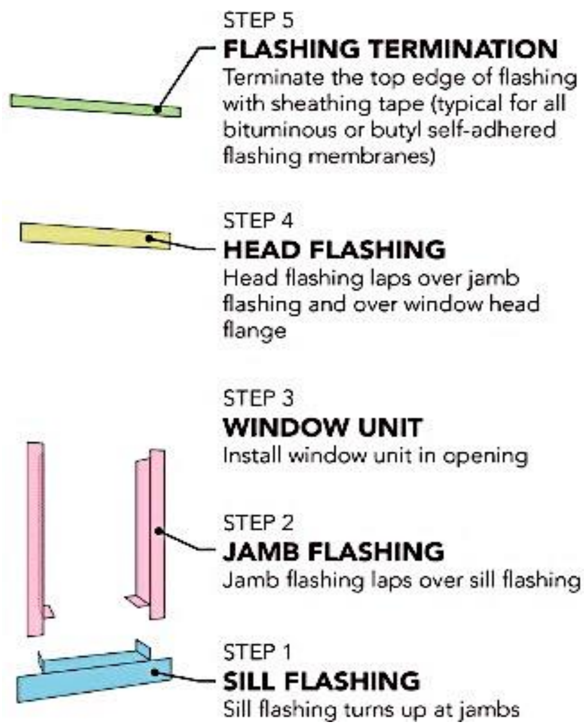


Figure 2. Flashing installation procedure according to chapter 7 of the Florida Building Code

2.1.3 Chapter 9: Roof Assembles Requirement

R908.7.2: Roof secondary water barrier for site-built single residential structures.

Minimum 4in (102mm) wide strip of self-adhering polymer.

R905.2.8.1: Base and counter flashing

- In according with manufacturer's installation.
- In compliance with RAS 111.
- A continuous metal minimum 4 in by 4 inch "L".

R905.2.8.2: Valleys

Valley linings shall be installed in accordance with the manufacturer's instructions before applying shingles.

Roof secondary water barrier | Base and counter flashing | Valleys

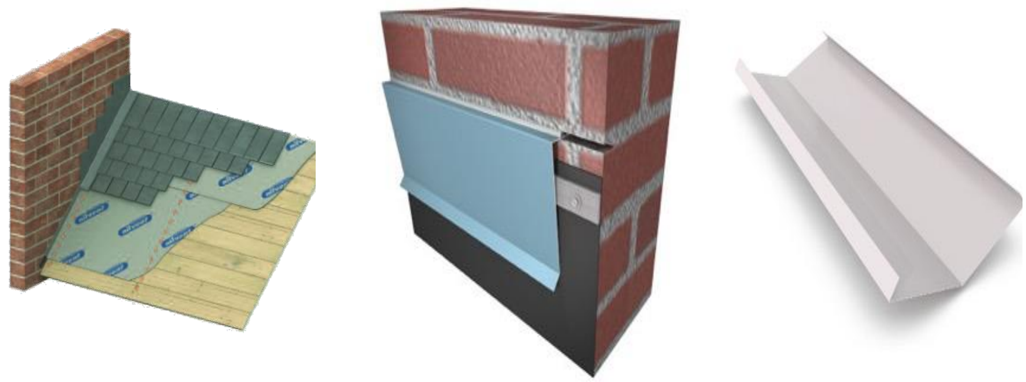


Figure 3. Roof assembles

2.2 Normative Standard Practices to Install Windows(ASTM E2112−07 2007)

2.2.1 American Society for Testing and Materials

Method A

Weather-Resistive Barrier (WRB) Applied after the Window Installation—Flashing Applied Over the Face of the Mounting Flange

Step 1. Horizontal sill flashing application

- Apply the horizontal sill flashing.
- Fasten the top edge of the sill flashing to the framing.
- Place fasteners along the edge of the rough opening.

Step 2. Sealant application to the back side of the mounting flange of the window and window installation

- Select sealant and apply it to the back side of the mounting flange of the window.
- Set the window and fasten the window perimeter.

Step 3. Sealant application to the exposed mounting flange at the side jambs of the window

- Apply sealant to the exposed mounting flange at the side jambs of the installed window.
- Continue sealant application at the jambs above the rough opening at the head of the window.
- For windows with mechanically joined mounting flanges: apply sealant to the full length of the joints or where the flanges meet.

Step 4. Jamb flashings installation

- Install the jamb flashings by pressing the flashing into the sealant applied to the exterior face of the mounting flanges.
- Use staples or fasteners to attach the flashing.
- Extend the bottom and top edge of the jamb flashing beyond the rough opening sill and head, respectively.

Step 5. Sealant application to the exposed mounting flange at the head of the window

- Apply sealant to the exposed mounting flange at the head of the installed window.

Step 6. Head flashing installation

- Install the head flashing by pressing the flashing into the sealant applied across the mounting flange.
- Extend the ends of the head flashing beyond the rough opening, over the top of the jamb flashing.
- Use staples or fasteners to attach the flashing into place along the top edge.

Step 7. WRB installation

- In water shedding fashion, install the WRB to the face of the building framing or sheathing.
- At the sill of the windows, tuck the WRB under the sill flashing and loose ends of the jamb flashing.

- Apply WRB in water shedding fashion over the jamb flashing and the head of the windows.
- Attach the WRB using staples or other fasteners.

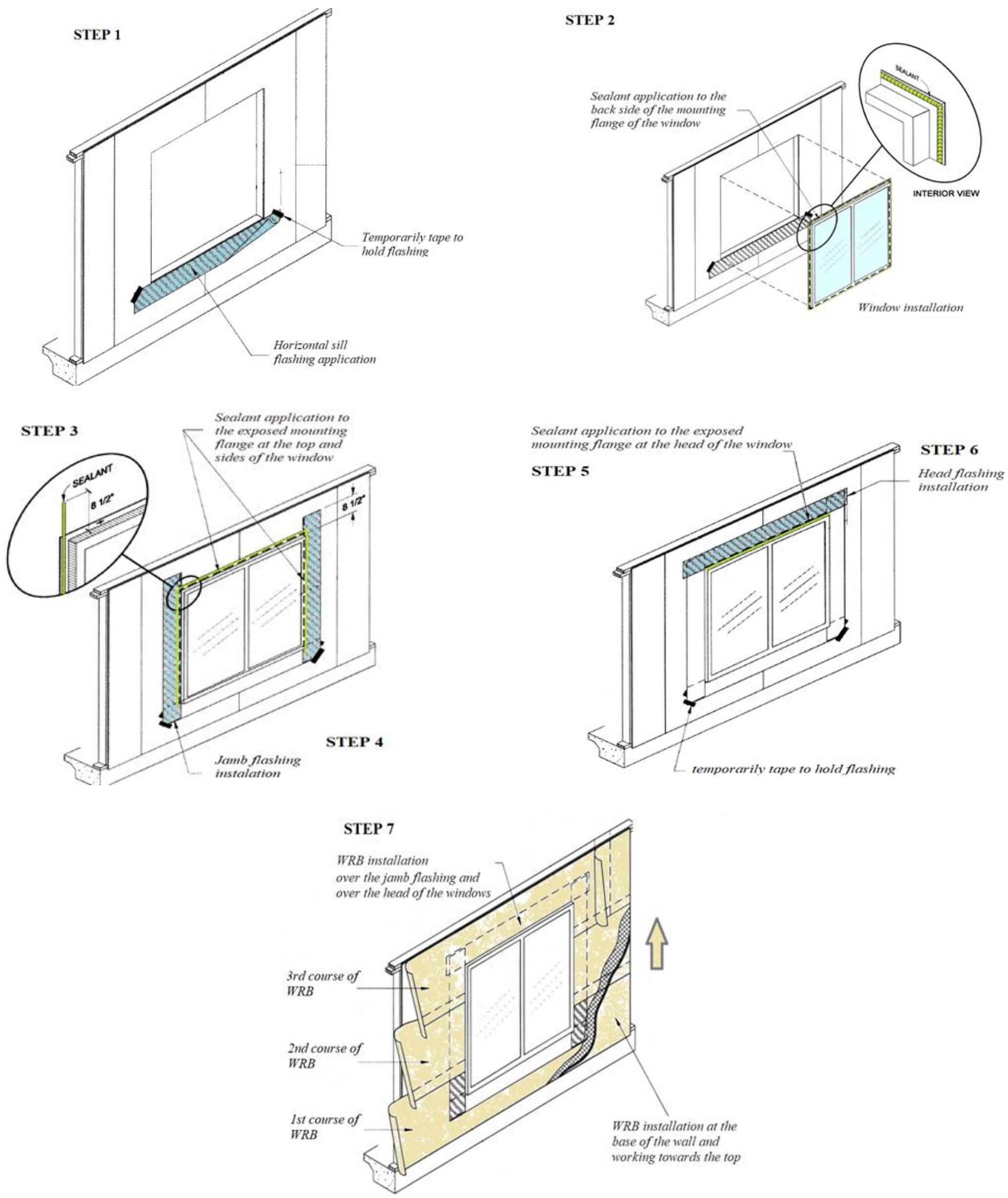


Figure 4. Method A (ASTM E2112−07 2007) installation procedure

Method A1

Weather-Resistive Barrier (WRB) Applied Prior to the Window Installation—Flashing Applied Over the Face of the Mounting Flange

Step 1. WRB installation and temporary sheathing tape

- Apply the WRB in water shedding fashion and installed it to the face of the building framing or sheathing flush with the rough opening of the window head, jambs, and sill.
- Cut the barrier on a diagonal.
- Gently raise the top edge of the barrier up and temporarily tape the top corners and center to the exterior weather resistant barrier surface above in order to allow for installation of the window and flashing later.

Step 2. Horizontal sill flashing application

- Apply the horizontal sill flashing and cut it long enough beyond the jamb flashing.
- Fasten the top edge of the sill flashing to the framing.
- Place fasteners along the edge of the rough opening.
-

Step 3. Sealant application to the back side of the mounting flange of the window and window installation

- Select sealant and apply it to the back side of the mounting flange of the window.
- Set the window and fasten the window perimeter.

Step 4. Sealant application to the exposed mounting flange at the side jambs of the window

- Apply sealant to the exposed mounting flange at the side jambs of the installed window.
- Continue sealant application at the jambs above the rough opening at the head of the window.
- For windows with mechanically joined mounting flanges: apply sealant to the full length of the joints or where the flanges meet.

Step 5. Jamb flashings installation

- Install the jamb flashings by pressing the flashing into the sealant applied to the exterior face of the mounting flanges.
- Use staples or fasteners to attach the flashing.
- Extend the bottom and top edge of the jamb flashing beyond the rough opening sill and head, respectively.
- Tuck the top of the jamb flashing under the flap of the WRB at the head.

Step 6. Sealant application to the exposed mounting flange at the head of the window

- Apply sealant to the exposed mounting flange at the head of the installed window.

Step 7. Head flashing installation

- Install the head flashing by pressing the flashing into the sealant applied across the mounting flange.
- Extend the ends of the head flashing beyond the rough opening, over the top of the jamb flashing.
- Use staples or fasteners to attach the flashing into place along the top edge.

Step 8. Application of a new sheathing tape

- Remove the taped, which holds the flap of the WRB at the head.
- Allow the flap to lay over the head flashing.
- Apply a new piece of sheathing tape over the entire diagonal cut made in the new WRB.
  Compress the tape against the WRB against and the head flashing.

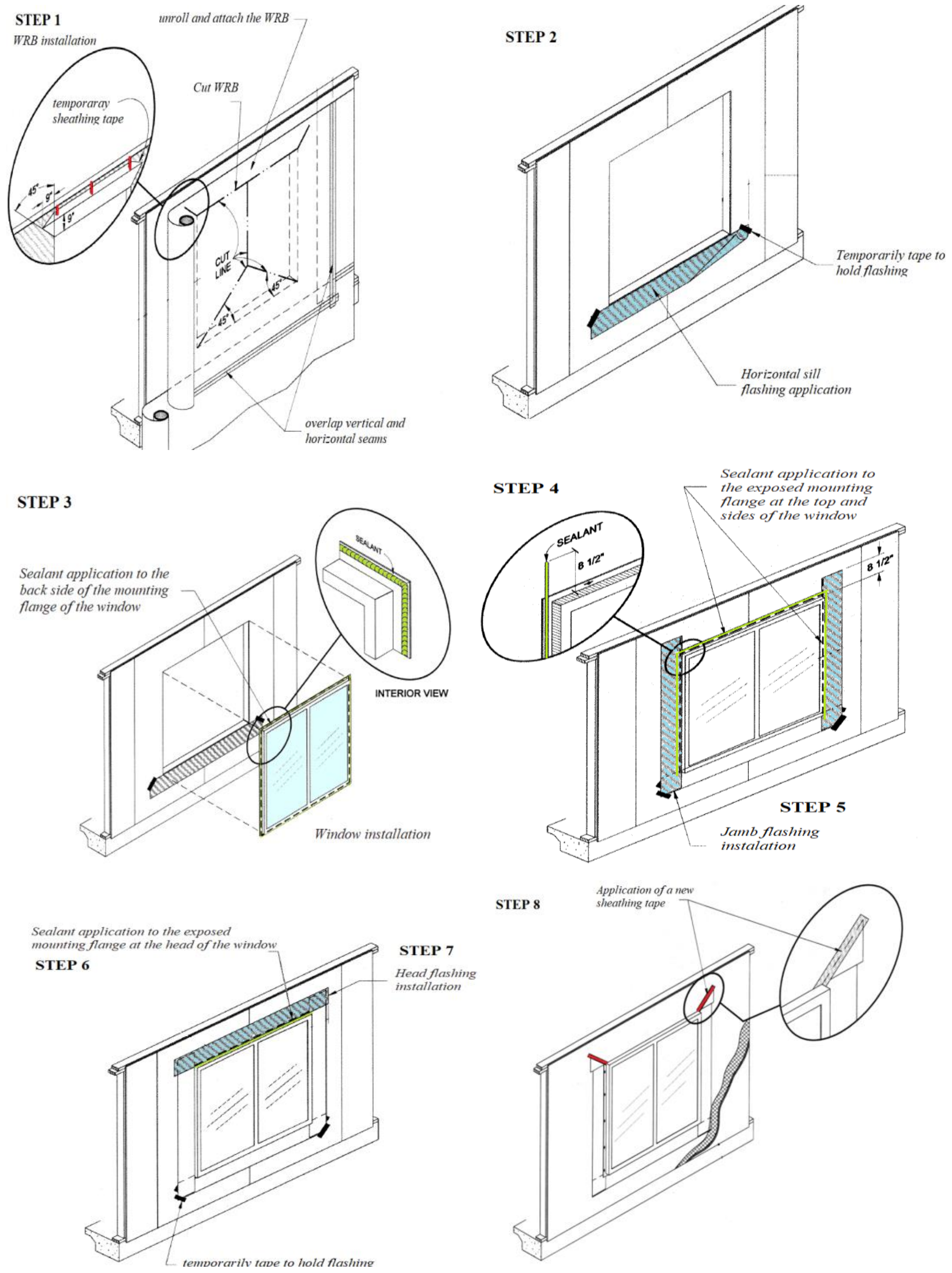


Figure 5. Method A1 (ASTM E2112−07 2007) installation procedure

Method B

Weather-Resistive Barrier (WRB) Applied After to the Window Installation—Flashing Applied Behind the Face of the Mounting Flange

Step 1. Horizontal sill flashing application

- Apply the horizontal sill flashing.
- Fasten the top edge of the sill flashing to the framing.
- Place fasteners along the edge of the rough opening.

Step 2. Jamb flashing application

- Apply the jamb flashing to the edge of the framing at each jamb.
- Place fasteners along the edge of the rough opening.
- Extend the jamb flashing beyond the rough opening dimension at the head and sill.
- The bottom end of the jamb flashing is to overlap the sill flashing.

Step 3. Sealant application of the back side of the window mounting flange

- Select sealant and apply it to the back side of the mounting flange of the window.
- Fasten the window perimeter.

Step 4. Window installation

- Install the window into the opening and fasten the window perimeter
- For windows with mechanically joined mounting flanges: apply sealant to the full length of the joints or where the flanges meet.

Step 5. Sealant application to the exposed mounting flange at the head of the window

- Apply sealant to the exposed mounting flange at the head of the installed window.

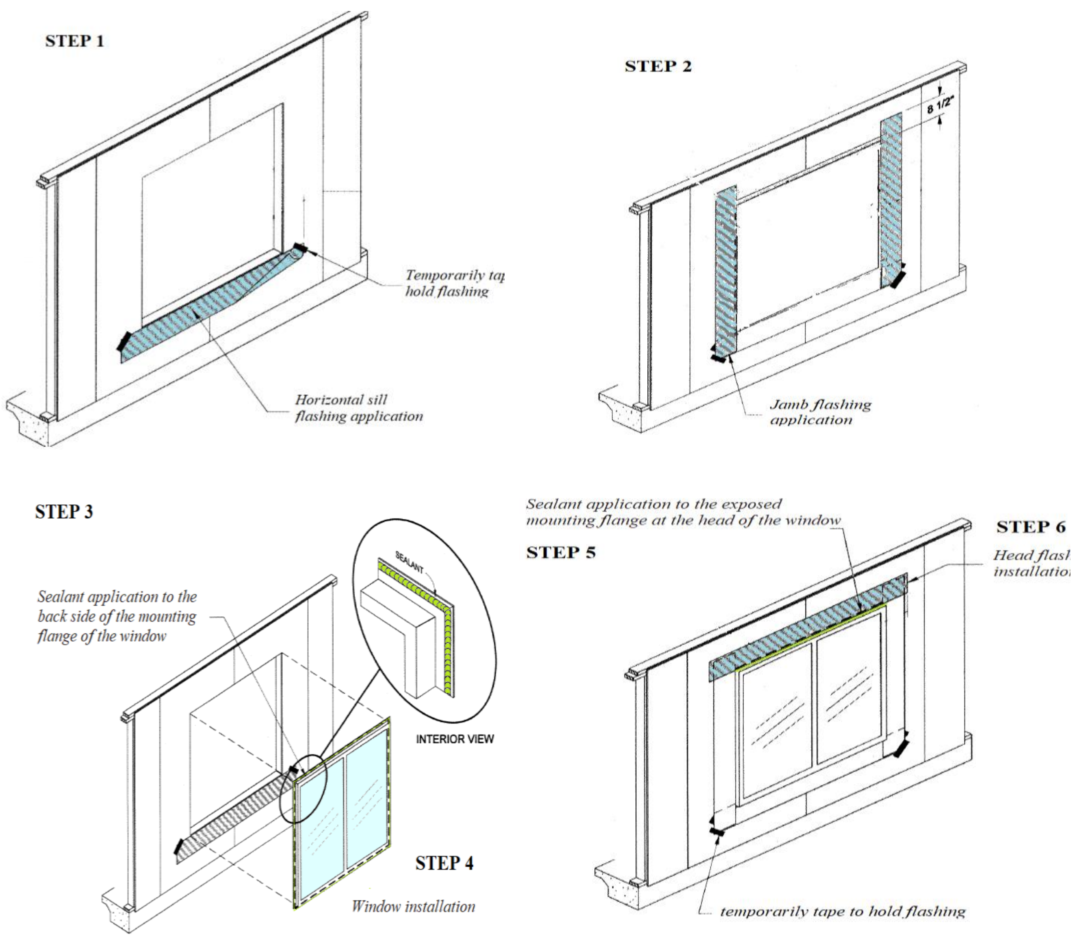
Step 6. Head flashing installation

- Install the head flashing by pressing the flashing into the sealant applied across the mounting flange.
- Extend the ends of the head flashing beyond the rough opening, over the top of the jamb flashing.

- Use staples or fasteners to attach the flashing into place along the top edge.

Step 7. WRB installation

- In water shedding fashion, install the WRB to the face of the building framing or sheathing.
- At the sill of the windows, tuck the WRB under the sill flashing and loose ends of the jamb flashing.
- Apply WRB in water shedding fashion over the jamb flashing and the head of the windows.
- Attach the WRB using staples or other fasteners.



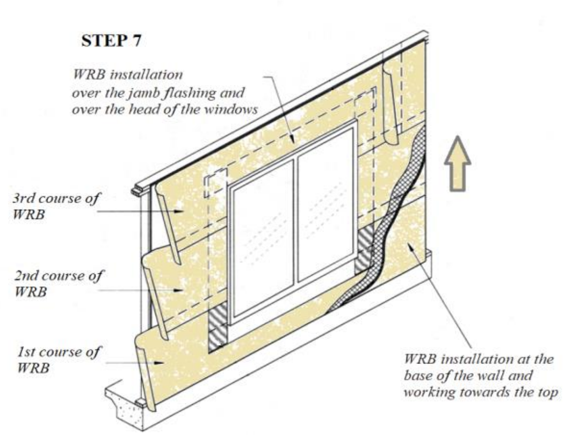


Figure 6. Method B (ASTM E2112−07 2007) installation procedure

Method B1

Weather Barrier Applied Prior to the Window Installation—flashing is applied behind the Mounting Flange

Step 1. WRB installation and temporary sheathing tape

- Apply the WRB in water shedding fashion and installed it to the face of the building framing or sheathing flush with the rough opening of the window head, jambs, and sill.
- Cut the barrier on a diagonal.
- Gently raise the top edge of the barrier up and temporarily tape the top corners and center to the exterior weather resistant barrier surface above in order to allow for installation of the window and flashing later.

Step 2. Horizontal sill flashing application

- Apply the horizontal sill flashing and cut it long enough beyond the jamb flashing.
- Fasten the top edge of the sill flashing to the framing.
- Place fasteners along the edge of the rough opening.

Step 3. Jamb flashing application

- Apply the jamb flashing to the edge of the framing at each jamb.
- Place fasteners along the edge of the rough opening.
- Extend the jamb flashing beyond the rough opening dimension at the head and sill.
- The bottom end of the jamb flashing is to overlap the sill flashing.

Step 4. Sealant application to the back side of the mounting flange of the window

- Select sealant and apply it to the back side of the mounting flange of the window.

Step 5. Window installation

- Install the window into the opening and fasten the window perimeter.
- For windows with mechanically joined mounting flanges: apply sealant to the full length of the joints or where the flanges meet.

Step 6. Sealant application to the exposed mounting flange at the head of the window and over the top edge of the jamb flashing.

- Apply sealant to the exposed mounting flange at the head of the installed window.

Step 7. Head flashing installation

- Install the head flashing by pressing the flashing into the sealant applied across the mounting flange.
- Extend the ends of the head flashing beyond the rough opening, over the top of the jamb flashing.
- Use staples or fasteners to attach the flashing into place along the top edge.
-

Step 8. Application of a new sheathing tape

- Remove the taped, which holds the flap of the WRB at the head.
- Allow the flap to lay over the head flashing.
- Apply a new piece of sheathing tape over the entire diagonal cut made in the new WRB.
- Compress the tape against the WRB against and the head flashing.

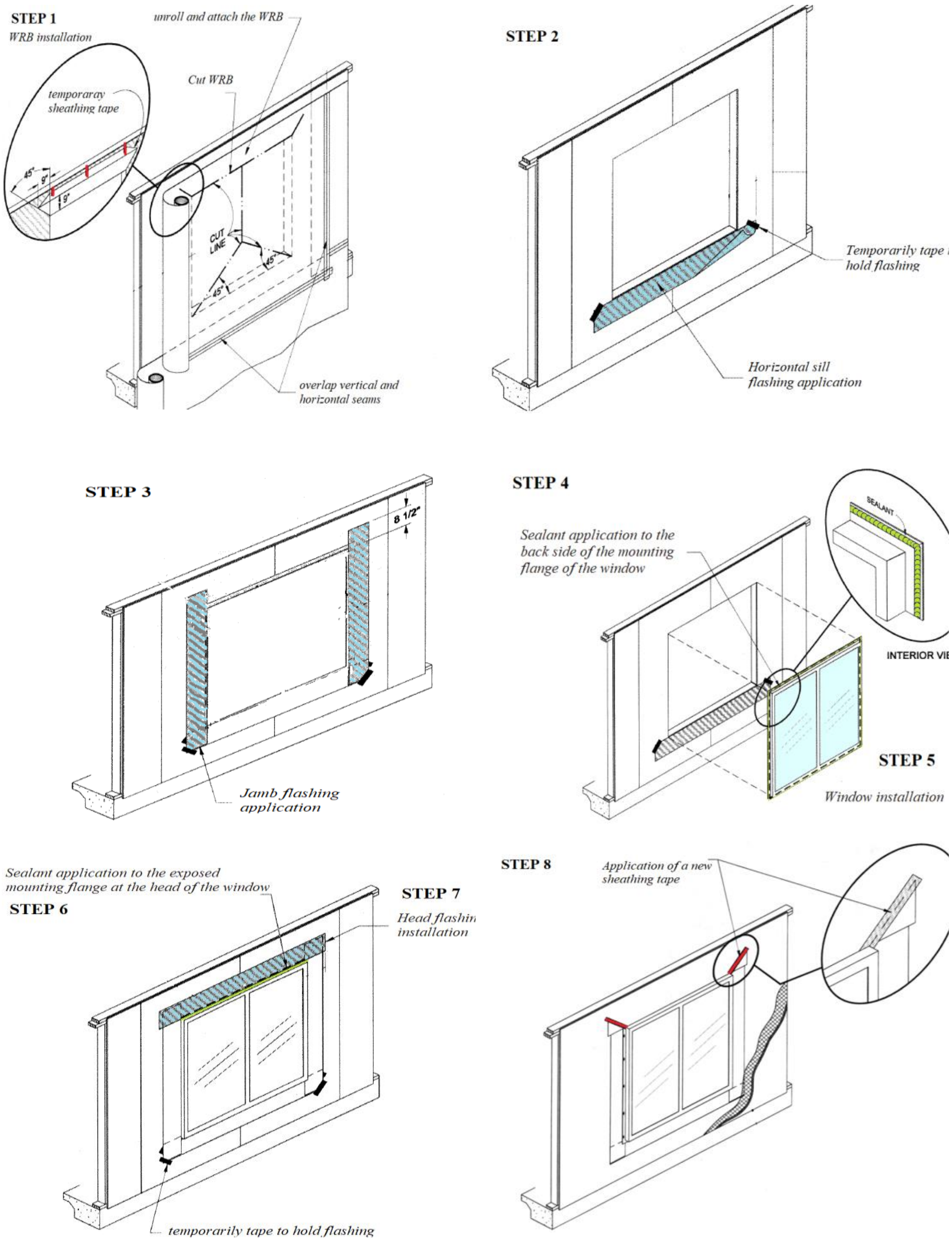


Figure 7. Method B1 (ASTM E2112−07 2007) installation procedure

Conclusions of ASTM E2112-07 methods

A comparison between the four methods presents in the Standard Practice for Installation of Exterior Windows, Doors and Skylights (ASTM E2112-07) was carry out and it is shown in Table 1.

Table 1.Comparison of Methods presented in ASTM E2112-07

Feature	Method A	Method A1	Method B	Method B1
WRB installation sequence	After the Window Installation	Prior to the Window Installation	After the Window Installation	Prior to the Window Installation
Flashing Location	Over the Face of the Mounting Flange	Over the Face of the Mounting Flange	Behind the Face of the Mounting Flange	Behind the Mounting Flange

2.2.2 Fenestration Manufacturers Association for Wood Systems (FMA/AAMA 100-12 2012)

Pre-installation

<u>Rough Opening</u>

No more than 6 mm (1/4 in) deviation from square, height, and width and 3 mm (1/8 in) deviation from plumb shall be allowed.

<u>Water-Resistive Barriers (WRB)</u>

The WRB shall be installed prior to the window installation. Under extreme wind/water exposure, it is recommended that creating a water seal between the WRB and sheathing at the window rough opening.

<u>Two Layer WRB Systems</u>

A two-layer WRB or building paper (BP) system shall be used in accordance with state and local codes for extreme weather. The window shall be flashed/integrated with inner layer WRB.

WRB installation

WRB Method A:

- Box cut WRB
- Seal with self-adhered flashing
- Apply sealant at jamb/head interface

WRB Method B:

- Box cut WRB
- Cut each jamb corner.
- Fold back jamb
- Apply sealant along jamb
- Integrate WRB to self-adhering flashing

WRB Method C:

- I-Cut of WRB
- Apply sealant onto sheathing
- Wrap into cavity
- Attach the WRB.

WRB Method A WRB Method B WRB Method C

Figure 8. WRB installation method (FMA/AAMA 100-12 2012)

Sill and flashing installation

- Rough opening wood sill area is clean.
- Cut jamb a proper length to form end dams.
- Cover the sill.

Window installation

- Inspect and clean windows.
- Run a proper diameter bead of sealant on the back surface.
- Apply a discontinuous bead of sealant on the interior surface.
- For rigid or semi-rigid sill pan, apply a continuous bead of sealant.
- Set the window in the opening.
- Hold the window into position and apply shims.

Jamb and head flashing installation

<u>Mechanically attached flashing installation</u>

- Apply a continuous bead of sealant.
- Apply jamb flashing in line.
- Apply mechanically attached flashing to head.

<u>Self -adhering flashing installation</u>

- Apply flashing of the window.
- Cut the jamb flashing and adhere the top end of the flashing.
- Use firm pressure to adhere the self-adhering flashing.

Mechanically attached flashing   Self-adhering flashing

Figure 9. Flashing installation method (FMA/AAMA 100-12 2012)

Post-installation procedures

- Verify that the window frame and the sash are installed plumb, level square and true, within the specified tolerances.
- Check free movement of operable Elements.
- Verify smooth operation of locks, cranks, latches and hinges.
- Verify assembly of all accessories.
- Verify blockages or obstructions in drainage holes.

2.2.3 Fenestration Manufacturers Association for Masonry Systems (FMA/AAMA 200-12 2012)

Pre-Installation

- Inspect defect of masonry rough opening and remedy any discrepancy.
- Check that the size satisfied window manufacturer's instruction.
- Verify that sill was installed correctly.
- Treat the masonry opening with flashing to against water intrusion.

Installation

<u>Limiting buck edge gaps</u>

- No edge gaps exceeding 3mm (1/8 in) between the buck and the masonry sill member.

<u>Smoothing buck surfaces</u>

Apply liquid flashing or sealant to all buck surfaces.

<u>Coating buck face</u>

Exterior face of buck and the return surface of the jambs shall be coated with a liquid applied flashing.

<u>Sealing up window edges and corners</u>

- Run a continuous 9 mm (3/8 in) nominal dimeter bead of sealant.
- Apply discontinuous bead of sealant on the interior surface of the flange at the sill.
- Apply continuous bead of sealant on all four sides of the interior surface of the flange or exterior edge of the buck.

Modification

Make sealant surface flat, cut excess shim material.

Smoothing buck surfaces | Coating buck face | Modification

Figure 10. Masonry Systems installation (FMA/AAMA 100-12 2012)

Post-installation

- Verify window frame and sash are installed plumb, level, square and true within the manufacturer's specified tolerances.
- Verify operable sashes can move freely within their frames and that weather-stripping or compressible seals make full contact with mating surface.
- Inspect blockages in drainage holes.
- Check location conflicts for windows weep holes.
- Verify continuity of sealant joints.

Window frame | Weep hole

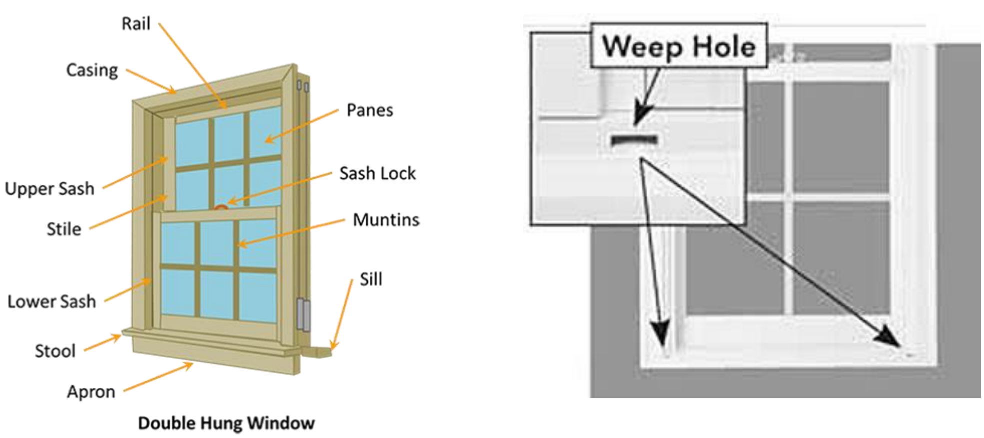


Figure 11. Masonry Systems post-installation (FMA/AAMA 100-12 2012)

Comparing FMA/AAMA standards vs ASTM E2112

A comparison between ASTM E2112-07 and FMA/AAMA standards was carry out and is shown in Table 2. Table 2 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.

Table 2. FMA/AAMA Standards vs ASTM E2112

FEATURE	FMA/AAMA 100/200	ASTM E2112-07
• Window rough opening must be drainable through sill pan flashing under the fenestration unit.	✓	Sill pan use is recommended.
• Install a perimeter air seal between window frame and rough opening at or near interior edge of the window frame.	✓	×
• Specific installation steps for self-adhering as well as illustrations of installation	✓	×

2.3 Standard Tests and Inspection Method for Water Penetration

In this section, 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.

2.3.1 ASTM Test

Modified AAMA 501.1

- Dynamic Wind Generation to Simulate Wind-Driven Rain in Windows, Curtain Walls, Architectural Metal Walls, Masonry, EIFS, and Concrete Facades.
- This approach applies a regulated wind source and calibrated spray rack to simulate a given wind/rain event.

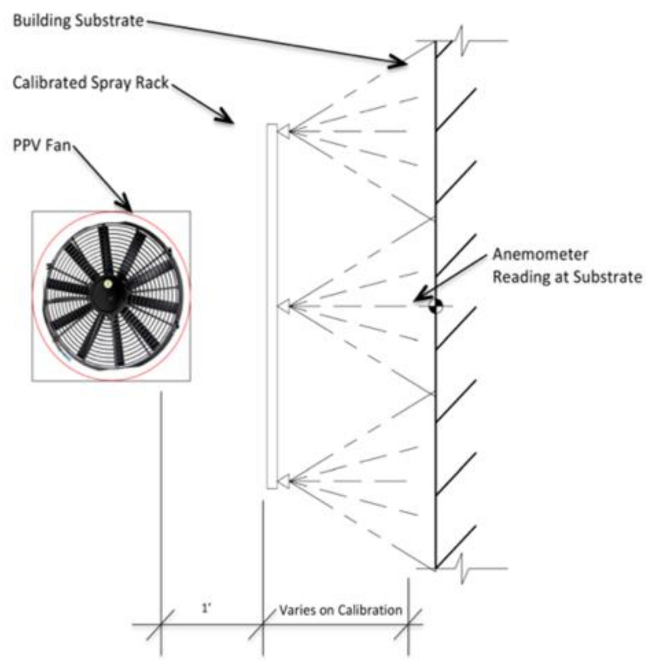


Figure 12. Testing Configuration (Williams and Kistler 2014)

D226/D226M—17

- This specification covers asphalt-saturated organic felts, with or without perforations.
- Determine the openness of the perforations in saturated felts:

$$V= (P \times A \times H)/S$$

V= vented area%

P= average number of perforations specimen

A= average area at one hole, mm^2 (in^2)

H= average open holes, %, and

S= average specimen area, mm^2 (in^2)

ASTM E331 - 00(2016)

- Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure.

- Difference
  ASTM E547 - 00(2016) - Cyclic Static Air Pressure.
  ASTM E2268 - 04(2016) - Rapid Pulsed Air Pressure Difference.

- The ASTM E 331 testing is performed by applying water to the exterior of the test specimen while lowering the pressure inside by means of an air chamber built on the inside or opposite side of the test specimen.

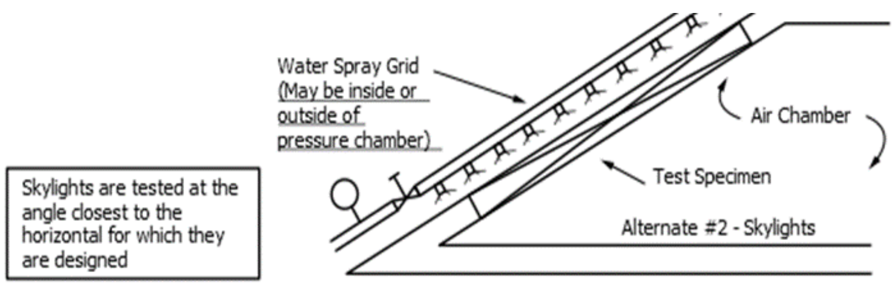


Figure 13. ASTM E331 − 00 2016 Procedure

ASTM STP 1314

Hose tests is much simpler than other test. In order to perform a hose test, one only needs a diameter of 19 mm (3/4 in.) garden hose, a special nozzle, a valve to control the water flow, a water pressure gauge, and an observer stationed on the interior side of the test area to look for leaks.

Figure 14. Hose test (J.KUDDER and ERDLY 1998)

2.3.2 Industry Inspection Method

Probe Method

Probe method for moisture involves using a penetrating probe meter to test for moisture within the walls, floors or ceilings according to the electrical resistance. To do this, small holes-about 3/16 of an inch-must be drilled into the building material. The holes are small and undetectable.

Figure 15. Probe method (Laurenzi 2018)

Infrared Thermography

- Thermography is a non-invasive technology that uses infrared cameras to "see" into the walls of the structure for damage-free moisture detection.
- It will photograph the structure using an infrared camera, which picks up what we recognize as heat.

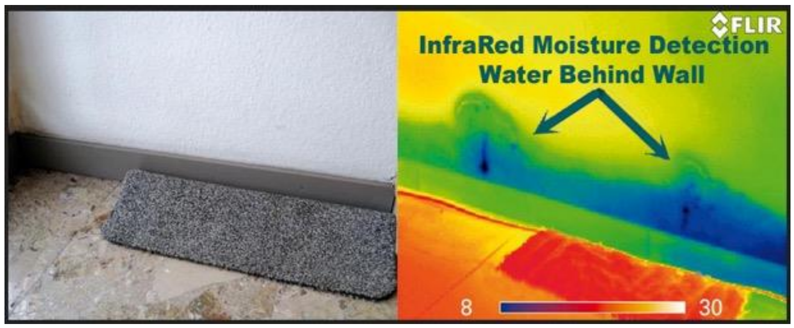


Figure 16. Infrared Thermography (Laurenzi 2018)

2.4 Previous Research

In this section 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.

2.4.1 Extreme Exposure Fenestration Installations—The Florida Challenge (Katsaros and Carll 2009)

(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 1st floor surface barrier CMU walls & 2nd 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.

2.4.2 *Water penetration Resistance of Residential Window Installation options for Hurricane-Prone Areas (Katsaros and Carll 2009; Salzano et al. 2010)*

(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.

2.4.3 *Water Penetration Resistance of Residential Window and Wall Systems Subjected to Steady and Unsteady Wind Loading(Lopez et al. 2011)*

(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.

2.4.4 Repair Methods for Common Water Leaks at Operable Windows and Sliding Glass Doors(Beers and Smith 1998)

(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.

3 Recommendations and Conclusions from Literature Review

3.1 Recommendations

- The Florida Building Code just provide some basic requirements for fenestration, not including installation procedures to prevent water intrusion.
- ASTM E 2112-07 windows installation method only apply to wood systems, on the other hand FMA/AAMA200-12 standard practice can be used for both wood systems and masonry systems and this standard is more water resistant. Therefore, in hurricane prone areas is recommended to use FMA/AAMA200-12 standard practice to install your windows due to this method can be applied for extreme wind driven rain condition.
- FMA/AAMA 100 and 200 test proved sill pan flashing was found to be effective to reduce water penetration. Therefore it is recommended to use sill pan flashing (**Error! Reference source not found.**) for windows installation.

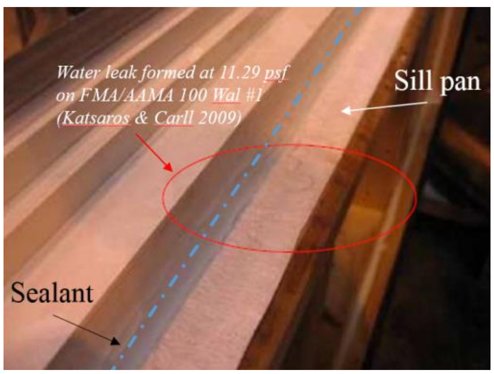


Figure 17. Sill pan

- According to Salzano et al. (2010) while water barrier method (Figure 18) performed well on the CMU walls, drainage method installation did not performed well.

Figure 18. Water barrier method

- Based on Salzano et al. (2010) study, the use of low expansion foam seals to prevent leakage present a good resistant to water as long as the excess of foam is not trim (Figure 19).

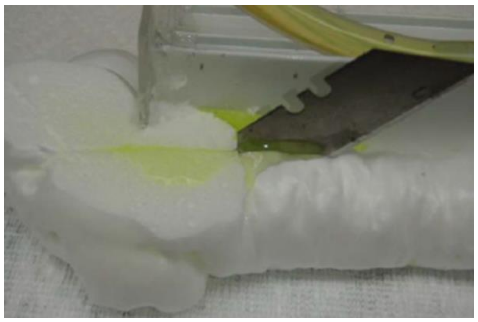


Figure 19. Trim foam seals

- According to Lopez et al. (2010), sill dam height (**Error! Reference source not found.**) 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.

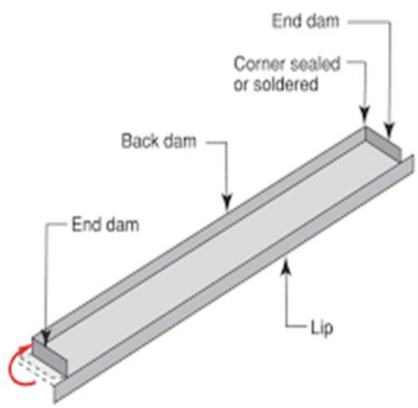


Figure 20. Sill dam

3.2 Conclusions

- ASTM E2112 four types of installation method have the same features, but sequence of window and flashing installation is different.
- The FMA/AAMA 100-12 provides more detailed installation method than ASTM E2112.
- Leaks were always observed in areas where adhesion between the windows frame.
- Low expansion foam seals prevent leakage for pressures up to 4788 Pa (100 psf), but only if the excess of foam is not trimmed. If the excessive foam is trimmed, it does not present any water resistance.
- Water leaks occurs through the window/wall interface.
- 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.
- Water penetrates or fills the air void underneath the sash and rises in proportion to the exterior pressure.
- Substantial leakage (1 litre/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.

4 Water-Damaged Buildings Database Analysis

Daniel L. Lavrich, P.E. collected documentation on the water leakage due to wind-driven rain, called Database of Water-Damaged Buildings that occurred to several structures in Florida during Hurricane Irma, including the building constructed date, number of units per building, number of stories, location (by zip codes only), and orientation of the front façade of the buildings. Limited information could be shared with the Research team because of Non-disclosure agreements in place. This information is presented in the first six columns in the Table 3. The locations of the water-damaged buildings due to Hurricane Irma are shown in Figure 21. Most of the affected buildings are located south east of the state of Florida.

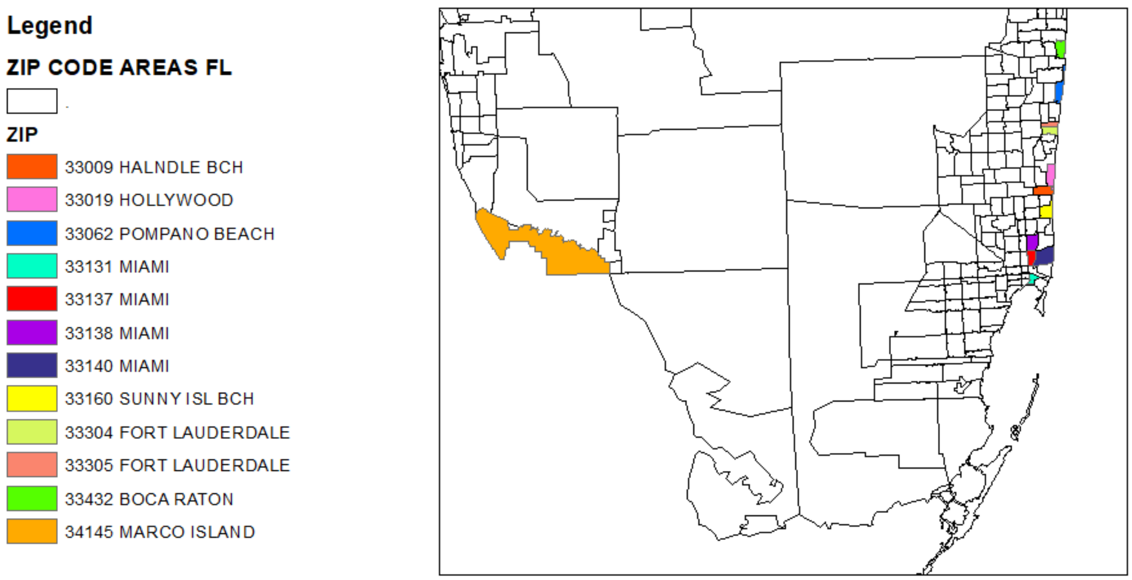


Figure 21. Location of the water-damaged buildings – Hurricane Irma

Table 3. Database of Water-Damaged Buildings

Building	Constructed Date	Units	Stories	Zip Code	Orientation	Wind Driven Rain at 10 m (in)	Wind Driven Rain (in)	Wind (mph)	Wind Direction	Gross claim	Water Damage claims	(Water Damage Claims / Gross claim) %	Water Damage Claims per apt unit
A	1999	195	32	33305	N-S	3.2	8	57	SSE	$ 5,000,000	$ 2,500,000	50%	$ 12,821
B	1973	269	19	33019	E-W	4.1	8	57	SSE	$ 7,200,000	$ 3,300,000	46%	$ 12,268
C	**2008**	**193**	**17**	**33062**	**N-S**	**4.5**	**8.8**	**60**	**SE**	**$ 7,400,000**	**$ 2,300,000**	**31%**	**$ 11,917**
D	1981	430	19	34145	E-W	24.7	33.5	155	E	$ -	$ -	-	$ -
E	1982	200	26	33140	N-S	4.8	9.8	63	SE	$ 5,700,000	$ 1,300,000	23%	$ 6,500
F	1970	201	16	33062	N-S	4.5	8.5	60	SE	$ 12,500,000	$ 1,000,000	8%	$ 4,975
G	1974	378	22	33432	E-W	3.9	8.3	58	SE	$ -	$ -	-	$ -
H	1977	145	22	33009	E-W	3.2	7.1	54	SSE	$ 18,500,000	$ 1,500,000	8%	$ 10,345
I	1966	336	6	33160	E-W	3.7	6.6	52	ENE	$ -	$ -	-	$ -
J	1971	110	11	33304	N-S	4.5	8	57	SSE	$ -	$ -	-	$ -
K	**2005**	**135**	**28**	**33019**	**E-W**	**4.1**	**8.8**	**60**	**SSE**	**$ 5,400,000**	**$ 1,000,000**	**19%**	**$ 7,407**
L	1968	51	7	33019	E-W	4.1	5.5	48	SSE	$ -	$ -	-	$ -
M	1980	36	10	33137	E-W	3.7	8.8	60	SSE	$ -	$ -	-	$ -
N	**2006**	**384**	**42**	**33131**	**N-S**	**4.1**	**10.1**	**64**	**ESE**	**$ -**	**$ -**	**-**	**$ -**
O	1982	246	27	33138	E-W	3.4	8	57	SSE	$ -	$ -	-	$ -
									TOTAL	**$ 61,700,000**	**$ 12,900,000**	Average	**$ 9,462**

4.1 Peak Wind Speed Estimation and estimate expected Wind Driven Rain due to the Hurricane Irma

With the information provided by Daniel L. Lavrich, it was possible to estimate the peak Hurricane Irma wind speed for each one of the buildings in addition to the expected wind driven rain (WDR), at 10 m and at the maximum expected total height of the building with the hazard model of the Florida Public Hurricane Loss Model. The rain intensity is assumed to increase with height with the same function than the wind speeds.

The Database of Water-Damaged buildings as well as the expected wind driven rain (WDR) at 10 m and at the maximum expected total height of the building are shown in the Table 3 in columns 7 and 8. In some cases, the WDR expected at maximum height can be more than twice that the WDR expected at 10 m. More details about the methodology followed to obtain those values were described before.

In Figure 22 the maximum expected wind speed per building at 10 m and at maximum height (assuming 8 ft of height per story) are shown per each one of the buildings considering the actual terrain. For buildings located in the same zip code, the maximum wind speed at 10 m is the same, however, the maximum speed at the maximum height is different due to the number of stories varies per building.

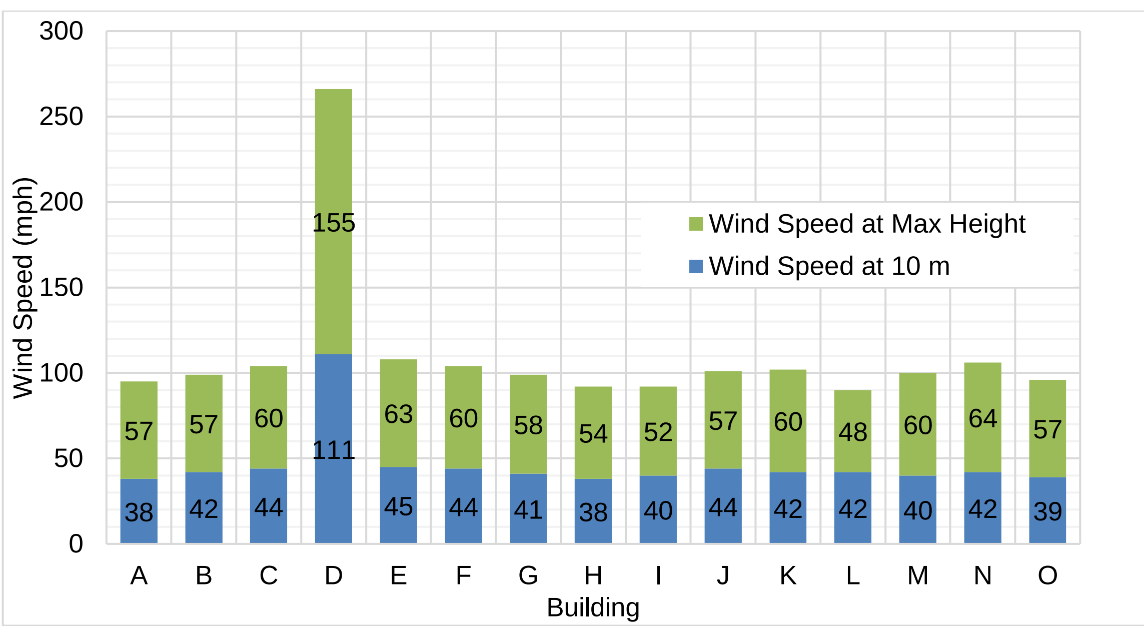


Figure 22. Maximum expected wind speed per building at 10 m and at maximum height

4.2 Direction of Peak Wind during Hurricane Irma

Due to the limited information regarding to the location of the buildings, only the zip code was used to approach the wind direction of the Hurricane Irma. Each building was located in the centroid of the respectively zip code, then the wind direction was selected from the table of "List of Maximum Sustained Winds and Gust in South Florida" (https://www.weather.gov/mfl/hurricaneirma) from the National Weather Service. It is important to mention that this is only a rough approach due to the lack of information. In Figure 23 shows the directions of the maximum sustained winds per each zip code.

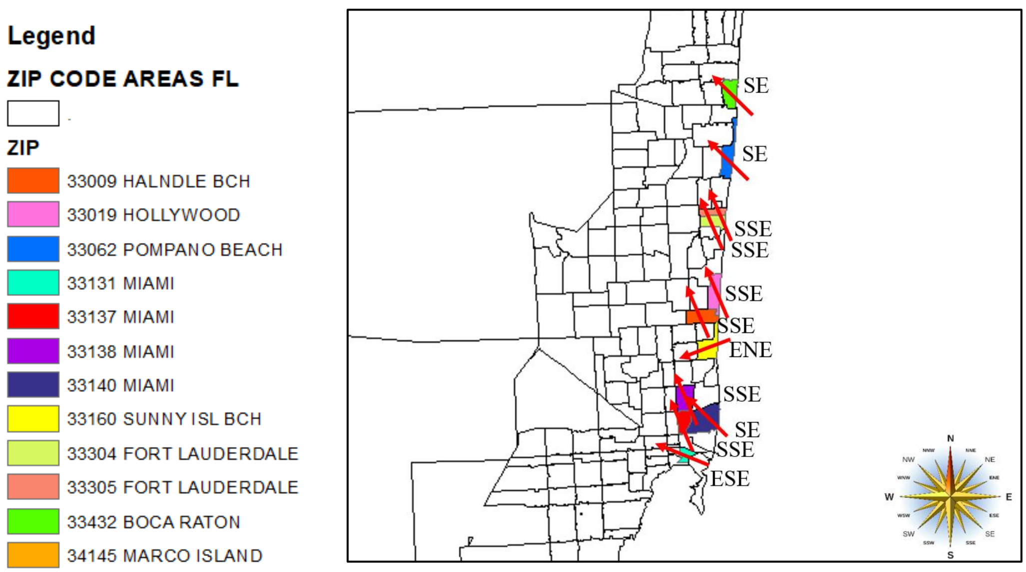


Figure 23. Wind direction estimation building location

4.3 State of Florida's Design Wind Speed vs. Irma Wind Speeds

The Figure 24 compare the Florida's Design wind speeds (category II, 3 sec. gust) in black, with the maximum wind speeds caused by hurricane Irma in 2017 in red. It is important to notice that registered wind speeds are lower than those provided by the current code. In general, wind speeds registered are lower than those provided by the code.

Figure 24. State of Florida's Design Wind Speed vs. Irma winds Category II (3sec.gust)

4.4 Hurricane Irma Claims

In addition to the analysis performed regarding to the expected wind speeds and the wind driven rain, for some buildings information exists about the gross claim from Hurricane Irma and the amount attributed to water damage. This information is also presented in Table 3 with the water damage share of the gross claim.

The maximum water damage share of the gross claim is 50% that corresponds to building A. Basically, the gross claim for building A was for $5 M and the water damage portion was $2.5 M, half of the total amount correspond to water damage. The total amount of the gross claim and the water damage portion for 7 of 15 water-damaged buildings are $61.7 M and $12.9 M, respectively, those values are shown and highlighted in green. In general, this information shows that water intrusion is a problem that causes large amounts of economic losses.

Finally, in the last column an analysis of the water damage losses per apartment unit for each building is presented. The economic losses amount to $ 9,462 on average per apartment unit.

4.5 Other Information on Water Leakage in High Rise Buildings

Dan Lavrich provided a link to a video series prepared by GCI Consultants, LLC via email on 7 June 2019. The information was conveyed from Mr. Michael L. Goolsby, RER Division Chief 2 of Miami-Dade County Department of Regulatory and Economic

Resources. GCI Consultants, LLC prepared the videos posted on several topics related to their business of Building Envelope Consulting, Hurricane Recovery Services and Construction Litigation Consulting. The videos discuss issues related to water intrusion through building envelope systems and so is pertinent to this project.

In one of the videos titled "Paul Beers – Explanation of water leakage during Hurricane Irma – Part 2," Paul Beers, GCI's CEO and Co-Founder, stated that following Hurricane Irma, he inspected over 50 buildings and that his company looked at over 100 buildings in Miami, and West Palm Beach. In addition, he stated that in west coast areas (i.e. Naples, Marco Island), GCI found structural failures such as blown out windows and significant structural wind damage. However, on the east coast GCI said the big story is the prevalence of water leakage – "thousands of buildings may have leaked."

CGI mentions sliding glass doors and windows showing signs of leakage. One of their findings determined after speaking with building managers and residents was that windows that did not leak before Hurricane Irma now are leaking during "normal" rain events. Beers' hypothesizes that discrete damage, such as cracks in the stucco, sealant failures, compressed weather seals etc. and other damage in the building envelope may be contributing to this increase in leakage observed.

In order to find water leakage reasons, such as where is leakage from GCI company researcher conducted a water infiltration test to recreate a condition (replicating the same wind speeds and rainfall intensities effect) as in Hurricane Irma. In the video introducing water leakage during Hurricane Irma, GCI found the biggest difference between Hurricane Irma from other storms is extent of the water leakage problem and that after Hurricane Irma, when small rain storms occur, windows continue to leak. GCI concluded three reasons for water leakage problems.

- Pre-existing defects in the fenestration such as excessive deflection of window framing.
- The intensity of wind and rainfall during Hurricane Irma exceeded the design rating of windows.
- Windows and doors suffer concealed damage during Irma, such as broken internal seal, broken water-resistant barrier that allow increased water leakage to occur.

The GCI videos are archived here: https://www.gciconsultants.com/videos.

5 Florida Public Hurricane Loss Model (FPHLM)

5.1 Introduction

- Florida Office of Insurance Regulation funded and commissioned the catastrophe model FPHLM to assist insurance rate making.
- Florida Commission on Hurricane Loss Projection Methodology certified the model continuously since 2006.
- Version 7.0 was certified in 2019.
- FPHLM is confirmed to be valuable as a forecast of insurance losses and the evaluation of mitigation strategies for residential homes.

5.2 Components of FPHLM

- The catastrophe model performs three operations: identify hazard and exposure; measure the severity of combined effects of hazard and exposure; evaluate the frequency with which these effects may occur.
- The structure of the model has three components: hazards, vulnerability, and actuarial losses.
- The FPHLM is divided into three independent programs based on the characteristics of the exposure:
    - Personal residential (PR) single family homes (1 or 2 story site built or manufactured homes);
    - Low-rise commercial residential buildings (LRB) (1 to 3 story low-rise, predominantly apartment buildings);
    - Mid/high-rise commercial residential buildings (MHR) (4 stories and higher, predominantly condominium buildings).

5.3 Mid/high-rise commercial residential buildings (MHR)

5.3.1 Description of Exposure

- MHR buildings are engineered buildings. Damage via water ingress through opening defects and breaches rather than structural failures occur during a windstorm.
- The vulnerability of MHR is modeled by a modular approach which separates individual buildings into typical single units.

- The buildings are classified as open or closed buildings to estimate wind vulnerability.

Closed building

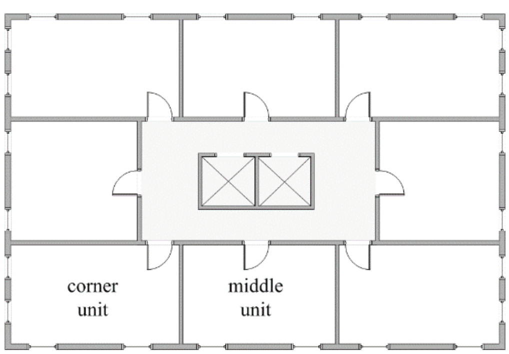
Open building

Figure 25. Closed and Open MHR buildings

- According to their location, apartments are divided into two types: “middle” and “corner”.

Closed building

Open building



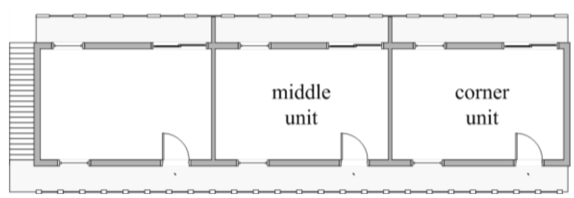


Figure 26. Middle and Corner units in Closed and Open buildings

- Typical opening types of MHR are “windows”, “entry door”, and “sliding door”.

Table 4. Typical MHR apartment unit models

Opening type	Unit type	Quantity*	Dimensions [m]	Total openings area [m^2]
Windows	Corner/Closed	6 (7)	1.5 × 1.2	11 (13)
	Corner/Open	7 (8)	1.5 × 1.2	13 (14)
	Middle/Closed	3 (4)	1.5 × 1.2	5 (7)
	Middle/Open	4 (5)	1.5 × 1.2	7 (9)
Entry door	All	1	0.9 × 2	1.8
Sliding door	All	1 (0)	1.5 × 2	3 (0)

*values in parentheses indicate quantity when no sliding door is present

5.3.2 Hazard Model

- A probabilistic hurricane rain model assesses accumulated wind-driven rain as a function of maximum wind speed.
- *WDR_1* is the wind-driven rain accumulated before the maximum wind speed occurs. *WDR_2* is the remaining wind-driven rain accumulated between the moment that maximum wind speed occurs to the end of the storm.

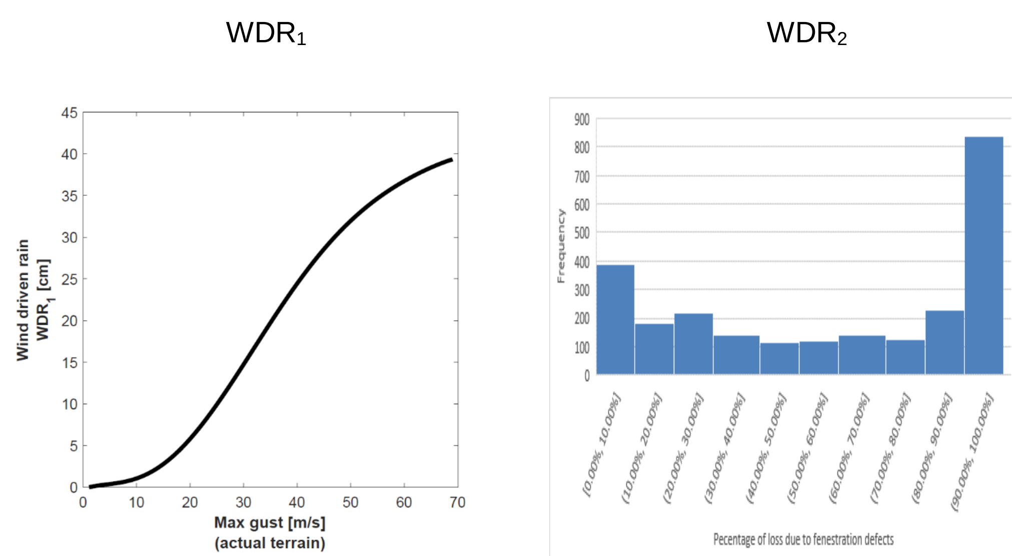


Figure 27. Mean accumulated impinging rain

5.3.3 Vulnerability Model

- The vulnerability model has three tasks: appraisal of exterior damage; estimation of interior damage by water ingress; estimation of building and contents vulnerabilities based on exterior and interior damage.

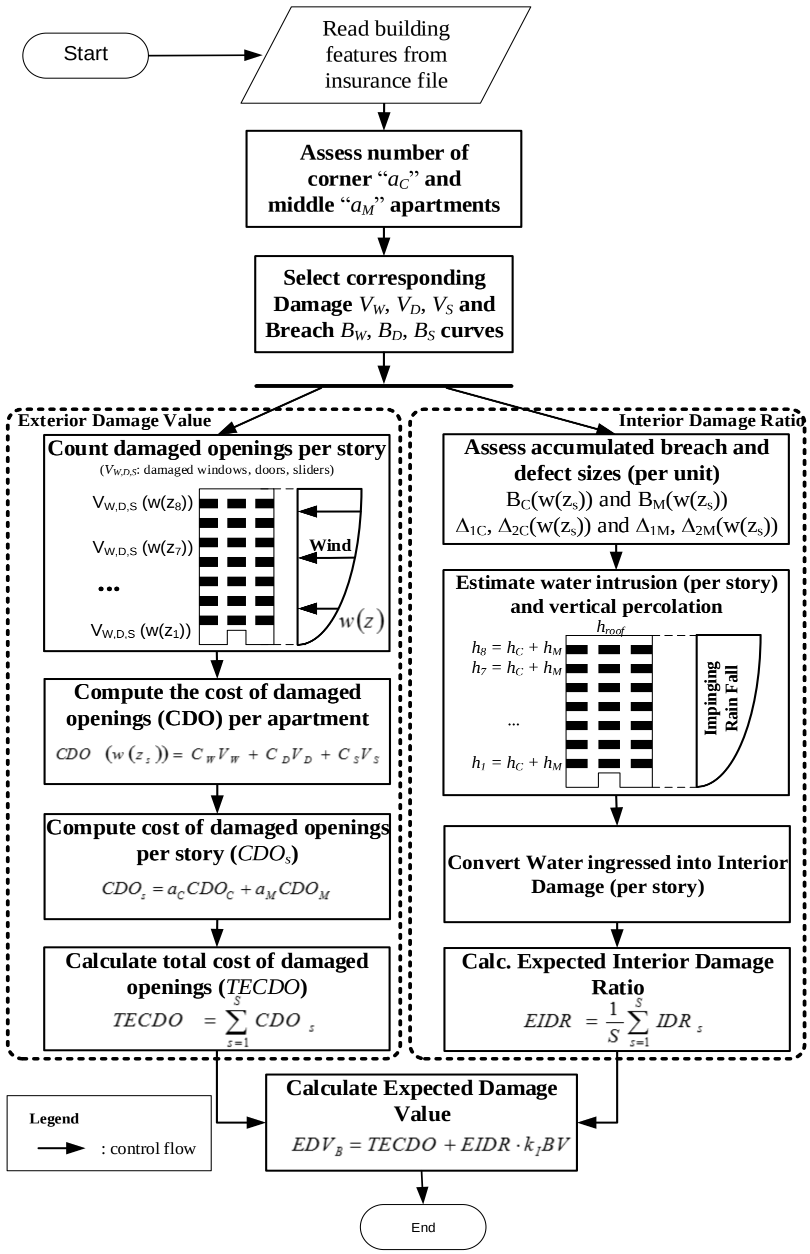


Figure 28. Hurricane vulnerability assessment of MHR

5.4 Outline for FPHLM with Workgroup

The FPHLM can estimate the hurricane vulnerability of mid/high rise buildings. Its interior damage model, based on a mechanistic model of rain intrusion, includes:

- Deficiencies as a non-negligible damage source at low wind speeds;
- Water penetration through all envelope components;
- Water percolation from story to story; and,
- Conversion of water accumulation into interior damage.

Hurricane Irma damage data collected can be used to calibrate the model. Once calibrated, the model can be used to estimate the benefits/cost ratios of possible mitigation measures.

5.5 Estimation of Impact of Defects by FPHLM

5.5.1 Description of Exposure

The FPHLM MHR v7.0 model evaluated the impacts of the fenestration defects through four independent portfolio analyses, as follow:

- Scenario analysis for hurricane Irma;
- Stochastic analysis;
- Modified scenario analysis for hurricane Irma;
- Modified stochastic analysis.

Where “modified” means the MHR model without water penetration from defects: defect areas for windows, doors and sliders were assigned 0 sf each.

The portfolio included 3,492 commercial residential policies with a known number of stories of 4 or higher, distributed throughout Florida. The FPHLM team built the portfolio from all the datasets it received for the 2018 Catastrophe Street Test (CST). This is the best source of information available because all insurance companies report their entire portfolios to the Office of Insurance Regulation (OIR) for the stress test. The frequency distribution of the number of stories and the frequency distribution of the building per county are shown below.

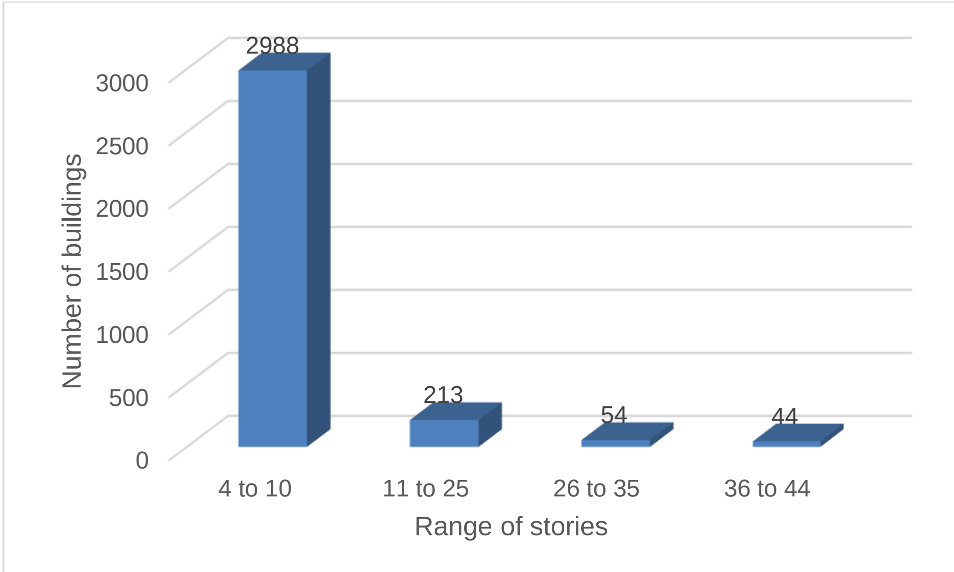


Figure 29. Frequency distribution of the number of stories

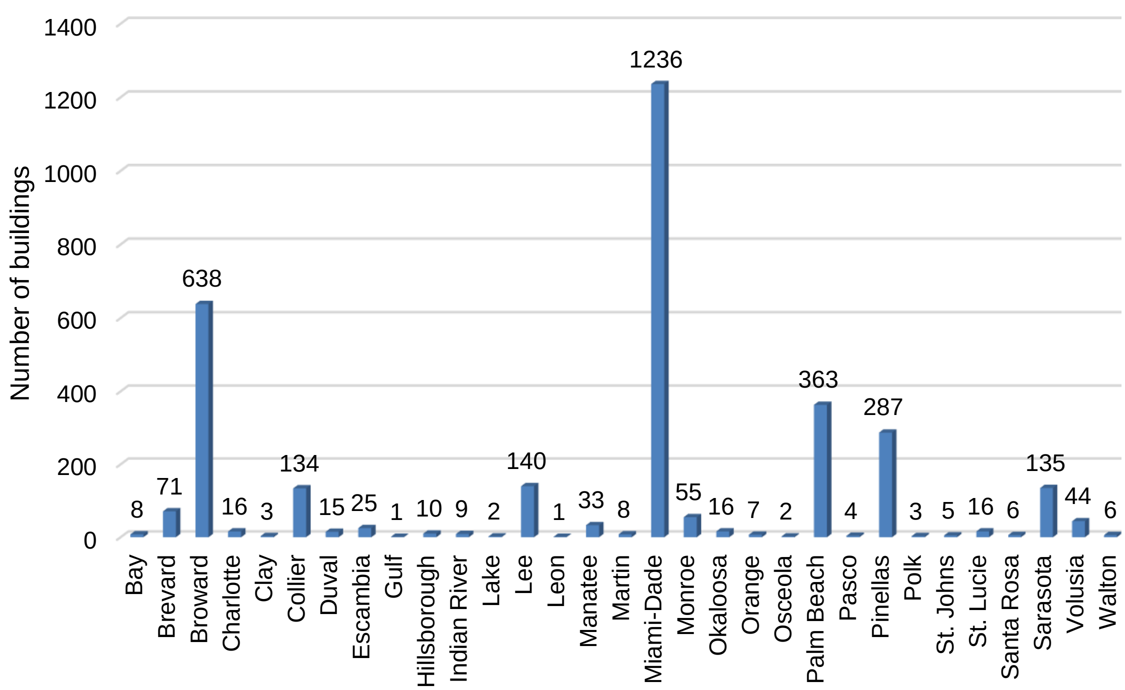


Figure 30. Frequency distribution of the buildings by county

5.5.2 Results of Analyses

The scenario analyses produced the overall expected loss from Irma for this portfolio. The stochastic analyses produced the annual average losses (AAL) for the portfolio, from 56,000 year simulations.

Figure 31 represents the percentage of portfolio loss for hurricane Irma, due to the fenestration defects (for doors, windows, and sliders). Figure 32 represents the percentage of portfolio average annual zero deductible loss (AAL) due to the fenestration defects. In each case, the percentage is the difference between total losses with defect and total losses without defect divided by total losses with defect.

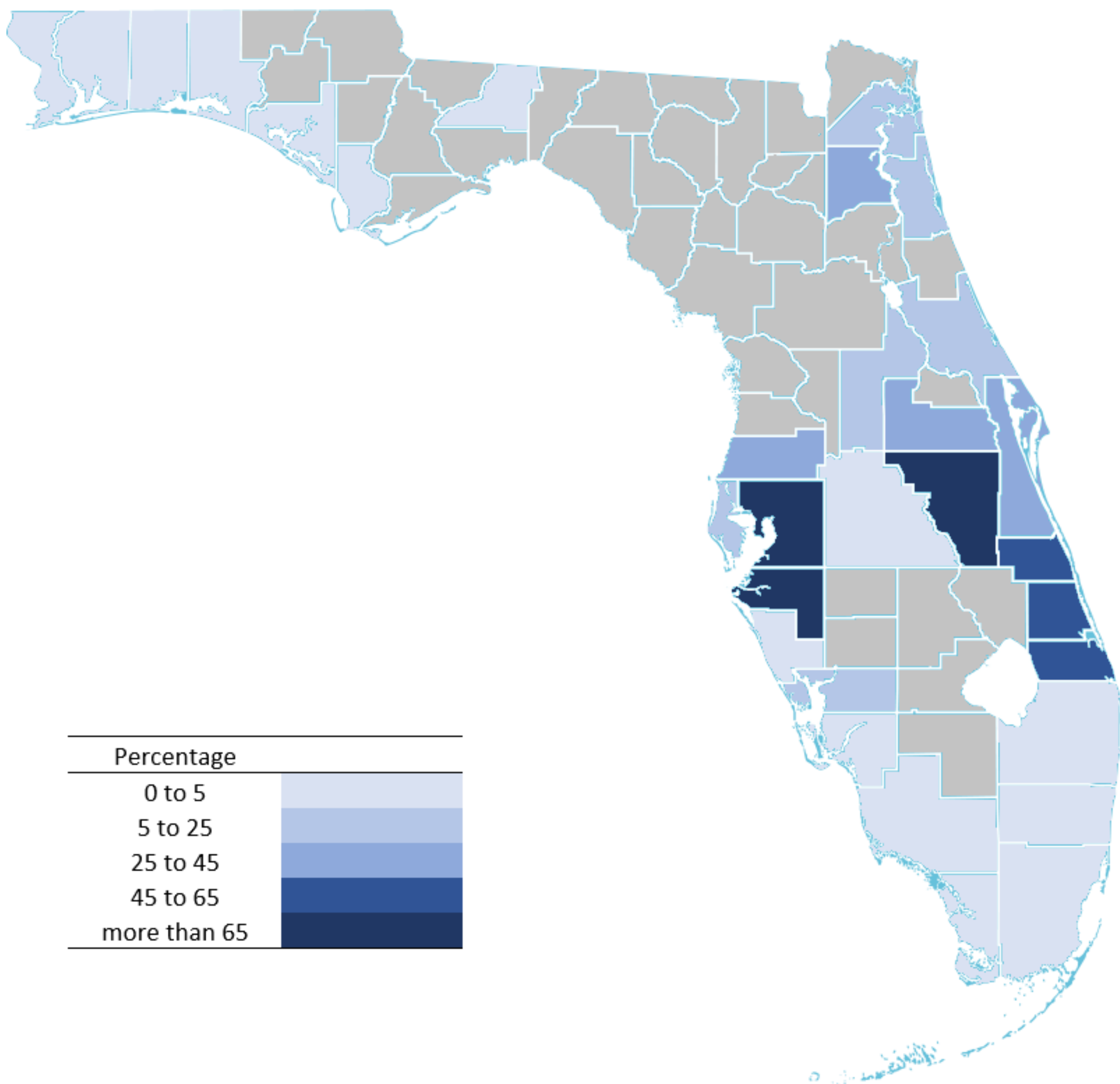


Figure 31. Percentage of portfolio loss due to fenestration defects for hurricane Irma

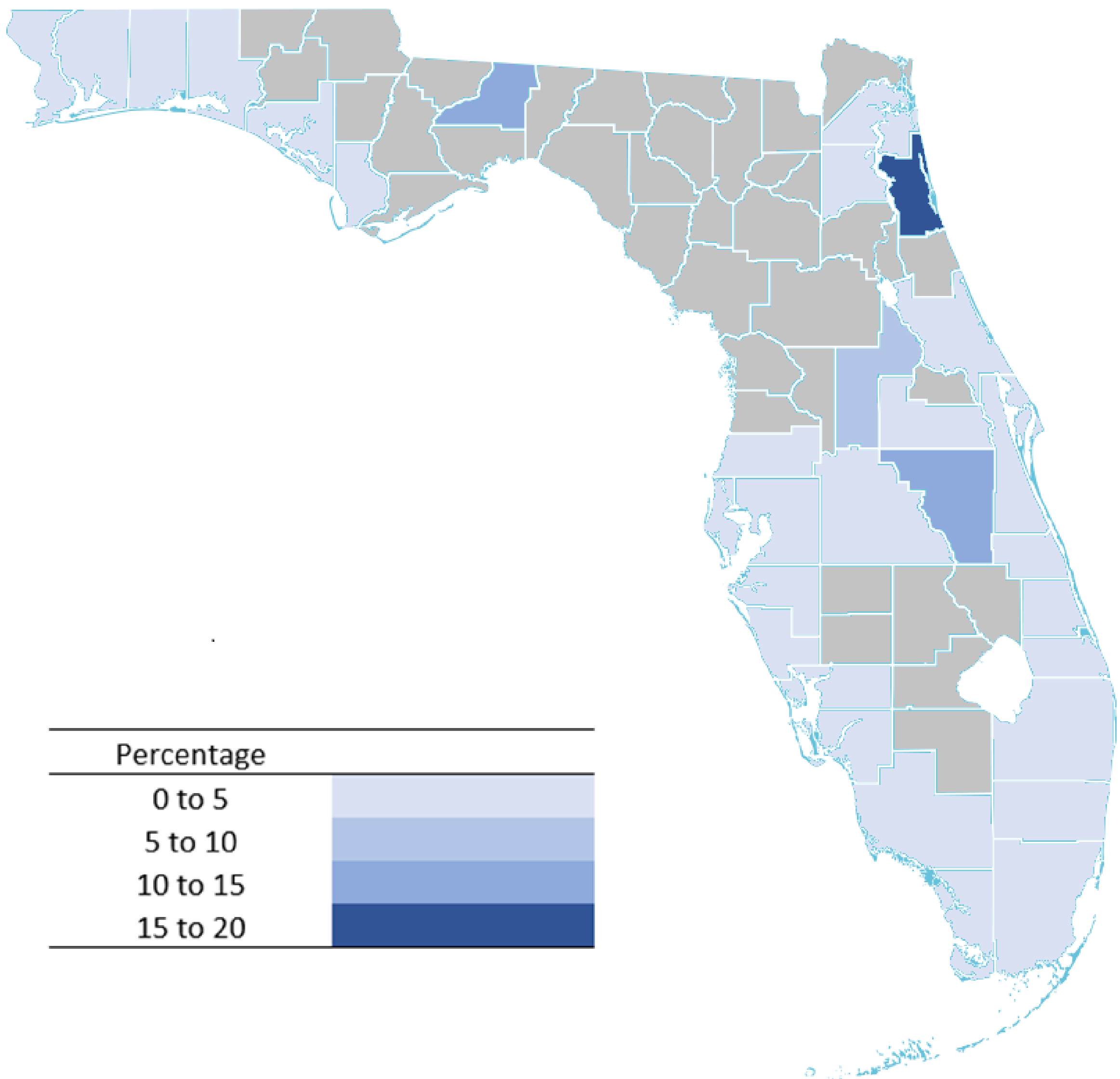


Figure 32. Percentage of average annual zero deductible loss due to fenestration defects

The results of Irma scenario loss and AAL are divided into 8 groups of pre or post 2002 buildings and less or more than 10 stories. Figure 33 to Figure 40 illustrate histograms for each group.

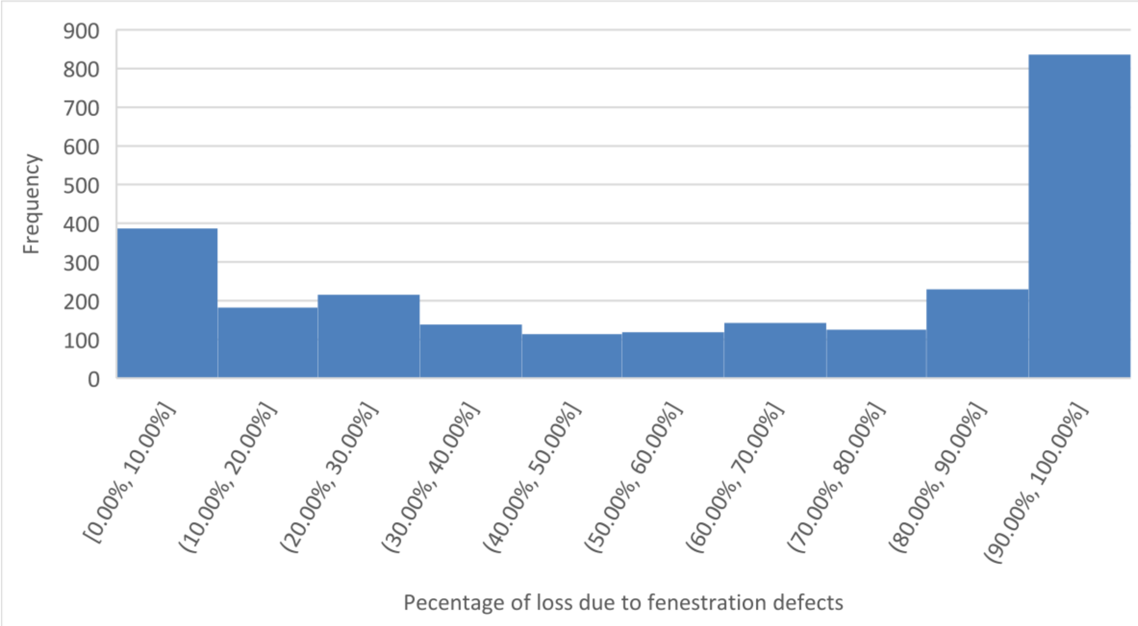


Figure 33. Histogram of losses due to defects in Irma scenario pre-2002 less than 10 stories

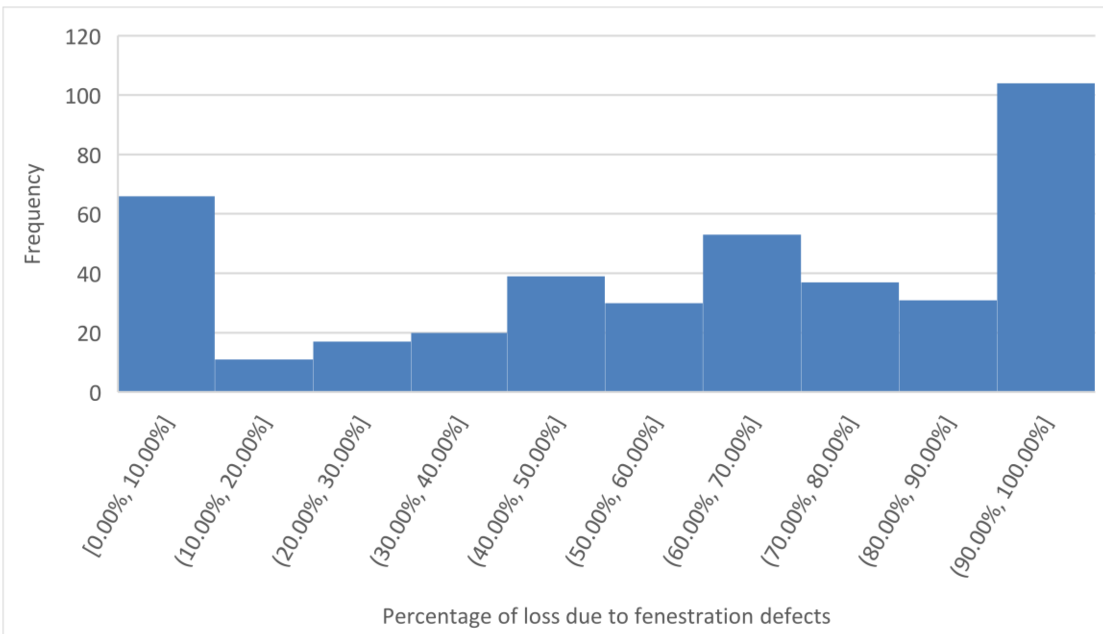


Figure 34. Histogram of losses due to defects in Irma scenario post-2002 less than 10 stories

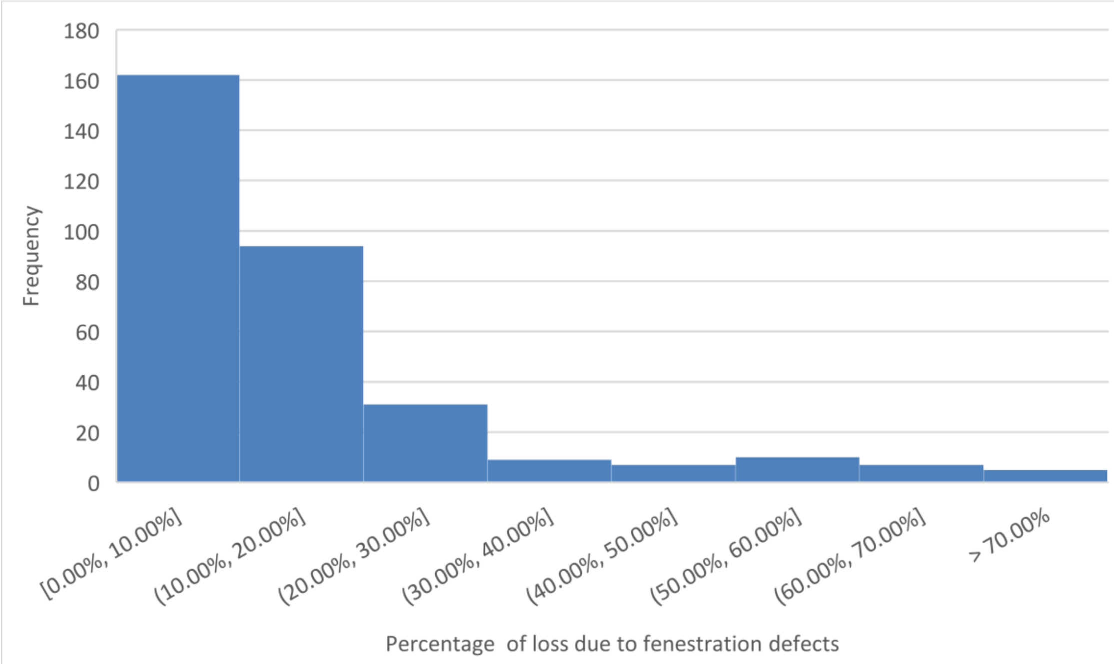


Figure 35. Histogram of losses due to defects in Irma scenario pre-2002 more than 10 stories

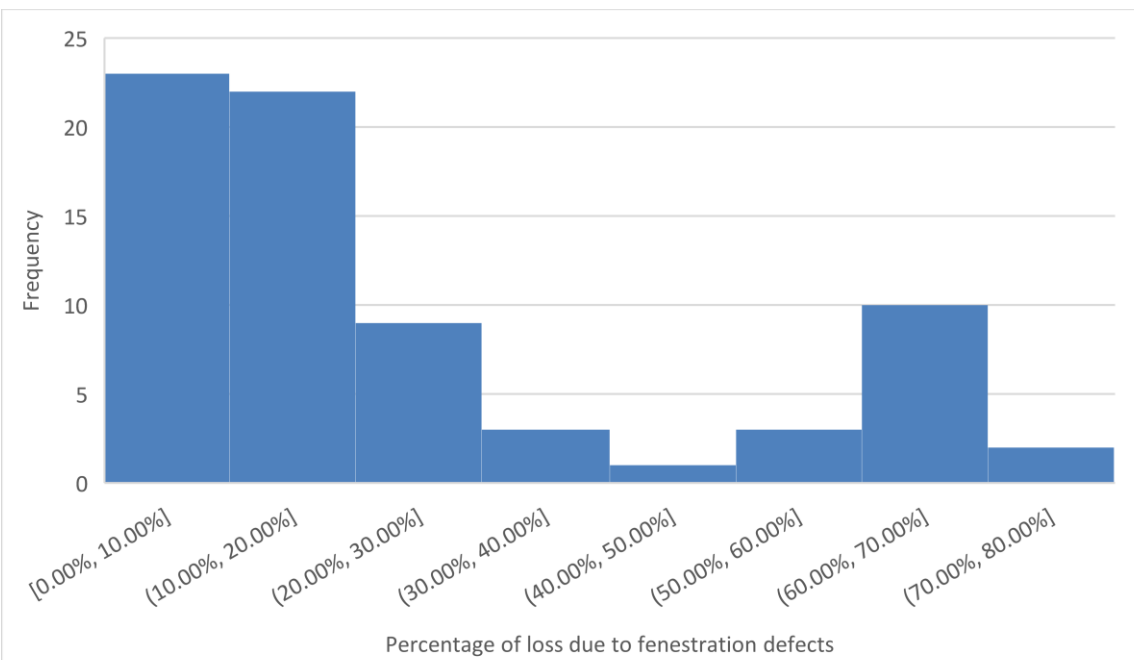


Figure 36. Histogram of losses due to defects in Irma scenario post-2002 more than 10 stories

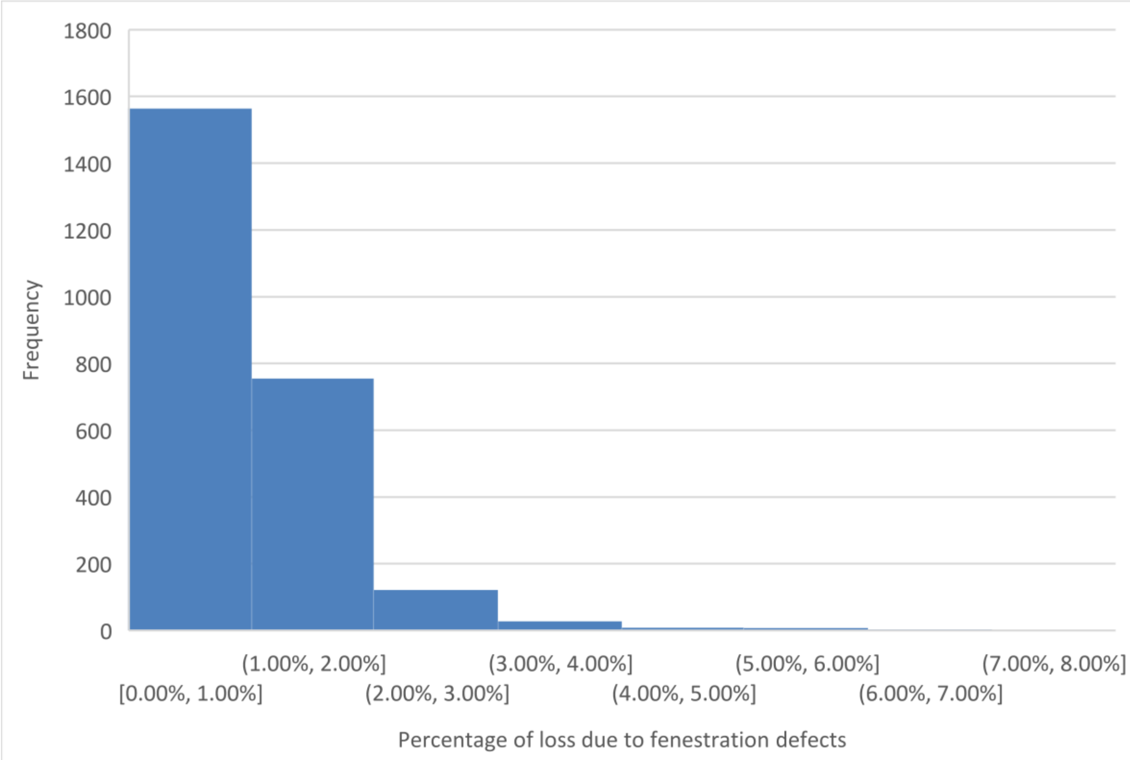


Figure 37. Histogram of AAL due to defects pre-2002 less than 10 stories

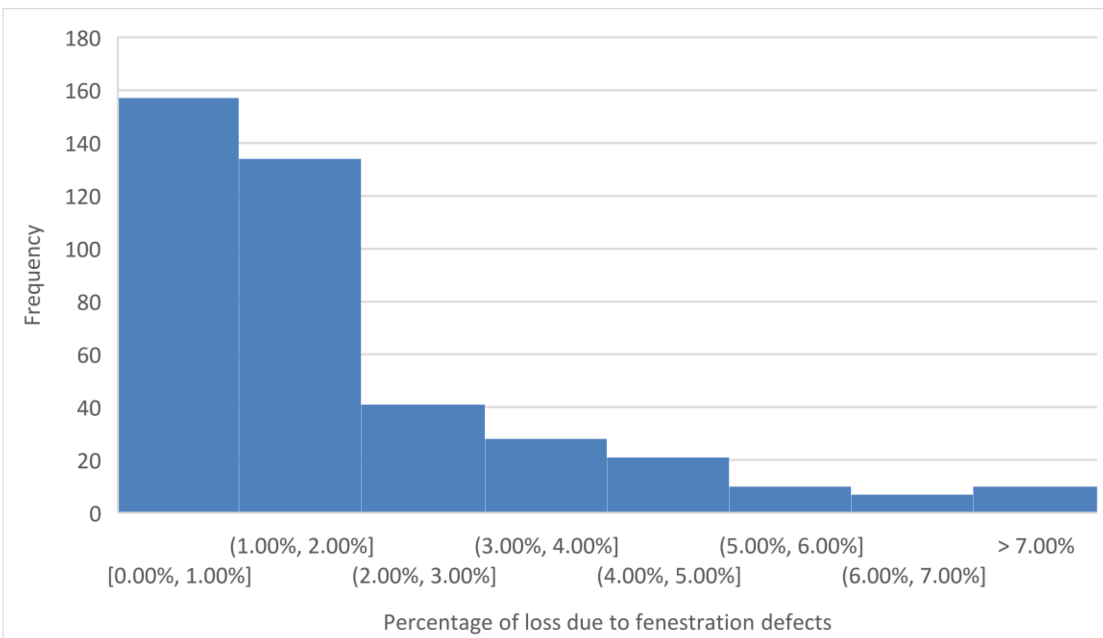


Figure 38. Histogram of AAL due to defects post-2002 less than 10 stories

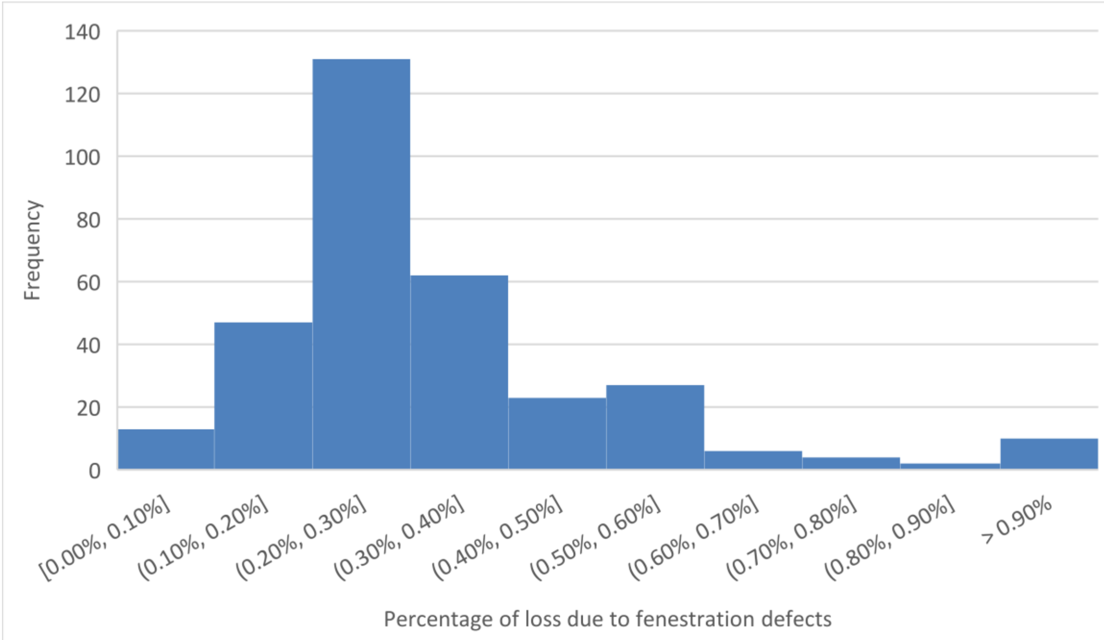


Figure 39. Histogram of AAL due to defects pre-2002 more than 10 stories

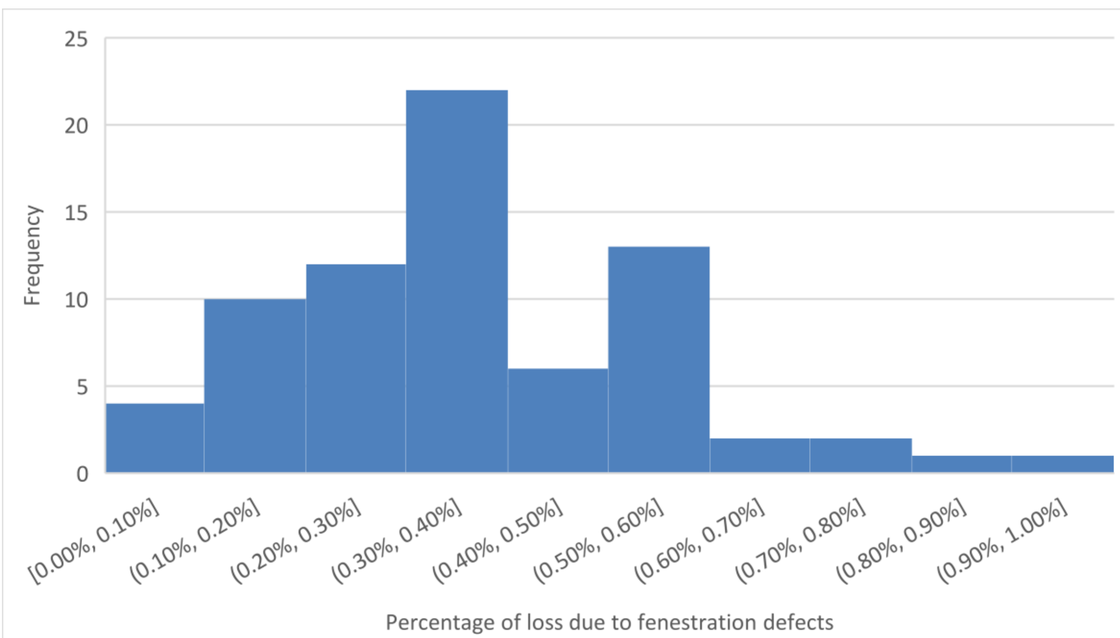


Figure 40. Histogram of AAL due to defects post-2002 more than 10 stories

5.5.3 Conclusion

- Percentage of scenario loss due to fenestration defects can be up to 100%. In other words, in many cases, in areas with low intensity wind speeds, like many counties for hurricane Irma, the entire loss can be due to the defects (see Figures 33 and 34). Notice the prevalence of darker colors on many east-coast counties, with lower wind speeds, in Figure 31.

- However, it must be noted that the absolute value in $ of the losses due to defects, projected by the FPHLM, are actually very low. In other words, the damage due to fenestration defects might represent up to 100% of the damage, but the projected value is very low. That does not align with the observation reported from hurricane Irma (see section 5). It shows that for low intensity events, ignorance or misrepresentation of the defects could lead to serious errors in estimation of loss.
- In the case of a portfolio analysis, for Hurricane Irma, the influence of the defects on the overall portfolio losses will depend on the magnitude of the wind speeds, and the makeup of the exposure in the areas affected by the hurricane, as shown by **Error! Reference source not found.** for Hurricane Irma.
- Percentage of AAL due to defects can be up to 16.4%, with the vast majority of the policies at less than 7%, because the stochastic sets include hurricane from categories 1 to 5 where the actual building damage becomes prevalent. In other words, for design events, the influence of the defects becomes negligible, since the envelope breach mechanism take precedence.
- The histograms show that there is little difference between pre- and post-2002 buildings regarding the influence of fenestration defects on the losses. In other words, there has been no improvements in that respect with the implementation of the FBC.
- Statistical conclusions regarding the buildings with more than 10 stories vs. the building with less than 10 stories are less clear, given the relatively small number of these buildings in the portfolio. The histograms show that the percentage of loss due to fenestration defects in the Irma scenario losses are less for building with more than 10 stories. The absolute amount of loss due to defects for taller buildings can be higher, but these buildings upper floors will be subjected to higher wind speeds, resulting in envelope damage, so that these defects-induced losses never reach 100% of the loss.

6 Recommendations for Future Studies

AAMA in 2005 recognized the fact that windows and doors will leak in a “highwind” event. The water intrusion testing standard is typically capped at about 12 pounds per square foot which relates to a wind velocity of about 68 mph. This confirms the fact that the testing criteria for water intrusion that is employed in the manufacturing and design of fenestrations is inferior and probably does not adequately protect the public from water intrusion in a hurricane prone-zone region.

The current standard for water intrusion testing of 15% of design pressure is far too low for the following reasons: 1) the testing is for a brand new assembly installed and tested in a laboratory environment, 2) there are no provisions or requirements for in situ testing after installation, and 3) there is no justification for the selection of 15% of design pressure to be used as a standard.

Instead of using 15% of design pressure, it would be better to incorporate an analysis of multiple tests where the design pressures and the probability of failure of the fenestrations were included as well as the economic cost to reach a determined pressure without leakage. After this probabilistic analysis it would be possible to create a table with the design pressures and the probability of exceedance to show the public the variation of the probability that, for example, a window experience leakage if we increase the design pressure. With this information, the public will have the possibility to choose “how much damage do they want to accept” and “how much money do they want to spend”.

To collect and organize the evidence of leakage on a floor by floor, elevation by elevation and building by building, a form was developed to assess water intrusion (Appendix A). This form was developed in order to be generic and eliminate identifiable information about the structures. However, it can also be used in a broader context. For instance: to record the maximum water leak distances per floor. By this procedure, it will be able to show the propensity of the forensic evidence of water leakage towards the specific cladding elevation.

One of the parameters that the FPHLM uses is the number of apartment per floor, which can be recorded through this form. Additionally, apartment are self-enclosed units, and it is useful to track the propagation if any of one unit to the other.

After obtain important information through the form, it will be possible calibrate the water penetration model of the FPHLM model against observed data as well as claim data, to better capture the influence of fenestration defects on overall building losses.

Then, it can be possible to incorporate the mitigation measure into the FPHLM to quantify the benefits of the mitigation as the difference between the damage without and with mitigation action. Finally, a preliminary benefit/cost analysis on selected apartment buildings can be carried out.

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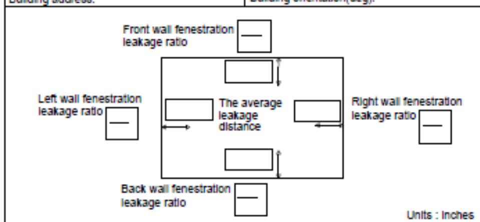
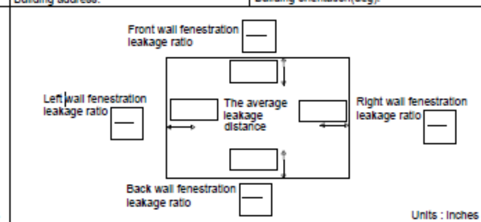
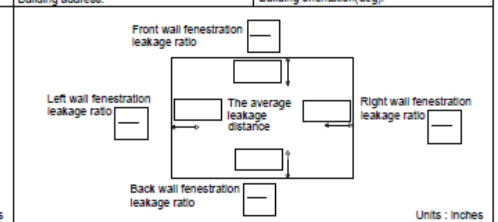
APPENDIX A – PROPOSED WATER INTRUSION ASSESMENT FORM

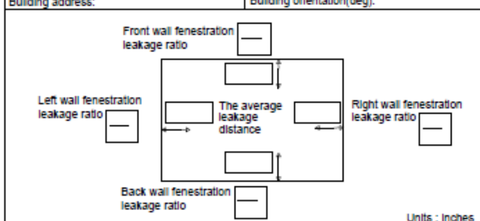
Sketch number:	Year built:	Sketch number:	Year built:	Sketch number:	Year built:
Building layout:	Total stories of building:	Building layout:	Total stories of building:	Building layout:	Total stories of building:
Survey date:	No. floor :	Survey date:	No. floor :	Survey date:	No. floor :
Building code:	Total apartment units per floors:	Building code:	Total apartment units per floors:	Building code:	Total apartment units per floors:
Building zip code:	Building types:	Building zip code:	Building types:	Building zip code:	Building types:
Building address:	Building orientation(deg):	Building address:	Building orientation(deg):	Building address:	Building orientation(deg):

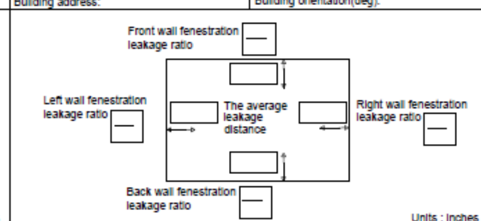


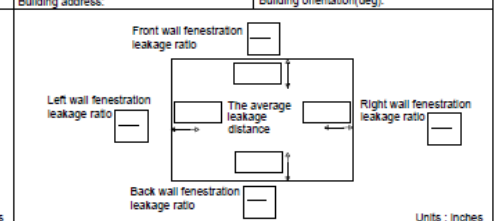




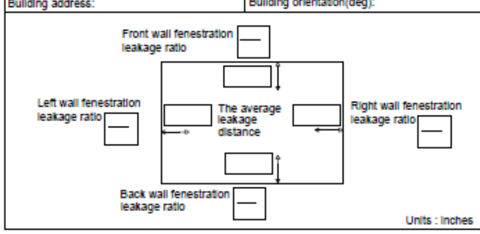
Sketch number:	Year built:	Sketch number:	Year built:	Sketch number:	Year built:
Building layout:	Total stories of building:	Building layout:	Total stories of building:	Building layout:	Total stories of building:
Survey date:	No. floor :	Survey date:	No. floor :	Survey date:	No. floor :
Building code:	Total apartment units per floors:	Building code:	Total apartment units per floors:	Building code:	Total apartment units per floors:
Building zip code:	Building types:	Building zip code:	Building types:	Building zip code:	Building types:
Building address:	Building orientation(deg):	Building address:	Building orientation(deg):	Building address:	Building orientation(deg):

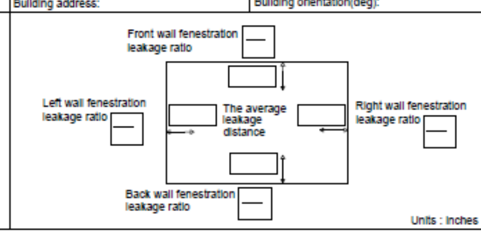


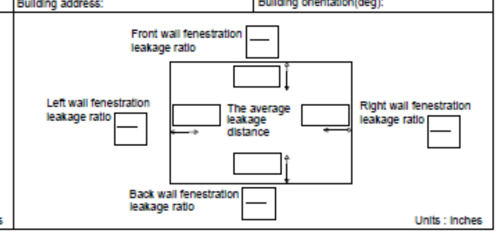




Sketch number:	Year built:	Sketch number:	Year built:	Sketch number:	Year built:
Building layout:	Total stories of building:	Building layout:	Total stories of building:	Building layout:	Total stories of building:
Survey date:	No. floor :	Survey date:	No. floor :	Survey date:	No. floor :
Building code:	Total apartment units per floors:	Building code:	Total apartment units per floors:	Building code:	Total apartment units per floors:
Building zip code:	Building types:	Building zip code:	Building types:	Building zip code:	Building types:
Building address:	Building orientation(deg):	Building address:	Building orientation(deg):	Building address:	Building orientation(deg):





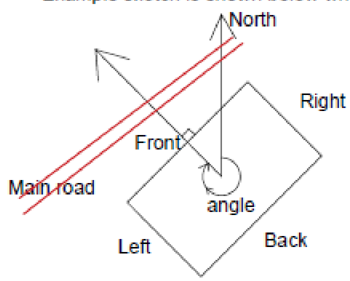


Explanation :

1. Each sketch represents one floor of the building.

2. The address format should follow this format:
   2814 TRACY CT Panama City Florida 32405 United States

3. How to determine the building orientation:
   - Front is defined as the wall elevation facing a main access road or providing main entrance to the building
   - After determining the front of the building, its orientation is the clockwise angle measured from the North to a perpendicular line to the building front wall
     Example sketch is shown below where the orientation is angle.



4. The leakage ratio is a fraction equal to the (number fenestration with leakage/total number of fenestration).
   Do not simplify this fraction.

5. The average leakage distance is a measure of the average distance in building plan that the water penetrated at each floor per wall direction.