

White Paper

Windows, Water and Wind

The Use and Misuse of Investigative Methods and ASTM Testing Protocols to Determine Wind-related Damage and Performance Deterioration to Window and Door Assemblies Following a Hurricane or Significant Windstorm

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| Abstract

The window and door industry in general has done an admirable job of accepting the mandate of improving performance of their products over time. These enhanced performances of increased energy efficiency, burglary safety, higher resistance to wind pressures, impact resistance to name a few, have progressed quickly, steadily, and markedly since Hurricane Andrew devastated south Florida in August of 1992. Since then, windows and doors have been tested to higher standards in search of compliance within those standards enabling manufactures to market new products. Most of the testing is performed in laboratories under controlled environments, although sometimes there is need for testing of window and door products in situ. ASTM and AAMA have developed standards for this condition particularly for **newly installed fenestrations**.¹

However, even with all the advancements in window and door performance, the air and water infiltration standards quantitatively lag the structural resistance standards of the assemblies. As an example, the threshold for water resistance to many operable window and door components per AAMA water test pressure standards, are only required to comply with .15 to .20 x positive structural design pressure of the component.² In addition, building walls and their components are not submarine bulkheads, they will leak at low pressures!

ASTM E1105 has developed a Standard for field testing of water penetration of installed windows and doors in situ. This standard has been commonly misused by some to determine window damage caused by high wind events. The standard was developed for the purpose of recreating water leaks that are known to occur,³ in order to repair and stop those leaks. The analytical error occurs when some investigations make the leap in logic that the water leak found during the administration of the ASTM test is automatic proof that the storm's wind driven rain was the cause of damage to the window or door assembly that created the leak, without fully understanding the actual pressures that were applied during a storm. Given the above shortcoming, the misuse of this test protocol typically results in preconceptions and unsubstantiated conclusions.

The proper method of investigating, evaluating, and analyzing window and door structural and water infiltration performance and observed damage during a high wind weather event, contains several components. One which relies on the ASCE 7, which is the Code adopted and accepted protocol for determining wind pressures acting on window and door components at any and all wind speeds.⁴ The calculation of the ASCE 7 wind standard, combined with a *site-specific* meteorological analysis of the exact wind speeds and directions at the subject building, is the proper protocol for evaluating water infiltration and wind damage to window and door components caused by the weather-related forces. Applying this standard gives us the rational and factual basis for determining whether the observed window and door sustained damaged and/or a reduction in performance, as a result of a particular high wind/rain event.



| Ten Typical Errors Found in the Investigation, Evaluation and Analysis of Reported Wind-Related Damage to Window and Door Assemblies

1. Storm winds damage windows on all sides of a building equally.
2. ASTM E1105 Water Penetration Testing, if successful, proves windows have been damaged by event winds.
3. Any and all observed frame deformation is caused by storm winds.
4. Frame movement can be conclusively determined by interior cracks at the gypsum, plaster or drywall finish adjacent to the window frame.
5. All window frame deflection has caused permanent frame damage.
6. A window or door that permits water infiltration needs to be replaced.
7. Random sampling of observed window damage can be extrapolated to include all windows.
8. Ingested gaskets at glass-to-frame intersection is always due to wind deflection of glass.
9. Water stains at window surrounds are due to glass-to-frame window seal failure.
10. Cloudy and/or stained insulated glass unit (IGU) failure is caused by wind driven rain.



| Recommendations for Forensic Investigators applying ASTM E2128 as a Guide, and Testing with ASTM E1105 to Determine Wind-Related Damage to Existing Window and Door Assemblies

1) All storms have a specific directionality, intensity, duration, and rainfall component. The windward direction of storms normally carry the greatest wind-driven rain volume. The leeward side of storms, depending on building configuration, is normally exempt from the wind driven rain anomaly.

2) Wind-forces caused by a hurricane are uniform and spread throughout the surfaces of a building. If the damage to gaskets and seals were caused by a specific storm, the damage would have been wide-spread and not isolated. Therefore, one can conclude that the observed condition was prevalent prior to the storm and not caused by the wind forces associated with the storm.

3) The ASTM E1105 Water Penetration Test is the actionable document used within the ASTM E2128 Standard Guide for Evaluating Water Leakage of Building Walls and is used as the Investigative Testing (Section 10) method within the evaluation. The ASTM E2128 is general in nature, as it has been formulated for all Building Wall components and not specifically for window and doors. In ASTM E2128 Section 10.1.1 “Objectives” the document states “The primary purpose of investigative testing is to recreate leaks that are known to occur.” This is an important distinction as many times windows and doors that contain no observable signs of water infiltration are tested erroneously and, in some cases, damaged after the fact. A common mistake of differential pressure water testing is submitting the component to higher pressures than the component experienced during a wind-driven rain event. This may result in the creation of new leaks and false narratives that the water infiltration origin occurred through the window or door component. In the end, if all protocols are followed correctly and the observed signs of water infiltration are recreated by the Water Penetration Test, there is a chasm of rational thought that must be crossed, that the leak was caused by a specific event and was neither pre-existing nor created by the test itself. The ASTM E1105 is better suited as a leak finding tool, and is often used to implement a series of repairs to address an existing leak issue, and is not a means to assess damage to windows or doors that have been impacted by a hurricane.

4) Water infiltration through windows and doors is a common anomaly, and there are numerous causes for the leaks. For example, water infiltrates through the operable members of a window and/or door assembly due to deteriorated gaskets, weather-stripping, and non-performing sealants, to name a few. These components wear out due to normal usage and untimely maintenance. Water can infiltrate anytime it is present in the assembly due to gravity, or wind pressure, or just standing in the deficient component. In addition, poor workmanship and improper installation also result in leaks.



7) Leaks through window and door sills are the predominant cause of water infiltration into wall cavities, as the sill is where water collects and pools, and depending on the intensity of the water event, can create enough head to flow over the designed damming within the sill. In addition, many sill systems contain anchors spaced along their length which also offer other points of water intrusion if improperly sealed or degraded over time. Many manufactures do not effectively address the issue of end-damming. As water collects on the sill, it pools. If the sills are poorly or improperly sloped or are affected by an event causing any appreciable amount of head, water will build-up and tend to leak into the wall cavities at the ends of the sill. This could be considered a design or fabrication defect, and the deficiency would be impacting the wall cavity from the inception of the installation.

8) Leaks at perimeters of window or door assemblies, for example at the interface of the building substrate and the exterior finish, are many times the cause of water infiltration that is blamed on the window components themselves. These leaks usually manifest as cracks in the interior gypsum, plaster or drywall surrounds, water stains at the wall base boards, and floor finish damage. In some cases, the infiltration originates from wall cavities on upper floors and due to gravity, has migrated to the assembly below. This is caused by missing or improperly applied sealant, and caulk which has degraded over time. Sealant deficiencies are the result of normal degradation and deterioration of the materials due to age and long-time exposure to the weather elements such as rain, heat, and UV exposure.



| Appropriate Protocol Using ASCE 7 and Rational Analysis to Determine Wind-Related Damage or Performance Deterioration Due to Wind-Related Events/Forces

The ASCE 7 is an extremely technical standard and contains many parts. The scope of this discussion will reference a non-technical view of Chapter 30, Wind Loads Components and Cladding (C&C). This section is the part of the standard which specifically applies to the envelope components and cladding of a building.

The Standard categorizes buildings by type, height, exposure, and importance factors, although what is most important for our discussion is the applicable pressure zones on the surfaces of the building model. All Components and Cladding at the vertical surfaces of a building would fall within Zone 4 and 5 as described in Chapter 30 of the Standard. Zone 4 (Interior Zone) occupying most of the elevation, and Zone 5 (End Zone) being the end condition at a distance calculated and described as “a”. (Refer to Figure 3 below) Zone 5 pressures are typically higher than Zone 4 pressures.

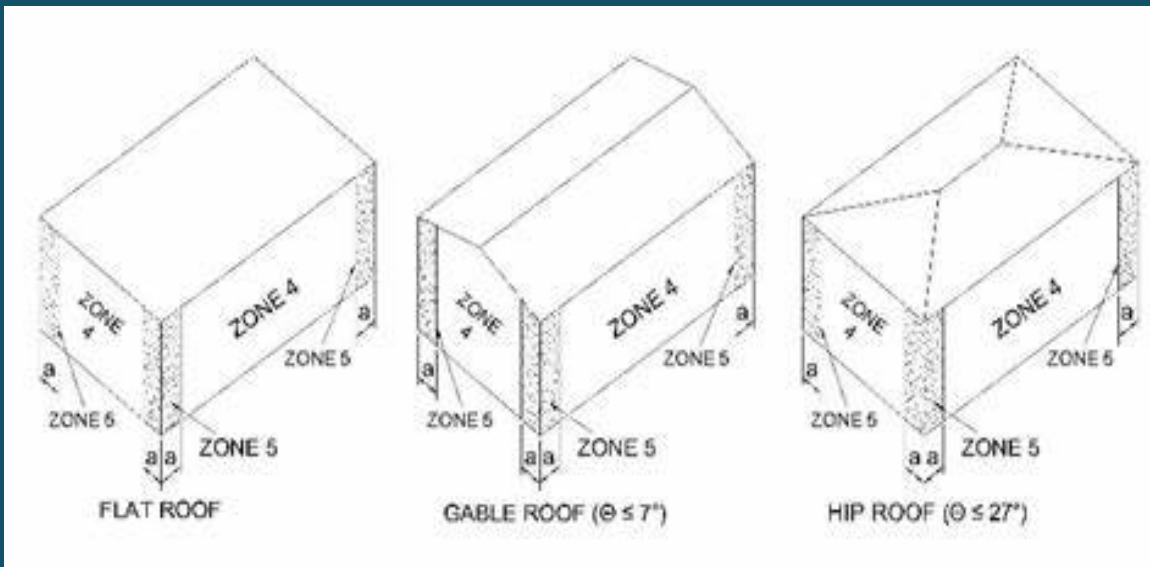


Figure 3 - ASCE 7 - Zones 4 & 5

In addition, the windward side of the building experiences positive wind pressure which increases with the height of the building. The leeward side of the building experiences negative wind pressure or suction, which stays constant through the entire height of the building. The building configuration also contributes to whether a window or door component falls within Zone 4 or 5 (see Figure 4 below). Interior corners are not always considered an end condition if they do not protrude beyond a tangent chord connecting the extreme ends of the building. Hypothetically, most building openings fall within the lesser Zone 4 wind pressure area.

Interior Corners Schematic

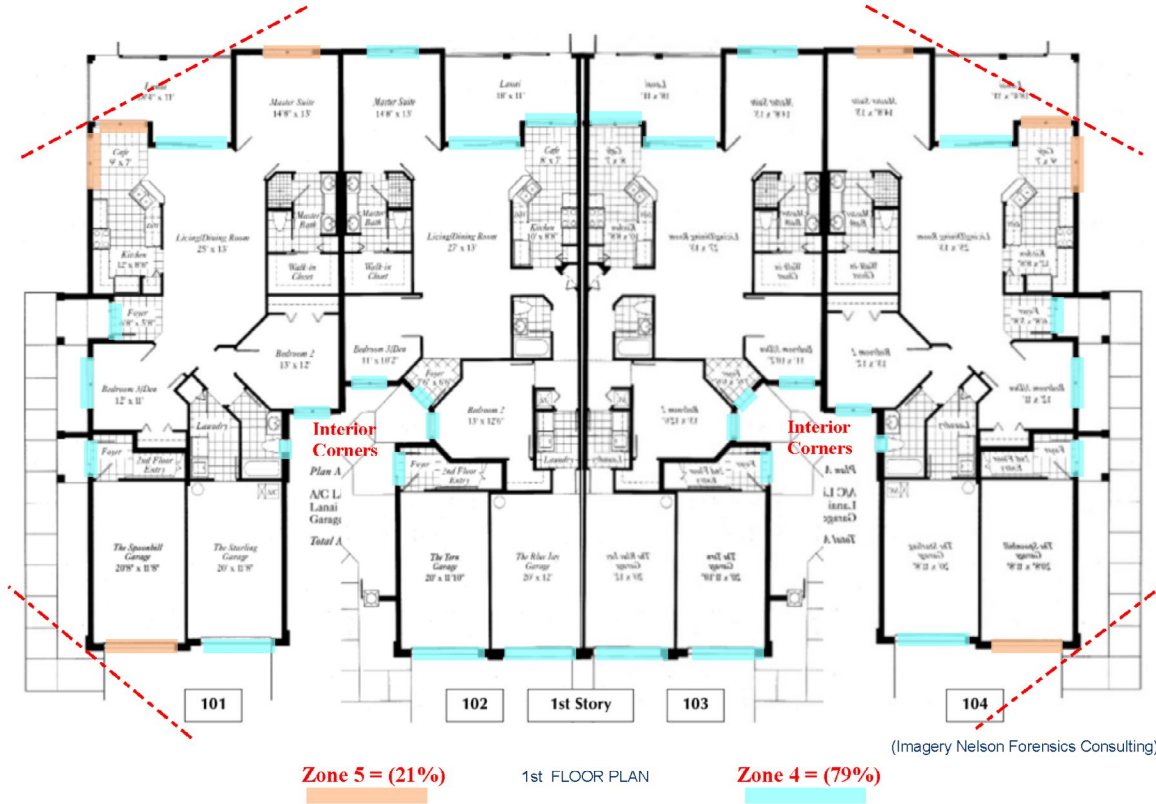


Figure 4 - Four-Unit Multifamily Building depicting percentages of windows within Zone 4 & 5

It is quite obvious that due to the application of ASCE 7 and its rational analysis of how wind impacts a building structure, all components in the building would not be affected equally throughout the structure, as building height, locations and zones all affect the outcome of observed damage patterns, concentrations and directionality.

All the above ASCE 7 pressures, their directionality and locations need to be logically applied to the building investigation, starting with the site-specific Meteorological analysis indicating wind intensity, duration, direction, and timing. The actual site specific three-second gust wind speeds from the Meteorological analysis are inserted in the ASCE 7 standard and calculated to attain actual storm-specific wind pressures and further interpolated for direction and location. This is then overlaid with rainfall intensity and timing. The combined information is compared to the observed window and door anomalies on site, and then evaluated for a cause-and-effect result.

As a final litmus test, the site-specific storm-related wind pressures are compared to the structural and water infiltration resistivity criteria for the performance grade classification of the products installed. The product's performance grade determination can be a difficult task for the investigator in the absence of a manufacture's label on the component (see Figure 5 below). At a minimum, the original installation date and the building code requirement for the components pressure resistivity at the time of installation can be used. This wind pressure comparison assists the expert in seeing the big picture of possible storm related damage as it pertains to the resistivity of the specific window or door.

The performance grade or resistivity of a window or door component is assigned by the manufacturer at the time of fabrication and after testing. A question arises as to consideration of a component's age, and whether it can perform to its original specifications. There is a two-fold consideration, structural resistivity and water and air infiltration resistivity. As per AAMA,⁶ structural test pressures are designated at 1.5x the design pressure as a performance requirement. It is highly unlikely that the structural resistivity of a window or door would degrade 50% in any reasonable time after its original installation. On the second front the water infiltration resistivity within the same AAMA document requires only 15-20% of the component's positive design pressure for compliance. Consequently, the water and air infiltration resistivity thresholds are easily reached and usually exceeded in common high wind and rainfall weather events. Thus, can be considered the component's resistive norm (see Figure 6 for optional performance grades of corresponding labels in Figure 5 below).



Figure 5 - AAMA Performance Grade Labels, SH and SGD

Optional Performance Grade	Applicable Product Designation	OPTIONAL PERFORMANCE GRADES							
		Design Pressure		Structural Test Pressure		Water Resistance Test Pressure			
		lb/ft ²	(Pa)	lb/ft ²	(Pa)	R, LC, C and HC		AW	
20	R	20	(960)	30.0	(1440)	3.00	(150)	---	---
25	R	25	(1200)	37.5	(1800)	3.75	(180)	---	---
30	R,LC	30	(1440)	45.0	(2160)	4.50	(220)	---	---
35	R,LC,C	35	(1680)	52.5	(2520)	5.25	(260)	---	---
40	R,LC,C	40	(1920)	60.0	(2880)	6.00	(290)	8.00	(390)
45	R,LC,C,HC,AW	45	(2160)	67.5	(3240)	6.75	(330)	9.00	(440)
50	R,LC,C,HC,AW	50	(2400)	75.0	(3600)	7.50	(360)	10.00	(480)
55	R,LC,C,HC,AW	55	(2640)	82.5	(3960)	8.25	(400)	11.00	(530)
60	R,LC,C,HC,AW	60	(2880)	90.0	(4320)	9.00	(440)	12.00	(580)
65	R,LC,C,HC,AW	65	(3120)	97.5	(4680)	9.75	(470)	12.00	(580)
70	R,LC,C,HC,AW	70	(3360)	105.0	(5040)	10.50	(510)	12.00	(580)
75	R,LC,C,HC,AW	75	(3600)	112.5	(5400)	11.25	(540)	12.00	(580)
80	R,LC,C,HC,AW	80	(3840)	120.0	(5760)	12.00	(580)	12.00	(580)
85	R,LC,C,HC,AW	85	(4080)	127.5	(6110)	12.00	(580)	12.00	(580)
90	R,LC,C,HC,AW	90	(4320)	135.0	(6470)	12.00	(580)	12.00	(580)

Table 3.1

Figure 6 - AAMA Optional Performance Grade Table 3.1.

| Conclusions

1) Water infiltration through exterior windows and doors has a wide array of possible causes and subsequent effects on interior materials. For example, long-term exposure to moisture and UV sunlight rays can and will cause damage to internal window sealants, insulated glass unit seals, corrosion of metal components, among many other effects.

2) The Evaluative process defined within the ASTM E2128 Guide and its investigative testing requires a knowledge of the principles of pressure measurement as well as an expert knowledge of building envelope characteristics and performance of envelope components. This is important because many factors that affect water infiltration into the interior of a structure are not always a result of window sealant failure.

Some of the investigative conditions listed in the ASTM Guide Section 9 “Inspection”⁷ are:

- 10.3.2 Placement of flashing relative to other components, and obstructions.
- 10.3.3 Interfaces between wall components. Critical interfaces include the integration of walls and windows, locations where wall materials or support conditions change, and where prefabricated units of the wall are joined.
- 10.3.4 Interface with other building components, such as copings, penetrations by mechanical equipment or structural supports, and foundations.
- 10.3.5 9.3.5 Wall attachments and appurtenances such as signs and canopies, balconies, and handrails.
- 10.3.6 Location and size of drip grooves or drip edges at the underside of horizontal surfaces.
- 9.3.8 Material conditions, including symptoms of deterioration, freeze-thaw damage, prolonged saturation, delamination, adhesive or cohesive material failures, efflorescence, and water-related damage to finishes.
- 9.3.9 Indications of wear and tear, maintenance, attempted repairs, damage from non-weather-related causes such as impacts, unaccommodated volume changes, or structural movements.
- 9.3.10 General assessment of workmanship and compliance with specified installation and execution as it affects water penetration.

3) **The ASTM E2128 as a Guide, along with its field-testing ASTM E1105 are not the proper protocol to determine high wind or wind-driven rain damage, as the protocol is established to locate leaks that are known to occur in the quest to repair.** Many times, the test is performed with differential pressures that exceed the window’s original fabrication performance standard, therefore can cause damage or at the very least erroneously determining a window or door’s failure to resist water infiltration. The chasm between the discovery of water infiltration using ASTM E1105 and whether the manifestation of the leak was caused by a specific weather event is large. This is the reason why this protocol is not appropriate in determining storm-related wind and water damage.

The protocol of applying site specific data, calculating storm related pressures using ASCE 7, locating zones of the building and comparing those findings with the window and door performance grades, is the rational and **defensible** approach through a direct study of the applied wind forces and its resulting cause and effect.

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| Citations

- 1 AAMA 502-12 Voluntary Specification for Field Testing of Newly Installed Fenestration Products.
- 2 ANSI/AAMA/NWDA 101/I,S2-97, Section 2 Table 2.1, Pages 4-5.
- 3 ASTM E2128-12 Standard Guide for Evaluating Water Leakage of Building Walls, Section 10 Investigative Testing, 10.1.1.1.
- 4 ASCE 7-16, “Minimum Design Loads and Associated Criteria for Buildings and Other Structures”.
- 5 AAMA / NWDA 101/I.S.2-97; Section 2 – Specific Requirements, Table 2.1, pages 5 and 6.
- 6 AAMA / NWDA 101/I.S.2-97; Section 2 – Specific Requirements, Table 2.1, pages 5 and 6.
- 7 ASTM E2128-12 Standard Guide for Evaluating Water Leakage of Building Walls, Section 9 Inspection, 9.3.2- 9.3.10.

