Windows, Doors, and Opening Protection

10.1 Introduction

Windows, skylights, vents, and glazed portions of doors are critical components of a building's envelope. Codes and standards use the term *glazing* to address all windows and openings containing glass. Specifically, ASCE 7-05 (which is incorporated by reference into both the IBC and IRC) provides the following definition for glazing:

> *GLAZING: Glass or transparent or translucent plastic sheet used in windows, doors, skylights, or curtain walls.*

Glazing systems simultaneously allow natural light to enter the building's interior and provide a scenic view of the coast. However, these systems are very vulnerable to damage from wind forces and windborne debris unless specifically designed to resist such forces and impacts. Recent MAT investigations and laboratory tests have shown windows and doors are also susceptible to wind-driven rain penetration. Special consideration should be given to these features of the building envelope. In all areas where buildings are constructed, windows and doors tend to be more vulnerable to damage than other portions of a building's envelope. In coastal areas—where high winds, windborne debris, and wind-driven rain are common and often intense—their vulnerabilities are more pronounced.

This chapter presents actions needed to ensure that windows and doors can resist the hazards common to coastal areas. This chapter describes typical failures in windows and doors, discusses requirements contained in national codes and standards, outlines the nuances of window- and door-testing and certification, and discusses some best-practices approaches to installing and protecting windows and doors. The chapter finishes with a discussion of garage doors.

10.2 Window and Door Failure

In coastal environments, numerous post-disaster investigations conducted by FEMA have shown that windows and glazed portions of doors are vulnerable to impact from windborne debris. This impact force is the principal failure mode for these systems. Debris from the natural environment (e.g., tree limbs) and from the built environment (e.g., roofing material, siding material, sawn lumber, etc.) can become windborne debris and break window and door glazing. Once broken, windows and glazed portions of doors can allow wind, windborne debris, and rain into the interior of the building. This can result in the following:

- Large amounts of water may enter a building and damage its contents and finishes. There is also the possibility that the water could compromise certain structural members. If water intrusion occurs, action will not only be needed to eliminate the water-induced damages on appurtenances (such as carpets, cabinets, and floors), but also to mitigate all potential long-term moisture problems associated with certain construction materials.

- Wind forces or pressures inside a building are dramatically increased when the building's envelope is breached. It is not uncommon to observe significant damage to structural and nonstructural building elements from this internal pressurization. Such damage may remain isolated to a small area or room or it may result in damage severe enough to initiate the complete structural failure of the building.

Water leakage around windows and doors is also quite common but because the effects of leakage are often subtle, the full effects of leakage are often not readily apparent. Leakage from poor flashing or weather stripping, from improper installation, or from doors or windows being inadequate to resist local conditions can allow water to enter a building's interior—even when the structure of the window or door remains intact. Water intrusion can cause rot and fastener corrosion that weaken the window or door frame or the wall framing itself. Leakage can also cause damage to interior finishes and facilitate mold growth.

Wind-pressure failure of glazing is also occasionally observed. Windows and doors can fail if they are not strong enough to resist wind pressures from a high-wind event or if forces exerted on the doors or windows exceed the strength of their anchorage. Figure 10-1 shows how the failure of a large window led to the loss of the roof structure. When strength is inadequate, the window or door's glazing or frames fail; when anchorage is inadequate, the entire door or window unit can be torn from its mounting. Negative pressure (i.e., suction) failures are more common but positive pressure failures can occur as well. Figure 10-2 shows a window separated from its frame due to positive pressures acting inward on a window system.

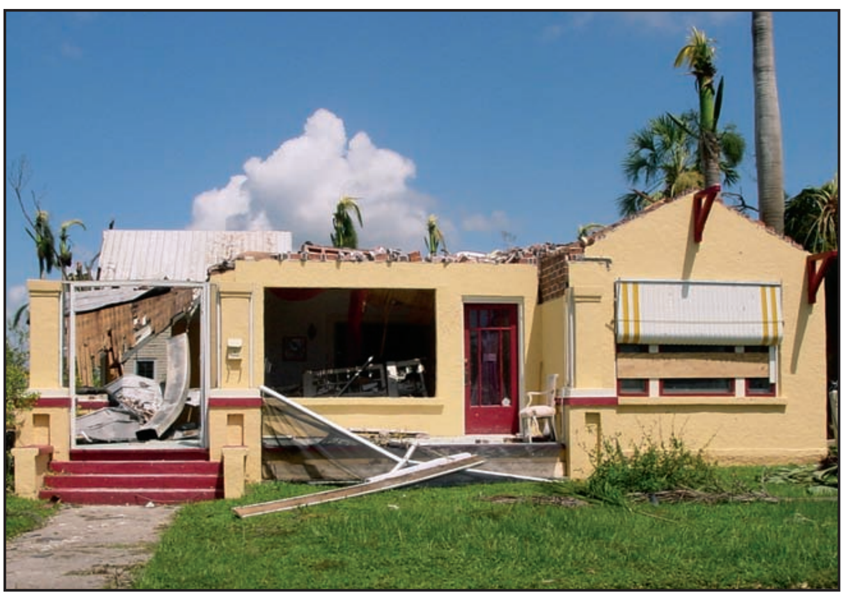

Figure 10-1.
PUNTA GORDA, FLORIDA:
Failure of a roof structure from pressurization of a house when the window failed on the windward face.
(Source: FEMA 488)

New and older buildings may have windows broken by debris if windows are not protected. Figure 10-3 shows a window on a home under construction that was broken by windborne debris, while Figure 10-4 shows an oceanfront home that experienced window breakage when unprotected glazing was impacted by windborne debris. Properly addressing these failures requires doors and windows to be: 1) correctly designed and anchored to resist wind pressures, 2) adequately protected to resist windborne debris, 3) sufficiently flashed and weather-stripped to limit water infiltration, and 4) appropriately selected to resist local conditions.

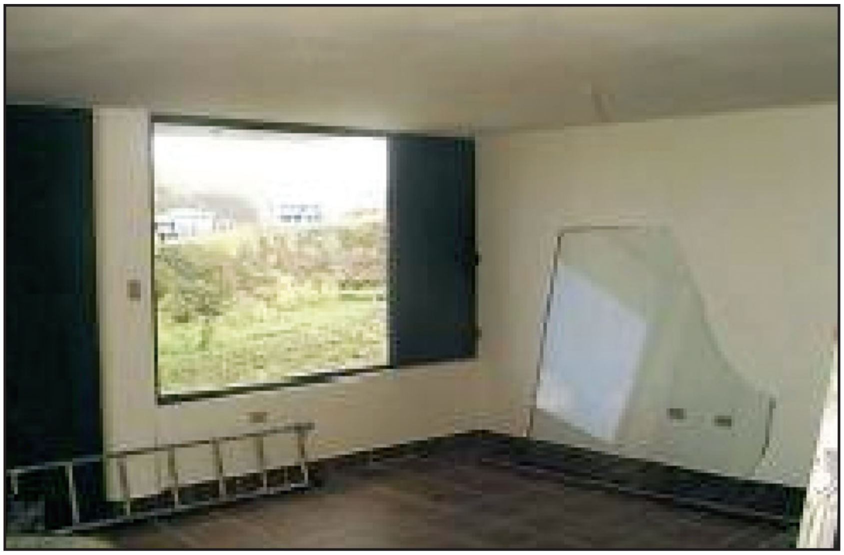

Figure 10-2.
PUERTO RICO, 1998:
Failure due to inadequate pressure rating of window. The window frame remained attached to the wall but the glazed portion was blown inward by positive pressures.
(Source: FEMA 55)

Figure 10-3.
PUNTA GORDA, FLORIDA:
Glazing failure due to windborne debris from displaced roofing.
(Source: FEMA 488)

Figure 10-4.
Glazing failure due to windborne debris. An oceanfront home damaged during Hurricane Ivan due to windows being broken by windborne debris.
(Source: FEMA 489)

10.3 Windborne Debris Protection Systems

Damage to glazing systems can be prevented, or at least minimized, by using glazing or opening protection systems that have been designed to resist wind and windborne debris forces specified in the building code. Impact-resistant (i.e., debris-resistant) systems provide protection through the use of laminated glass or polycarbonate glazing systems. The use of physical-opening protection systems such as shutters, screens, or structural wood panels (as allowed by the IBC and IRC in certain hazard areas) is also a common means of achieving protection for glazing.

> **NOTE**
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> It is very important to note that shutters, screens, and other panel systems that protect glazing from debris impacts are rarely, if ever, rated to reduce wind pressures on the windows they protect. A system that typically has been rated for a pressure rating has been rated to resist that pressure in order to avoid blow-off or excessive deflection—not to decrease pressure on a window or door that the system protects.

By far, the most effective solution is impact-resistant glazing systems. These systems provide "in-situ" protection and require no human action or involvement after installation; the protection system is in place at all times and does not need to be installed prior to storm events. Further, these systems do not need to be closed, lowered, or installed like storm panels or shutter systems. While impact-resistant glazing systems are one of the more expensive options for debris protection, their use may be determined to be appropriate for high-end homes (where the relative cost of laminated systems as compared to the total building cost can be low) and for buildings used for vacation homes (which are not continuously occupied). Their application may also be appropriate on the upper levels of homes or buildings, where the installation of shutters may prove difficult.

Shutters, screens, and panel systems are the next-most-desirable option after impact-resistant systems. These systems protect vulnerable glazing from windborne debris but only when installed in place before the event strikes. Some styles of shutters (e.g., roll-up or accordion-style) are made to be deployed or positioned to protect glazing with little effort; many have electric-powered motors that facilitate their operation. Of course, electrically operated shutters need power to run and occasionally power is lost early during a storm. Other styles, often called "storm panels," are designed to be easily removed and kept in storage and installed only when a storm is approaching. If in place during a high-wind event, properly tested and certified shutters, screens, and storm panels are as effective as laminated, in-situ systems. However, installing these panels requires more effort and planning by home and property owners.

Wood structural panels (which include plywood and OSB) are allowed by the IBC and IRC in certain applications. Often these panels are large, single panels that are unwieldy and difficult to install—particularly when winds begin to build and the panels need to be installed in order to protect upper-floor windows, glazing, or skylights. It is also difficult to prevent a homeowner from using wood structural panels if these custom wood panels meet the deflection requirements for which they are used. Wood structural panels, however, are relatively inexpensive and may be the most appropriate method for low-cost housing.

10.3.1 Impact-resistant Glazing Systems

Laminated glazing systems typically consist of assemblies fabricated with two (or more) panes of glass and an interlayer of a polyvinyl butyral (or equivalent) film laminated into a glazing assembly. Laminated systems are non-porous and have slightly different pass/fail criteria in ASTM E1996. During impact testing, the glass panes in the system can fracture but the interlayer must remain intact to prevent water and wind from entering the building. Depending upon the level of protection (i.e., enhanced or basic), tears are allowed in the film used in windows but tears must be less than $^{1}/_{16}$ inch wide and less than 5 inches long and cannot allow a 3-inch-diameter ball to pass through the tear. After impact testing, the laminated glazing systems must resist the cyclic pressure tests of ASTM E1886.

Polycarbonate glazing systems are also used in place of traditional laminated glazing systems. Polycarbonate systems typically consist of plastic resins which are molded into sheets which provide lightweight, clear glazing panels with high impact-resistance qualities. The strength of the polycarbonate sheets is much higher than non-laminated glass (i.e., more than 200 times stronger) or acrylic sheets or panels (more than 30 times stronger). Several brands of polycarbonates used as glazing (such as Lexan® and Makrolon®) are commonly available. Both impact-resistant windows and shutter systems may be constructed using polycarbonates.

10.3.2 Shutter, Screen, and Panel Systems

Shutters, screens, and non-wood panel systems are separate systems and are tested independently from the glazed portions of the windows and door they protect. While certified shutters protect glazing from debris impact for an identified missile at a prescribed impact speed, most shutter systems are porous and do not significantly reduce wind pressures on the glazing itself. Glazing protected by shutters does not need to be debris-impact-resistant but it does need to be strong enough to resist design wind pressures.

During testing, the shutter system must withstand the impact of the test missile while preventing the missile from penetrating the “innermost plane” of the test specimen. Also, after successful testing, there can be no openings formed that allow a 3-inch-diameter ball to pass through them.

To be effective, shutters should fully cover the glazing they are meant to protect. In retrofit installations, shutters are occasionally observed that do not cover the entire window or are obstructed by window unit air conditioners or other appliances (see Figure 10-5).

Also, as a best-practices approach, shutters should be anchored to the wall surrounding the window, and not to the window or door frame itself. Shutters should never be anchored to the window frame unless: 1) the window is properly anchored to the wall in a fashion that resists imposed wind pressures, and 2) the shutter is certified to perform properly when attached to the window or door frame. Typical installation of shutters, screens, and panels requires brackets or other mounting devices (such as anchors) to be secured to the walls or other elements that surround the window and not the window or door itself.

Shutters installed on upper floors or in difficult-to-reach areas can be challenging to install or operate. Several motorized styles are available to facilitate the operation and deployment of shutters in difficult-to-reach areas. If motorized shutters are used, the shutter system should also be manually operable. If not, loss of electrical power can render the shutters ineffective prior to an event and might prevent opening after an event.

10.3.3 Wood Structural Panels

Wood structural panels are not required to be tested and certified, but are assumed to offer an acceptable level of protection if installed as prescribed. The IBC and IRC specify minimum panel-thickness requirements along with maximum spans for the wood structural panels. Limiting panel spans places upper limits on the stresses within the panel and controls deflection of the panel. Like shutters, wood structural panels are considered porous and are not certified to reduce wind pressures on the glazing itself. Windows and doors protected by wood structural panels must still meet wind-pressure requirements specified in the code.

10.4 Protection Requirements for Windborne Debris

While the potentially devastating effects of windborne debris have been known for years, windborne debris provisions have only recently been introduced into national codes and standards. The 1995 edition of ASCE 7 first specified the debris-impact protection requirements for glazing from windborne debris. That standard stated that glazing in the lower 60 feet of all buildings located in regions where the basic 3-second gust wind speed equaled or exceeded 110 mph had to be protected against windborne debris or that buildings had to be designed to resist higher internal pressures. The standard allowed buildings in these high-wind areas to have unprotected glazing but required that the structure be designed to resist higher wind pressures (from internal pressurization). This approach, while valid from a structural standpoint, allowed building contents and furnishings to be damaged by water entry from broken glazing. Further, this approach left the building envelope unprotected against known hazards. Loss of windows due to windborne debris may result in damage that is many times the replacement cost of the building. This is due to what is often extensive damage to building contents and the loss of operations of the damaged building. These costs were comparable to a full-building loss, although the structure had not failed.

Since 1995, the performance requirements for windborne debris protection have increased while the locations where windborne debris provisions are required have been lessened slightly. Currently, the IBC and IRC no longer allow designers to have the option of designing buildings for higher internal pressures with unprotected glazing in windborne debris regions; the glazing must be protected. This ensures that new buildings not only can resist wind pressures but also can provide protection against windborne debris and minimize impact to homes and businesses, thereby reducing insurance claims caused by water entering broken glazing

The IRC, IBC, and ASCE 7-05 currently define windborne debris regions as follows:

> **Windborne Debris Region:** "*Portions of hurricane-prone regions that are within 1 mile of the coastal mean high-water line where the basic wind speed is 110 mph (49 m/s) or greater; or portions of the hurricane-prone region where the basic wind speed is equal to or greater than 120 mph (54 m/s); or Hawaii.*"
>
> and where hurricane-prone regions are defined as:
>
> **Hurricane-prone Regions:** *Areas vulnerable to hurricanes, defined as:*
>
> 1. *The U.S. Atlantic Ocean and Gulf of Mexico coasts where the basic wind speed is 90 mph (40 m/s), and*
> 2. *Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa.*

As defined, windborne debris regions in the continental United States extend along the Gulf of Mexico from Texas to the southern tip of Florida, and along the Atlantic Coast from the southern tip of Florida to Massachusetts. This also includes Hawaii, U.S. territories and protectorates, and most of coastal Alaska.

The windborne debris regions described in the 2006 IBC and IRC are less extensive than what was specified in ANSI/ASCE 7-95. In the 1995 standard, all hurricane-prone areas with a basic wind speed of 110 mph or greater were considered to be windborne debris regions. Now only hurricane-prone areas with a basic wind speed of 110 mph that are within 1 mile of the coast are considered to be in the windborne debris region (except in Hawaii, where all portions of all islands exist, by definition, within the windborne debris region).

> **NOTE**
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> Delineating windborne debris regions is not an exact science and would benefit from further research. While post-event assessments indicate that 3-second gust winds as low as 80 mph can dislodge aggregate surfaced roofing with sufficient momentum to damage glazing, recent research suggests that in wooded areas, the 2006 windborne debris regions may be conservative. According to the best practices recommended in recent FEMA MAT reports from the 2004 and 2005 hurricane seasons, windborne debris protection is suggested for all Exposure C areas where wind speeds are 110 mph or greater.

The requirements for residential construction are listed in IRC Section R301.2.1.2. This section requires that glazed openings in buildings located in windborne debris regions be protected from windborne debris and that such protection must meet the requirements of the Large Missile Test of an approved impact-resisting standard, or ASTM E1996 and ASTM E1886 (using Missiles C or D). Section 1609.1.2 of the IBC has requirements that take into consideration the use of the building and location of the glazing. Glazed openings within 30 feet of grade must resist the Large Missile Test of ASTM E1996 (using Missile D or E) and glazed openings more than 30 feet above grade must meet the Small Missile Test of ASTM E1996. It is important to understand that when glazing protection is required, it is required for all glazing on a building. It is an incorrect assumption that the protection only needs to be installed to protect openings on the "side of the building" that receives positive (or predominant) wind pressures. Further, the approved systems need to be inspected for compliance. Figure 10-5 illustrates how a panel shutter was installed incorrectly around window-mounted air conditioning units, leaving much of the window unprotected.

Figure 10-5.
PENSACOLA, FLORIDA:
Shutters had been attached to this building in order to protect it from windborne debris. However, areas above and below the air conditioning units were left unprotected.
(Source: FEMA 489)

ASTM E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials* is a consensus-based testing protocol for certifying glazing systems. However, certification to ASTM E1886 in and of itself is not adequate to determine adequacy of a glazing system for a given area.

> **NOTE**
> The Engineering Wood Association (formally the American Plywood Association) has prepared five brochures that present hurricane-resistant shutter design for wood-frame and masonry buildings. The brochures are available online at the Engineering Wood Association Web site at http://www.apawood.org.

ASTM E1886 is not a standalone document and requires input from a "specifying authority" or the AHJ—such as a city, county, or state code enforcement office—which determines actual testing conditions and regulates compliance with such tests and conditions. The test method standardizes the size and weight of a small missile, the size and range of weights for large missiles at various speeds, and sets forth the methods to test assemblies for missile impacts and subsequent cyclic pressure tests (although it remains the responsibility of the specifying authority to provide the actual testing criteria). These criteria include: number of test specimens, basic wind speed, missile impact speed, number and location of impacts required during certification, and the number of cycles and duration of the cyclic load testing.

ASTM E1996 augments ASTM E1886 by specifying the weight of the large missile to be used in testing per ASTM E1886 and the impact velocities for the large and small missiles. The ASTM standards identify more stringent requirements for buildings in higher basic wind speed zones and for critical facilities. Table 10-1 presents two ASTM E1996 large missile requirements for different wind zones and building classifications.

The ASTM standard defines basic protection levels for glazing for all buildings, and for buildings requiring enhanced protection. Section 6.2.1 of ASTM E1996 describes facilities and their required protection level. The wind zones listed in ASTM E1996 are:

> **Wind Zone 1** – Areas where the basic wind speed is greater than or equal to 110 mph and less than 120 mph, and Hawaii.
>
> **Wind Zone 2** – Areas more than 1 mile from the coastline where the basic wind speed is greater than or equal to 120 mph and less than 130. The coastline is delineated by the mean high-water mark.
>
> **Wind Zone 3** – Areas where the basic wind speed is greater than or equal to 130 mph and areas within 1 mile of the coastline, where the basic wind speed is greater than or equal to 120 mph.

This may be confusing to designers, builders, and local officials, because it appears that these are different criteria than what is presented in the IBC and IRC. However, this is not the case. The ASTM standard wind zones help define the missile size and speed to be used for debris impact-resistance testing and are needed to carry out the tests required by the codes. Local officials need to closely review the certification of tested glazing systems to determine if they are appropriate for that jurisdiction, building location, and building use. Particular attention should be given to:

- Basic (design) wind speed. (It should match the ASCE 7-05 basic wind speed map or the maps contained in the IRC or IBC.)
- Design wind pressures. (Pressures should be based upon C&C loads per ASCE 7-05, the IBC, or IRC.)
- Size of the appropriate missile (which depends upon building use, building height, and wind speed).

Table 10-1.
(Source: ASTM E1996)

TABLE 2 - Applicable Missiles

Missile Level	Missile	Impact Speed (m/s)
A	2 g ± 5% Steel Ball	39.62 (130 f/s)
B	910 g ± 100 g (2.0 lb. ± 0.25 lb.) 2x4 in. 52.5 cm ± 100mm (1 ft. - 9 in. ± 4 in.) Lumber	15.25 (50 f/s)
C	2050 g ± 100 g (4.5 lb. ± 0.25 lb.) 2x4 in. 1.2 m ± 100mm (4 ft. ± 4 in.) Lumber	12.19 (40 f/s)
D	4100 g ± 100 g (9.0 lb. ± 0.25 lb.) 2x4 in. 2.4 m ± 100mm (8 ft. ± 4 in.) Lumber	15.25 (50 f/s)
E	4100 g ± 100 g (9.0 lb. ± 0.25 lb.) 2x4 in. 2.4 m ± 100mm (8 ft. ± 4 in.) Lumber	24.38 (80 f/s)

TABLE 3 - Description Levels

NOTE 1 – For Missiles B, C, D and E also use Missile A for porous shutter assemblies (see 8.4)

Levels of Protection	Enhanced Protection (Essential Facilities)		Basic Protection		Unprotected	
Assembly Height	**≤ (30 ft) 9.1 m**	**≥ (30 ft) 9.1 m**	**≤ (30 ft) 9.1 m**	**≥ (30 ft) 9.1 m**	**≤ (30 ft) 9.1 m**	**≥ (30 ft) 9.1 m**
Wind Zone 1	D	D	C	A	None	None
Wind Zone 2	D	D	C	A	None	None
Wind Zone 3	E	D	D	A	None	None

It is also important to note that wind pressures specified on product approval or certification sheets for shutters, screens, and panel systems are the pressures at which the system was tested for resistance to blow-off. These systems have not been tested to reduce the pressures on the windows and glazing they protect and, therefore, the window or glazing system behind the opening protective device must still be designed to resist the design wind pressure; the protective device only prevents debris impact to the glazing.

Both the IRC and IBC contain exceptions that permit 7⁄16-inch thick (minimum) wood structural panels to be for used for windborne debris protection. It is important to note that these panels should not have a maximum dimension of more than of 8 feet and they must be properly fastened to the building to resist wind forces appropriate for that location. In addition, when wood structural panels are used for windborne debris protection, the IRC and IBC both require that the panels be: 1) precut, 2) attached to the framing surrounding the glazed openings, 3) secured with attachment hardware provided, and 4) the attachments shall be designed to resist the C&C loads determined in accordance with IBC Section 1609 (i.e. ASCE 7-05). Table R301.2.1.2 of the IRC and Table 1609.1.2 of the IBC contain prescriptive attachment schedules (i.e., details) suitable for buildings with mean roof heights up to 33 feet for basic wind speeds up to 130 mph. Figure 10-6 shows a glazed door that was not protected with any type of system and was subsequently damaged by windborne debris.

Figure 10-6.
PENSACOLA, FLORIDA:
Failure of glazing from windborne debris created by dislodged tile roofing.
(Source: FEMA 489)

The IBC contains other exceptions, which allow greenhouses with no public access and glazing in the upper floors of taller buildings to be constructed without windborne debris protection. Exceptions to glazing protection in taller buildings apply when: 1) the glazing is at least 60 feet above the ground, and 2) the glazing is located a minimum of 30 feet above any aggregate surfaced roofs within 1,500 feet of the building glazing in question. (These exceptions are consistent with the requirements of ASTM E1996.)

Prescriptive standards generally assume that a building's envelope (e.g., walls, wall coverings, windows, roof decking, roof coverings, etc.) will remain intact and the building will not be damaged by the impact from windborne debris. The assumption is that a hole in the exterior of the building may be created, but it will not expose the inside of the facility to winds that would result in high internal pressures acting on the structural system. ICC-600 requires glazing in windborne debris regions to be protected to meet the large missile criteria of ASTM E1886 and ASTM E1996 to prevent damage. ASCE 7-05 also states in Section 1.4 that, “Buildings and other structures shall be designed to sustain local damage with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage.” However, it is very important to note that walls, roof decks, and other non-glazed building components are not required to be impact-resistant systems by the IRC, IBC, or ASCE 7-05. Only some state codes (such as the Florida Building Code) contain impact-resistance requirements for non-glazed building components. These requirements are limited to hazard areas defined as High Velocity Hurricane Zones (HVHZ) and only for critical and essential facilities operating within the HVHZs. FEMA 361 and the ICC-500, which provide design criteria for safe rooms and storm shelters, respectively, require all roof, wall, glazing, doors, and openings on the safe room or shelter to be debris-impact resistant.

10.5 Window and Door Leakage

Hurricanes and coastal storms can pose significant problems from water-infiltration due to wind-driven rain. Leakage can occur between the door or window and their frames and between the door/window frames and the walls onto which they are mounted. Coastal storms such as tropical storms and hurricanes generate winds that may approach or exceed the wind speeds observed during design wind events. As such, these winds generate high-wind pressures on the outsides of the buildings, exploiting any vulnerability around doors and windows and allowing water to enter buildings. Further, leakage rates typically increase with greater wind speeds. While the amount of water entry that can result from leakage around windows and doors will typically be much less than the amount of water entry that can result from a breach in the building envelope, actions can and should be taken to help reduce leakage around doors and windows. These actions are often code-plus or best-practices approaches.

10.5.1 Code Requirements for Window and Door Leakage

Proper door and window construction is critical to reducing water infiltration. Section R613.4 of the IRC and Section 1714.5.1 of the IBC require windows and sliding doors to be certified per AAMA/WDMA/CSA 101/I.S.2/A440, *Standard/Specification for Windows, Doors, and Unit Skylights*. Hinge doors must be certified per ASTM E330, *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Uniform Static Air Pressure Difference*. Both standards specify wind-pressure and water-leakage criteria that must be met in order to comply with code requirements.

In general, water-leakage tests are conducted at much lower differential pressures (typically 20 percent) than the pressures used to determine the strength of the glazing, window, or door assembly. This implies that some water entry through doors and windows should be anticipated during an event that produces design wind pressures and wind-driven rain.

10.5.2 Reducing Window and Door Leakage

FEMA 499, Technical Fact Sheet No. 22: *Window and Door Installation*, Window and Door Installation, provides some best-practices approaches that can be taken to reduce water infiltration. Pan flashing (i.e., flashing under window sills), weather stripping, and threshold seals are discussed. Other actions can be taken to reduce the potential for water entry. These include:

Vestibules. Designing a vestibule to protect a door entry is one method of managing water infiltration problems. Through this approach, both the inner and outer doors can be equipped with weather stripping, and the vestibule itself can be designed to tolerate water. For example, water-resistant finishes (e.g., concrete or tile) can be specified, and the floor can be equipped with a drain. As a result, a secondary layer of protection is provided for the primary entrance (via the vestibule and vestibule door).

Door swing. Out-swinging doors offer an advantage compared to in-swinging door assemblies. With out-swinging door assemblies, the weather stripping is located on the interior side of the door, where it is less susceptible to degradation than the exposed weather stripping on in-swinging door assemblies. Also, some interlocking weather-stripping products are available for out-swinging door assemblies that provide better performance than those used on in-swinging door assemblies.

Finish selection. One design approach to deal with leakage is to avoid running carpet (or other finishes that can be damaged by water) entirely to the edge of walls that contain a large amount of glazing. Instead, a strip of water-resistant material (such as tile) could be specified along the wall so if light to moderate leakage occurs, the potential for damage to interior finishes and contents is greatly reduced.

10.6 Window and Door Assembly Capacities

Window and door assemblies must be strong enough to withstand wind pressures acting on them and be fastened securely enough to transfer those wind pressures to the adjacent wall. Pressure failures of doors or windows can allow glazing to fracture or glazing frames or supports to fail. Anchorage failures can allow entire door or window units to be ripped from their walls, as shown in Figure 10-7. Either type of failure results in the failure of the building envelope and allows wind and water into the building.

10.6.1 Code Requirements for Strength and Anchorage

Both the IRC and IBC contain specific requirements for the wind resistance of windows and doors. Section R613.3 of the IRC requires that exterior windows and doors be designed to resist the wind pressures specified in Table R301.2(2). Table R301.2(2) lists positive and negative wind pressures for C&C for various locations within the building. Areas near roof and wall edges and areas near corners, where turbulence creates localized high wind pressures, must be designed for higher loads. Table R301.2(2)

Figure 10-7.
PUNTA GORDA ISLES, FLORIDA: Anchorage failure in sliding glass door failure.
(Source: FEMA 488)

is based upon Exposure B conditions for buildings with a mean roof height of 30 feet or less. Table R301.2(2) pressures must be multiplied by factors listed in Table R301.2(3) for different mean roof heights and exposures.

The IBC requirements are similar but are less prescriptive and more performance-based. While the IRC has tabulated wind pressures, Chapter 16 of the IBC specifies acceptable methods of calculating wind loads and (in Section 1603.1.4) requires that construction documents list wind pressures for C&C.

IBC Section 1405.12, Exterior Windows and Doors, requires windows and doors to be tested in accordance with IBC Section 1714.5, which lists two methods of establishing wind resistance. Section 1714.5.1 allows doors and windows to be labeled per AAMA/WMDA/CSA 101/I.S.2/A440; Section 1714.5.2 allows doors and windows to be tested per ASTM E330. The latter option has additional requirements regarding glass supports and framing that are outlined in Section 2403 and pressure ratings for Section 1714.5.2 are outlined in Chapter 16, the structural design chapter of the IBC.

AAMA/WMDA/CSA 101/I.S.2/A440 lists design test pressures of 15, 25, 30, and 40 psf. Windows and doors used in areas where wind pressures are greater than 40 psf need to be tested per ASTM E330. For residential construction, local officials must ensure that products proposed are adequate to resist the C&C loads of Table R301.2(2). For engineered construction, the designer should specify wind pressures required for windows and doors and should base them on C&C loads from either Chapter 6 of ASCE 7-05 or Chapter 16 of the IBC.

Section R613.8.1 of the IRC requires that windows and glass doors be anchored in accordance with published manufacturer's recommendations. The manufacturer's installation instructions should match those used when the units were tested and certified. Substitute anchorage systems are allowed if they "provide equal or greater anchoring performance as demonstrated by accepted engineering practice."

IRC contains Figures R613.8(1) through R613.8(8) that provide minimum anchorage details. The details require windows and doors to be anchored in a fashion that adequately transfers loads from the windows and doors to the adjacent walls (the walls are called "substrates" in that code). When the space between the window or door frame and the wall's rough opening is 1½ inches or less, shims or bucks can be installed and fasteners can extend from the door or window frame to the wall. When the space is greater than 1½ inches, the bucks need to be securely fastened to the wall and the door, or window frames need to be securely fastened to the bucks. This requirement limits the shear length of fasteners to 1½ inches and reduces the potential for bending failures in the fasteners.

The IBC requirements are similar but do not provide the prescriptive details contained in the IRC. IBC Section 1405.12.1 requires windows and doors to be installed in accordance with approved manufacturer's instructions. The IBC requires fastener size and spacing be provided in the instructions and that the fastener size and spacing be based upon the maximum loads used in certification or compliance tests.

For adequate performance, the manufacturer's installation instructions must be followed. Local authorities should require that the installation instructions be present onsite. Further, installations should be inspected to ensure that compliance has been achieved with those instructions.

To minimize issues related to corrosion, the use of fiberglass or vinyl frames are recommended for buildings located within 3,000 feet of an ocean shoreline. The use of stainless steel frame anchors, fasteners, and hardware is also recommended within these areas. In areas where severe termite or insect infestation problems exist, wood frames should either be treated or should be constructed with wood that is naturally insect- and rot-resistant. Shims and bucks should be pressure-treated. Since some pressure treatment increases the moisture content of framing, the use of material that is kiln dried after treatment is suggested to control shrinkage.

In areas where insect infestation problems exist, metal door assemblies are recommended. If concrete, masonry, or metal wall construction is used to eliminate termite problems, wood used for blocking or bucks should be treated or naturally insect- and rot-resistant species of wood should be used.

10.7 Garage Doors

Post-event hurricane and tornado assessments include numerous examples of failures of garage (or vehicle-access) doors. Garage doors have experienced:

- **Outward-acting Suction Failures.** Doors have buckled and pulled outward, as shown in Figure 10-8.
- **Inward-acting Positive Pressure Failures.** Doors have buckled or pushed inward, as shown in Figure 10-9.
- **Hardware Failures.** Failures in the hardware that laterally supports garage doors and allows them to open and close.

Failures of garage doors can allow significant amounts of water and wind to enter a building. Because it is common for garages to be constructed (at least in part) with water-resistant materials, water entry is often less of a concern than the internal pressure increase that garage-door failures create. A garage-door failure is a breach of the building envelope. The breach increases internal pressures within that area of the building and may lead to building failure.

Because of their size and relatively long spans (as compared to windows and other doors), garage doors must resist higher forces from the same wind pressures that act on windows and access doors. However, garage doors typically have room to deflect more than windows and access doors and the increased deflection can be used to resist loads (provided that the tracks do not fail).

Section R613.5 of the IRC requires garage doors to be tested in accordance with ASTM E330, *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Uniform Static Air Pressure Difference* or ANSI/DASMA 108, *Standard Method for Testing Sectional Garage Doors: Determination of Structural Performance Under Uniform Static Air Pressure Difference* and requires doors to meet the acceptance criteria of ANSI/DASMA 108. ASTM E330 establishes the methods used to apply and measure wind pressures; ANSI/DASMA 108 establishes failure criteria related to building failure.

Like the testing of windows and doors per AAMA/WDMA/CSA 101/I.S.2/A440, neither ASTM E330 nor ANSI/DASMA 108 establishes test pressures. Therefore certification data must be closely examined to determine if the labeled product is appropriate for the design wind pressures at the proposed location. Also, some municipalities require garage doors to be tested at pressures in excess of the design wind pressures. The C&C wind pressures in Table R301.2(2) of the IRC provide minimum design pressures that the labeled door should meet.

Table R301.2(2) lists positive and negative wind pressures on C&C for basic wind speeds between 85 mph and 170 mph. Positive pressures act toward the building surface; negative pressures act away from the building surface. As discussed in Section 10.6, the listed pressures relate to Exposure B conditions for buildings with a 30 foot mean roof height; the values must be multiplied by the adjustment factors listed in Table R301.2(3) for other exposure categories and other mean roof heights.

Figure 10-8.
Negative pressure failure of garage door.
(Source: FEMA 488)

Figure 10-9.
Positive pressure failure of garage door.
(Source: FEMA 549)

Table R301.2(2) also lists wind pressures for various locations within a building that constitute "effective wind areas." The locations include three areas specified for the roof (Zones 1, 2, and 3 corresponding to the interior, corner, and eave and gable zones) and two areas specified for the walls (Zones 4 and 5). Zone 4 wall pressures are for locations away from corners; Zone 5 pressures are for areas within 4 feet of the corner, where wind pressures are higher. IRC Figure R301.2(7) graphically shows the locations of the C&C wind zones.

While some manufacturers provide wind speed and exposure ratings for their products, labels on many garage doors do not include wind speed or wind pressure ratings. While not required to be included on the product labeling, ANSI/DASMA 108 does require that the positive and negative pressure used in testing be recorded on the ANSI/DASMA 108 Test Report Form. The standard also requires that the model number, description, and operating hardware be documented. Where wind speed or wind pressures are not specifically provided for the product, builders and officials can refer to the Test Report Form to ensure that the garage door assembly has been tested to resist the design wind pressures listed in Table R301.2(2). In windborne debris regions, the IRC Section R301.1,2 also requires that glazing in garage doors be protected from windborne debris.

10.8 Additional Resources

American Society for Testing and Materials:

- ASTM E1886, *Performance of Exterior Windows, Curtain Walls, Doors, and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*

- ASTM E1996, *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricane;*

- ASTM E2112, *Standard Practice for Installation of Exterior Windows, Doors and Skylights*

- ASTM E330, *Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference.* (www.astm.org)

American National Standards Institute:

- ANSI/DASMA 108, *Standard Method for Testing Sectional Garage Doors: Determination of Structural Performance Under Uniform Static Air Pressure Difference*