Natural Hazard Mitigation

INSIGHTS

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Industry Perspective: Impact Resistance Standards

We've all seen the images of people scrambling to protect their homes' windows and doors from an approaching hurricane. Conventional wisdom used to be that the winds themselves were responsible for most damage. But Hurricane Andrew's devastation of south Florida in 1992 changed our thinking. Post-disaster investigations indicated that much of the damage occurred because windows and doors were compromised by wind-borne debris.

Recognizing the need to protect these vulnerable openings from high winds and debris, building code authorities and standards organizations developed three separate protocols to test how well a door or window will withstand impacts.

These protocols evolved along similar paths and their requirements overlap in many respects. It is clear to IBHS, however, that one standard is more appropriate and universally applicable than the others. If you build, own or insure property in a high-wind region, you need to

A palm tree impaled by a wood missile after Hurricane Andrew.

When windstorms sweep up objects and propel them through the air at high speeds, they become dangerous missiles – also known as wind-borne debris – heading for homes and businesses. Tree limbs and street signs can easily turn into missiles, but, in reality, wind-borne debris can be anything, from small rocks and pebbles to mailboxes and two-by-fours.

know how these three protocols differ, what you should look for in a product certification or specification and what IBHS recommends.

Breach of the building envelope by wind-borne debris.

The Chain Reaction

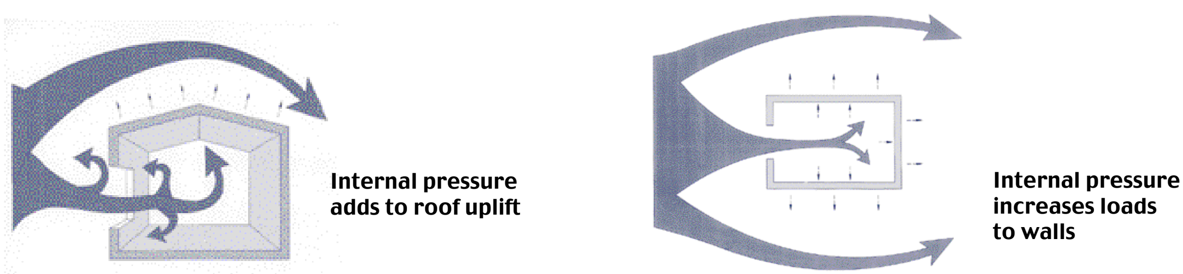
While the initial damage created by wind-borne debris is minor, it sets in motion a dangerous chain reaction. Imagine a two-by-four punches a hole in your home or office window. The wind then knocks out the remaining windowpane, completing the breach of the building envelope.

Now wind can enter your home or office unimpeded, bringing the elements along with it. Rain destroys the floors, walls, furniture, equipment and inventory, as well as doing irreparable damage to precious items such as photographs and family mementos.

Along with the breach of the building envelope, your home or office's internal pressure increases dramatically, adding stress to the structure. This extra internal pressure works in tandem with the external pressures to blow off the roof or, in a worst case scenario, pull apart the entire structure.

By definition, the building envelope is composed of several building components that work together to protect the building's structure and its contents from the elements. The most common building components are windows, doors, siding and the roof system. In high winds, the most vulnerable parts of the building envelope are the windows and doors.

Figure 1



Wind-borne debris broke open the windows. Wind entering the windows led to roof failure.

Windows and doors are especially vulnerable to wind-borne debris.

Who Determines Wind-Borne Debris Requirements?

Simply safeguarding the most vulnerable sections of the building – the doors and windows – can do much to secure the building envelope. Most homeowners and business owners in high-wind regions rely on permanent or temporary shutter systems or impact-resistant window and door systems to protect them. To make sure these owners have access to quality products that will protect their buildings in the event of a hurricane, three organizations have developed and adopted impact resistance test protocols:

- American Society for Testing and Materials (ASTM),
- Southern Building Code Congress International, Inc. (SBCCI) and
- South Florida Building Code commission (SFBC).

A Brief History

In response to the widespread destruction of Hurricane Andrew and the recognized need to protect doors and windows, Dade and Broward Counties in southeast Florida developed, adopted and enforced the first wind-borne debris impact requirements in 1994. In 1999, the South Florida Building Code (SFBC) commission incorporated these requirements into Section 2315, making them a permanent part of the building code.

While SFBC was busy implementing its protocol in southern Florida, SBCCI began working on a test method of its own which would be applicable in the Southeast and Mid-Atlantic regions of the United States. In 1997, the SBCCI Wind Committee finished "SSTD 12-97: SBCCI Test Standard for Determining Impact Resistance from Wind-borne Debris." The SBCCI Wind Committee was unable to convince the entire SBCCI membership to endorse and incorporate the standard into the Standard Building Code (SBC). Consequently, this is a stand-alone document – local and regional building code authorities can adopt it separately from the SBC, though few have.

The differences between SFBC Section 2315 and SSTD 12-97 proved frustrating to manufacturers trying to develop products to meet both protocols. Also, consumers found the situation confusing. The American Society for Testing and Materials saw a need to develop a single consensus national standard for the entire impact-resistant system industry. So in 1996, ASTM began working on ASTM E 1996.[1]

ASTM E 1996 is based largely on the earlier SFBC and SBCCI test methods, but improves upon them in two respects. First, it references the latest version of "ASCE 7: Minimum Design Loads for Buildings and Other Structures", instead of regional codes, to determine wind loads and pressures. Second, this standard specification uses ASTM E 1886[2], a national standard test method for missile and pressure testing adopted in 1997. To date, ASTM E 1996 is the most flexible, well-written and user-friendly standard specification for impact testing and cyclic pressure testing – the two primary test indicators of resistance to wind-borne debris.

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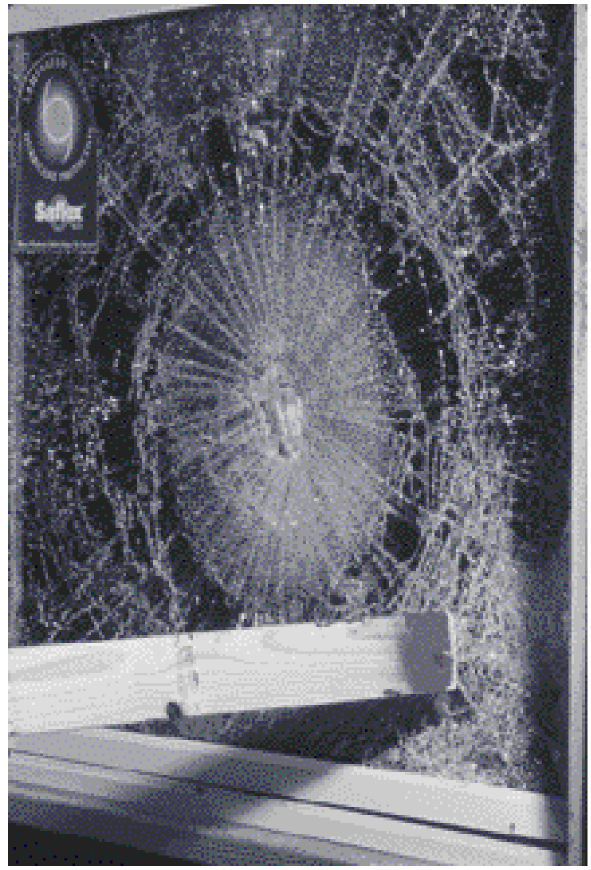


An impact-resistant window system after being hit by a large missile. Though the glass has shattered, it remains intact, thus preventing wind and rain from entering the building.

The Tests

Overall, the three documents are quite similar. Each outlines test protocol and pass/fail criteria for impact resistance. Each requires one or more missile tests on the specimens, followed by a cyclic pressure-loading test. All test specimens must then meet predetermined acceptance criteria. Table I compares the three protocols.

The Impact Test

This test simulates the impact of wind-borne debris on shutters, doors or windows. All three protocols have provisions for both a large missile test and a small missile test. In high-speed winds, heavier, larger objects tend to stay close to the ground. For that reason, the large missile test is required for any product that will be installed less than thirty feet above ground. Gravel and other light objects can be carried to greater heights. Consequently, all three tests use small missiles for products that will be installed higher than thirty feet above ground. For ease in testing, a manufacturer can choose to use the large missile test at all heights.

Table I: Comparison of Three Impact Test Standards

TEST	ASTM	SBCCI	SFBC
Small or Large Missile Test?	The large missile test is required for openings below 30 feet above ground. A small or large missile test is required for openings more than 30 feet above ground.		
Large Missile Test	No. 2 or better Southern Yellow Pine/Douglas Fir 2x4 lumber between 4.5 lbs. and 9 lbs. Traveling between 40 feet per second (fps) and 80 fps.	Agency grade marked 2x4 lumber weighing between 4 lbs. and 9 lbs. and traveling from 40 fps to 50 fps.	2x4 lumber weighing 9 lbs. and traveling at 50 fps.
Small Missile Test	30 spherical steel balls with diameters of 8 mm, weighing 2 grams and traveling at 130 fps.	30 spherical steel balls with diameters of 8 mm, weighing 2 grams and traveling between 130 fps and 132 fps.	30 pieces roof gravel weighing approximately 2 grams and traveling at 80 fps.
Cyclic Pressure-Loading Test [1,2]	Loading Sequence	Sequence Range	Number of Cycles
	1	Positive 0.2P to 0.5P	3500
	2	Positive 0.0P to 0.6P	300
	3	Positive 0.5P to 0.8P	600
	4	Positive 0.3P to 1.0P	100
	5	Negative 0.3P to 1.0P	50
	6	Negative 0.5P to 0.8P	1050
	7	Negative 0.0P to 0.6P	50
	8	Negative 0.2P to 0.5P	3350
Acceptance Criteria	No opening more than 5” long or large enough to allow a 3” diameter sphere to pass (non-porous system).	No opening more than 5” long or large enough to allow a 3” diameter sphere to pass (non-porous system).	No missile penetration and no crack larger than 1/16” wide and 5” long (any system).

General Notes:

1. All of the publishing authorities use the same relative cyclic pressure-loading test, although the maximum pressure “P” changes.
2. “P” denotes the maximum inward (positive) and outward (negative) air pressure differentials defined by the design pressure from the publishing authority.

Missile Type and Size: All three tests use two-by-fours to simulate large missiles and steel balls or roof gravel to simulate small missiles.

- ASTM E 1996:

  The ASTM standard calls for the use of either large or small missiles for testing based on: 1) the height of the protection system above ground; 2) the basic wind speed at the site and 3) the desired level of protection – Enhanced versus Basic. Enhanced Protection is required for essential facilities, such as hospitals and hurricane shelters, and all remaining structures fall under Basic Protection. Tables I and II summarize the criteria for missile selection.

- SBCCI Standard SSTD 12-97:

  The size and weight of the large missile depend on the design wind speed for the region. Tables I and III list this information. SBCCI uses the same type of small missiles as ASTM. See Table I for small missile requirements.

- South Florida Building Code (SFBC):

  The SFBC large missile test is equivalent to the SBCCI standard for a design wind speed greater than 110 mph (fastest-mile). Specifications for the large missile are summarized in Table I.

Table II: ASTM E 1996 Missile Selection Based on Height, Wind Speed and Protection Level

Protection Level	Enhanced Protection [3] (Essential Faciilities)		Basic Protection [4]	
Assembly Height [1]	< 30 ft	> 30 ft	< 30 ft	> 30 ft
Wind Zone 1 [2]	C [5,6]	C [5,6]	B [5,6]	A
Wind Zone 2 [2]	C [5,6]	C [5,6]	B [5,6]	A
Wind Zone 3 [2]	D [5,6]	C [5,6]	C [5,6]	A

Missile Level	Missile Description	Impact Speed (fps)
A	2 gram (±5%), 8 mm N steel ball	130
B	4.5 lb. (±0.25 lb.) 2x4, 4 ft (±4 in.) lumber [7]	40
C	9.0 lb. (±0.25 lb.) 2x4, 8 ft (±4 in.) lumber [7]	50
D	9.0 lb. (±0.25 lb.) 2x4, 8 ft (±4 in.) lumber [7]	80

General Notes:

1. "Assembly Height" refers to the elevation above ground that the system being tested is to be installed.
2. "Wind Zone" refers to the three-second gust wind speed as determined using the latest version of ASCE 7 and the following classification:

   Wind Zone 1 - basic wind speed between 110 and 120 mph

   Wind Zone 2 - basic wind speed between 120 and 130 mph more than one mile away from the coast

   Wind Zone 3 - basic wind speed greater than 130 mph more than one mile from the coast, or greater than 120 mph within one mile from the coast
3. "Enhanced Protection" is intended for essential facilities such as hospitals and hurricane shelters.
4. "Basic Protection" is intended for all other buildings requiring protection.
5. For missiles B, C and D, also use missile A for porous shutter assemblies.
6. Missiles B, C and D consist of a No. 2 or better Southern Yellow Pine or Douglas Fir 2x4 lumber having an American Lumber Standard Committee accredited agency mark.
7. 2x4 missiles should be free of defects within 12 inches of the impact end.

Table III: SBCCI Large Missile Selection Table

Wind Speed [mph(–from SBC, Table 1606)][5]	Large Missile Cannon
90 < Wind Speed ≤ 100	Missile Weight = 4 lbs. Missile Length = 3'-9" Missile Speed = 40 fps
100 < Wind Speed ≤ 110	Missile Weight = 8 lbs. Missile Length = 7'-6" Missile Speed = 40 fps
Wind Speed ≥ 110	Missile Weight = 9 lbs. Missile Length = 9'-0" Missile Speed = 50 fps

General Notes:

1. All weight +/- 1/4 lb.
2. All speeds +/- 1 fps.
3. Wind speed is fastest-mile.
4. All lengths +/- 1'-0".
5. Wind speeds referenced are determined by the Standard Building Code, which uses fastest-mile wind speeds as opposed to the three-second wind gust speeds referenced in ASCE 7 and ASTM E 1996.

Previously, the small missile test used roof gravel, instead of steel balls. As of January 2000, the SFBC requires the use of 5/16-inch diameter steel balls weighing no more than 2 grams. This is consistent with both the ASTM and SBCCI standards. See Table I.

Impact Speeds and Locations: The three tests have some important differences regarding when, where and how fast the missiles hit the specimen.

• ASTM E 1996:

The large missile impact test requires a single impact by a two-by-four piece of lumber on three separate specimens. See Tables I and II for the required speed of the missile and Figure 2 (page 9) for the impact location for each of the three specimens.

The small missile test requires three impact areas on each of three specimens. Ten steel balls simultaneously hit each location as pictured in Figure 3 (page 9). Tables I and II list the appropriate test speed.

• SBCCI Standard SSTD 12-97:

The SSTD 12-97 large missile test calls for two impacts by a two-by-four piece of lumber on each of three test specimens. See Tables I and III for missile speed requirements and Figure 4 (page 9) for location details.

For the small missile test, a total of thirty small missiles, in three groups of ten, hit each specimen at the required speed listed in Table I. Figure 4 (page 9) shows the required impact locations for small missile impact tests.

• South Florida Building Code (SFBC):

Like the SBCCI standard, two missile impacts are required for each of three test specimens.[3] These two impacts occur at the center and near a corner of each specimen, as in the SBCCI test. See Figure 4 (page 9) for missile impact locations and Table I for impact speeds.

The SFBC small missiles also strike the same locations as in the SBCCI tests. See Figure 4 (page 9) for missile impact locations and Table I for impact speeds. Previously, the missile speed was considerably lower than that required for the ASTM and SBCCI tests. Effective January 2000, the SFBC requires that the missiles travel at 130 feet per second, the same as the ASTM and SBCCI tests.

These condominium windows were damaged by wind-borne debris. The additional wind pressure blew apart the walls.

The Cyclic Pressure-Loading Test

Once the impact test is complete, the specimen must hold together under the push-and-pull pressures of a hurricane. Because different regions have different levels of exposure, the three protocols use the design wind speed for the region to establish "P", the maximum positive and negative change in wind pressure. Table I summarizes this portion of the test, which is the same for each of the three test protocols.

The test takes each specimen through a standard hurricane in eight steps (the Loading Sequence). In each step, the specimen is loaded with a varying amount of wind pressure (the Sequence Range), which mimics the build-up in wind speeds as the hurricane passes directly over the specimen. Between Steps 4 and 5, the eye of the hurricane passes and the wind comes from the opposite direction, hence the change from positive to negative pressure. A hurricane never stays at a particular wind speed for more than an instant. To better reflect natural wind gusts and turbulence, a range of test pressures is specified for each step – anywhere from 0.0P to 1.0P. Finally, the Number of Cycles reflects the time spent at a particular wind level.

Definition of "P": Each protocol has a distinct way to determine the maximum air pressure differential.

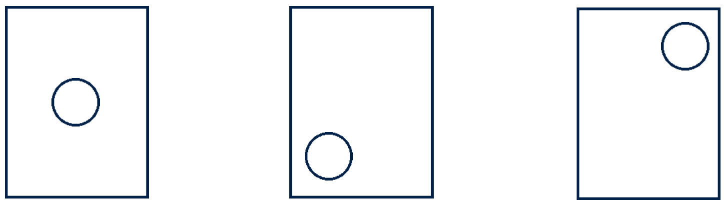
- ASTM E 1996:

  ASTM calculates the maximum positive and negative pressure loads – "P" – from the design Components and Cladding loads specified in the latest version of ASCE 7.

- SBCCI Standard SSTD 12-97:

  The SBCCI standard requires that "P" be equal to the design loads calculated using the Standard Building Code, Section 1606.

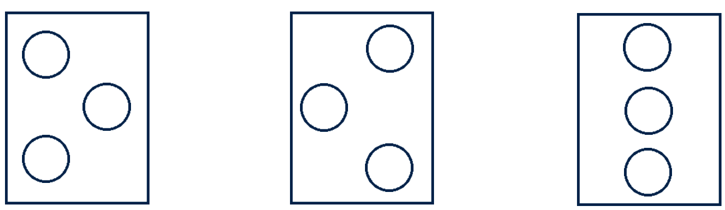
Figure 2: ASTM Large Missile Impact Locations



Specimen I   Specimen II   Specimen III

The circles designating the impacts have a radius of 2.5 inches. The center of the corner impact circles (Specimens II and III) are located 6 inches from supporting members.

Figure 3: ASTM Small Missile Impact Locations

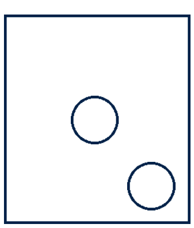


Specimen I   Specimen II   Specimen III

Each specimen consists of a 10-inch radius circle and, except for the center circle, is located 11 inches from any supporting members.

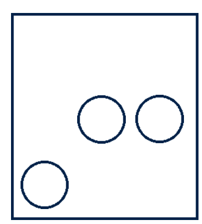
It is acceptable if the impact circles overlap each other due to the size of the specimen being tested.

Figure 4: SBCCI and SBC Large and Small Missile Impact Locations



Large Missile Impact Locations

The first missile must impact the center of the specimen within a 5-inch radius circle. The second missile must impact the specimen within a 5-inch radius circle centered no more than 6 inches away from any supporting member. All three specimens receive impacts in the same locations.



Small Missile Impact Locations

Three groups of small missiles are distributed uniformly over a two square-foot area located at the center of the test specimen, the center of the long dimension of the specimen and at a corner of the specimen. This translates to a circle with a radius of 9.6 inches. All three specimens receive impacts in the same locations.

• South Florida Building Code (SFBC):

To establish a value for "P", the SFBC code references the Components and Cladding loads presented in ASCE 7-93, as opposed to the latest version of ASCE 7.

The Acceptance Criteria

For each of the three protocols, the criteria for passing the impact and cyclic pressure-loading tests depend on whether the system being tested is porous or non-porous.

The following is a discussion on the acceptance criteria for each of the protocols:

• ASTM E 1996:

In order to pass the small and large missile tests, a porous impact protective system must resist the missiles without penetration. The maximum movement of the system during impact and cyclic pressure-loading also must be noted for future installation requirements.

Non-porous systems must resist the missiles and the cyclic pressure-loading, allowing no penetration large enough for passage of a 3-inch diameter sphere and no opening longer than 5 inches. This criteria allows for penetration of the non-porous impact protective system, but does not expose the interior and contents of the building to internal pressurization and extensive water damage.

All three specimens tested must pass both the required missile test and the subsequent cyclic pressure-loading test for ASTM approval.

Impact-resistant systems are considered porous if more than ten percent of the total surface area is open. Examples include screens or nets specially designed to block incoming debris, but not the wind itself. In such a case, the screen stops the missile, and the window prevents wind and rain from entering the building. Non-porous impact protective systems, on the other hand, cover the opening and resist the wind in place of the original window. One example of a non-porous impact protective system is a plywood shutter system.

Look for the ASTM E 1996 approval designation on new products.

• SBCCI Standard SSTD 12-97:

The criteria for passing both the SBCCI missile and cyclic pressure tests are identical to those specified for ASTM E 1996.

The three specimens tested must pass both the required missile test and the subsequent cyclic pressure-loading test for SBCCI approval.

• South Florida Building Code (SFBC):

The SFBC acceptance criteria for both the large and small missile tests are more stringent than the other two tests. Specimens pass if there is no penetration of the impact protective system by the missile and if, during the cyclic test, no crack forms longer than 5 inches or wider than 1/16 inch through which air can pass.

All three specimens being tested must pass both the required missile test and the cyclic pressure-loading test for approval for use in south Florida.

Conclusions

Hurricane Andrew demonstrated once and for all that windows and doors are susceptible to damage from wind-borne debris. In response, both the South Florida Building Code officials and the Southern Building Code Conference International put much time and effort into developing impact resistance test protocols. Each standard is intended to ensure that compliant products would perform with a minimum level of wind-borne debris resistance. While these two tests are similar in nature, they require manufacturers of impact-resistant systems to perform two separate sets of tests. Also, consumers found it difficult to distinguish between the two test standards.

Clearly a consensus national standard is necessary – regional test protocols simply are not in the best interest of the industry. The recent development of ASTM E 1996 is a step in the right direction. While based mainly on the earlier SFBC and SBCCI standards, this comprehensive standard incorporates the latest versions of other related national standards, such as ASCE 7. It is also the most flexible and well-organized standard on the topic. As we increase our understanding of the interaction between wind-borne debris and the building envelope, ASTM E 1996 will be updated to reflect this new information. IBHS will continue to participate on the committee responsible for both ASTM E 1996 and ASTM E 1886 (ASTM Committee E 06.51.17).

As a homeowner, business owner or insurer in high-wind regions, you should look for products that have been tested to meet, as a bare minimum, one of these three test protocols for the appropriate location on your building (i.e. above or below 30 feet). On new products, look for the ASTM E 1996-approved designation. This standard ensures that you get the best quality product available.

Do Wood Structural Panels Provide Sufficient Last-Minute Protection for Windows and Doors in a Hurricane?

Typically, home- and business owners wait until the last minute to protect their windows and doors against an approaching hurricane. Often their only option is to fasten wood structural panels over the vulnerable openings. Currently, "SBC Appendix J, Special Requirements for Buildings Constructed in Hurricane-Prone Regions"[4] provides homeowners with a detailed method for low cost, do-it-yourself protection using wood structural panels.[5]

Until recently, this prescriptive method had never been tested to any impact resistance protocol. Since this method has now been incorporated into the next generation of model codes, the IBC and the IRC, it was time for the method to be evaluated using one of test methods summarized in this paper – SBCCI

Table IV: Revision of Table J103

	Fastener Spacing			
Fastener Type	**Panel Length < 2ft**	**2ft ≤ Panel Length < 4 ft**	**4 ft ≤ Panel Length < 6 ft**	**6 ft ≤ Panel Length ≤ 8 ft**
10d Double Hd. Nails	16”	6”	4”	4”
16d Double Hd. Nails	16”	9”	6”	4”
2 1/2” #6 Screws	16”	16”	12”	9”
2 1/2” #8 Screws	16”	16”	16”	12”

General Notes:

1.This table is based on 110 mph wind speeds and a 33-foot mean roof height.
2. Fasteners shall be installed at opposing ends of the structural panel.
3. Nails shall be 10d or 16d double-headed nails.
4. Where screws are attached to masonry or masonry/stucco, they shall be attached utilizing vibration anchors having a minimum withdrawl capacity of 490 pounds.

Standard SSTD-12-97. This standard was used instead of ASTM E 1996 only because ASTM had not finalized E 1996 at the time of the testing in 1998.

The testing, sponsored by IBHS[6], demonstrated that this system was effective overall, but contained some inconsistencies and ambiguities – the nail type specified in Table J103 proved unclear and the required spacing was inadequate to pass SSTD-12 consistently. Table IV shows IBHS' recommended modifications. In particular, the nail listing should remain as "Double-Headed Nails", but the footnote must be modified, calling for either 10d or 16d double-headed nails. In addition, the fastener spacing for panels between two- and four-feet long should change from 9 inches to 6 inches. The spacing for panels between four- and six-feet long should be modified from 6 inches to 4 inches. While the recommended decrease in the spacing for 10d double-headed nails may seem conservative, it allows for continued use of the fastener. If a homeowner is willing to increase the fastener size to 16d double-headed nails, the spacing requirements remain the same as originally recommended in Table J103. Either way, the use of the double-headed nails makes the removal of the panels after a storm easier than if single-headed common or box nails were used.

A test sample from IBHS' study.

While building code officials and Appendix J requirements allow the use of nails, screws and pre-installed anchors, IBHS recommends that only wood structural panels fastened with pre-installed anchors be recognized as meeting the impact resistance requirements.[7] Last minute installations of panels with nails, and even screws to some extent, lack the reliability and confidence necessary to predict if the panel will stay on through a hurricane. But for homeowners who continue to put up wood structural shutters as a last minute quick fix, the method presented in Appendix J provides some basic protection if, and only if, the fastening schedule in Table IV is followed with diligence.

Endnotes

[1] ASTM E 1996: Standard Specification for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Wind-borne Debris in Hurricanes.

[2] ASTM E 1896: Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials.

[3] This standard also allows for single impacts on specimens if a total of six specimens is used.

[4] While this document is not directly referenced in the SBC, it is available for areas to adopt and enforce as needed.

[5] Appendix J recommends installing wood structural panels over unprotected openings. Acceptable panel materials include both plywood and OSB (Oriented Strand Board). The minimum 7/16-inch thick panels should be secured to the home's structure on two opposing sides. The appendix lists the required size of the fasteners – either double-headed 10d common, double-headed 12d box nails, #6 wood screws or #8 wood screws. The fastener schedules are based on a 110-mph fastest-mile design wind speed and a 33-foot mean roof height. The 110-mph fastest-mile wind speed is consistent with the maximum design wind speed found in the Standard Building Code and covers all areas excluding Dade and Broward counties. These counties have already established impact resistance criteria that are equal to or greater than the SBCCI standard.

[6] Hurricane Test Laboratory, Inc, Missile Impact and Cyclic Load Test Reports, SBCCI SSTD 12-97, 'IBHS #1 and IBHS #2', Riviera Beach, FL, March, 1998.

[7] APA – The Engineered Wood Association recommends using pre-installed #10 screws at each corner and 6 inches on center on two opposing sides. More information on APA – The Engineered Wood Association's Hurricane Shutter Design can be obtained from their web site, www.apawood.org.

References

For further details on a specific protocol, you may want to obtain the following documents:

American Society for Testing and Materials. ASTM E 1996-99: Standard Specification for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Wind-borne Debris in Hurricanes. Philadelphia, PA: ASTM, 1999.

American Society for Testing and Materials. ASTM E 1886-97: Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials. Philadelphia, PA: ASTM, 1997.

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