Hurricane Performance

Protecting the Building Envelope

Under normal circumstances, buildings are designed to allow wind to flow over the structure. During a hurricane, a fully intact building envelope or "outer skin" allows wind to flow at, over and past the structure without damage. Preserving the building envelope, therefore, is among the most important steps to maintaining the integrity of the structure and ensuring non-destructive windflow during hurricane-force winds.

During the sustained, high-speed winds of a hurricane, objects can be lifted and become an airborne missile or wind-borne debris. Large missiles, such as roof shingles and other construction materials, are common at heights up to 30 ft. (9 m) above grade; small missiles, such as roof gravel, are most prevalent at heights above 30 ft. (9m).

When wind-borne debris breaks glass windows and doors, the building's protective exterior "envelope" is compromised, potentially allowing strong winds to rush into the structure. These trapped wind forces then exert tremendously increased pressure on the roof and outward pressure on exterior walls, and can eventually cause total destruction.

Laminated glass with Saflex® interlayers in properly designed windows and doors can withstand the damaging impact of wind-borne debris and remain in the opening during the remainder of the storm and may even function as a barrier after being broken, helping to preserve the integrity of the interior until repairs can be made.

Summary Chart of Saffir-Simpson Hurricane Scale

CATEGORY	WIND SPEED	STORM SURGE(HT)	DAMAGE
1	74-95 mph (119-153 kph)	4-5 ft. (1.2-1.5 m)	**Minimal** (Typically non-structural elements)
2	96-110 mph (154-177 kph)	6-8 ft. (1.8-2.4 m)	**Moderate** (Roofing materials, door and window damage, some trees toppled)
3	111-130 mph (178-209 kph)	9-12 ft. (2.7-3.7 m)	**Extensive** (Structural damage to wall residences and utility buildings, minor amount of curtain wall failure)
4	131-155 mph (210-249 kph)	13-18 ft. (3.9-5.5 m)	**Extreme** (More extensive curtain wall failures, complete roof structure failures, extensive damage to doors and windows)
5	>155 mph (>249 kph)	>18 ft. (>5.5 m)	**Catastrophic** (Complete roof and building failures, complete destruction of mobile homes, severe window and door damage, massive evacuation of residential areas within 5-10 miles of shoreline may be required)

Codes and Standards

Meeting Building Codes and Standards

In order to meet hurricane building codes, commercial and residential window and door systems have to meet vigorous impact, simulating wind-borne debris and subsequent impact. Test procedures call for the entire system to resist wind-borne debris impact followed by pressure cycling. To comply with the test requirements for an impact-resistant product, the systems may also need to pass additional tests such as air and water infiltration, structural load and forced-entry resistance.

Properly designed window and door systems incorporating laminated glass made with Saflex®, Saflex HP® or Vanceva Storm® interlayers perform well during large missile impacts and cycling. When focusing on the use of laminated glass, it is critical to understand the importance of the overall system design including:

- Glass size of the window or door opening
- Glazing installation within the frame
- Framing component design
- Glazing materials thickness and composition

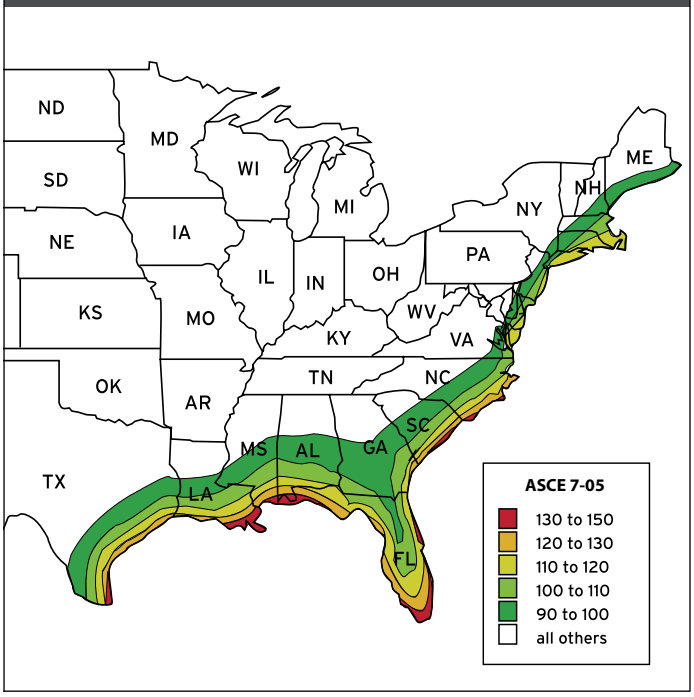
Solutia's Saflex, Saflex HP and Vanceva Storm interlayers help properly designed laminated glass openings meet the tough testing requirements for hurricane resistance. Solutia's interlayers are commonly found in windows, doors and skylights that meet the most stringent hurricane resistant system requirements for performance and qualify for all state approval programs including:

- Model building codes such as International Building and Residential Codes (IBC and IRC)
- State product approval programs including Florida Building Code (FBC) and the Texas Department of Insurance (TDI)
- Relevant testing protocols and standards including Dade County TAS 201, 203, ASTM E1886, ASTM E 1996 and SSTD 12

Where the Standards are Applied

The map below indicates the wind speeds in the ASCE 7 standard that tend to govern the ASTM impact standards. The ASTM test method has a corresponding specification, ASTM E 1996, that indicates what missile size shall be used depending upon application and wind speed, location of impact, pass/fail criteria and substitution limitations. For example, below 30 feet from grade is typically the zone for impact by a timber (large missile), whereas above 30 feet from grade is the zone for impact by 2 gram steel ball bearings (small missile).

ASCE 7-05 Windspeed Map



Missile and Wind Zone Chart for ASTM E 1996

MISSILE LEVEL	MISSILE	IMPACT SPEED FEET/SEC (MPH)	TYPICAL USE
LEVEL A	2 gram steel ball (small missile)	130 (89) 39.6 m (143 km/hr)	Above 30 ft. (9 m) Wind Zone 1 through 4 FBC & HVHZ Area
LEVEL B	2 lb. lumber	50 (34) 15.2 m (54 km/hr)	Skylights ≤ 30 ft. (9 m) Wind Zone 2 (Basic)
LEVEL C	4.5 lb. lumber	40 (27) 12.1 m (43 km/hr)	Less than 30 ft. (9 m) Wind Zone 1 & 2 (Basic)
LEVEL D	9 lb. lumber (large missile)	50 (34) 15.2 m (54 km/hr)	Less than 30 ft. (9 m) Wind Zone 3 & 4 (Basic) Wind Zone 1 & 2 (Enhanced)
LEVEL E	9 lb. lumber	80 (55) 24.3 m (88 km/hr)	Less than 30 ft. (9 m) Wind Zone 3 & 4 (Enhanced)

Wind Speed and Missile Chart of Basic Level Protection

WIND ZONE	WIND SPEED MPH (KM/HR)	HVHZ MISSILE Level ≤ 30 ft. (9 m)	ASTM BASIC MISSILE Levels ≤ 30 ft. (9 m)	ASTM & FBC SMALL MISSILE > 30 ft. (9m)
1	110 (177)	D	C (B for skylights)	A
2	120 (193)	D	C	A
3	130 (209)	D	D	A
4	140 (225)	D	D	A

Saflex® Hurricane Protection

Designing Impact-Resistant Systems

As codes and standards evolve, it is critical for architects and designers to gain an understanding of window system requirements to meet hurricane regulations – and laminated glass made with Saflex®, Saflex HP® or Vanceva Storm® is the best place to begin.

When designing hurricane-resistant window and door systems, the key elements are the framing system, laminated glass and sealant. All must work together to withstand air and water infiltration, structural, impact and cycling loads. Different interlayers and thicknesses have a direct effect on the performance during impact and cycling loads.

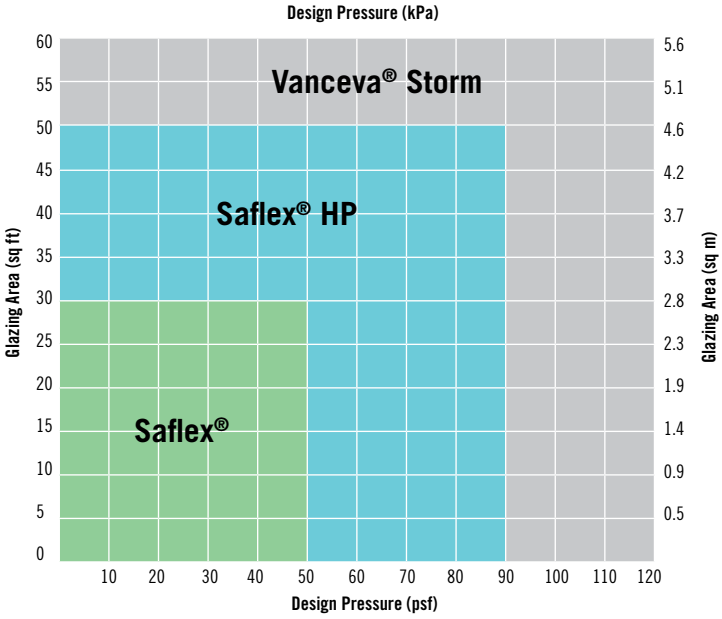
As shown in the following chart, interlayers are recommended based on window type, glass size, geometry and performance pressure. For instance, a typical large missile system (or window system below 30 ft.) utilizes laminated glass with an interlayer that is 0.090 in. in thickness, while thinner, specialty interlayers using composite technology are also available (Vanceva Storm 0.075 in. thick). A typical small missile system (or window system above 30 ft.) utilizes laminated glass with an interlayer that is a minimum of 0.060 in. in thickness.

Designing for Essential Facilities: Level E Protection

While most hurricane-related building codes are designed to protect homes and businesses during a hurricane, experts still advise people to evacuate. A tough building standard known as ASTM E1996 "Level E" was designed to protect essential facilities like hospitals, emergency shelters and institutions, where the people inside usually do not have an option to evacuate. However, until now, there were few solutions available for achieving Level E. Those that were available were so costly that they were often value-engineered out of the plans.

In early 2008, Saflex introduced a hurricane interlayer system that could meet Level E in a single piece of laminated glazing. The new Saflex Level E hurricane solution uses a combination of Saflex's most powerful interlayers, laminated between two pieces of glass under heat and pressure. The resulting piece of glass looks and functions like a single piece or ordinary glass but is stronger and tougher than even standard laminated glass. It's a convenient and cost-effective solution for architects and building owners who demand the highest level of protection.

Typical Glass Performance for Standard Four Side Glazing Using Recommended Conditions.



Note: Experienced product performance. Based on panels glazed with structural silicone, minimum 12 mm (1/2 in) glass bite; standard test temperatures 15 – 35 degrees C (59 – 95 degrees F). Not guaranteed for all samples.

Typical Standards for Wind-Borne Debris Impact Tests

Large Missile Impact Test (For windows, doors, skylights, glazing and shutters between grade and 9 m [30 ft.] above grade)	**Three identical test specimens.** • Missile is 5 x 10 cm timber weighing 4 kg (2 x 4 in. timber weighting 9 lbs.). • Two impact points at 15 m/sec (50 ft./sec.): one at center and one within 15.2 cm (6 in.) of a corner • All three specimens must survive impacts without penetration before proceeding to cyclic pressure loading.			
Small Missile Impact Test (For windows, doors, skylights, glazing and shutters above 9 m [30 ft.] above grade)	**Three identical test specimens.** • Missile is steel sphere weighing 2 gm (0.07. oz.). • 30 small missile impacts at 40 m/sec (130 ft./sec.): 10 at center, 10 near long edge, 10 near corner • All three specimens must survive impacts without penetration before proceeding to cyclic pressure loading.			
FOLLOWED BY: **Cyclic Pressure** (Applied to all three specimens following large or small impact tests; duration of each cycle is 1-3 seconds; all inward-acting pressure cycles are applied first, followed by outward-acting cycles.	**Inward Acting Pressure**		**Outward-Acting Pressure**	
	RANGE	CYCLES	RANGE	CYCLES
	0.2Pmax-0.5Pmax	3,500	0.3Pmax-1.0Pmax	50
	0.0Pmax-0.6Pmax	300	0.5Pmax-0.8Pmax	1,050
	0.5Pmax-0.8Pmax	600	0.0Pmax-0.6Pmax	50
	0.3Pmax-1.0-Pmax	100	0.2Pmax-0.5Pmax	3,350

Pmax is design wind pressure (inward and outward) from the building code, based on an unbreached building envelope.

All three specimens must survive the missile impacts as outlined for a specific standard. If no tear or crack longer than 12.7 cm (5. in.) or no opening through which a 7.6 cm (3 in.) sphere can pass has formed in any of the three specimens upon completion of the pressure cycles, they are deemed to have passed the test. See specific test method, code protocol or specification for individual pass/fail criteria.

Technical Performance

Additional Benefits of Laminated Glass

In additional to the proven hurricane-protection capabilities, Saflex®, Saflex HP® and Vanceva Storm® interlayers deliver all the other benefits inherent in laminated glass:

- **Safety:** Protecting building occupants and pedestrians from accidental glass impact, breakage, or fallout.
- **Security:** Providing burglary and forced-entry resistance, ballistic (bullet) protection and bomb blast resistance.
- **Acoustic:** Reducing the transmission of unwanted sound into a building's environment.
- **Solar:** Filtering more than 99 percent of UV rays, controlling visible light radiation & reducing heat build-up & thermal stress.

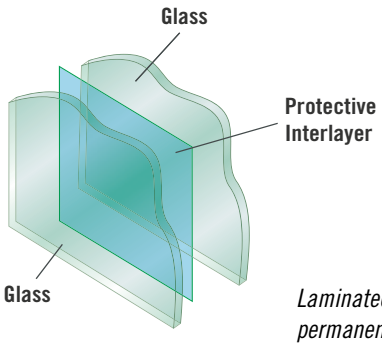
In addition, Saflex interlayers for hurricane protection are available in a range of earth- and sky-tone shades, enabling architects to specify laminated glass to match industry standard tinted glazing. Interlayers are also avaliable in a range of translucent whites that can be used alone or combined with Saflex standard colors to create a broad array of hurricane performance and aesthetic designs.

For additional information regarding designing for Hurricane protection using Saflex interlayers including technical information specific to Hurricane testing requirements, call 1-877-674-1233.

Extreme Wind & Impact – Glass Constructions		
MISSILE	CODE/STANDARD	GLASS CONFIGURATION
Large	FBC TAS 201/3 Dade	Glass – 2.29 mm (0.090") Saflex – Glass Glass – 2.54 mm (0.100") Saflex HP – Glass Glass – 1.91 mm (0.075") Vanceva VS 02 – Glass
Large	SBCCI Apdx SSTD-12	Glass – 2.29 mm (0.090") Saflex – Glass Glass – 2.54 mm (0.100") Saflex HP – Glass Glass – 1.91 mm (0.075") Vanceva Storm – Glass
Large	ASTM E1996	Glass – 2.29 mm (0.090") Saflex – Glass Glass – 2.54 mm (0.100") Saflex HP – Glass Glass – 1.91 mm (0.075") Vanceva Storm – Glass
Small	FBC TAS 201/3 Dade	Glass – 1.52 mm (0.060") Saflex* – Glass
Small	SBCCI Apdx SSTD-12	Glass – 1.52 mm (0.060") Saflex* – Glass
Small	ASTM E1996	Glass – 1.52 mm (0.060") Saflex* – Glass

*** Typical minimum gauge interlayer for indicated performance. Large missile automatically qualifies for small missile applications. Glass thickness and type determined by use of ASTM E 1300.**

Saflex Hurricane Products and Physical Properties				
PROPERTY	UNITS	TEMPERATURE	TEST	TYPICAL VALUES
Emissivity	–	19.5 °C	ASTM C1371	0.94
Tensile Strength	kg/cm2	23 °C	JIS K6771	260
Elongation	% strain	23 °C	JIS K6771	230
Specific Heat	J/kg°K	40 to 80 °C	ASTM E1269	2,190
Thermal Conductivity	W/mK	32 to 90 °C	ASTM D5930	0.200
Specific Gravity	–	22°C	ASTM D792	1.07
Refractive Index	–	23 °C	Interference Microscopy	1.485
Properties of Saflex HP Interlayer Saflex HP Physical Property Data (interlayer only)				
PROPERTY	UNITS	TEMPERATURE	TEST	TYPICAL VALUES
Emissivity	–	19.5 °C	ASTM C1371	0.94
Tensile Strength	kg/cm2	23 °C	JIS K6771	240
Elongation	% strain	23 °C	JIS K6771	190
Specific Heat	J/kg°K	40 to 80 °C	ASTM E1269	2,190
Thermal Conductivity	W/mK	32 to 90 °C	ASTM D5930	0.200
Specific Gravity	–	22°C	ASTM D792	1.06
Refractive Index	–	23 °C	Interference Microscopy	1.488



Laminated glass is formed by permanently bonding an interlayer between two pieces of glass.