

CONSUMER REFERENCE EDITION

Project Safe Windows

FINDING THE BREAKING POINT

A Protecting People First Foundation Report

Documenting Window Performance in the 2004 Florida Hurricanes



CHARLEY



FRANCES



IVAN



JEANNE



A Protecting People First Foundation Report
Engineering analysis provided by ABS Consulting

2004 FLORIDA HURRICANES

► Project Safe Windows - An Overview

The 2004 hurricane season brought unprecedented devastation to the residents of Florida and the Gulf Coast. Combined, hurricanes Charley, Frances, Jeanne and Ivan caused over 100 deaths and billions of dollars in property damage.

The Protecting People First Foundation, an organization dedicated to protecting people and property through technology awareness, saw an opportunity to study the deadly lessons offered by these hurricanes and share them with the public in the hopes that future death, injury and property loss can be mitigated in similar disasters.

To this end, the Foundation launched Project Safe Windows, an engineering-based initiative, to study the impact of these four powerful hurricanes on various window-protection technologies.

A team of engineers from ABS Consulting, an internationally recognized risk-management firm, joined with field researchers from the Foundation to study the performance of windows and protective-glazing technology in more than forty homes, businesses and public facilities. Collectively, this team documented outcomes ranging from total devastation due to insufficient window protection, to miraculous mitigation of nature's wrath thanks to modern technology. They also documented a death resulting from flying debris; this death could have been prevented had proper technology been in place.



Photo courtesy PGT Industries

Protective glazing works, however, not all products work equally. Some are more effective than others and the difference among performances of various technologies is dramatic in some cases.

Finding the Breaking Point is offered to the public, emergency management officials, the insurance industry, facility managers and any other interested parties in the hope that the valuable lessons documented within this report lead to greater safety in the future.

This aerial photograph demonstrates the devastating impact of Hurricane Charley.

▶ Methodology of Study

The research undertaken by the Project Safe Windows engineers and researchers involved site inspection of damaged properties and extensive interviews with property owners, building contractors and insurance adjusters. Photographs of each subject property were taken to further document the evidence described in this report.

Where appropriate, physical measurements of windows and window openings were taken. Wind speed calculations in the area of the subject properties were determined by ABS engineers using USWIND,™ a catastrophic modeling program developed by EQECAT,™ a subsidiary of ABS Consulting. The wind field model incorporated in USWIND™ is based on a model developed by the National Oceanic and Atmospheric Administration, with model inputs derived from information provided by the National Hurricane Center. The Florida Commission on Hurricane Loss Projection Methodology has extensively reviewed the program, and certified it for use in the State of Florida for insurance-related purposes. It should be noted that only Hurricane Charley was a “design event” meaning that it was a storm with wind speeds in excess of a building’s design capacity to remain intact.

The window protection technologies studied are listed below. Included in this report is a technical description of each technology, along with field observations about the performance of each technology in the four hurricanes as documented by Project Safe Window team members:

Protective Technologies profiled in this report include:

- ▶ Hurricane Shutters
 - Accordian Shutters
 - Roll Down Shutters (manual and motorized)
 - Panel Shutters
- ▶ Hurricane Screens
- ▶ Impact Resistant Glass (Laminated glass)
- ▶ Plywood
- ▶ Safety and Security Window Film
- ▶ Tempered Glass
- ▶ Insulated Glass Units

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► Descriptions and Performance Characteristics of Window Protection Technologies

Glass is a part of our every day life. While it provides a window to the world, glass can also become a lethal weapon when nature's fury strikes. As a result, many technologies have been developed to provide protection against flying glass and also to protect glass windows in buildings from wind pressure and wind-borne debris.

This section of the report provides a general technical description of the types of protective glazing studied by Project Safe Windows engineers and researchers.

Glass design involves several considerations by the architect and engineer, including light admittance, thermal transmittance, aesthetics, design loads, and assembly. A wide variety of window materials and assembly options are available. Glass is a brittle material that behaves elastically up to its ultimate tensile strength. Glass fails in tension at relatively low stress levels because of numerous sub-microscopic surface cracks. For this reason, care must be exercised in the selection of mounting methods and during frame design, since stress levels sufficient to fracture glass are possible if the pane is restrained against movement.

The most common type of glass is annealed glass, a reflection of the glassmaking process where sheets of glass are cooled slowly before reaching the cutting table. When ordinary annealed glass is struck by an object and subsequently broken, several large cracks typically form, resulting in the creation of large glass shards that can be potentially hazardous if they fall or blow away from their frames.

Moving Beyond Annealed Glass – Where Protection Against Mother Nature Begins

► Heat-strengthened glass and fully-tempered glass

Heat-strengthened glass and fully-tempered glass are created by exposing glass to a process of reheating and sudden cooling. The resulting product is two to five times stronger than ordinary annealed glass of the same thickness, and is also more resistant to thermal shock. Another benefit is that, unlike ordinary annealed glass, tempered glass usually breaks into many small pieces, posing a less serious threat to persons nearby if glazing fallout were to occur, or if a person accidentally impacts the glass. For this reason, tempered glass is commonly used in swinging doors, sliding patio doors and storefront windows. Project Safe Windows researchers documented several examples of this glass type in the case studies included in this report.



This picture clearly shows the large number of dangerous annealed glass shards produced by the broken windows several floors above ground level. Not only was the immediate area below the windows filled with glass and broken frame debris, but jagged and sharp wind-borne debris was carried many yards away from the building perimeter.



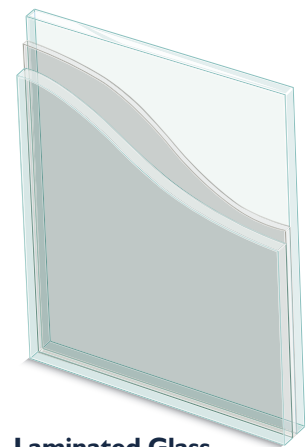
The expansive panels of annealed glass did not fare well in this building during Hurricane Jeanne. Many panels were damaged either by the sheer force of the wind or by being impacted by flying objects. Several glazing options could have either allowed the panels to survive entirely intact or at least reduced or even eliminated the scattering of glass shards.

► Insulating glass (IG)

Insulating glass (IG) is made up of two panes of glass separated by a spacer around the perimeter, with a sealant applied to bond the plates to the spacer to form a hermetically sealed unit. IG units provide better thermal insulation, reduce external noise, and greatly restrict condensation when compared to single pane glass. IG units are common in multi-story office buildings, and are becoming more widespread in residential construction. From the standpoint of hurricane protection, IG units offer the added benefit of placing two panes of glass between building occupants and the exterior elements. Thus, the outer glass pane provides a level of debris-impact protection for the inner glass pane. Post-storm investigations have uncovered instances where the outer pane of an IG unit broke, while the inner pane remained intact, thus preserving the integrity of the window enclosure.

► Laminated glass

Laminated glass consists of a tough plastic interlayer made of polyvinyl butyral (PVB) or ionoplast bonded between two panes of glass under heat and pressure. Once bonded, the glass sandwich behaves as a single unit and looks like an ordinary single pane of glass. Laminated glass is a durable, high performing, aesthetically pleasing product. Once broken, the interlayer will usually keep the broken glass pieces together and in place inside the window frame if properly glazed. For this reason, combined with the benefits of increased strength due to the presence of two bonded plates, annealed glass is used instead of tempered glass to allow sight through it in the event one or both of the panes are broken. Annealed glass is also primarily used in laminated glass because it is so much less expensive than tempered glass and because it is much more easily cut. Composite glass is another category of laminated glass which utilizes layers of either annealed or tempered glass, PVB, polyester and an abrasion-resistant coating. Numerous case studies were developed on laminated glass as part of the Project Safe Windows initiative.



Laminated Glass

► Window Films

Safety and security and solar control window films are applied to the surface of a glass pane to absorb heat, reflect sunlight, or to contain fallout after breakage. Window films are designed for two primary uses; solar control and security protection. There are films that provide both security protection and solar control properties. When it comes to protection afforded against wind-borne debris, there is a clear difference between solar control window film, which is generally 1.5 – 2 mil (.0015-.002 in.) thick, and security window film, which ranges in thickness from 4 mil to 15 mil.

Safety and security window film is a single or multi-layered polyester film that transforms ordinary window glass into a shield against dangerous flying or falling shards of glass, which can result in death, serious injury and extensive property damage. The thicker multi-layered laminates of clear or tinted films use an adhesive to hold the window glass together when it is shattered by terrorist bombings, accidental explosions or by forces of nature like hurricanes. This adhesion to glass fragments eliminates dangerous shard formation which occurs in untreated glass. Applied security and safety film dramatically reduces the hazards to personnel from flying glass.



Window Film

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Providing Protection Beyond the Window

In addition to the protective glazing technologies described above, Project Safe Windows researchers evaluated other technologies that afford protection against wind-borne debris in a hurricane. These technologies include:

▶ Hurricane shutters

Hurricane shutters are typically made of metal, vinyl or occasionally clear polycarbonate and come in a variety of styles. Some, such as roll-downs, sliding, and hinged, are permanently affixed to the exterior of the window or door and can be put in place manually or mechanically. Others are bolted or screwed into place at first signs of a major storm event.

Hurricane shutters provide excellent protection against damage from rain and wind as well as forced entry. They can be used to enclose and protect outdoor areas such as balconies as well.



Hurricane Shutters



Hurricane Screens

▶ Hurricane Screens

Hurricane screens are usually constructed of a permanently mounted durable metal “see through” mesh or a woven polypropylene netting which can be temporarily installed prior to the onset of a storm.

▶ Plywood

Plywood is constructed of a number of thin layers of wood called plys or veneers which are bonded together using synthetic or natural glues. Typically adjacent layers of wood are bonded with their grain directions at right angles to one another which enhances the strength of the product.



► The Consumer Guide to Window Protection in Hurricanes

	Large Missile Impact	Small Missile Impact	Passive Protection	Pre-storm Installation	Cost Per Sq. Foot ²	Insurance Premium Discount
MIAMI-DADE CODE-COMPLIANT						
Hurricane Shutters						
Accordion	Yes	Yes	Partial ⁶	Yes	\$16-\$25	Yes
Rolldown	Yes	Yes	Partial ⁶	Yes	\$35-\$50	Yes
Panel ⁴	Yes	Yes	No	Yes	\$8-\$12	Yes
Hurricane Screens						
Rigid	Yes	Yes	Yes	Yes	\$15-\$22	Yes
Flexible	Yes	Yes	Partial ⁶	Yes	\$10-\$15	Yes
Laminated Glass⁸	Yes	Yes	Yes	No	\$27-\$37	Yes
NON-MIAMI-DADE CODE-COMPLIANT						
Plywood^{4, 5} (7/16" minimum)	No	Yes	No	Yes	\$2-\$4	No
Tempered Glass⁷	No	No	Yes	No	\$20-\$40	No
Insulated Glass Unit⁷ (Non-Tempered Glass)	No	No	Yes	No	\$10-\$15	No
Security Window Film^{1, 3} (Mechanical Attachment)	Partial	Yes	Yes	No	\$15-\$35	No
Security Window Film¹ (Wet Glaze Attachment)	No	Yes	Yes	No	\$12-\$22	No
Security Window Film¹ (Unattached)	No	Partial	Yes	No	\$5-\$12	No
Solar Control Window Film¹	No	No	No	No	\$3-\$5	No
Annealed Glass⁷	No	No	No	N/A	\$8-\$15	No

1. Industry experts report that after application, films may take anywhere from two weeks to three months to "dry" and attain their maximum level of effectiveness.

2. In comparing costs of employing protective glazing solutions, consideration must be given to the replacement costs of shattered glass, often high, if the installed technology operates as intended in holding shattered glass intact. Also, due to sometimes significant regional differences in labor costs for installing these mitigation products, prices may vary in your area.

3. A limited number of mechanically anchored and wet glazed security film systems have reportedly passed various hurricane testing protocols.

4. Labor costs for deploying this type of protection may be in the range of \$300 per storm event.

5. Meets Florida Building Code requirements for wind zones up to 130 mph.

6. Classified as partial passive protection because the installed technology must actually be deployed to be effective.

7. Glass prices, particularly for tempered glass, may vary dramatically according to thickness.

8. In new construction, the cost of laminated window glass should be compared to the cost of any other window glass *plus* the cost of any additional glazing protection for that window.

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► Report Findings and Recommendations

- Modern building codes are intended primarily to provide a minimal level of protection for people and property from hazards associated with natural disasters. The public should adhere to applicable building codes at all times. The public should also consider upgrading existing properties to meet current building codes whenever possible, even when such upgrades are not required by law.
- The majority of buildings in Florida are not subject to the most current and more stringent building codes that require impact-resistant glazing, hurricanes shutters, hurricane screens, mechanically attached security window film, or other code-compliant technologies. These property owners should be advised that if they are unable to afford upgrading their property to become code compliant, they should consider other protective glazing technologies that, while falling short of current building codes, may provide meaningful levels of property protection. These technologies are profiled in this report.
- Residents of homes with hurricane protection, including protection that meets the most stringent building codes, should never be lulled into a false sense of security that they are not in danger during a hurricane while in their home. People should heed evacuation warnings even if they have window protection in place.
- Security window film performance could be systematically improved if more applications used a wet glaze silicone to adhere window film to the frames of a window or mechanical attachment systems.
- Solar control window film should never be considered acceptable protection against hurricane force winds. It is designed for solar control purposes and any safety benefit is incidental. Safety and security films are designed specifically to hold glass fragments together when glass breaks.
- Both the public and private sectors should encourage and support local and state consumer protection agencies in efforts to curb overly aggressive vendors who overstate the protection afforded to consumers by any window protection technology.
- The insurance industry should focus more on tracking and reporting home damage due to failure of building openings such as windows. This analysis on the amount of hurricane related property damage due to building opening failures would likely lead to greater use of protective glazing technologies.
- The government and financial institutions should offer low cost loans to home owners and business owners who invest in protective glazing technologies. Discounts should reflect effectiveness of technology.
- Current damage prediction models used by the State of Florida to predict how a structure will perform in various hurricane conditions should evaluate technologies that do not meet building codes but still provide meaningful levels of protection. This would provide valuable information to millions of property owners who are not subject to current building codes but who could benefit from the protection of technologies that are proven effective in varying degrees. This information would also prove valuable to insurance companies who could use the modeling data to make decisions about premium rebates that could be provided to property owners based on the type of protective glazing installed.

- ▶ Additional research can provide valuable insight into the performance of structures against hurricane wind loadings. Following Hurricane Charley, a team of field researchers from Applied Research Associates (ARA) inspected nearly 300 homes as part of a research effort to study the validity of ARA's modeling program used by the State of Florida to predict property damage in various hurricane conditions. The Federal Emergency Management Agency (FEMA) should provide the funding necessary to allow companies like ABS Consulting and ARA to develop additional data and complete analysis of how the structures studied performed in actual hurricane conditions as compared to projected performance in the currently available models.
- ▶ Building code officials should consider training personnel to conduct periodic field inspections of technologies meeting building codes to ensure that these technologies are installed in the field in accordance with the test protocols that resulted in the certification of technologies as code compliant.
- ▶ A public awareness campaign should be undertaken to promote the value of protective glazing. The PPF stands ready to lead this initiative and will work with other partners committed to public safety and personal protection to implement such a campaign.



Damage to homes from Hurricane Charley in North Captiva



- ▶ Satellite photos on cover courtesy National Oceanic and Atmospheric Administration (NOAA)
- ▶ The Protecting People First Foundation provides this Project Safe Windows report for general information only. The information contained in this report is based on sources we believe reliable, but we do not guarantee its accuracy. The Foundation makes no endorsement, express or implied, of any individual product or protective window technology. The contents of this report should not be construed as advice specific to the installation of protective window technology in any structure; the needs and requirements of each installation are different and can only be properly assessed through inspection by a qualified installer of protective window technologies. This report should not be relied upon to evaluate whether a particular technology will bring a structure into conformance with applicable Florida building codes. Local building code officials should be consulted as to whether or not a specific technology installation meets current building code requirements.
- ▶ *The Consumer Reference Edition of Finding the Breaking Point* along with the full version *Finding the Breaking Point* supercede all previous Project Safe Window interim reports issued by the Protecting People First Foundation. Only these final reports, and any subsequent editions forthcoming, should be considered by consumers when making decisions about the purchase of protective window technology.
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