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HIGH IMPACT

A Look at Impact-Resistant Glazing Standards

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When looking at recent building codes and new test standards, it's clear that impact-resistant glazing standards are here to stay. In hurricane-prone regions of the United States, building codes have been revised and new test standards adopted to ensure the integrity of building envelopes during hurricanes.

Where It All Started

Following Hurricane Andrew in 1992, Florida's Dade, Broward and Monroe counties adopted the first mandatory glazing impact-resistant standards in the United States, under the South Florida Building Code (SFBC).

Palm Beach County, Florida, followed suit and adopted appendix (J) of the Standard Building Code for impact-resistant design as an option for local building departments.

In 1998, the Texas Department of Insurance (TDI) adopted Standard 1-98, Appendix E, *Building Code for Windstorm Resistant Construction*, requiring impact-resistant glazing for 14 Texas communities within 25 miles of the Gulf of Mexico, designated as a high-risk hurricane prone region. The American Society for Testing and Materials (ASTM) and the American Society of Civil Engineers (ASCE) also developed impact test standards in 1994.

This year, Florida approved a new statewide building code which will take effect in 2001, that includes a Windborne Debris Protection Standard requiring impact-resistant glazing or shutters for all portions of 35 Florida counties falling in the hurricane prone windborne debris region per ASCE 7-98 *(see figure 1, below left).* Additionally, all coastal areas of the East Coast and the Gulf of Mexico are likely to adopt some form of impact-resistant standards.

South Florida's Role

Contrary to popular belief, the SFBC was not a knee jerk reaction to Hurricane Andrew by local officials responding to public criticism. The principles included in the current code, developed long before Hurricane Andrew devastated South Florida, were based upon Australian standards written in the late 1970s following Cyclone Tracy, which destroyed 90 percent of housing in Darwin, Australia in 1974.

Engineering studies of Cyclone Tracey concluded that the vast majority of damage caused by hurricanes is due to windborne debris and fluctuating pressures. The experts concluded that the single-gust concept of design is inadequate to protect against sustained, turbulent winds that change direction slowly and carry debris.

Based upon these findings, original window protection codes and standards were written with an either/or provision requiring that either a building be designed to resist breaching of the building envelope by flying debris, or the structure must be designed for full internal pressurization (*see figure 2, above*).

Most current codes and standards have eliminated the option of designing the structure against full internal pressurization, instead requiring the building envelope be designed to resist impact from flying debris and cyclic (fluctuating) pressures.

Small and large missile impact testing requirements are the basis for designing against internal pressurization by protecting windows. Several agencies and organizations such as the SFBC (Dade, Broward and Monroe Counties), ASCE, ASTM, Southern Building Code Congress International (SBCCI), International Building Code (IBC) and Texas Windstorm Insurance Association (TWIA), have published codes, standards or test methods with provisions for window protection.

Test Protocol

The following is based upon the SFBC test protocol PA 201. The SBCCI, TWIA, ASCE and ASTM standards closely follow the SFBC test protocol, although they do vary slightly, primarily with regard to the weight and speed of the projectiles.

All impact test protocols have two basic components; impact with projectiles representing windborne debris; either large missile (projectile is 2- by 4-foot timber), or small missile (projectile is two gram steel balls); and cyclic structural loading representing fluctuating wind pressures.

Glazed openings below 30 feet from grade must be large missile-resistant, while glazed openings above 30 feet must meet the requirements of either the small missile tests or the large missile tests (*see figures 3 and 4 above*).

Until June 1, 2000, SFBC allowed roof gravel to be used for small missile systems. Due to the inconsistency of roof gravel projectiles, the protocol was modified requiring two gram steel balls be used and all products certified with roof gravel be re-tested with steel ball projectiles.

Each test specimen is impacted three times; at the center of the glass, the corner of the glass and midspan of the framing member (*see figure 5 below*). Following impact, the test specimen is subjected to 9000 cycles of positive and negative loads (cyclic structural loading) per the table below:

Three test specimens must survive the missile without penetration. If, upon completion of the pressure cycles, no tear or crack greater than 5 inches or opening through which a 3-inch sphere can pass has formed in any the three specimens, they are deemed to have passed the test.

What We Learned in Miami

I have witnessed many impact-resistant tests, have reviewed hundreds of test reports and have seen many systems pass and just as many fail. There are four major design elements that affect impact test results.

1. The size of the lite and magnitude of the design loads significantly affect test results. It is critical that reasonable test specimen sizes are used to maximize the benefits of the test results. Because impact-resistant systems are necessary in hurricane-prone regions, the design wind loads tend to be very high. In Miami, maximum design loads for 30-story-plus buildings are typically as high as 160 psf.

On a recent project, an out-of-state glazing subcontractor signed a contract for a five-star hotel, without having large missile impact resistance testing of the storefront area of the building. During testing, he learned that the spans required by the architect exceeded that of his systems and he was forced to make modifications and the cost impact was substantial. The new systems required the use of high-performance, composite polycarbonate laminated glass, which is significantly more expensive than the traditional laminated glass he had intended to use. Additionally, in an effort to find a substitute for the composite glass, he spent extensive time and money testing various alternatives, but to no avail.

2. Once the size and wind-load requirements have been established, it is important to evaluate whether your existing frame structure can withstand the necessary pressure and fatigue of repetitive cycling. If your frame structure cannot, you must decide if it must be modified or if a new product is required. Often it is better to start from scratch than to attempt to modify existing products for impact testing.

3. After the structural framing system has been determined, you must select a suitable glazing infill. The thickness and composition of the infill are crucial in the performance of the system. Laminated glass and composite products are currently the items of choice. New products are introduced regularly and each has its limitations and varies in its ability to accommodate value-added products including coatings and frits.

4. Lastly, an appropriate glazing method must be selected. The glazing infill can (and usually will) break from the impact, but must remain in the frame during cycling. For large missile systems, this was initially achieved by mechanically attaching a laminate tail to the frame.

Over time, this method has been replaced by adhering all edges of a mechanically retained infill to the framing system, via a structural silicone sealant placed on the inboard surface with a glass bite of at least 5/8-inches (*see figure 6 on page 48*). Mechanical attachment of laminate tails has become far less common.

For large missile tests, impact at mid-span of a stopless structurally glazed framing member typically crushes the glass edges, resulting in failure during the structural cycling. Consequently, stopless structural glazing of large missile impact-resistant systems has not been consistently achievable.

Conversely, shop-glazed, four-sided structural silicone systems, incorporating post applied mechanically attached exterior elements proven by testing to protect glass edges from crushing, have been shown to pass the subsequent cycling phase.

We have been through a great deal in South Florida since the impact-resistant codes were introduced. What seemed impossible just a few years ago is now common practice. As the areas adopting impact-resistant glazing requirements grows it is important that we learn from the South Florida experience and continue to develop systems and materials that meet and exceed code requirements.

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