Structural Glazing Solutions for Protective Glazing

Axel H. Giesecke, Kenneth Yarosh
Dow Corning GmbH
Rheingaustrasse 34, D-65201 Wiesbaden, GERMANY

Key Words
1=Structural Silicone Glazing (Structural Glazing) 2=Protective Glazing 3=Silicones 4=Bomb Blast Resistance

Abstract

Tragic world events have opened our eyes to the vulnerability and false sense of security in today's buildings around the globe. The horrific loss of life and property from terrorist attacks on these structures has forced building owners, investors, government authorities, building occupants and insurance companies to seek new solutions to protect people from these events as well as from extreme climatic natural disasters.

As a result, building designers face ever increasing stringent standards in today's modern building construction. These designers are relying on the unique properties and uncompromising strength of silicone structural glazing products to play an added active role in new protective and safety glazing systems. These advances are helping to defend against extreme events such as bomb blast resistance, hurricane and earthquake protection, burglary protection, noise control and fire resistance.

This paper will review developments with silicone sealants in safety and security systems. The primary focus of this paper will be on facades which are designed to mitigate bomb blast. The basic design requirements of a bomb blast mitigating window design are similar to those for windows designed to withstand hurricanes, earthquakes, burglary protection and the like. It also explains how the use of silicone sealants will further open up new possibilities for protective functionality in façade and window systems.

Introduction

Today, a state-of-the-art façade is much more than just a building envelope which protects its building's occupants from the elements. Today's modern façade designs include multiple functionality such as lightening, heating, cooling, protection, etc. Protection is the most fundamental aspect in the pyramid of human needs and therefore gains continuously increased importance. New requirements imposed by standards, regulations and customer expectations are creating demand for high performance products. Building specifications are becoming more stringent and finding means to protect human life is gaining greater importance.

Protective glazing (safety and security) is a good example. In the Middle East and Europe, many new commercial buildings are being specified to have bomb blast resistant

windows and facades. Existing buildings are also being retrofitted with protective film and sealant systems. The purpose is to protect the building's occupants from injuries caused by blast born debris. Americas and Asia are faced with an increased demand for protective glazing products too because the building owners want to protect themselves from the relentless weather in the form of storms and hurricane and at the same time facilitate insurance coverage in the event of a disaster.

At the same time it is still important in today's environment of terrorist attack and extreme weather conditions that people not be forced to live their daily lives in closed bunkers. We still need and have the right to enjoy our lives in aesthetically pleasing buildings with a permanent view to the outdoors while still protected from reasonable external threats. Structural Silicone Glazing is an ideal technology to meet all these demands.

The project DS2 in London or the Scottish Parliament in Edinburgh are examples for Structural Silicone Glazing facades, which meets these demands. These modern buildings display an aesthetically pleasing design combined with various technical functions, such as wide daylight openings, energy savings and protection against bomb blast.

Structural Silicone Glazing technology enables energy efficient facades with wide daylight openings and combined with laminated glass, improved protection from bomb blasts. This is only possible with Structural Silicone Glazing technology due to the outstanding and unique properties of silicones. Silicone sealants offer excellent weather resistance, durability, flexibility, adhesion and a viscoelastic behaviour which is critical for bomb blast resistant window designs [1][2][3]. European Standards endorsing Structural Glazing Systems and Structural Glazing Silicone Sealants have been developed [4] [5]. With these new standards, qualifying Structural Sealant can receive a CE-mark which recognizes that the product as appropriate for the critical requirements of this modern construction design.

Requirements of Structural Sealant Adhesives

The design details for Structural Glazing show that the IGU secondary seal as well as the Structural Glazing Adhesive are fully exposed to the weather.

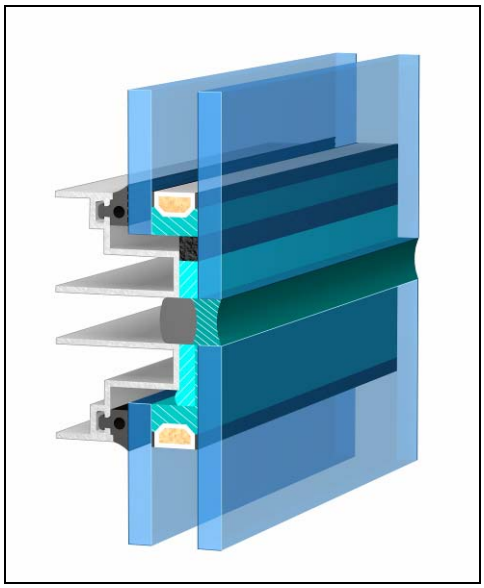

Figure 1: Generic Design Sketch
Stepped IGU in Structural Glazing

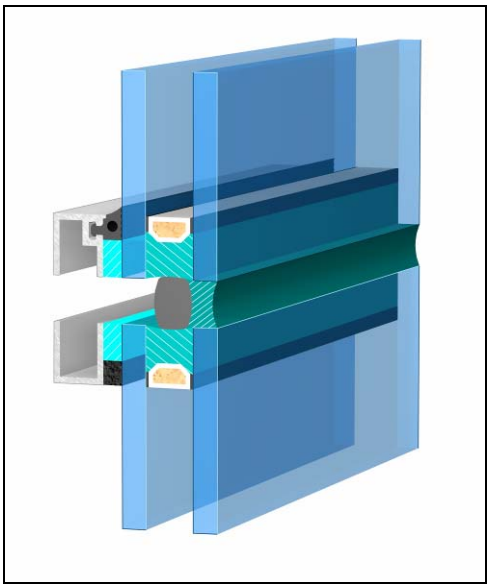

Figure 2: Generic Design Sketch
Symmetrical IGU in Structural Glazing

Weather causes several physical and chemical stress factors on building components. These factors need to be taken into consideration in order to design a long-lasting and reliable façade capable of protecting the investment of the building owner. Several examples of these stress factors are shown in Table 1:

Sun Light:	
UV-Radiation	High energy – capable to de-bond molecules
Visible Light	Temperature effect
IR-Radiation	Significant Temperature effect
Rain / Water:	
Moisture	Moisture load
Air:	
SO_X	aggressive chemical – capable to cause chemical reaction
NO_X	aggressive chemical – capable to cause chemical reaction
O_2 / Ozone	aggressive chemical – capable to cause oxidations

Table 1: Environmental Stress Factors

The construction design details shown previously clearly necessitate a dual seal system for the IGU, which is capable of resisting the climatic stress factors. Silicone sealants are based on polydimethylsiloxane (PDMS) polymer, which has a completely different polymer structure than organic polymers, such as used in polysulfide or polyurethane sealants. The structure of silicone polymer, polydimethylsiloxane (PDMS), is shown in Figure 3.

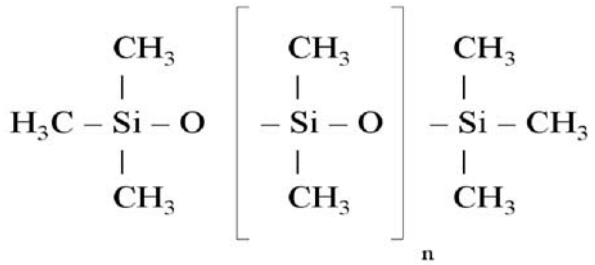

Figure 3: Chemical Structure of Polydimethylsiloxane (PDMS)

The key-differentiating feature of PDMS polymer is its inorganic siloxane (Si-O-Si) backbone, which provides the outstanding durability and excellent elastomeric properties. The PDMS polymer has a special Molecule-Structure which is shown in Figure 4.

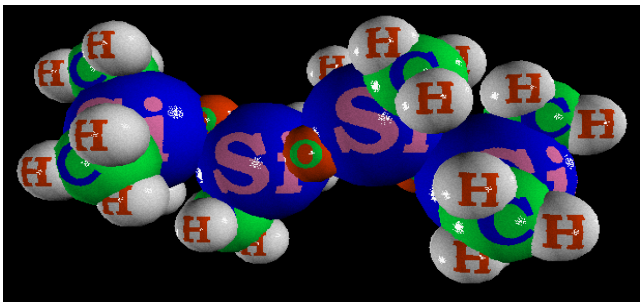

Figure 4: PDMS Molecule-Structure

The unique polymer structure provides silicones with an inherent durability, resistance against UV-radiation, high performance properties, which are stable over a wide temperature range, and as a result, outstanding weather resistance. These unique properties are the reason why silicones are the material of choice when high quality and high durability sealants are required.

The knowledge and experience on the performances of the Structural Glazing Silicone has led naturally to an expansion in the use of silicone structural glazing techniques in new high performance façade systems. In particular for protective glazing applications where façade and window systems are required to offer additional protection and resistance against bomb blast, structural silicone sealants have been selected to play an active role in the performances of the system.

Performance of Structural Glazing under Bomb Blast Load

Properly designed structural glazing systems can perform exceptionally well under bomb blast loads. Structural silicone plays a very important role in the performance of any protective glazing system. Silicone sealant has a long history of performance as an adhesive and sealant for glass. Properly formulated silicone sealants have high strength which is necessary to anchor or secure laminated glass to a frame during blast impact. A silicone sealant is also durable and flexibility to allow the window system to perform when exposed to the elements for many years.

In July 2000, a 20 kg bomb blast in the center city of Madrid, Spain destroyed a 4 sided structurally glazed building. This building was recently "face-lifted" with a new façade over the existing structure. The float glass was completely shattered but what was observed was the glass shards fully attached to the structural silicone sealant around the perimeter of the frame. The sealant maintained full adhesion to the glass and framing through the bomb blast.

Structural glazing systems have been tested in actual bomb blast conditions. Figure 5 below shows the result of a bomb blast test on a structural glazing system used on an actual project. The structurally glazed curtainwall system was subjected to a charge of 12 kg of TNT at a distance of 6.5 m from the test specimen at a height of 0.8 m. The peak reflected pressure was 383.7 kPa. Total blast energy was 547.7 kPa-msec and the duration of the blast load was 6.17 msec.

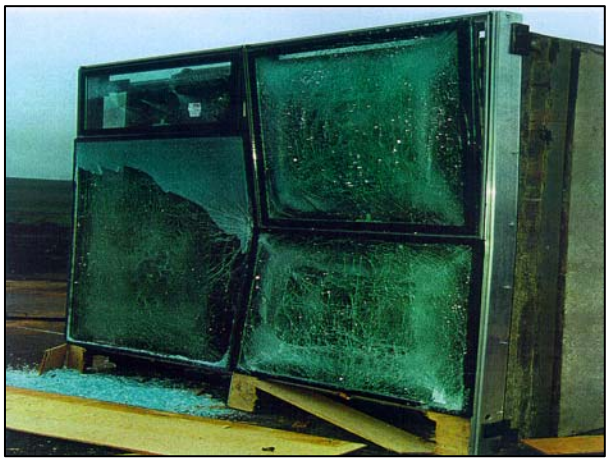

Figure 5: Performance of Structural Glazing System after Bomb Blast Exposure

After exposure to the bomb blast, the system was evaluated and found to have performed successfully. The laminated glass was fully retained in the window openings by the structural silicone sealant.

For any structural glazing design, the silicone sealant is only one component of the system. The system is comprised of a framing system which must be properly and securely attached to the structure. The structure itself must be designed to withstand the specified blast. The framing must be able to stay attached to the structure during the

blast. The sealant's primary role during the blast is to keep the glass in the frame during the blast. The glass must be a laminated glass approved for this application. The use of laminated glass reduces the damaging affect of glass shards entering the occupied areas of the structure. Without the use of a high strength structural silicone to attach the laminated glass to the frame, personal injury from flying glass could occur.

Design Values for Structural Glazing under Bomb Blast Load

Design of structural glazing systems which are intended to withstand bomb blast loads can be a complex process. The performance of the system is dependent on many variables such as the structure, rigidity or flexibility of the framing system, size of the window openings, type of glass and laminate used, explosion pressure loads and finally the type and design of the structural silicone attachment. Systems designed to mitigate a bomb blast must be tested and evaluated as a system. The structural silicone sealant is a critical component of these designs but alone will not determine the successful performance of a system. ASTM C1564 Standard Guide for the Use of Silicone Sealants for Protective Glazing Systems discuses design considerations for protective glazing systems.

Structural silicone sealants have been proven through actual high speed testing to have the strength properties needed for these designs. In a recent study [3], two structural silicone sealants were evaluated in high speed tensile test which simulates the high speed blast loads on a window system. These two structural silicone sealants have an allowable design stress of 140,000 Pa in structural glazing applications. At normal tensile testing pull rates of .00083 m/s, these sealant have peak tensile values in excess of 840,000 Pa for a safety factor of 6. At the high speed testing at pull rates of 1.1 m/sec to 5.0 m/sec, these same sealants had peak tensile values over 1,600,000 Pa on average for the various joint dimensions tested. Figure 6 shows the results of high speed testing of one of these sealants. This testing demonstrates again the suitability of high performance structural silicone sealants in bomb blast mitigating window designs.

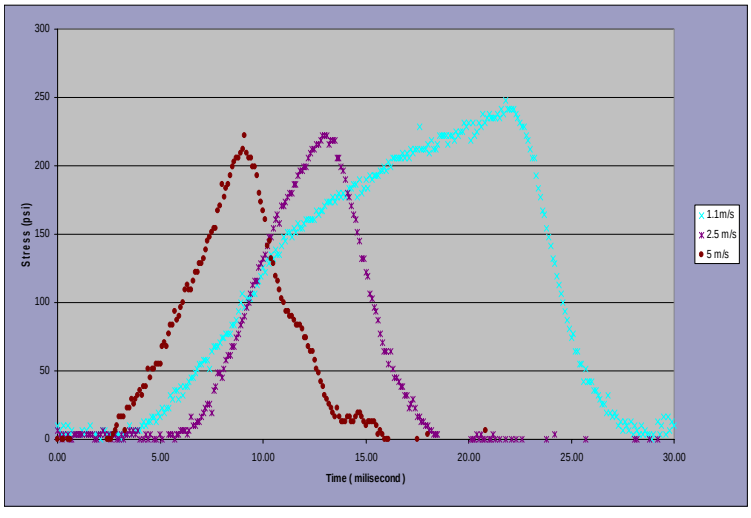

Figure 6: High speed tensile testing of a Structural Silicone Sealant

Structural Glazing Projects with Protective Functions

Of the thousands of structurally glazed building worldwide, only a small but significantly growing percentage of those are designed for protective function. It is fair to say that almost all new government buildings including office buildings, courthouses and embassies utilize a bomb blast mitigating window design. Many existing building have been retrofitted using protective film and silicone sealant. Also, many new commercial buildings such as banks and hotels in high profile locations have been designed or retrofitted with protective glazing systems.

In the figures on the following pages are some examples of buildings which have utilized high performance structural silicone sealants in their protective glazing window systems.

Bishop Gate 99 in London (Figure 7) was renovated in 1996 with 15,000 m^2 of 4-sided structural glazing façade with Low-E coating and sound control performance. This building was designed to withstand an 8000 Pa bomb blast.

Figure 7 – Bishop Gate 99 - London

DS-2 in London (Figure 8) used 15,000 m^2 of 4-sided SG façade. The podium on the lower 5 floors was designed to mitigate bomb blast.

Figure 8: DS2 – London
Bomb Blast Resistant Podium (5 stories)

Existing buildings can be renovated with the use of a protective film and a structural silicone corner bead which is applied from the film to the perimeter framing system (Figure 9). These systems are tested and approved by the protective film manufacturer.

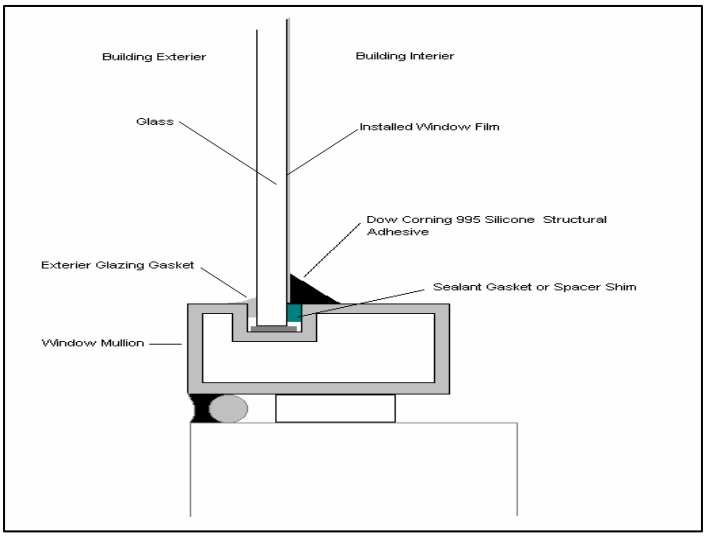

Figure 9: Renovation with Protective Film and Structural Silicone

Summary

The threat of terrorist attack is real in today's world. The loss of life and property from these horrific events can be reduced with the use of new façade systems designed to withstand bomb blast loads. Building owners, investors, government authorities, and insurance companies are all interested in safer buildings. An important element of safer buildings is a safer window.

Structural silicone sealants can provide to all interested party a product with a proven track record of performance for bomb blast mitigating window systems. Silicone chemistry is appropriate for these demanding designs. High performance structural silicone sealants provide outstanding durability and adhesion, high strength and flexibility for long term performance. Structural silicone sealants have been independently tested and certified to comply with major European standards. When used with appropriate materials such as laminated glass, high performance window systems using structural silicone sealants can provide not only an aesthetically pleasing building but one that is much safer for the building's occupants in the event of bomb blast or natural disaster.

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