Silicone Structural Glazing Systems: 20 Years of Durability and Performance

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As architects in the late 1960s and early 1970s sought a structural support system that would allow them to create smooth, uninterrupted glass facades, manufacturers of silicone sealants introduced new products and technologies that they said would revolutionize the industry.

Small-scale tests, unprecedented warranties on materials, and strict application specifications assuaged initial skepticism. By the mid-1980s, structural silicone glazing attachment systems, comprised of continuous flexible silicone rubber anchors, were becoming widely used across the United States to erect high performance curtainwall facades.

Since then, these structures and the silicone glazing systems have gained worldwide acceptance and have allowed some of the greatest achievements in architectural design to define skylines across the globe.

The Challenge – Curtainwall Environment

Curtainwall construction must withstand a unique mix of environmental pressures. Sealant joints must withstand UV exposure and environmental pollution such as acid rain, function under daily thermal movements and wind loads, and withstand strains of seasonal thermal cycles, extreme winds and seismic events. Ultraviolet light passes through glass and degrades materials, therefore the structural sealants must maintain their integrity through UV exposure.

Figure 1.

Wind is another force that causes stress on curtainwall elements. Wind exerts rotational forces on the surface of the secured curtainwall glass, causing the glass panel to deflect in a trapezoidal pattern. (Figure 1) The forces are then transferred to the frame through the silicone in a combination of tension and shear forces.

The Introduction - Silicone Application

Because of this combination of forces, a flexible and elastic sealant is necessary. Manufacturers who initially stood by their products' performance did so because silicone is the only known product that maintains excellent adhesion to glass through natural and artificial weathering. The use of structural silicone glazing provides a natural thermal break between the glass and framing members. The structural silicone attachment is also a barrier to the passage of air and water. This built-in thermal barrier keeps the interior framing members and insulation dry and comfortable.

Silicones have also proved essential in sealing aluminum and glass construction components together. Curtainwalls are primarily a skin of glass and aluminum, and structural silicone glazing attaches glass to a metal frame using silicone adhesive sealants. Under a normal temperature range from -40°C to 100°C, aluminum expands and contracts approximately 2.5 times the rate of glass, steel and concrete; therefore, the relatively thin aluminum skin attached to a concrete or steel structure will have a large amount of thermal movement within it. This movement must be accommodated with expansion joints and with the flexible anchorage of the structural silicone glazing system. Silicone adhesives and sealants have shown themselves to be effective in such applications absorbing differential thermal movements during exterior weathering.

There are several basic requirements of the structural silicone in curtainwall construction. Joints designed with silicone structural sealants provide superior durability in several key areas:

1. The joint must withstand daily thermal movements. At one per day, there will be 36524 cycles in a 100 year period;
2. The silicone must be able to resist wind loads for the specified wind period. Specified wind loads are typically based on a one in 50 or 100 year return period;
3. High rise buildings today are receiving windload specifications of 4-7 kilopascals or as much as 80-140 pounds per square foot;
4. Silicone materials attaching glass to frames must withstand the pollution in the environment, including the damaging effects of acid rain;
5. The silicone materials must be able to perform during seismic events;
6. The joint must be able to perform after extended exposure to UV.

Figure 2

The Sustainability – Testing Standards

During the wind events of the past 35 years, structural silicone buildings have withstood windstorms on a daily basis around the globe. This is largely due to high industry standards and the extensive performance tests carried out to improve the reliability of silicone structural sealant.

ASTM C1184 Standard Specification for Structural Silicone Sealants specifies a minimum tensile strength for structural specimens after room temperature cure, seven-day water immersion, testing at -29°C, testing at 88°C and after artificial weathering on glass for 5000 hours in a UV florescent or xenon device.

This U.S. specification was the only specification regarding structural silicone usage for many years. Currently there are similar specifications and test methods in Europe, such as the Guideline for European Technical Approval for Structural Sealant Glazing Systems, and in China. Within each of these specifications, specimens are subjected to artificial UV, moisture and heat weather tests. Standard sealants used for weatherproofing facades have little or no weather testing requirements.

This type of testing has shown the superior durability of silicone materials compared to other organic elastomeric materials during the past 30 years in accelerated weathering chambers. Besides silicone sealants, no other formulations have the ability to maintain the long-term performance required for structural glazing applications.

Hilliard et al. published photos of the mock up in 1971 of one of the first structural silicone tests. The tests strained the glazing application to the point of failure. [1]

Figure3: Mock up test to failure February 1971

Figure 4: 2005 photograph of the facade of the first 4 sided SSG project erected in 1971.

In the 1970s, Hilliard et al. conducted tests that correlated the accelerated weathering of small specimens to the weathering of full-size panels. More thorough laboratory testing was conducted by Schmidt et al. in 1981 [2], and by Carbary and Fulton on granite panels in 1989 [3] to compare lab scaled test panel performance against full-size panels. These documented tests, in conjunction with the thousands of full-scale mock tests conducted on the world's high-rise buildings, have improved the correlation and accuracy of laboratory testing to the full-scale applications.

Zarghamee, Schwartz and Gladstone's studies on seismic requirements for structural silicone were conducted using a full-size mock up subjected to movements of 76mm per story height. [4] The sealants attaching glass to the frames did not fail in any way during their tested 1/140 to 1/175 anticipated shear movements.

National and international standards have since been developed based on these wind and seismic tests, including the most comprehensive guide for structural sealant glazing, ASTM C1401 Standard Guide for Structural Sealant Glazing, which considers both windload and shear forces.

The Future – Performance, Development

This testing and data have proven themselves as buildings constructed using silicone structural sealant glazing have withstood 35 years of windloads. The curtainwall designs incorporated in today's construction practices coupled with the growth in factory-assembled unitized curtainwalls have proven to be beneficial.

This performance has provided building occupants with comfortable spaces free of air and water infiltration thanks to the thermal break between glass and metal inherent with the structural silicone application. Silicone glazing systems are showing through the test of time what has been predicted in laboratory and full scale mockups, maintaining their adhesion, cohesion, strength and elastomeric nature. The advantages of this system of curtainwall fabrication are becoming clearer with each passing cycle of the seasons, each wind event, and each seismic event.

After more than 20 years of reliable performance, there is no evidence to suggest that these glazing systems will not work reliably after 30, or more years of continuous, excellent service.

References

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