Structural Silicone Glazing (SSG) Design Guidelines

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FOREWORD

The objective of this guide is to describe proper guidelines and glazing procedures for structural glazing. To be consistent with terminology common to the industry, the term "structural glazing" shall be used herein to refer to structural silicone glazing (SSG). The information contained herein is not intended to replace manufacturers specific recommendations. The manufacturer of the silicone to be used for structural glazing should be consulted for proper application of the product.

Prior AAMA publications included TSGG-04, two sided structural glazing for skylights, and CW13-85, a structural glazing design guide. It was decided to combine them into a single guiding document regarding structural glazing, for both vertical and sloped applications.

Structural glazing offers a unique appearance and simplicity of construction that often cannot be achieved any other way. In addition, as will be discussed later, this form of construction can improve many of the performance characteristics of the system or building.

Structural glazing uses a structural silicone sealant to adhere glass or metal panels to supporting framing members. The incorporation of a structural silicone sealant into the system allows the architect a new level of design freedom, eliminating the need for exterior retainers and covers. It is now possible to design buildings with a completely flush appearance, very clean architectural lines and smoother rain runoff, shedding dirt and allowing for easier cleaning.

In many structural glazed systems, the weatherseal bead is continuous around the entire perimeter and flush with the surface of the lite. This continuous seal can help ensure performance against air infiltration and water penetration.

Structural glazed buildings have an excellent track record of success in two of the most severe building exposures: earthquakes and hurricanes. When structural silicone sealant is used to adhere the glass to the supporting framing members, the glass is cushioned and adhered in place such that the possibility of glass edges impacting framework can be reduced. In hurricanes, heavy winds can generate high loads and a pumping effect upon the windows. The use of structural silicone sealant allows the glass to be retained with evenly distributed elastic support.

The structural silicone sealant and weatherseal act as an excellent thermal break and air seal. This results in some of the most thermally efficient systems available today.
Properly designed and installed, structural silicone has performed well in the presence of UV exposure, adverse weathering conditions and in extremely harsh environments. These qualities allow structural silicone sealants to continue as the only type of sealant approved for structurally adhered glazing applications.

In addition to the performance advantages of structural glazing, there is the inherent simplicity in the system. By adhering the glass directly to framing members, certain components such as glazing gaskets, anti-walk blocks, glazing channels, thermal breaks, exterior covers, etc., may be eliminated. However, proper design, good workmanship, and attention to detail are essential for optimum performance.

This structural glazing procedural guide is intended as a reference to address the items that must be considered when designing and installing a system utilizing this building technique. Special emphases shall be given to:

1. System design including the structural silicone sealant joint, framing members, and related tolerances.
2. Material selection including the glass, aluminum, sealant and related or alternative materials.
3. Installation requirements including cleaning, priming, as well as field glazing vs. shop glazing comparisons; and
4. Quality assurance.

1.0 SCOPE

This document covers design guidelines for silicone structural glazing, including:
- panels glazed with use of backup support framing,
- glazing of glass, insulating glass units, laminated glass, and panels to mullions in both vertical and sloped applications,
- exterior or interior applications
- offset glass
- proper substrates and sealants
- Compatibility of materials in a structurally glazed system - aluminum framing systems

This document does not intend to provide design guidelines for:
- fin glazing,
- point supported glass, or other mechanically retained systems that do not use a sealant in
some location for the purpose of affixing glass to a frame.
- Structural glazing tapes
- Weatherseal design and butt glazing, which is not considered structural,
- framing systems other than aluminum
- glass design or construction of glass units.

2.0 REFERENCE STANDARDS

2.1 AMERICAN ARCHITECTURAL MANUFACTURERS ASSOCIATION (AAMA)

AAMA 2603-13, Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels

AAMA 2604-13, Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels


AAMA 611-14, Voluntary Standards for Anodized Architectural Aluminum

AAMA TIR A11-04, Maximum Allowable Deflection of Framing Systems for Building Cladding Components at Design Wind Loads

2.2 AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE/SEI 7-10, Minimum Design Loads for Buildings and Other Structures

2.3 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)


ASTM C920-14a, Standard Specification for Elastomeric Joint Sealants

ASTM C1036-11e1, Standard Specification for Flat Glass
ASTM C1048-12e1, Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass


ASTM C1184-14, Standard Specification for Structural Silicone Sealants

ASTM C1249-06a(2010), Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications


ASTM C1392-00(2014), Standard Guide for Evaluating Failure of Structural Sealant Glazing

ASTM C1394-03(2012), Standard Guide for In-Situ Structural Silicone Glazing (SSG) Evaluations

ASTM C1401-14, Standard Guide for Structural Sealant Glazing

ASTM E1300-12ae1, Standard Practice for Determining Load Resistance of Glass in Buildings

ASTM E2188-10, Standard Test Method for Insulating Glass Unit Performance

ASTM E2189 -10e1, Standard Test Method for Testing Resistance to Fogging in Insulating Glass Units

ASTM E2190-10, Standard Specification for Insulating Glass Unit Performance and Evaluation
2.4 ALUMINUM ASSOCIATION SPECIFICATIONS FOR ALUMINUM STRUCTURES (SAA)

SAA-46, Aluminum Association Standards Anodized Architectural Aluminum

3.0 DEFINITIONS

3.1 Please refer to AAMA Glossary (AG-13) for all additional definitions except for those appearing below (which apply only to this specification).

3.1.1 CONVENTIONAL SYSTEM - The lite of glass or panel infill is mechanically retained on all sides of the opening.

3.1.2 CURATIVE - A material which speeds up the cure of reaction of another substance when added in minor quantities.

3.1.3 DUTCHMAN - A device or temporary fastener applied to a field glazed system to hold the glazing in place while the sealant cures.

ELASTICITY - Pliability, ability to take up expansion and contraction; opposite of brittle.

3.1.4 FILLER - A material which is pressed into an opening or joint so that the compound applied to seal the joint will exert pressure and form good contact against the sides of the joint or opening.

3.1.5 PEEL ADHESION TEST - A quantitative measure of bond strength, whereby the material is pulled away from the mating surface at a 180 degree angle to the plane to which it is adhered - Values are generally expressed in Newtons (pounds) for a standard width peel or Newtons/meter or pounds per lineal inch width and as to whether failure mode was adhesive or cohesive.

3.1.6 FACTOR OF SAFETY - Factor designed to compensate for the many variables associated with structural glazing; the ratio of breaking stress to the allowable stress.

3.1.7 SHEAR - A strain put on a sealant between two surfaces when there is differential movement along the length of the joint, such as occurs when an aluminum channel expands to a greater length than a glass lite when both are subjected to the same pronounced rise in temperature.
4.0 DESIGN REQUIREMENTS

4.1 Framing Systems

There are two basic classes of framing systems used in structural glazing applications. The discussion in this publication will be limited to Class I framing systems.

Class I Framing Systems

This class, which is divided into two types, (A and B) provides structural framing support on all edges of individual glazing infill units. As in captured glazing systems, the framing material, generally aluminum extrusions, shall be capable of supporting the applied loads and providing adequate support and resistance to deflection.

Two sided SSG: Two sided SSG framing systems provide captured support to at least two opposing edges of a glazing infill. The remaining edge(s), which are not mechanically captured, are supported by a structural silicone sealant. This is commonly referred to as two-sided structural glazing. Many sloped glazing systems have progressed from the conventional cap glazing system to the two-sided structural silicone technique. With a retainer or cap glazing system, all edges of the glass unit are retained with a metal glazing cap. This type of system usually experiences a greater amount of water infiltration due to the damming caused by the purlin cap and butt jointed corner intersections with the sloping rafter caps. The flush purlin detail (see Figure 3) minimizes water and dirt retention. Although two-sided sloped glazing systems reduce the amount of water infiltration, good design practice should incorporate an integral mechanical gutter system to control water infiltration and condensation for all sloped glazing applications.

Four sided SSG: Four sided SSG framing systems provide structural silicone sealant support to all edges, Four sided SSG guidelines also apply to: three edges or two adjacent edges of a glazing infill.

In a Class I framing system the remaining edges, which are not supported with a silicone sealant, are mechanically captured.

Class II Framing Systems

This class consists of glass panels supported at the vertical or sloped edges by glass stiffeners with a structural silicone sealant. The assemblies are two or more panes in height...
with no inward/outward support of the horizontal butting edges of the glass. This type of system is not included in the scope of this document.

4.2 Structural Requirements

Structural glazing can be incorporated into many different types of framing systems including curtain walls, storefronts, skylights and sloped glazing systems, strip windows, operating windows and sliding glass doors, as well as most other applications where conventional captured glazing is used. The rules that apply to the structural design of conventional framing systems also apply to structurally glazed framing systems. Building dynamics, such as building sway, live load deflections and seismic movements, must be analyzed to see what loads are applied to the silicone and glass or metal framing, and to ensure movements can be accommodated without damage.

4.3 Design Loads

Structurally glazed systems may be exposed to many different loading conditions. Windows curtain walls, skylights and sloped glazing systems must be designed for wind, dead, snow and earthquake loads. These loads may be determined by applicable codes.

4.4 Wind Load

Negative wind pressures are the primary load which dictates the structural silicone sealant joint design. Negative wind loads are often greater than positive wind loads, especially in skylights and sloped glazing applications, tall buildings or on exterior corners. The higher wind loading in corner zones may be balanced (i.e., both sides experience a positive load or both sides of a corner are subjected to a negative load) or unbalanced (i.e., a portion of the positive load is applied to one side while a portion of the negative load is applied to the other side).

4.5 Dead Loads

Dead load is a constant load applied to a structural element. This load may induce stress on the structural silicone. In glazing applications, dead load on the structural silicone sealant usually is a result of the glass weight. This may occur in cases where there is no fin to support the glass at the horizontal or where the glass is sloped outward from the vertical plane. Structural silicone sealants have been approved to support up to 7 k Pa (1 psi) in dead
load depending upon the physical properties of the material. It is recommended that the sealant and glass supplier review all applications which require the silicone to withstand dead load. Some glass types, such as insulating glass, may not be appropriate for glazing without dead load support.

4.6 Snow Load

Snow load only becomes a design consideration when the framing members are sloped off of the vertical plane such that snow may accumulate on the glass. The additional weight of the snow on the structural joint is generally within the allowable compression stress range of the sealant.

4.7 Earthquake Loads

Observations after earthquakes indicate that properly designed structurally glazed framing systems are generally able to accommodate seismic movements. These systems have few metal projections through the glass plane which may contact the glass and cause breakage during an earthquake. The building engineer must specify the inter-story lateral drift so that this movement can be considered in the design of the framing system. Inter-story lateral drift may also introduce shear stresses in the sealant which must be analyzed by a competent engineer.

4.8 Design of Aluminum Framing Members

A structural glazed framing system is designed similar to a conventionally glazed system to withstand the imposed loads. The stress in the aluminum support member must be limited in accordance with the "Specifications for Aluminum Structures," section of the Aluminum Association’s "Aluminum Design Manual." The framing deflection should be limited in accordance with AAMA TIR-A11, "Maximum Allowable Deflection of Framing Systems for Building Cladding Components at Design Wind Loads." Skylights and sloped glazing systems should be designed in accordance with AAMA “Structural Design Guidelines for Aluminum Framed Skylights”

4.9 Geometry and System Selection

In framing systems with captured glazing, part of the depth of the structural member extends beyond the exterior of the glazed infill. In structural glazed framing systems, however, the
structural framing members may not protrude past the exterior of the glazing. Therefore, structural glazed framing systems may have to extend deeper into the building interior to achieve the same strength as conventionally glazed framing systems.

Support of corner mullions or corner glazing is often achieved by the use of structural glazing. Glass or metal plates may act as shear panels to transfer wind load and sometimes dead load to adjacent mullions, glazing units or building structure. Design of corner support must include analysis of the corner system as a unit, as well as analysis of the components of the unit, and take into account the transfer of loading from components to the corner unit and back to the structure.

4.10 Thermal Expansion and Building Movement

Structurally glazed windows, wall systems as well as skylights and sloped glazing systems, must be designed to withstand thermal movements induced by extreme environmental temperatures. Proper design must accommodate these movements without permanent deformation or damage to the framing members, components or glass. The design may include interlocking or two-piece framing members or intermittent vertical and horizontal expansion joints along with slotted connections to allow for this movement. Movements may place silicone structural joints in shear or extension/compression, and need to be considered in joint design, as well as be approved by the silicone manufacturer.

In structurally glazed systems, less metal may be exposed to the exterior than a captured system; however, consideration should be given that aluminum which is exposed to the exterior may experience a surface temperature of up to 82°C (180°F) due to absorption of radiant energy by the exposed metal surfaces.

The interior surface temperature is dependent on the characteristics of the thermal break, if any, within the frame depth, insulating properties of the glazing materials and the anticipated interior ambient air temperature, both before and after the interior space is conditioned.

A structural silicone joint must be designed to assure that the system performs as intended. Critical design parameters relating to the sealant joint relate to the joint's ability to support the lite when subjected to design loads and ability to accept the potential movements. With vertical applications, the structural silicone joint is normally a tensile design. For two-sided
sloped glazing applications, an edge or shear-bead design is commonly used. It is also important to provide detailing such that the joint is accessible for the sealant to be properly applied, during both initial glazing and re-glazing.

Figure 1 illustrates a typical vertical mullion structural glazed joint utilizing monolithic glass.

Figure 2 illustrates a typical vertical mullion structural glazed joint utilizing insulating glass.

Figure 3 illustrates a typical structural glazed purlin joint for a two-sided sloped glazed application using an edge or shear-bead design

Minimum generic and practical requirements for a structural joint are as follows.
Figure 1 – Typical Vertical Mullion with Structural Silicone Joint and Monolithic Glass
Figure 2 Typical Vertical Mullion With Structural Silicone Joint and Insulation Glass

Figure 3 – Skylight or Sloped Glazing Silicone Joint with a two-sided application
1. The nominal structural silicone sealant bite should be designed at a minimum of 6 mm (1/4 in).

2. The nominal sealant thickness should be designed at a minimum of 6 mm (1/4 in).

3. The structural silicone sealant bite should be equal to or greater than the thickness.

4. The minimum structural silicone sealant bite for rectangular units in vertical applications is calculated with the equation:

   \[
   \text{Structural Silicone Sealant Bite (mm)} = \frac{0.5 \times SS \times WL}{SDS}
   \]

   Where:

   \(SS\) = Short side dimension of lite (mm)
   \(WL\) = Allowable Stress Design (ASD) wind load (kPa)
   \(SDS\) = Silicone Design Strength (kPa)

   \[
   \text{Structural silicone sealant Bite (in )} = \frac{(0.5) \times SS \times WL}{SDS \times 12 \text{ inches/foot}}
   \]

   Where:

   \(SS\) = Short side dimension of lite (ft)

   \[Note: For structural sealant bite exceeding 38 mm (1.5") per the calculation below, special consideration should be given to constructability and how the joint will be fully filled. Consult the sealant manufacturer as needed.\]
WL = Allowable Stress Design (ASD) wind load (lb./ft.\(^2\))
SDS = Structural silicone sealant Design Strength (lb./in\(^2\))

In sloped applications, the deadload weight of the glass will counteract some of the uplift or negative windload. An additional term has been added to the equation for sloped glazing that is not used for vertical applications to account for this effect.

In order to calculate the sealant depth for sloped applications, the following data is required:

<table>
<thead>
<tr>
<th>Span</th>
<th>Angle</th>
<th>DL</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>Angle</td>
<td>DL</td>
<td>SS</td>
</tr>
<tr>
<td>- Lesser Glass Unit Dimension</td>
<td>- Slope Off Horizontal</td>
<td>- Dead Load of Glass</td>
<td>- Design Shear Strength of Sealant</td>
</tr>
<tr>
<td>mm (ft)</td>
<td>Degrees (Degrees)</td>
<td>k/m(^2) (lb/ft(^2))</td>
<td>kPa (psi)</td>
</tr>
</tbody>
</table>

**NOTE:** A design shear strength for silicone sealants of [Need SI equivalent] (20 psi) is commonly used for structural silicone glazing (SSG) applications. Alternate values may be used. Consult the sealant manufacturer for shear strength data.

The sealant depth equation for rectangular lites in sloped applications is as follows:

SI Sealant Depth =
\[
\frac{[WL - (DL \times \text{Cosine of Angle})] \times \text{Span}}{20 \times \text{SS}}
\]

IP Sealant Depth =
\[
\frac{[WL - (DL \times \text{Cosine of Angle})] \times \text{Span}}{24 \times \text{SS}}
\]

For geometric variations of pattern units (triangular, trapezoidal or other irregular shaped units, etc.) the above sealant depth equation may require modification. These applications should be verified by the sealant manufacturer during the shop drawing review.

If required sealant depth exceeds the design thickness of the exterior glass ply, an alternate method of structural glazing or framing pattern should be pursued.
Figure 4 illustrates the structural silicone sealant bite required based upon an accepted industry practice of 138 kPa (20 psi) sealant allowable design stress.

The structural silicone sealant joint should be able to be filled using standard caulking practices. To facilitate filling the joint, the joint bite should not be more than 3 times the sealant thickness, as a general rule of thumb. For ratios in which the bite exceeds the thickness by more than 3 times, extra care and precaution should be taken to ensure the joint can be completely filled.

Room temperature curing sealant should be exposed to the moisture in the air for proper curing. Two part chemical curing sealants also may require some access to the outside air to aid in byproduct evaporation.

4.11 Design Reviews
To ensure that the joint design is appropriate given the known performance of the building components (particularly the structural silicone sealant) manufacturers often require that the design is reviewed by their technical staff before a sealant is approved for this critical application. Adhesion and compatibility testing to verify that the structural silicone is acceptable for contact with adjoining materials is also required.

Silicone sealants exhibit high moisture vapor transmission (MVT) relative to many other common sealing materials and elastomers. Water vapor can facilitate transport of other substances (e.g. acids, alkalines, hydrocarbons, etc.) through continuous silicone sealant joints. Therefore, it may also be advisable to check compatibility of materials and conditions separated by silicone sealant joints in areas where moisture may be present. Special attention should be paid to potential contact with materials containing oils, plasticizers, elemental sulfur or volatiles.

Compatibility; ASTM C 1087

Incompatible glazing accessories (gaskets, spacers, setting blocks, etc.) can lead to sealant discoloration and/or loss of adhesion to the substrate. To ensure compatibility, tests of the accessory materials must be performed with the structural silicone sealant using ASTM C 1087.

4.12 Factor of Safety

Structures and structural components must be designed to carry some reserve load capacity beyond that expected under normal use. The reserve capacity, known as the Factor of Safety (FS), is provided to account for a number of variables which may have an effect on the structural element's load carrying capacity. To provide for the uncertainties of the installed joint, structural silicone sealants are designed with strength in excess of the material's design strength, also known as working strength. The term Factor of Safety (FS) has been commonly used in the industry to refer to this excess sealant strength.

For structural silicone, the variables may include:

- Sealant adhesion to, as well as compatibility with, the substrate.
- Surface preparation of substrate (cleaning and priming).
- Shelf life and prior storage of sealant.
• Environmental conditions during sealant application.
• Workmanship and quality control during sealant application.
• Time required obtaining complete cure prior to removal of temporary retention devices.
• Fabrication and erection tolerances of metal and glass.
• Secondary loads not considered directly in sealant joint design, e.g., loads due to thermal and building movements and glass edge rotation at sealant joint.
• Fatigue effects on sealant joint.

ASTM C 1184 has been adopted defining the minimum strength requirements of a structural silicone sealant. In this specification the sealant's tensile adhesion strength is evaluated in a variety of conditions including room temperature, 88°C; 29°C (190°F; -20°F), one week water immersion, and 5,000 hours of accelerated weathering. The minimum acceptable strength for a sealant that is to be considered to be structural in any and all of these conditions is 345 kPa (50 psi). Therefore a sealant with a design strength of 138 kPa (20 psi) must have a minimum factor of safety of 2.5. (The factor of safety as defined by the lowest strength measured in any of the ASTM C 1184 test conditions (F_{ult}) divided by the sealant design strength (SDS). Some code officials and project specifications can require sealants with design strengths of 138 kPa (20 psi) to have safety factors in excess of 2.5 to 1.

138 kPa (20 psi) has often been used as a widely accepted design stress for structural silicone. To be certain of the appropriate design stresses the design professional must consult the sealant manufacturer.

4.13 Stress/Strain Modulus

A structural silicone sealant must be both strong enough to resist design loads and flexible enough to accept movements. ASTM C 1184 provides more information on acceptable modulus values.

4.15 Maximum Deflection

Generally, the deadload of a structurally glazed lite is supported by a setting block. The setting block is positioned so that at least 1/2 of the glass lite thickness rests on the block. Proper design of a structural silicone joint requires that the glass remain supported by the setting block when subjected to design loading; 3 mm (1/8 in) maximum movement for a 6 mm (1/4 in) glass lite. For an insulating glass unit, the setting block must support the inboard
glass lite as well as 1/2 the outboard glass lite. See Figure 5. Support both plies when laminated glass is used
Figure 5 – Horizontal Mullion with Structural Silicone Joint and Insulating Glass

Structural Silicone Thickness
(1/4” minimum)

Structural Silicone Sealant

Structural Silicone Bite

Horizontal Mullion

Silicone Compatible Setting Block

Silicone Compatible Spacer or Gasket

Silicone Weather Seal
5.0 MATERIALS SELECTION AND SPECIFICATION

5.1 Structural Silicone Sealant

The enabling technology making structural glazing possible is structural silicone sealants with the appropriate adhesion, elastomeric strength and long term durability characteristics. In addition, the sealant must maintain these properties over a very wide temperature range since some structural joints may experience temperature extremes from -40°C up to 82°C (-40°F up to 180°F). Silicones have demonstrated the combination of long term durability, temperature stability, and reliable adhesion to a wide variety of substrates necessary for structural glazing.

A silicone sealant must be selected which successfully performs two divergent functions. The structural silicone sealant must be flexible enough to accommodate the movements resulting from thermal and other loads. The sealant must also be firm enough to support the lite under negative wind load.

In addition to the structural performance of the sealant being considered, a sealant must be selected which meets application and production needs that may be unique to the project.

Qualification per ASTM C 1184

Some of the performance requirements of a structural silicone sealant are defined in ASTM C 1184. This specification is based upon a sealant’s performance in tensile adhesion joints (ASTM C 1135) before and after a series of accelerated weathering conditions. Any structural silicone selected must comply with this minimum performance requirement.

5.2 Glazing Infills

Glazing infills used in conjunction with structural glazed framing systems must be reviewed carefully to insure the completed assembly performs to the specified design criteria. Common infills include monolithic glass, insulating glass, laminated glass, spandrel glass, and metal panels. Each product is available in a variety of treatments and finishes that can affect its adhesion characteristics.

When a glass ply has a coating or film on any surface in contact with a structural silicone including the insulating glass secondary seal, it needs to be tested for adhesion; edge
deletion of the coating/film may be required. Insulating glass units to be used in a structural glazing system must be ordered with silicone secondary edge seals in accordance with ASTM C 1249 Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications. The silicone seal within the airspace of insulating glass should be designed to withstand the structural load on the outboard glass lite. This design may take into account some load sharing resulting from the insulating glass airspace geometry. The insulating glass unit fabricator should be advised when units are to be used in a structural glazing application. Sealed insulating glass units are tested according to ASTM E 2188 and E 2189 and rated according to ASTM E 2190. The Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications is ASTM C1249.

Laminated glass is made by sandwiching an interlayer, such as polyvinyl butyryl (PVB), between two or more lites of annealed, metal coated reflective, heat strengthened or fully tempered glass. Sealant that comes in contact with edges of the laminated unit may cause minor edge imperfections of the PVB affecting visual appearance if exposed to view, which may be the case at the exterior or interior lite.

Spandrel glass with plastic opacifiers and other non-ceramic or pyrolitic coatings shall not be used unless properly edge deleted, unless approval of this application is furnished by both the glass fabricator and sealant manufacturer.

Plastic sheet glazing such as polycarbonate and acrylic is typically characterized by a higher rate of expansion and contraction than aluminum or glass; therefore, generally it is not structural glazed.

Several types of panels may be suitable for structural glazing. These composite materials and the application of the panel must be reviewed and tested carefully for adhesion and for compatibility with the structural sealant. Most stone and marble materials are not suitable for structural glazing applications.

Formed or cast aluminum, bronze, stainless steel or other suitable materials may be desired in structural glazing applications. As with all materials, the manufacturer of the substrate, curtain wall manufacturer, silicone manufacturer and installation contractor must work in conjunction with one another to establish appropriate joint design and application procedures.
5.3 Substrates

All substrate materials which are used in conjunction with structural glazing systems may be tested for adhesion by the silicone supplier. Written verification of such adhesion testing may be submitted to the Architect prior to commencing erection of the framing. Substitution of a sealant other than that tested may require retesting for adhesion and compatibility.

It is considered good practice to repeat compatibility and adhesion testing on each project, to help ensure that nothing has changed in formulation or chemistry since the last tests that could adversely affect performance.

NOTE: The principal framing members for most structural glazing applications will be made from aluminum. However, there may be instances where other materials are used or are used in accessory items which require bonding of the structural silicone. The substrate to which the silicone is bonded can adversely affect the overall bond strength. Care must be exercised in selecting substrates so as to minimize or eliminate this reduction in performance.

Aluminum - Principal metal framing shall be manufactured from commercial quality aluminum of proper alloy, temper and configuration to meet the structural and aesthetic job requirements and receive the specified finish. For most architectural applications, alloy 6063 and tempers T5 and T6 are the most commonly specified for structural glazing. Other aluminum alloys or tempers may be required to achieve special structural requirements. The choice of alloy and temper can also affect finishing, especially anodizing. The framing manufacturer will normally furnish the most optimum combination which meets all of the specifications. The specifier must require that the particular material to be used on the job be tested by the sealant supplier for silicone compatibility and adhesion. Mill finish aluminum is not acceptable for structural glazing.

Framing members shall meet deflection criteria as outlined in TIR A11 in order to be suitable for structural glazing applications. The framing member shall be reviewed for suitability by the framing manufacturer and the sealant supplier for structural glazing.

Painted or 300 series stainless steels are sometimes used but their high cost and lack of shape flexibility severely limit their use. The material and finish shall be reviewed for suitability by the framing manufacturer and the sealant supplier for structural glazing.
5.4 Finishes

In structural glazing, the framing finish becomes a structural part of the system. The structural integrity of the system demands a good bond between the finish and the structural silicone sealant AND between the finish and the framing substrate. All finishes to be used in conjunction with structural glazing must be tested for adhesion of the silicone to the finish AND for adhesion of the finish to the substrate.

The most common finishes used for structural glazing are anodized aluminum and painted substrates. There are many types of these finishes and each must be evaluated for its suitability for silicone glazing. Consultation with the framing manufacturer and the sealant supplier is recommended before a finish is specified for a particular project.

5.5 Anodic Finishes

Anodic finishes shall be either Architectural Class I or Class II and comply with the Aluminum Association’s Aluminum Design Manual and AAMA 611, "Voluntary Standards for Anodized Architectural Aluminum." They shall be designated as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>AA-M12C22A41</th>
<th>AA-M12C22A31</th>
<th>AA-M12C22A42</th>
<th>AA-M12C22A32</th>
<th>AA-M12C22A44</th>
<th>AA-M12C22A34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>0.02 mm(0.7 mil)</td>
<td>Clear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>0.01 to 0.02 mm(0.4 to 0.7 mil)</td>
<td>Integral Color</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2-step Color</td>
<td></td>
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</tbody>
</table>

Anodic finishes are achieved by immersing the aluminum member which is to be finished into a tank containing an acid solution (electrolyte) through which an electric current is passed. As the electric current flows, the acid liberates oxygen which combines with the aluminum surface to form an aluminum oxide layer or "coating." This "anodic coating" is actually formed from the metal surface and is an integral part of the metal member, as opposed to other types of coatings which are applied onto the surface.

Since these finishes are an integral part of the metal, there is no concern for the adhesion of these coatings to the metal itself. However, it is very important that certain care be taken in the anodizing process to ensure adequate adhesion of the structural silicone to the aluminum oxide substrate.

The appearance as well as the physical properties of anodic finishes is governed principally
by three factors.

1. The aluminum alloy and temper.
2. The surface treatment prior to anodizing
3. The type of electrolyte and operating techniques used in the anodizing process.

It has been known for some time that the sealing of the oxide coating is a very important step in the anodizing process. The aluminum oxide coating is a porous surface. These pores must be sealed to provide maximum resistance to staining and corrosion. Clear and integrally colored coatings are usually sealed in de-ionized boiling water or metal salt sealers to prevent stain absorption.

However, surfactants and wetting agents used in sealing of anodic coatings may result in surfaces which could result in poor adhesion of some silicones. Because of the many variables inherent in the anodizing process, it is suggested that the anodizer work closely with the sealant manufacturer to determine what steps and procedures are necessary to obtain anodized surfaces which provide adequate silicone adhesion. This may require the submitting of a series of anodized samples which have undergone various steps and procedures to determine which combinations give adequate adhesion of the silicone. During production, adhesion testing must be performed as a regular routine.

As with applied coatings, random production samples of the anodized extrusions must be tested for adhesion. Structural silicone sealant manufacturers will usually provide this service to their customers.

5.6 Organic Finishes

The organic coatings most frequently used on architectural projects are either acrylics, polyesters, fluoropolymers, or siliconized polyesters. The organic coatings considered are factory applied, not field applied. The specific selection of the type of organic coating used or specified will be determined by many factors including exterior durability requirements, overall cost, color and gloss desired, size of the architectural project, location of the project, etc. In all cases, the organic coating chosen must comply with either AAMA 2603, "Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels," or AAMA 2604, "Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels," or AAMA 2605, "Voluntary Specification, Performance
Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels," whichever is appropriate for the overall performance level desired, and as designated by the architect.

Pre-treatment of metal surfaces shall be done in accordance with the procedure prescribed in AAMA 2603, AAMA 2604, or AAMA 2605 for aluminum or as recommended by the paint manufacturer for other metals. Once an organic coating type has been selected, but prior to any production runs of the painted architectural components, sample coupons of the selected organic coating on the extruded aluminum chosen for the project must be tested to assure good adhesion of the sealant to the selected coating. These samples must receive the same treatment as the actual framing and/or infill panels will receive during the project production run.

The adhesion of the organic coating to a substrate is a direct function of proper pre-treatment. Thorough cleaning and chemical pre-treatment of the aluminum or other substrate is very important. Frequent, in-plant testing such as the boiling water adhesion test specified in AAMA 2604 or AAMA 2605, and control of the pre-treatment is required to ensure satisfactory performance of the coating system.

Formalized quality control programs are standard operating procedures for applicators of organic coatings to architectural aluminum. These quality control programs start with checks of the mill finish aluminum and end with the painted extrusion or panel. These programs are designed to minimize potential problems in the use of painted surfaces with structural glazing systems. The minimum quality control checks required are as follows:

1. Examination of mill finish aluminum to ensure that there are no heavy deposits of oxides, carbon, dried-on oils or other contaminants which will not be removed by the chemical pre-treatment process.
2. Frequent control checks and monitoring of the chemical pre-treatment stages to ensure strict compliance with the pre-treatment chemical manufacturer's requirements.
3. Visual examination of the chemically cleaned aluminum or other substrate prior to the application of the organic coatings to ensure proper cleaning has occurred. Field painted or touched up surfaces should not be structurally glazed.
4. Continuous quality control of the finished extrusions or panels to ensure that the coating manufacturer's specifications for adhesion are being met.
A quality control check list and log must be maintained by the applicator on a daily basis. The sealant contact area should be clearly shown on the parts drawings furnished to the applicator.

Off-line physical testing, especially the boiling water cross-hatch adhesion test (as outlined in AAMA 2604 or AAMA 2605) should be performed during each shift of every job. Usually, this quality control procedure will serve as an early warning of pre-treatment problems. This test is also recommended for AAMA 2603 coatings used in structural glazing applications even though it is not a specific requirement for the specification.

5.7 Chemical Conversion Coatings

Chemical conversion coatings are to be applied in accordance with AAMA 2604 or AAMA 2605. In cases where the aluminum member is hidden and an aesthetically pleasing finish is not required, a chemical conversion coating (such as chrome phosphate) is often used to improve adhesion properties of the substrate over mill finished aluminum. Mill finish aluminum exhibits inconsistent surface quality and is difficult to clean. This makes it a poor substrate for structural silicone adhesion. Silicone sealants will generally develop good long term adhesion to some chemical coatings e.g., Alodine® a registered trademark of Henkel Corporation). Architects wishing to specify conversion coatings should consult with the framing manufacturer and the sealant manufacturer to ensure that acceptable adhesion will result from their specifications. Adhesion pre-testing is recommended for this type of coating.

5.8 Adhesion/Cohesion

The performance of a structural silicone sealant is dependent upon its ability to obtain full adhesion to the glazing infill and framing. A sealant with ideal elastomeric properties is of no use unless that material can be shown to reliably obtain adhesion. Before any structural
When a project is initiated, the ability of the sealant to adhere where necessary must be determined using preconstruction adhesion evaluations. Adhesion testing is generally performed using ASTM C 794, ASTM C 1135 or a modification of either of these tests.

One criteria of these tests is referred to as cohesive failure. When a joint is stressed to failure the sealant may either pull clearly off of the substrate (adhesive failure), or the sealant bond may be so strong that the sealant breaks within itself and never loses bond with the substrate (cohesive failure). For a silicone sealant to be acceptable in a structural application the sealant must exhibit at least 75% cohesive failure helping to ensure that the full strength properties of the sealant are attained in application.

5.9 Glazing Accessories/Gaskets

Extruded rubber components play a prominent role in structural glazing systems in the form of setting blocks, spacers, and gaskets. Structural glazing systems that are conventionally glazed on one or more sides will typically use extruded gaskets at the interior and exterior sides of the glass.

Two concerns with extruded gaskets in structural glazing applications are:

1. Design of the gasket.
2. Compatibility of the gasket with the sealant(s) used in the system.

In typical gasket glazing systems, all four (4) sides of the glass are glazed with the same gasket. This may not be the case in structural glazing. The conventionally glazed sides will be glazed with a specific gasket but the structurally glazed sides will be glazed with any of the various structural glazing spacer materials. It is critical that the extruded gasket is designed to be used with the spacer selected in the specific metal system. If the gaskets or spacers are not designed properly (shape, size, and compound), the system may be subject to uneven loading, resulting in unexpected glass breakage, improper performance of the spacer, or even improper performance of the structural silicone sealant bead.
5.10 Full Contact Compatibility

The spacer used to form and back the structural silicone sealant bead is in full contact with the structural sealant bead. Compatible compounds do not discolor light-colored sealants and have no effect upon their adhesive properties when tested to the requirements of ASTM C 1087.

5.11 Point Contact Compatibility

Unlike the spacer used to form and back the structural sealant bead, these gaskets are not in full contact with the structural sealant bead. The structural sealant bead and the weather bead only contact the gaskets at the small area where the sealant beads terminate at the conventionally glazed sides. This type of compatibility also applies to full contact cap beads.

In spite of this small contact area (known as "point contact" or "incidental contact") compatibility of the sealant beads with the gaskets is still an important issue. Although silicone compatible formulations of organic rubber now exist, others have been found to be incompatible with sealants used in structural glazing applications. In the presence of ultraviolet light, incompatible compounds usually discolor the sealant they come in contact with and may eventually cause adhesion loss of the structural silicone to either the framing member or infill. For this reason, compatibility tests are run with light and dark sealant, so discoloration is easily discerned. Manufacturers will report acceptable applications of their structural sealant with point contact material based on the compatibility test results.

In addition to sealant compatibility, the ability of the weatherseal sealant(s) to achieve a seal to abutting gaskets is usually desirable. Even though most gasket glazed systems provide for water drainage, it is prudent to keep as much water out of the system as possible.

Spacers - Two (2) adhesive bond formations (sealant to glass lite and sealant to support mullion) are essential in structural glazing. It is commonly accepted that in some designs the structural silicone may also adhere to the gasket or spacer if its free movement. The spacers must meet full contact compatibility requirements.

Setting Blocks - Setting blocks support the total dead load of the glass and must be extruded from silicone compatible material having a Shore a durometer of 85 ± 5. Applications where the sill of the lite is structurally glazed generally use a setting block which supports 1/2 of the thickness of the outermost lite. The setting blocks needs to partially support both lites if
laminated glass is used. This setting block must meet full contact compatibility requirements.

5.12 Other Compounds
The use of any material (such as bond breakers or release agents) that can be transferred to the substrate adhesion surfaces must be avoided.

5.13 Installation

Installation instructions for structurally glazed framing should be extensive. They must not only direct the proper fabrication and erection of the framing but instruct the glazier in the proper method of applying the structural silicone sealant. To a great extent these instructions will vary with framing system design. One key area of difference is in whether the system is to be shop or field glazed. Other areas which must be addressed are cleaning and/or priming the framing for the application of the silicone and provisions for re-glazing the system after erection and provisions for temporary retention of the glazing while the structural silicone cures.

5.14 Glazing Methods

The choice between shop and field glazing is more involved than simply choosing whether the structural silicone sealant will be applied in the shop/factory or will be applied in the field (at the job site). The pros and cons of both system designs must be carefully considered prior to specifying one or the other. Careful consideration must be given to the suitability of the application environment, the quality control procedures required and the impact of the design choice on overall project cost and required project completion time. All applicable codes should be consulted to determine if field silicone structural glazing is allowed.

5.15 Shop Glazing

Framing which is shop or factory glazed shall have the structural silicone sealant applied according to the written recommendations of the silicone supplier with the framing and glazing in a fully supported position. The glazed assembly shall remain in the initial position until the sealant is fully cured except in applications where 2-sided pressure sensitive adhesive tape is used as a temporary retainer and the glass is properly supported during the curing of the silicone sealant. Shop glazed assemblies shall be braced or stiffened in such a manner to prevent undue stresses on the glass edge seal and structural joints or movement of the glazing during curing which may cause shear stresses in the sealant when transporting
the assemblies to the erection site.

A shop glazed system is recommended for four-sided structural glazing because it provides better quality control in the application of the structural seal. A variant of the shop glazed system often used for four-sided structural glazing is the application of a silicone-bonded metal hanging strip or "carrier frame" to the glazing in the glass factory. This glass and hanger strip unit is then bolted or otherwise attached to the main structural framing in the field. Some of the benefits of shop glazing are as follows:

- Shop glazing may allow for better, more uniform environmental conditions than in the field, including temperature, humidity, lighting, reduced dust and dirt, and freedom from contamination.

- The production and assembly work flow can be set up to provide optimum visual and physical access to the work for sealant application tooling and inspection/verification.

- Shop application of sealants allows the opportunity for application and cure without loadings on the glass and structural joints which result from winds, thermal movements and/or stack pressures.

- Shop glazing allows a better opportunity for setting up and effecting improved procedural and administrative control systems covering personnel and sealant applications and quality control procedures.

- Shop glazed systems are most efficient when used in conjunction with unitized framing designs. The pre-glazed, unitized frames can be moved to the job site and erected in a manner similar to that used for conventional captured glazing. It may be possible with this design to stage the building only once for erection of the units and application of the weatherseal at the same time.

See Figure 6.

Note that the sealant can be applied easily into the sealant joint on each half of the split mullion and the individual windows can be brought together in the field after the sealant has
cured.
Provisions must be made to prevent differential movement between the glass and glazed framing system until the structural silicone sufficiently cures. After the silicone has sufficiently cured and bonded, the frames are moved to the job site and erected in sections which may include several glazed openings per frame unit. It may be necessary to brace or stiffen the units temporarily until erected to prevent racking of the units during transportation and erection.

5.16 Field Glazing

In field glazing, the structural joint is applied in the field (at the job site). It is recommended that field glazing should only be employed in one or two-sided structural glazing applications. Before four-sided structural glazing is to be done in the field, the application should first be approved by the metal, glass and sealant manufacturers. Due to the potential for surface frost, structural silicone sealant should not be applied to metal that is colder than 4°C (40°F). The structural sealant should not be applied at a temperature above the maximum acceptable temperature for that sealant. The silicone should not be applied to wet or damp surfaces such as might be present when condensation forms on the framing. These two
restrictions result in a limitation on the possible glazing times available for field glazed systems. Extensive quality control procedures should be instituted to account for the limitations resulting from variations in temperature and humidity.

During initial glazing, application of the structural sealant is always done after the glass or other infill has been set into the framing. The glazing must be held in place by temporary retainers until the structural sealant joint has cured. Special extrusions may sometimes be used as temporary retainers and serve the dual purpose of weatherseal, thus potentially eliminating the need for double staging.

Quality control procedures for field glazing must be increased beyond those required for shop glazing. Job conditions will normally result in the appearance of dust, dirt and other construction debris on the surfaces where structural silicone is to be applied. Great care must be exercised in cleaning and preparing these surfaces for silicone application. The recommendations of the silicone supplier and the framing manufacturer must be strictly enforced. The completed joint must be protected from environmental impact and normal construction processes during the curing period. Masking of the glazing and metal trim members may be required when field glazing, depending on the system design.

The application of structural silicone at the erection site must be done in compliance with local codes and in strict compliance with the written instructions furnished by the framing manufacturer and the silicone supplier.

NOTE: Structural silicone sealants applied in the field require greater attention to site cleanliness, surface preparation and sealant application procedures than shop glazed systems or conventional glazing. The erection contractor must ensure that strict compliance is maintained by establishing a quality assurance program at the job site. (See Quality Assurance section of this Guide).

5.17 Temporary Retention

Since structural silicone sealants do not have full adhesive or cohesive strength immediately after application, a temporary retaining device (called a dutchman) must be applied to the field glazed system to hold the glazing in place while the sealant cures. The dutchmen must be stiff enough, and applied at sufficiently close spacings, to prevent the glass from having excessive movement. Typically, a dutchman can be a wood block, plastic clip or aluminum
extrusion which may be screw applied, or twisted into, the framing system. A two-sided adhesive tape, used as the structural spacer, may be considered sufficient temporary support (for two-sided structural glazing), provided the tape manufacturer has approved the use of their product for this application. Two-sided, pressure sensitive adhesive tape retainers must not be used on three- and four-sided structural glazing applications.

CAUTION: Two-sided pressure tape may not adhere to damp or cold 7°C (45°F) surfaces, and may lose effectiveness on hot surfaces. Figures 7 and 8 represent the installation of temporary fasteners for monolithic and insulating glass respectively. The UV stability and weatherability of pressure-sensitive tapes should be verified.
Figure 7 – Vertical Mullion with Monolithic Glass and a Temporary Glass Retainer.
(Dutchmen)
Most room-temperature-vulcanizing silicone sealants reach full cure in approximately 10 to 21 days. At lower temperatures full cure may take considerably longer. Any holes left by the temporary clips that would allow water infiltration of the glazing system must be sealed after removal of the clips. Temporary clips must be adequately designed and positioned to restrict movement of the glass edge under positive or negative loads.

5.18 Cleaning and Priming

This application procedure is a general guide for installing silicone building sealants. Following these procedures closely will help ensure good sealant performance. Since silicone building sealants are applied in many different environments and situations, this procedure is not meant to be a complete quality assurance program. It is only a starting point. Sealant manufacturers will assist the installer with recommendations for specific applications.

The basic steps for proper joint preparation and sealant application are:
1. Clean. Joint surfaces must be clean, dry, dust free, and frost free.
2. Prime. If required, primer is applied to the clean surface(s).
3. Set. The glass or panel to be glazed is set in place according to standard practices. Depending on the specific design, a spacer will be installed during glazing or a backer will be packed into the joint.
4. Shoot. Structural silicone sealant is applied by "pushing the bead" into the joint cavity.
5. Tool. Dry tooling techniques are used to strike a flush joint and make certain the sealant has the proper configuration and fully "wets" the joint walls.
6. Check. Adhesion testing is performed after the sealant cures.

5.19 Cleaning

Surfaces must be cleaned with a solvent before the sealant is applied. The solvent used will depend on the type of dirt or oil to be removed and the substrate to be cleaned. Non-oily dirt and dust can usually be removed with a 50% solution of isopropyl alcohol (IPA) and water. Oily dirt or films may require a more aggressive degreasing solvent. Regardless of which solvent is chosen, use the "two-cloth" cleaning method.

Organic Solvent Usage - not every kind of contaminant is effectively removed by every solvent, and some substrates can be seriously damaged by certain solvents. Follow the solvent manufacturer's safe handling recommendations and local, state and federal regulations regarding solvent usage.

"Two-Cloth" Cleaning Method
Clean, soft, absorbent, white lint-free cloths must be used. The two-cloth cleaning method consists of a solvent cloth wipe followed by a dry cloth wipe.

1. Thoroughly clean all surfaces of debris. If using organic cleaning solvent, mask now or after step 4.
2. Pour or dispense acceptable cleaning grade solvent onto the cloth. A plastic (solvent resistant) squeeze bottle works well for organic cleaning solvents. Do not dip the cloth into the container of solvent, as this will contaminate the cleaning agent.
3. Wipe vigorously to remove surface contaminants. Check the cloth to see if it has picked up contaminants. Rotate the cloth to a clean area and re-wipe until no additional dirt is picked up.
4. Immediately wipe the cleaned area with a separate clean, dry cloth. Organic solvent must be removed with the dry cloth before the solvent evaporates, otherwise the cleaning will be less effective. Some surfaces or weather conditions will allow a small amount of residual organic solvent to remain. If this is the case, the surface must be allowed to dry before continuing.

5.20 Priming

For some surfaces a prime coat is required for some sealants to develop adhesion. Since there are a variety of types of primers, consult the manufacturers recommendations for specific applications instructions. Some sealant suppliers offer a cleaner/primer allowing cleaning and priming all in the same step.

5.21 Setting Procedure

Some general rules to follow when using silicone sealant in glazing applications are as follows:

Care must be taken to ensure that joint surfaces that have been prepared are not contaminated.

In some field glazing applications, the silicone may not be applied the same day the substrates are assembled. In this case, the joint preparation (cleaning and priming) should be accomplished immediately prior to shooting the silicone.

Temporary fasteners or clips should be used to retain the structurally glazed material until the silicone has fully cured.

5.22 Sealant Application Procedure

It is critical that the sealant fill the entire joint or cavity and firmly contact or "wet" all surfaces intended to receive sealant. If the joint is improperly filled, good adhesion will not be achieved and sealant performance will be weakened.

Sealant must be applied as follows:

Masking tape may be utilized to keep excess sealant from contacting adjacent areas.
Apply the sealant in a continuous operation using a caulking gun or pump. A positive pressure, adequate to fill the entire joint width, must be used. This can be accomplished by "pushing" the sealant bead ahead of the application nozzle. Care must be taken to ensure complete fill of the sealant cavity. This is critical since the effectiveness of the silicone in structural applications is largely dependent on the structural silicone sealant bite. In the event that the sealant does not fully fill and contact the entire cavity, the amount of sealant that is present and effective must be adequate to support the design load on that lite without exceeding the design strength of the structural silicone sealant. Every effort must be made to completely fill the entire cavity: special gunning nozzles or dual applications may be required.

Tool the sealant with light pressure before a skin begins to form (typically 10 to 20 minutes). Tooling forces the sealant against the back-up material and the joint surfaces. Do not use liquid tooling aids such as water, soap, or solvents, e.g. isopropyl alcohol (IPA). These materials may interfere with the sealant cure and adhesion.

Remove the masking tape before the sealant skins over (within about 15 minutes of tooling).

5.23 Re-Glazing

Remedial work must be anticipated, and provisions included during the design of the system, to permit re-glazing in a planned manner. If a different structural silicone sealant is used for maintenance work, then its strength and other properties must be evaluated by the sealant manufacturer for complete compatibility with the system performance criteria established during the original installation. Written quality control procedures must be established during the system design phase of the project. These procedures must address:

- temporary closures
- glazing removal
- cleaning of substrates
- transportation and installation
- installation of the structural silicone sealant
- provision for temporary retainers until the sealant has cured
- finally, installation of the weatherseal
Quality assurance is not only necessary during the system fabrication and installation but, more importantly, for repair or remedial work which is often performed in less than optimum environmental and working conditions.

6.0 QUALITY ASSURANCE

6.1 Quality Control Manual

Structural glazing requires a very high degree of quality control, especially during the installation of the structural silicone sealant. The Quality Control Manual shall be prepared and appropriate training conducted prior to the installation of the structural silicone. It is important that the system designer prepare instructions and quality guidelines outlining the required measures necessary to achieve a successful installation. In the same vein, it is equally important that the sealant manufacturer furnish a quality control manual for the application of the sealant. If there are other suppliers of critical materials, they are expected to supply quality guidelines. It is recommended that the responsible subcontractor submit a written quality control manual to the architect prior to beginning erection of the wall. At a minimum this manual should include:

1. Glazing/Re-Glazing procedures and guidelines must include instructions for erecting the framing and properly sealing the joints in the framing. Procedures must be given for installing gasketing, setting the glazing materials, inserting spacers for the silicone joint and installing the temporary retainers.

2. Glazing guidelines and sealant application procedures/instructions, received from the silicone supplier, must include instructions for surface preparation priming directions, sealant shelf life, environmental application conditions and required inspections and testing. Care must be exercised that the procedures received from the framing manufacturer and the sealant manufacturer are mutually supportive and not contradictory.

3. Supplemental guidelines or procedures received from the paint supplier, glazing supplier or other involved parties, may also be necessary. Paint suppliers may require periodic adhesion testing of the painted framing members used in conjunction with structural silicone sealants. Glazing infill manufacturers may have special guidelines concerning the application of sealants to the glazing, particularly glazing which has a coating applied to the interior surface. Special instructions may be required for the application of sealants to the edges of insulating glass units (i.e., most glass suppliers require non-acetoxy silicone be used if it makes contact
with the insulating edge seal). Paint suppliers usually have procedures to be followed by the applicator to ensure proper pre-treatment and good paint adhesion. The quality control manual must set up a procedure for assuring that these procedures and their accompanying process testing are being done.

4. A quality control manual must always include a section addressing schedules for interim testing and documentation of process approvals. Suggested areas of documentation are as follows:

a. Testing performed by the silicone manufacturer documenting silicone adhesion to the finished surface furnished by the silicone supplier. Records must be kept of testing and approval of all substrates for silicone adhesion. Laboratory testing will normally be done prior to the installation of structural silicone. Field confirmation testing should be administered and monitored throughout the course of the project.

b. Test results documenting the compatibility of components such as gaskets, setting blocks, framing sealants, etc., for incidental or full contact with structural silicone and weatherseal joints. All gaskets, setting blocks, spacers and other accessories which come in contact with the structural silicone must be tested for compatibility. A record must be kept that these items were tested and approved by the silicone supplier. The record must also show whether the items were approved for full or incidental contact.

c. Testing performed by the applicator or an independent test laboratory documenting proper pre-treatment of the organic finish or conversion coating (if any) showing that the finish complies with the tests of =AAMA 2604 or AAMA 2605, for dry, wet and boiling water adhesion. For structural glazing finishes complying with AAMA 2603 must also be tested for dry, wet and boiling water adhesion. Painted framing members usually require pre-treatment of the metal prior to application of the paint. Poor pre-treatment can cause the paint to lose adhesion from the metal. Most paint suppliers require that their licensed applicators check for proper pre-treatment and paint application procedures on a regular basis. In addition to the original approval of the coating for structural silicone applications the architect must require that records be kept in the quality control manual of periodic re-checks of the coated framing for adhesion. Records must be kept of off-line physical testing, especially the boiling water cross-hatch adhesion tests on a regular basis (i.e., once per shift during the painting of the framing which will be used for structural applications).

d. The sealant suppliers approval of the design of the structural silicone joint.
Silicone suppliers will normally review drawing details with regard to the design of the silicone joint. A record of all such reviews for each joint design used on the job must be kept in the quality control manual. If the joint design is required to be changed after approval, a record of this transaction must also be kept.

e. The glass suppliers review and approval of the glazing details by the glass supplier if the glass lites are greater than 3.7 m² (40 ft²) or have an aspect ratio greater than 2.5:1. On-site adhesion tests of structural and weather seal silicones should be made on per manufacturers’ guidelines. In-place adhesion tests should be randomly made on a minimum 2% of the installed panels or windows or per sealant manufacturers’ guidelines or project specifications.

f. The glass supplier and the sealant suppliers approval of the use of non-pyrolytic glass coatings (if any).

6.2 Glazing Manual

A copy of the approved glazing procedures including the application of structural silicone shall be kept in the area where glazing is performed. This manual shall be available for reference by the glaziers during the entire time glazing is performed.

6.3 Setting of the Glazing

It is important that glaziers have available at the job site, and are trained in, complete glazing instructions, including detailed instructions on the application of the silicone. Improper setting of the glazing could result in changing of the structural joint size or coverage. There are clear distinctions between structural silicone sealants and other sealants. The glazing manual must plainly indicate how each is to be applied and at what time during the erection sequence. The design parameters for structural glazing are such that joint details and application procedures (i.e., priming requirements) will vary from job to job. For this reason the manual must be readily available at the site of glazing and silicone application.

6.4 Maintenance and Inspection Manual

After the completion of the glazing of the building, matters pertaining to glazing inspection and maintenance are normally relegated to the Building Manager or Maintenance Superintendent. Structural glazing has requirements for inspection and routine building maintenance which differ significantly from conventional glazing methods. The contractor
shall furnish to the building owner a manual outlining the required post-glazing maintenance and inspection procedures necessary to ensure long term performance of the structural glazing system. The manual shall include but not be limited to the following inspection, maintenance and testing provisions.

6.5 Inspection

Inspection procedures should be outlined such that the owner or his representative may determine if the structural bond is performing as designed. Included should be a step by step description of all required inspections including the field adhesion test. A time schedule of inspections should also be included. For inspection procedures consult ASTM C 1394 Standard Guide for On-Site Structural Silicone Glazing (SSG) Evaluation.

Any evidence of silicone adhesion problems, excessive movement or separation between the glazing system and the adjacent supporting members should be reason for remedial action. Insulating glass units which exhibit the formation of condensation or fogging within the air space must be replaced immediately and the cause for the failure determined and remedied. If there is doubt concerning the structural adequacy of a silicone joint the Field Adhesion Test (Figure 9) must be performed to determine if a problem exists. It is also prudent to inspect the glazing system when reasonable judgment would indicate a need to inspect the effects of storms, civil disorder, vandalism or other such occurrences.

6.6 Maintenance

This portion of the manual shall include methods for cleaning the structural glazing and procedures for re-glazing to be used in the event glazing failure occurs.

The maintenance section of the manual must indicate normal cleaning procedures for the framing, glazing and silicone joints. Recommendations must include cleaning agents and any precautions necessitated by the use of structural glazing. In addition, the maintenance instructions must include complete instructions on re-glazing should the need arise. These instructions must include a recommended source(s) for the glazing, de-glazing instructions, types of sealants to be used and complete instructions on re-glazing.

6.7 Testing

6.7.1 System Testing
Structurally glazed systems are no different from conventional captured glazed products as far as performance requirements are concerned. Both are often required to be tested in accordance with AAMA/ASTM standards. A particular project specification may require either laboratory or field testing, or in some instances, both. It should be noted that most project specifications will also identify allowable levels of air and water infiltration as well as structural integrity based on the appropriate AAMA/ASTM test procedure.

When considering the structural adequacy of an installation, the allowable cohesive and adhesive strengths of the structural sealant as specified by the sealant manufacturer must not be exceeded.

Additional testing may be required to verify sealant joint designs or any other unusual conditions that the standard test criteria do not cover. Tests may also be required to verify the structural integrity of the insulating glass units.

The structural performance testing must not take place until a completed cure cycle of the structural sealant has elapsed. The cure cycles may vary relative to the width and depth of the joints the temperature and moisture content of the air as well as within the various product offerings of the manufacturers.

It should be noted that because of the statistical nature of glass breakage, full scale mock-up tests to evaluate curtain wall framing may not be technically adequate to determine glass structural properties other than perhaps deflection characteristics.

For statistical reasons, specified glass may break during mock-up tests at loads or load durations below those specified for glass in the building. At test loads or durations higher than those specified for the glazing assembly, the probability of testing without a break decreases rapidly.

Conclusions drawn from a few breaks will be misleading if break origins are not evaluated. However, repeated breakage in the same opening during mock-up tests justifies careful review of test chamber construction, glass supporting members, glass quality, sealant strength and glazing details and procedures.

6.7.2 Sealant Adhesion Testing
Significance and Use:

This is not a precise, scientific test but a simple screening procedure which may help detect a problem such as improper cleaning or many of the field issues that could affect adhesion.

6.7.3 Preferred Method

As a check for adhesion, a simple field adhesion test (Figure 9) may be run after the sealant is fully cured (usually within 10 to 21 days). For structural application the adhesion should be tested at least once on every floor that has structural units/applications. The results should be recorded on the attached adhesion log form or in a project log book. The hand pull test procedure is as follows:

1. Make a knife cut horizontally from one side of the joint to the other.
2. Make two vertical cuts (from the horizontal cut) approximately 50 mm (2 in) long at the side of the joints.
3. Grasp the 50 mm (2 in) piece of sealant firmly and pull at a 90° angle or more.
4. For adhesion to be acceptable, the sealant must tear cohesively within itself before releasing adhesively from the substrate.

Figure 9 – Field Adhesion Test – Structural Silicone Joint
6.8 Repair of Sealant in Adhesion Test Area

Sealant may be easily replaced in the test area by merely applying more sealant in the same manner as it was originally installed (assuming good adhesion was obtained). Care must be taken to ensure that the new sealant is in contact with the original, and that the original sealant surfaces are clean, so that good bond between the new and old sealant will be obtained.

6.9 Alternate Method

Another simple screening test can be done on a flat surface if it is difficult to get access to a structural joint to test the adhesion.

1. The surface must be cleaned and primed following the recommended procedures for the specific project.
2. A piece of polyethylene sheet or bond breaker tape can be placed on the surface, under 50 mm (2 in) of the strip of sealant.
3. A strip of sealant must be applied approximately 100 mm (4 in) long, 25 mm (1 in) wide and 3 mm (1/8 in) deep. Tool the sealant to ensure good contact with the substrate.
4. After complete cure (10 to 21 days) lift the sealant tab off of the bond breaker tape.
or if tape was not used, undercut the sealant with a razor blade and pull firmly at 90° or greater.

5. For adhesion to be acceptable, the sealant must tear cohesively within itself before releasing adhesively from the substrate.
6.10 Stakeholders

A successful structural silicone glazed project requires cooperation between several stakeholders. These parties may include the building owner, the architect, the consultant, the Building Code Authority, the General Contractor, the structural glazing system
The ultimate success of the project is dependent on the organization, clear definition and understanding of the involvement of each individual party. Typical roles of these parties are listed below.

The building owner approves the design concept and is responsible for long term maintenance of the building.

The architect develops and reviews the design concept and establishes the performance criteria. The architect will also insist that job submittals include a complete schedule of the types of tests to be performed, the timing of tests and process checks and a procedure for logging approvals and, if necessary, retests.

The consultant provides technical expertise and consultation.

The Building Code Authority establishes the minimum building requirements which relate to the specific project location.

The General Contractor selects the subcontractors and oversees the construction progress. He furnishes an inspection schedule and a description of field checks. (The sources of this information may be manufacturers, material suppliers, and the glazing contractor or others).

Some of this information will be obtained from the framing manufacturer, some will come from the sealant supplier and some will be job specific and may come from the glazing contractor or even the general contractor.

The structural glazing system subcontractor assures that the glazing details have been reviewed and approved for the application by the appropriate material suppliers and design professionals.

The metal (and metal coating) manufacturer assures that the metal and its coating meet or exceed the requirements for silicone structural glazing.

The framing manufacturer provides the glazing/re-glazing procedures and guidelines

The glass manufacturer assures that the glass and its coating meet or exceed the requirements for silicone structural glazing.
The sealant manufacturer assures that the sealant meets or exceeds the requirements for silicone structural glazing. This requires verification that the sealant will adhere to the appropriate glazing infill and metal surfaces, and that the sealant is compatible with accessory materials that it may come into contact with. This may require a review of the projects details and specifications as well as project specific testing. The sealant supplier must submit specific guidelines for the installation of the structural silicone and the weatherseal joints.

It is recommended that maintenance manuals be provided to the building owner.
<table>
<thead>
<tr>
<th>Date Applied</th>
<th>Applied By (Initials)</th>
<th>Test Date</th>
<th>Test Location (Elevation, Unit Number, etc.)</th>
<th>Primed (Y/N)</th>
<th>Acceptable Adhesion (Y/N) and % Elongation</th>
<th>Acceptable Joint Fill (Y/N)</th>
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NOTE: Information relating to adhesion testing and acceptable joint fill can be obtained from the sealant manufacturer and from ASTM C 1401 Guide for Structural Sealant Glazing.
**PRODUCT QUALITY CONTROL LOG - ONE PART SILICONE SEALANTS**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Tester Initials</th>
<th>Sealant Lot Number</th>
<th>Acceptable Cure Rate (Y/N)*</th>
<th>Acceptable Cured Properties (Y/N)*</th>
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* Procedures for determining acceptable cure rate and acceptable cure properties must be supplied by the sealant manufacturer for the specific sealant used.
PRODUCT QUALITY CONTROL LOG - TWO PART SILICONE SEALANTS

<table>
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<th>Project</th>
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<tbody>
<tr>
<td>Location/Elevation/Unit ID</td>
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<tr>
<td>Base: Catalyst Ratio (specify weight or volume ratio)</td>
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**Anticipated Snap Time**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Tester Initials</th>
<th>Approximate Temperature/ % Humidity</th>
<th>Base Lot Number</th>
<th>Catalyst Lot Number</th>
<th>Evaluation of Full Mix* (Y/N)</th>
<th>Evaluation of Cure Rate (minutes)*</th>
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* Procedures for determining sealant cure rate and thoroughness of mixing should be provided by the sealant manufacturer for the specific sealant used.