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# Standard Guide for Structural Sealant Glazing[1]

This standard is issued under the fixed designation C1401; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 Structural sealant glazing, hereinafter referred to as SSG, is an application where a sealant not only can function as a barrier against the passage of air and water through a building envelope, but also primarily provides structural support and attachment of glazing or other components to a window, curtain wall, or other framing system.

1.2 This guide provides information useful to design professionals, manufacturers, contractors, and others for the design and installation of a SSG system. This information is applicable only to this glazing method when used for a building wall that is not more than 15° from vertical; however, limited information is included concerning a sloped SSG application.

1.3 Only a silicone chemically curing sealant specifically formulated, tested, and marketed for structural sealant glazing is acceptable for a SSG system application.

1.4 The committee with jurisdiction for this standard is not aware of any comparable standard published by other organizations.

1.5 The ~~calculations and~~ values stated in SI units are to be regarded as ~~the standard. Values in parenthesis and inch-pound units are for information only.~~ standard. The values given in parentheses after SI units are provided for information only and are not considered standard. SI units in this guide are in conformance with IEEE/ASTM SI 10.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

B117 Practice for Operating Salt Spray (Fog) Apparatus
C99 Test Method for Modulus of Rupture of Dimension Stone
C119 Terminology Relating to Dimension Stone
C162 Terminology of Glass and Glass Products

[1] This guide is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.10 on Specifications, Guides and Practices.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

C503 Specification for Marble Dimension Stone
C509 Specification for Elastomeric Cellular Preformed Gasket and Sealing Material
C510 Test Method for Staining and Color Change of Single- or Multicomponent Joint Sealants
C568 Specification for Limestone Dimension Stone
C615 Specification for Granite Dimension Stone
C717 Terminology of Building Seals and Sealants
C719 Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)
C794 Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants
C864 Specification for Dense Elastomeric Compression Seal Gaskets, Setting Blocks, and Spacers
C880 Test Method for Flexural Strength of Dimension Stone
C920 Specification for Elastomeric Joint Sealants
C1036 Specification for Flat Glass
C1048 Specification for Heat-Strengthened and Fully Tempered Flat Glass
C1087 Test Method for Determining Compatibility of Liquid-Applied Sealants with Accessories Used in Structural Glazing Systems
C1115 Specification for Dense Elastomeric Silicone Rubber Gaskets and Accessories
C1135 Test Method for Determining Tensile Adhesion Properties of Structural Sealants
C1172 Specification for Laminated Architectural Flat Glass
C1184 Specification for Structural Silicone Sealants
C1193 Guide for Use of Joint Sealants
C1201 Test Method for Structural Performance of Exterior Dimension Stone Cladding Systems by Uniform Static Air Pressure Difference
C1248 Test Method for Staining of Porous Substrate by Joint Sealants
C1249 Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications
C1253 Test Method for Determining the Outgassing Potential of Sealant Backing
C1265 Test Method for Determining the Tensile Properties of an Insulating Glass Edge Seal for Structural Glazing Applications
C1294 Test Method for Compatibility of Insulating Glass Edge Sealants with Liquid-Applied Glazing Materials
C1330 Specification for Cylindrical Sealant Backing for Use with Cold Liquid-Applied Sealants
C1369 Specification for Secondary Edge Sealants for Structurally Glazed Insulating Glass Units
C1392 Guide for Evaluating Failure of Structural Sealant Glazing
C1394 Guide for In-Situ Structural Silicone Glazing Evaluation
C1472 Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width
C1487 Guide for Remedying Structural Silicone Glazing
C1521 Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints
C1564 Guide for Use of Silicone Sealants for Protective Glazing Systems
D1566 Terminology Relating to Rubber
D2203 Test Method for Staining from Sealants
D4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Skylights, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
E330 Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference
E331 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
E547 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference
E631 Terminology of Building Constructions
E783 Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
E1105 Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference
E1233 Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential
E1300 Practice for Determining Load Resistance of Glass in Buildings
E1424 Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure and Temperature Differences Across the Specimen
E1425 Practice for Determining the Acoustical Performance of Windows, Doors, Skylight, and Glazed Wall Systems
E1825 Guide for Evaluation of Building Exterior Enclosure Materials, Products, and Systems

E1886 Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials
E1996 Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes
E2128 Guide for Evaluating Water Leakage of Building Walls
E2203 Specification for Dense Thermoplastic Elastomers Used for Compression Seals, Gaskets, Setting Blocks, Spacers and Accessories
E2099 Practice for the Specification and Evaluation of Pre-Construction Laboratory Mockups of Exterior Wall Systems
E2431 Practice for Determining the Resistance of Single Glazed Annealed Architectural Flat Glass to Thermal Loadings
G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]

2.2 *IEEE/ASTM Standard:*[2]
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.3 *Aluminum Association Manual:*
Aluminum Design Manual[4]

2.4 *ANSI/ASCE Standard:*
ANSI/ASCE 7, Minimum Design Loads for Buildings and Other Structures[5]

2.5 *AAMA Standards:*
501.1 Standard Test Method for Metal Curtain Walls for Water Penetration Using Dynamic Pressure[6]
501.2 Field Check of Metal Curtain Walls for Water Leakage[6]
TIR-A11–1996 Maximum Allowable Deflection of Framing Systems for Building Cladding Components at Design Wind Loads[6]

2.6 *ANSI Standard:*
Z97.1 Safety Performance Specifications and Methods of Test for Glazing Materials Used in Buildings[5]

2.7 *CPSC Standard:*
16 CFR 1201 Standard on Architectural Glazing Materials[7]

## 3. Terminology



3.1 *Definitions:*

3.1.1 Refer to Terminology C119 for definitions of the following terms used in this guide: dimension stone, granite, hysteresis, limestone, and marble.

3.1.2 Refer to Terminology C162 for definitions of the following terms used in this guide: chip, chipped glass, double glazing unit, flat glass, glass, heat-strengthened glass, heat-treated, laminated glass, lite, pyrolitic coating, safety glass, skylight, spandrel glass, tempered glass, thermal stress, toughened glass, and wave.

3.1.3 Refer to Terminology C717 for definitions of the following terms used in this guide: adhesive failure, bicellular sealant backing, bite, bond breaker, butt glazing, cell, chemically curing sealant, closed cell, closed cell material, closed cell sealant backing, cohesive failure, compatibility, compound, cure, durability, durability limit, elastomeric, elongation, gasket, glazing, glazing construction site, hardness, joint, lite, modulus, open cell, open cell material, open cell sealant backing, outgassing, premature deterioration, primer, seal, sealant, sealant backing, secant modulus, service life, setting block, shop glazing, silicone sealant, spacer, standard conditions, structural sealant, substrate, thickness, and tooling.

3.1.4 Refer to Terminology D1566 for the definition of the following term used in this guide: compression.

3.1.5 Refer to Terminology E631 for the definitions of the following terms used in this guide: air-leakage, anchorage, anchorage system, building envelope, cladding system, curtain wall, glaze, mechanical connection, mockup, operable, panel, performance standard, sealed insulating glass, shop drawing, specification, static load, tolerance, water-vapor retarder, weephole, and working drawing.

3.1.6 Refer to Terminology G15 for the definition of the following term used in this guide: chemical conversion coating.

3.2 *Definitions of Terms Specific to This Standard:*

[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from the Aluminum Association, 900 19th St., N.W. Washington, DC 20006.
[5] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from the Architectural Aluminum Manufacturers Association (AAMA).
[7] Available from the Consumer Product Safety Commission (CPSC), Washington, D.C. 20207.

3.2.1 *aspect ratio (AR), n*—the ratio of the long dimension of the glass to the short dimension of the glass. AR is always equal to or greater than 1.0.

3.2.2 *negative pressure, n*—an applied load, usually wind induced, that tends to pull a glass lite or panel away from a building surface.

3.2.3 *opacifier, n*—an opaque material applied to the interior facing surface of a glass spandrel panel, which can include materials, such as adhesively applied organic films, a liquid-applied silicone coating, or a fired-on ceramic enamel frit.

3.2.4 *panel, n*—a cladding material other than glass that is manufactured or fabricated from solid, laminated or composite assemblies of materials such as dimension stone, metal or plastic.

3.2.5 *positive pressure, n*—an applied load, usually wind induced, that tends to push a glass lite or panel inward from a building surface.

3.2.6 *snap time, n*—the time in minutes at which a multicomponent sealant tears within itself and does not string when a spatula is removed from the curing sealant.

3.2.7 *stick system, n*—a metal framing system of numerous elements that is construction site assembled and field glazed, usually in-place on the face of a building.

3.2.8 *thermal bridge, n*—a method that transfers thermal energy, usually by means of a metallic path from the interior to the exterior of a window or curtain wall system.

3.2.9 *unitized system, n*—a panelized metal framing system that is preassembled and usually shop-glazed, with the panels transported to a construction site for erection on a building.

3.3 *Symbols:*



$A$ = solar absorptivity coefficient.
$\alpha$ = coefficient of linear thermal movement mm/mm/°C (in./in./°F).
$B$ = structural sealant joint bite mm (in.).
$C$ = perpendicular distance between parallel sides m (ft).
$\Delta L$ = thermal movement mm (in.).
$\Delta T_s$ = summer temperature differential °C (°F).
$\Delta T_w$ = winter temperature differential °C (°F).
$F_d$ = allowable structural sealant dead load stress kPa (psi).
$F_t$ = allowable structural sealant tension stress kPa (psi).
$F_v$ = allowable structural sealant shear stress kPa (psi).
$f_t$ = computed tensile stress kPa (psi).
$f_v$ = computed shear stress kPa (psi).
$H$ = heat capacity constant.
$L$ = side of lite or panel m (ft).
$L_1$ = long side of lite or panel m (ft).
$L_2$ = short side of the lite or panel m (ft).
% = shear movement percent.
$P_w$ = lateral load due to wind kPa (psf).
$R$ = radius of a lite or panel m (ft).
$T$ = structural sealant joint thickness mm (in.).
$T_a$ = ambient summer temperature °C (°F).
$T_s$ = summer surface temperature °C (°F).
$T_w$ = ambient winter temperature °C (°F).
$W$ = unit weight of lite or panel kg/m$^2$ (lb/ft$^2$).
$\varphi$ = angle in degrees.

## 4. Summary of Guide

4.1 *General*—This guide has been subdivided into major headings. A very brief description of each major heading is provided to assist the reader in locating general areas of information. For a more detailed listing of guide topics and section headings, refer to Appendix X1 for a complete listing of the numbered sections and their descriptors.

4.2 *Predesign Considerations (Section 6),* in general, the responsibilities and relationships of the various participants in SSG system development and implementation.

4.3 *Performance Criteria Considerations (Sections 7 – 14),* SSG system structural loads, movements, construction tolerances, weather tightness, sound transmission, fire resistance, and durability.

4.4 *System Design Considerations (Sections 15 – 18),* information is provided about the basic types of SSG and related systems, as well as system weatherproofing concepts.

4.5 *Component Design Considerations (Sections 19 – 26),* framing systems, framing finishes, glass, panels, structural sealants, weather seal sealants, and accessory material information.

4.6 *Structural Sealant Design Considerations (Sections 27 – 31),* structural joint location and configuration, adhesion and compatibility concerns, theoretical structural design, and other design and weather seal considerations.

4.7 *Testing Considerations (Sections 32 – 37),* predesign scale model wind and snow load testing, design and fabrication component testing for quality, adhesion, and compatibility, and full-size assembly mock-up testing information.

4.8 *Shop Glazing Considerations (Sections 38 – 42),* materials prequalification, quality control programs, and inspection and testing quality assurance issues.

4.9 *Construction-Site Glazing Considerations (Sections 43 – 47),* materials prequalification, quality control programs, and inspection and testing quality assurance issues.

4.10 *Post-Installation Considerations (Sections 48 – 51),* quality control, maintenance, and periodic monitoring programs.



## 5. Significance and Use

5.1 The old saying "A chain is only as strong as its weakest link" is very applicable to a SSG system. In reality, a SSG system, to be successful, must establish and maintain a chain of adhesion. For example, a factory applied finish must adhere adequately to a metal framing member, a structural glazing sealant to that metal finish, that structural glazing sealant to a reflective coating on a glass lite, and lastly, that reflective coating to a glass surface. This guide will assist in the identification and development of, among others, performance criteria, test methods, and industry practices that should be implemented to obtain the required structural glazing sealant adhesion and compatibility with other system components.

5.2 Although this guide has been arranged to permit easy access to specific areas of interest, it is highly recommended that the entire guide is read and understood before establishing the requirements for a particular SSG system.

5.3 This guide should not be the only criteria upon which the design and installation of a SSG system is based. The information herein is provided to assist in the development of a specific program with a goal of achieving a successful SSG system installation. Information and guidelines are provided for the evaluation, design, installation, and maintenance of a SSG system and many of its various components. Considering the range of properties of structural glazing silicone sealants, as well as the many types of framing system designs, material combinations that can be used, various material finishes, and the many types and varieties of accessories, the information contained herein is general in nature.

5.4 Generally, the design, fabrication, and installation of a SSG system requires more technical knowledge and experience then is required for a conventionally glazed window or curtain wall system. To ensure the success of a SSG system, it is important that suppliers, fabricators, and installers of materials and components have a sound knowledge of SSG system requirements and become involved in the design and planning for each application. Suppliers of, among others, sealants, framing finishes, glazing materials and components, and various accessories should review and agree with the developed SSG system plans, requirements, and quality control program.

5.5 The results of not planning for and implementing quality control programs during at least the design, testing, fabrication, and installation phases of a SSG system's development can result in less than desirable results, which can include nuisance air or water leakage or catastrophic failure where life safety of the public can be at risk (**1, 2**).[8]

## PREDESIGN CONSIDERATIONS

### 6. Roles of Major Participants

6.1 *General*—Responsibility for the design, implementation, and maintenance of a SSG system depends largely on the contractual relationships between the participants and their extent of participation. This relationship can vary on individual projects, but it should be established clearly at the beginning and understood by all concerned parties. The following descriptions briefly describe the normal roles and duties generally ascribed to the participants, which usually is adequate for the development of a SSG system.

6.2 *Building Owner*— The building owner should review and approve the design concept and budget for the development and implementation of a SSG system. It is the building owner's responsibility to establish and maintain a realistic post-construction inspection and testing program to evaluate structural sealant integrity. Typically, the building owner also should authorize required maintenance, structural repairs, and replacement of components expeditiously.

6.3 *Architect*—The architect should provide the basic system design concept, performance criteria, and a cost estimate for the owner's review and approval. The architect also should provide the owner with an explanation of the SSG system design concept, degree of risk involved, and maintenance and eventual replacement requirements. The architect has the responsibility to conduct a feasibility review of the basic design concept, system features, and material requirements with potential manufacturers and contractors. The architect also should engage a SSG system consultant, if one is needed, and provide contract documents (working drawings and specifications) in accordance with the chosen construction method and the architect's professional services agreement. Construction administration by the architect usually includes, among others, shop drawing, product data, sample review, and approval or other appropriate action. The architect also makes on-site visits in accordance with the professional services agreement.



6.4 *Consultant*—A consultant usually is engaged by the architect but also can be engaged by the general contractor, curtain wall subcontractor, or the owner. The consultant provides guidance and technical expertise and establishes requirements for the design and implementation of the SSG system, among others.

6.5 *Building Code Authority*—All codes accept traditional glazing with conventional mechanical glazing retainage; however, some jurisdictions may permit SSG systems only with supplementary mechanical retainage. Other code jurisdiction requirements can include, among others, establishment and certification of specific structural sealant material properties, controlled inspection of a SSG system installation, and post-installation periodic inspection and certification programs. For example, the ICBO Evaluation Service, Inc., a subsidiary of the International Conference of Building Officials (ICBO), which publishes the Uniform Building Code (UBC), requires fulfillment of certain criteria before a structural sealant is acceptable for use in jurisdictions that have adopted the UBC. Code acceptance criteria may involve testing and conditions of testing that normally are not conducted by structural sealant manufacturers or require conditions of use that will limit the type and character of a SSG system. Additionally, other code requirements for example impact resistance may also have an effect on the design of an SSG system (See 8.6) The building code and the specific code jurisdiction authorities should be consulted prior to any SSG system detailed design.

6.6 *Contractor*—The contractor selects the subcontractors and reviews, approves, and submits to the architect submittals, such as shop drawings, product data, and samples. The contractor also performs the construction and other services in accordance with the contract documents and the approved submittals. Supervision, direction, and coordination of the construction and other services, to assure compliance with the contract documents, also is performed by the contractor. Most importantly, the contractor has the responsibility for and control of construction means, methods, techniques, sequences, and procedures unless the contract documents direct otherwise.

[8] The boldface numbers in parentheses refers to the list of references at the end of this standard.

6.7 *SSG System Designer*—This responsibility often is the architect's, however, a SSG system consultant or a curtain wall subcontractor also can perform this work. Responsibilities include the design of the SSG system to meet the architect's design parameters and performance criteria and development of specific material selection criteria for glass, panels, metal finishes, sealants, gaskets, and other SSG system components. Importantly, the system designer also should develop a SSG system that can be resealed or reglazed, easily and adequately, if glass, sealant, or other component replacement is necessary.

6.8 *SSG System Subcontractor*—Responsibilities include obtaining the approval of, among others, panel, metal finish, glass, and sealant manufacturers for use of their products in a SSG application; preparation and submittal of shop drawings to the general contractor for processing and approval; and, fabrication and installation of the SSG system in accordance with, among others, the contract documents, approved shop drawings, mock-ups, and component manufacturer's recommendations. Sometimes a separate SSG system installation subcontractor is retained. Coordination between the system manufacturer and the installer is required.

6.9 *Metal Framing Fabricator or Supplier*—Responsibilities include coordinating with the metal supplier and the finish applicator; monitoring of metal surface finish quality control; and, approval of the product for the specific SSG application. The metal framing fabricator also has the responsibility to provide representative production run samples of metal finishes for adhesion and compatibility evaluation by the structural sealant manufacturer.

6.10 *Glass Manufacturer or Fabricator*—Responsibilities include review of the project design requirements; recommendation of glass thickness and type to meet, among others, wind load and thermal stress conditions as specified for the SSG system; quality control of the secondary seal of insulating glass units and any glass coatings, such as reflective or low-emissivity; and, approval of the glass product(s) for a specific SSG application. The glass manufacturer also has the responsibility to provide production run representative samples of the glass type(s) for adhesion and compatibility evaluation by the structural sealant manufacturer. The glass manufacturer also has the responsibility to determine with the cooperation of the fabricator of the insulating glass units, if a separate party, the compatibility of at least the structural sealants and accessories that may have an effect on the performance of the insulating glass unit edge seal.



6.11 *Panel Manufacturer or Fabricator*—Panel types include metal, composite, plastic, and stone among others (See Section 23). Responsibilities include: review of the project design requirements; recommendation of panel type to meet, among others, wind load and thermal stress conditions as specified for the SSG system; quality control of any panel finishes or coatings and approval of the panel product(s) for a specific SSG application. The panel manufacturer also has the responsibility to provide production run representative samples of the panel type(s) for adhesion and compatibility evaluation by the structural sealant manufacturer.



6.12 *Structural Sealant Manufacturer*—Responsibilities include conducting structural sealant compatibility testing with, among others, spacers, gaskets, setting blocks and other sealants; adhesion testing of the structural sealant(s) to the panel surface, metal finish and glass substrates; review and approval of the structural sealant joint dimensions provided by the SSG system designer; recommendation of a sealant(s) for the structural and weather seals, as well as, if necessary, a primer; and approvals of the sealant products for the specific SSG application.

6.13 *Accessory Material Suppliers*—Accessory material suppliers have the responsibility to provide spacers, gaskets, setting blocks and other products of the correct material formulation, hardness, shape, and tolerances as specified by the architect, consultant, or SSG system designer. The accessory material supplier also has the responsibility to provide production run representative samples of the accessories for adhesion and compatibility evaluation by the structural sealant manufacturer.

## PERFORMANCE CRITERIA CONSIDERATIONS

## 7. General

7.1 Typical performance criteria that are applicable to a conventional glazing system also apply to a SSG system; however, some of these performance criteria may require different treatment, extra care, or additional criteria. The following typical performance criteria are described where SSG issues need to be considered. Typically, some combination of the following structural loads and movements, depending on an engineering analysis of a particular SSG system's design requirements, may have to be considered. For example, the effect of wind load and thermal movement is a commonly encountered combination that may have to be evaluated when designing a structural sealant joint. Additional general glazing, as well as performance criteria information, is available from industry associations, such as the American Architectural Manufacturers Association (AAMA), the Glass Association of North America (GANA) (formerly the Flat Glass Marketing Association, and the American Society of Civil Engineers (ASCE).

## 8. Structural Loads

8.1 *Dead*—A SSG system, depending on a particular design, may require the structural sealant joint to resist a constant dead load stress. This usually occurs when glass or panels are unsupported by setting blocks or other mechanical devices and also at suspended soffit construction. The allowable dead load stress for design will depend on the modulus of the structural sealant and the dimensions of the structural sealant joint. Some structural sealant manufacturers will not permit glass or panels to be suspended or unsupported by setting blocks or other means. For those sealant manufacturers who permit dead load stressing of the structural sealant, there has been a precedent to limit the dead load stress to no more than 7 kPa (1 psi). The structural sealant manufacturer should be consulted early during SSG system design since not all sealant manufacturers will permit a constant dead load stress on the sealant joint or permit exceeding a 7 kPa (1 psi) limit.

8.2 *Wind*—The realistic establishment of negative and positive wind loads is important (**3, 4**). It is primarily the wind loading conditions, except for some seismic zones, which determine the size and shape of a structural sealant joint in a SSG system. Other secondary loading conditions, such as dead load and thermal movement also can contribute to the design of a structural sealant joint. The building code applicable to a SSG system will establish minimum requirements for the wind load to be resisted by a curtain wall or window system and therefore a SSG system. Often, cladding wind loads are not adequately described by those building codes that use a simple table of wind load values. The ASCE standard ANSI/ASCE 7, which also is referenced in some of the national model building codes, provides a detailed analysis and description of the wind loads to be resisted by a curtain wall or window system. The building code and the ANSI/ASCE 7 determined wind load values typically apply to buildings of square or rectangular shape with vertical walls. The use of a building code or the analytical procedure in ANSI/ASCE 7 may not be sufficient for these buildings, particularly when of other shapes. Often, this is the case when a building is in an urban environment; of unusual configuration; closely related to other buildings as in a campus setting; or, in an area of unusual or unpredictable wind patterns. For these and other reasons scale model testing of a building in a boundary layer wind tunnel (BLWT) may be necessary (see 33.1.1).



8.3 *Snow*—For sloped wall surfaces or skylights, the effect of snow loading and drifting patterns on a SSG system must be considered. The building code and ANSI/ASCE 7 establish values that can be used for design. Also, the AAMA skylight and sloped glazing, 501.1 and 501.2, will provide the design professional with design information for snow loading and control on sloped surfaces. Since the actual pattern and velocity of wind flow around a building can have a dramatic impact on drifting and snow load, however, the use of a scale model testing facility to establish these patterns and loads is recommended (see 33.1.3). Snow and ice loads usually cause a long-term compressive stress on a structural sealant joint and can become another of the secondary loading conditions that should be evaluated when designing a SSG system. The effect of snow load on vertical wall surfaces usually is not a performance criterion; however, the additional dead load generated by hardened snow or ice sheets, which can form on vertical and other surfaces, may need to be considered.

8.4 *Live (Maintenance)*—Normally, loads transferred directly to a window or curtain wall framing member by maintenance platforms will not have a significant effect on the structural joints in a SSG system; however, the use of continuous maintenance tracks, as well as intermittent tie-back buttons or other devices, may have an influence on the practical aspects of SSG system design, such as adequate access to apply the structural sealant in the joint opening and the development of thermal bridges (see 11.4.1).

8.5 *Seismic:*

8.5.1 Seismic design largely is based on probability and economics (**3**). The magnitude and frequency of seismic loads cannot be determined with the same degree of accuracy as other types of building loads. It is possible the magnitude of loading may vary by a factor of two or more; therefore, due to economic reasons, a commonly accepted earthquake design philosophy is to control major structural damage while allowing some minor nonstructural damage as a result of an earthquake.

8.5.2 The applicable building code should be consulted for seismic design guidelines. There are benefits to using a SSG system in areas prone to earthquakes. The resilient attachment of a glass lite or panel to the supporting framework by the structural sealant joint has proven to be beneficial in controlling and in some cases eliminating breakage normally experienced during a small to moderate earthquake. Since the lite or panel is not captured in a metal glazing pocket the opportunity for it to impact the metal glazing pocket surfaces is minimized, eliminating a primary cause of breakage. Depending on system design, however, adjacent glass lite or panel edges could contact each other and cause breakage or other effects. Also, when a glass lite break does occur, the SSG system, due to continuous attachment of the glass edge, can retain much if not all of the broken glass, depending on glass type, and provided that the structural joint retains sufficient integrity. Resilient attachment of a glass lite also has proven beneficial in other violent natural occurrences such as hurricanes.

8.5.3 The level of performance required of a SSG system during and after an earthquake will vary depending on the system design philosophy. The SSG system should remain stable after an earthquake. For example, depending on the magnitude of an earthquake, glass may or may not break. Laminated glass often is used in seismic regions so that it can remain in the opening if it does break; however, whether or not remedial work is required to regain SSG system functionality, for example, air or water resistance and structural performance, is a choice for the designer, depending on building code requirements, which will affect the design and cost of the SSG system.

8.5.4 Racking motion of a building frame in an earthquake will cause planar motion of a glass lite or panel, typically causing a shear stress in a structural sealant joint. Although conventional SSG systems perform well in an earthquake, consideration should be given to isolating the lite or panel from building frame movement. One method to consider is to structurally adhere the lite or panel to a subframe, then attach the subframe to the primary curtain wall or window framing members with mechanical fasteners in slotted holes (**5**).

8.6 *Missile Impact—* Windborne debris has been established as a principal cause of glass breakage during windstorms (**6**). The designer of a SSG system may have to make provisions in the system design to resist large and small missile impacts (**7**). At lower floors, large objects, such as framing members and facade elements from nearby collapsed structures and at lower and upper floors windborne gravel from ballasted roofs, the largest source of glass breakage, tend to strike a building envelope. If the building envelope does not remain intact during a windstorm, the wind-induced increase to a building's internal pressure adds to the wind-induced external suction on leeward walls and roofs, thereby increasing the possibility of a structural failure or collapse of facade elements. In addition, breaching the envelope allows damage to the building interior and potential harm to occupants. Guide C1564 can be used to determine the design and installation requirements for the missile impact structural sealant in addition to those required for SSG. Test Method E1886 and Specification E1996 can be used to determine the performance of a window or curtain wall when impacted by a missile and exposed to a cyclic pressure differentials, as is commonly encountered during these storms. Various building codes and governmental authorities such as the BOCA National Building Code, South Florida Building Code, and the International Building Code include requirements for building envelope resistance to missile impacts. The provisions in these codes are not consistent with each other, with changes occurring each year, and they vary in required test methods, test protocol, and resultant performance. The ANSI/ASCE 7 national wind load standard, which is referenced by building codes, also contains provisions for resistance to missile impact. Additionally, those that insure buildings in coastal areas may also have requirements such as those contained in the Building Code for Windstorm Resistant Construction by the Texas Windstorm Insurance Association. The designer of an SSG system, particularly for coastal regions, should consult local code, governmental, and insurance authorities to determine the requirements for resisting missile impacts and their effect on the design of an SSG system prior to any detailed design.

## 9. Movements

9.1 *Building Motion*—Tall buildings will respond to wind pressure and other lateral forces, such as earthquakes, by swaying laterally or twisting due to torsional moments. The magnitude of these movements can be determined by a structural engineer or by scale model testing in a BLWT (see 33.1.1). These movements usually are expressed as an offset at each story relative to adjacent stories (story drift). These movements can create a shear stress, which may have to be considered with other secondary stresses in the design of the structural sealant and other joints of a SSG system.

9.2 *Thermal Movement*—The effect of thermal movement always must be considered and provided for in the design of a SSG system. If not, excessive air leakage and water infiltration, as well as potential structural problems, can occur. The effect of thermal movement within the structural sealant joint, due to differential thermal movement between glass or panels and the supporting framework, should be investigated for any effects on the structural sealant joint that may have to be considered along with other structural sealant joint secondary stresses.

9.3 *Live Load*—Deflection caused by structure or floor live loading should be considered for SSG system sealant joints, such as expansion joints, that occur usually at each floor level in multistory construction. The building structural engineer can supply live load deflection criteria for use in designing the SSG system. Actual live loads can be highly variable (**8**). A multistory building, with the same design live load for all floors, will have the actual live load, which can be substantially less than a code prescribed value, vary from floor to floor and from one area of a floor to another. Very rarely will the live load be uniform everywhere. Where live load, and thus deflection of a structure varies, the relative difference in live load deflection between floors should be considered in the multistory SSG system expansion joint width design.

9.4 *Dead Load*—Deflection caused by structure or floor dead loading also should be considered for SSG system expansion joints. The building structural engineer can supply dead load deflection criteria for SSG system expansion joint design.

9.5 *Framing Effects:*

9.5.1 *Elastic Frame Deformation*—Multistory concrete structures, and to a lessor degree steel, shorten elastically almost immediately due to the application of loads (**8, 9**). Frame shortening, the degree of which can be estimated by a structural engineer, will cause an irreversible narrowing of SSG system expansion joints that typically occur at each floor level in multistory construction. Frame shortening can be compensated for by building each floor level slightly higher, in effect negating most of the short-term shortening that occurs before SSG system installation. Lower floors of multistory structures will experience greater shortening then upper floors. For each concrete column, the amount of shortening is dependent on, among others, the amount of reinforcement and the time of application of loads (dead load of additional floors and live load). Additionally, joint width narrowing can be considered during the design of an SSG system expansion joint. Some of the frame shortening affect will occur before the cladding is erected and the size of the SSG system expansion joint opening is established. Presently, the amount of shortening that occurs before the joint opening is established is determined by an informed estimate, and therefore, should be conservative.

9.5.2 *Creep*—The time dependent deformation of materials while loaded, in particular for a concrete structure, should be included in SSG system floor level expansion joint design. This deformation, which occurs at a decreasing rate as time progresses, can cause a continuing decrease in the width of an expansion joint opening in multistory and other buildings. Creep, in contrast to elastic frame shortening, can occur over a long period of time (**8, 9**). The building structural engineer can provide creep deflection criteria for SSG system expansion joint design.

9.5.3 *Shrinkage*—Concrete framed structures will undergo long-term shrinkage for a period of months (**8, 9**). The rate of shrinkage is dependent on the initial amount of concrete mix water present, ambient temperatures, rate of air movement, relative humidity of the surrounding air, the shape and size of the concrete section, and the amount and type of aggregate in the concrete mix, among others. Reference (**10**) lists guidelines for some shrinkage values for concrete and other materials. Shrinkage criteria can be provided by a structural engineer and included in the SSG system floor level expansion joint design or can be compensated for in the construction of the formwork. Shrinkage effects should be included in the design of a SSG system expansion joint in multistory construction. Some of the frame shrinkage affect will occur before the cladding is erected and the size of a SSG system expansion joint opening is established. Presently, the amount of shrinkage that occurs before the expansion joint opening is established is determined by an informed estimate, and therefore, should be conservative.

9.6 *Seismic*—For successful seismic performance, the SSG system must be capable of retaining required performance levels without glass or other breakage while accommodating differential movements between building stories. As was previously indicated, SSG system structural sealant joints have performed well during small to moderate earthquakes. The structural sealant joint permits the lite or panel and framing to move somewhat independently of one another, while generally maintaining seals and preventing edges from contacting the SSG system metal framing members or each other. Seismic performance can be enhanced by increasing the thickness of the structural sealant joint. This will decrease the shear stress developed in the structural sealant joint during racking of the SSG system; however, it may increase the tendency of adjacent glass lites or panels to come into contact with each other. This increase also should be evaluated for its impact when, at other times, the primary lateral load is applied. Depending on the structural sealant modulus and the structural joint thickness, a glass lite or panel could be pulled off setting blocks with a sufficiently large negative applied load. Another technique to enhance seismic performance is to structurally seal a lite or panel to a subframe, usually by shop glazing, which then is mechanically attached to a metal framing system or the building frame in a manner that permits differential movement, both vertically and horizontally, between the subframe and the framing system or building (**5**). The subframe mechanical attachment mechanism then is designed to accommodate the expected seismic movement.

## 10. Construction Tolerances

10.1 *General*—The SSG system design must respond to tolerances likely to effect its fabrication and installation (**11**). The SSG system performance criteria should specify the allowable material, fabrication, and erection tolerances. Minimum and maximum deviation from other performance criteria also need to be realistically established. Bowed glass, under- or over-sized glass, straightness of framing members, and gasket size variation all must be considered during system design relative to their effect on the dimensions of a structural sealant joint opening.

10.2 *Material*—Dimensional tolerances of materials that are glazed structurally to the supporting framework must be considered. Examples of tolerances to be considered are out of plane glass or panels, dimensionally under or over sized glass or panels, and straightness, as well as profile dimensional tolerances of gaskets and spacers used in conjunction with a structural sealant joint. A structural sealant joint opening should not become too small, due to a glass or panel dimensional tolerance that makes the opening smaller than intended, and thereby perhaps structurally deficient. Conversely, the effects of a dimensional tolerance that would tend to enlarge a joint opening also must be considered. Concerns that may develop include inadequate support of the glass or panels on setting blocks, an increase in the elongation characteristics of the structural sealant, and a potential inability to control the structural sealant application and resulting joint profile, primarily due to the glass or panel not sitting tightly on the spacer or gasket that forms one face of the joint opening.

10.3 *Fabrication*— Dimensional tolerances for fabrication of components also must be considered for their effect on the structural sealant joint opening. The fabrication tolerances of the framework, for example, straightness of framing members, squareness of unit frames, and aluminum framing cutting tolerances, need to be considered in conjunction with the material or fabrication tolerances of glass or panels that will be glazed structurally to the supporting framework. This is necessary so that the structural sealant joint opening dimensions will be within the acceptable dimensional tolerance range.

10.4 *Erection*—For a shop glazed SSG system the effect of erection tolerances on the structural sealant joint are usually not applicable; however, for a field glazed system, the effect of erection tolerances becomes important to SSG system successful performance. Erection tolerances must be considered and controlled adequately to insure that a structural sealant joint opening is created at the construction site that meets at least the specified minimum and maximum joint opening dimensions. Adequate field quality control procedures are required.

## 11. Weather Tightness



11.1 *General*—The purpose of an exterior wall is to separate the interior, conditioned spaces of the building from the exterior elements; therefore, an exterior wall must respond to performance characteristics, which include, among others, air infiltration, water infiltration, thermal performance, and acoustical performance. In general, SSG has little effect on these performance characteristics compared to other parameters, such as type of fenestration system, wall system design, type of glazing, and fabrication workmanship.



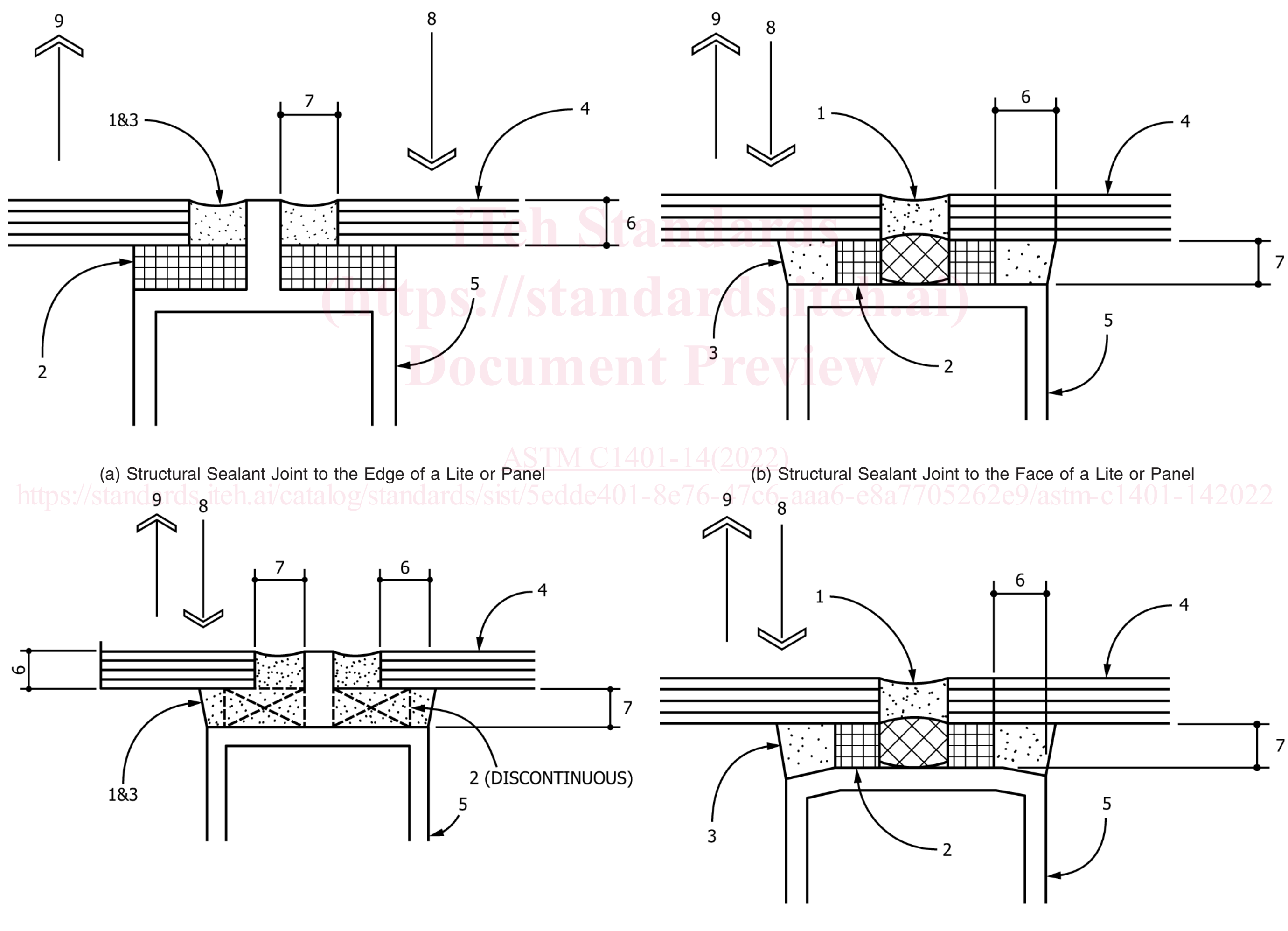
11.2 *Air Infiltration or Exfiltration*—Air infiltration or exfiltration for a SSG system can be considerably less than for a conventional glazing system. This usually is a result of the structural sealant joint, which is continuous, as well as the completely sealed nature of these systems. Many openings that can occur in a conventional glazing system do not occur in a SSG system; however, weepholes or tubes, weatherseal sealant joints between curtain wall and window units, floor level expansion joints, and termination conditions of a curtain wall or window system, can be a source of air leakage if not designed and installed properly. The use of an operable panel or vent within a wall or window system also can be a source of air leakage. A vent usually is conventionally weather sealed with gaskets, which can experience inadequate or nonuniform sealing pressure or compression set, resulting in air leakage. Usually it is these conditions that contribute the majority of air leakage to a SSG system.

11.3 *Water Infiltration*—There can be a false sense of confidence that a SSG system is inherently water-tight since a structural sealant joint is continuous, and therefore, there are no entry points for infiltrating water. This is true for a four-side but not for a two-side SSG system. Weep tubes, weatherseal sealant joints between curtain wall and window units, preformed gaskets at other than four-side SSG systems, floor level expansion joints, and termination conditions of a curtain wall or widow system can be a source of water leakage if not designed and installed properly. An operable vent also can be a source of water infiltration for the reasons described in 11.2. It also should be apparent that air leakage paths can be prime sources of water infiltration during a rain storm. A SSG system should be designed so that condensed vapor and infiltrated water, from whatever source, can be controlled and drained adequately to the exterior. This precludes the contact and build up of water against the structural sealant joints, which may over a period of time contribute to potential adhesion loss. Typically, an internal drainage system, to intercept infiltrated water and weep it to the exterior, should be included in a window system and also at horizontal nonstructural sealant joints, that occur typically at each floor level, in a multistory curtain wall system. Consideration also should be given to directing condensate or infiltrating water, that flows downward on the interior face of a spandrel glass or other panel, away from a SSG joint at the bottom of the spandrel glass or panel.

11.4 *Thermal Performance:*

11.4.1 *Condensation Resistance*—The condensation resistance of a SSG system can be quite good. This is a result of the aluminum supporting framework being mostly within the conditioned envelope of the building, with the glass or panels separated from the framework by a thermal break, the structural sealant joint; however, there are areas in a SSG system that might not be broken thermally. Usually these areas occur at maintenance platform tracks, tie-back buttons, operable panels or vents, projecting fins (see Fig. 1c), or other devices that can create a thermal bridge to the supporting metal framework and therefore can become potential points of condensation or frost formation. Attempts should be made to minimize thermal bridges. An adequate water-vapor retarder and insulation system should be designed for the opaque wall areas to control the flow of vapor into the SSG system and potential frost or condensate formation at any thermal bridges. Mechanisms should be provided so that condensed water within the wall system is drained to the exterior to preclude the potentially detrimental build-up of water against structural sealant joints.

11.4.2 *Thermal Transmittance*—A SSG system can be among the most energy efficient of all presently available glazing systems for the reasons described in 11.4.1. This is especially true with four-side and to a lesser degree for two-side SSG systems.




(a) Structural Sealant Joint to the Edge of a Lite or Panel

(b) Structural Sealant Joint to the Face of a Lite or Panel

(c) Structural Sealant Joint to the Edge and Face of a Lite or Panel

(d) Structural Sealant Nonrectangular Joint to the Face of a Lite or Panel

LEGEND

(1) Weather seal
(2) Spacer
(3) Structural Sealant
(4) Glass Lite or Panel
(5) Metal Framing System
(6) Bite (*B*)
(7) Thickness (*T*)
(8) Positive Lateral Load
(9) Negative Lateral Load
(10) Movement Due to Lateral Load
(11) Sealant in Compression Due to Lateral Load
(12) Sealant in Tension and Shear Due to Lateral Load

**FIG. 1 Typical Structural Sealant Joint Configurations**

## 12. Sound Transmission

12.1 Sound transmission control through a SSG system is no different than through a conventional glazing system; however, the resilient mounting of glass or panels and the usually completely sealed characteristics of a SSG system usually will provide better sound attenuating characteristics than conventional glazing. Sound transmission characteristics can be determined by performing acoustic testing on a full-size mock-up that typically is used to verify other performance criteria, such as wind load resistance. For relatively small SSG windows, 1.9 to 2.2 $m^2$ (20 to 24 $ft^2$) in area, Practice E1425 can be used to establish acoustical properties.

## 13. Fire Resistance

13.1 Concerns related to the fire resistance of a SSG system are no different than those associated with a conventionally glazed system. It has been reported that in a fire situation the first element to fail is the glass, which cracks due to thermal stress soon after the onset of the fire. This phenomenon may also be the case when non-glass panels are used in a SSG system. As the fire temperature climbs, the supporting aluminum framework and panels will then lose strength, resulting in deformation of the framework members, followed by failure of the structural sealant. In a fire situation, a SSG system should be more advantageous due to its potential ability to retain broken glass or panel fragments for a period of time, preventing them from raining down on pedestrian areas below.

## 14. Durability

14.1 *History*—In general, SSG work began with an all-glass entry and lobby system first marketed in 1965 by PPG Industries as the PPG TVS system. These all-glass systems, including supporting mullions, were two-side structurally glazed. The first two-side aluminum framed SSG systems were developed about 1970. These systems initially were designed only for glazing with monolithic glass. The first large application of a four-side, monolithic glass, SSG curtain wall system, was the former SHG Incorporated headquarters building in Detroit, MI, which was built in 1971. This is the oldest four-side SSG curtain wall system installation when considering durability and successful performance. The use of insulating glass in SSG systems began about 1976 for two-side and about 1978 for four-side support systems (**12**).



14.2 Presently, there is no method available to adequately predict the durability limit of a SSG system; therefore, it is not possible to predict a future point in time when a SSG system may lose its effectiveness, exhibit premature deterioration, and require remedial work. Given this uncertainty, a SSG system can have more risk than a conventional glazing system. Presently, the best measures to employ to achieve durability are to use proven materials and techniques of good quality; to have an effective quality control program during fabrication and erection; and, to build upon the successful performance of previous SSG systems. Some environmental and laboratory testing for a short time period has been performed indicating that for the testing circumstances a structural sealant does not detrimentally change in properties and performance (**13**).

### SYSTEM DESIGN CONSIDERATIONS

## 15. General

15.1 In general, the major factors influencing SSG system selection are building code requirements, desired aesthetic appearance, glass or panel type(s) required, cost, field-glazing versus shop-glazing, and post construction inspection and maintenance requirements. In addition to custom designed systems, proprietary systems from various manufacturers are available, which may provide the desired aesthetic appearance, and also may help to reduce costs and provide an opportunity for examination and evaluation of similar completed installations.

15.2 Features and advantages of SSG systems include more design freedom; reduction of glass thermal breakage potential; provision of a natural thermal break with very little or no exposed metal; reduced air and water infiltration; the potential for a less costly system compared to conventional glazing; the potential to reduce breakage from wind and seismic loads and dead loads, such as snow; and field or shop glazing potential. The choice between a shop or field glazing program should be evaluated carefully (**14**).

15.3 The major concerns of SSG work include partial or complete reliance on adhesion as the primary support system for glass lites or panels, with less redundancy than a mechanically attached system, and uncertainty over long-term durability. Other potential problems of SSG work include compatibility of gaskets, setting blocks and other sealants with the SSG system; sealant adhesion to metal finishes, factory-applied paint finishes, and reflective glass coatings; structural sealant and primer, if required, being within their respective shelf-lives; obtaining adequate quality control during sealant installation; and providing for replacement of structural sealant joints due to construction damage or other concerns.

## 16. Basic Systems

16.1 *General*—There are numerous variations to the basic systems presented in this section, which are dependent on the many designs available from a curtain wall or window contractor. These variations are offered only as generalizations. Generally, there are two basic types of SSG systems, where the structural sealant joints occur on two- or four-sides of a glass lite or other rectangular shape panel. The role of the structural sealant in both systems is equally important. A two-side SSG system requires the same attention to detail as a four-side system. For both types, the structural sealant transfers loads imposed upon a glass lite or panel to a metal framing system. The following includes a general description of basic SSG systems.

16.2 *Two-side:*

16.2.1 A two-side SSG system provides structural support of a glass lite or panel using a structural sealant for two opposite sides of a panel, with the other two sides retained using conventional mechanical fasteners (Fig. 2). Manufacturers have standard designs available for interior or exterior glazing of the structural sealants. Usually, these systems are designed so the structural sealant retains vertical glass or panel edges providing an aesthetic effect of a horizontal ribbon of glass or panels bordered by exposed metal mullions. This same effect also can be obtained vertically by using the structural sealant for the horizontal edges and the exposed metal mullions for the vertical edges.

16.2.2 This type of SSG system, with mechanical fasteners on two sides, can have a lower degree of risk then a four-side system, which has no mechanical fasteners. Two-side systems are available for construction-site or shop glazing of a structural sealant. Construction-site glazing requires structural sealants with a relatively long cure time of up to three weeks, depending on the particular structural sealant, which will require temporary support of a glass lite or panel until the sealant cures. Shop glazing can



FIG. 2 Two-Side SSG System

use these same structural sealants or other formulations that can cure in three hours to two days, facilitating handling of system components. Preference should be given to shop glazed SSG systems, which are more controllable relative to obtaining adequate sealant adhesion then construction-site glazed systems. Shop glazing also is preferred, to gain better control of the structural sealant installation, if an edge retained by the structural sealant is the long side of a glass lite or panel, particularly with a panel that has an aspect ratio of about 2:1 or greater.

16.3 *Four-Side:*

16.3.1 A four-side SSG system provides structural support of a rectangular glass or panel using structural sealant for all four sides. There are no mechanical connections or fasteners to retain a glass or panel to the metal framing system (Fig. 3). Sometimes, various types of metal retention devices are used to provide some degree of mechanical retention should a loss of structural sealant adhesion occur (Fig. 4). These systems also are available both as custom and proprietary designs.

16.3.2 A four-side SSG system can provide the aesthetic appearance of an all-glass or panel facade with no visible metal parts and relatively narrow sealant or other joints between panels. With no exposed metal parts and completely sealed joints, these systems can be very energy efficient compared to conventional metal and glass curtain wall or window systems. They also can have a higher degree of risk then two-side SSG systems since they rely only on the adhesion of a structural sealant to retain the glass lites or panels. With no exterior metal mullion caps, thermal stressing of a glass lite is reduced since there is no shading of the glass edge by the cap, and wind load induced stressing of the lite is more evenly distributed to the metal framing system by a structural glazing sealant, thus reducing the possibility of localized cracking of glass.

16.3.3 To gain optimum control of structural sealant application and minimize the risk of a structural sealant failure, four-side SSG systems should be designed for shop glazing of the structural sealant. There are other benefits of shop glazing that can contribute to efficiencies in scheduling and installation, such as, fewer weather-related technical issues to resolve than with construction-site glazing. In general, construction-site structural sealant installation should not be considered without consultation with and approval from at least the structural sealant manufacturer, metal framing supplier, and the glass or panel manufacturer. Typically, system maintenance of a four-side SSG system occurs at the building.



FIG. 3 Four-Side SSG System