NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB07-05 (2019)**

Point Supported Glazing

Architectural glass that is monolithic, laminated, or insulating has traditionally been supported by capturing the edges of the glass. As architects have expressed their desire to make the walls of buildings more transparent, engineers have developed methods to reduce the amount of framing required to support the glass. It has been increasingly popular to attach the glass to the structure using fittings directly connected through holes in the glass or with fittings through the joints between the glass. These fittings allow improved transparency and offer additional architectural opportunities in the detailing of the bolted connections.

Performance Considerations

One of the complexities of glass structural performance, as opposed to steel or other metals, is glass does not always fracture at the point of maximum stress. Experimental testing has produced a "failure prediction model" which takes into account the random nature of the location of surface damage or flaws that determine the "break origin" of in-service glass. ASTM E1300, *Standard Practice for Determining Load Resistance of Glass in Buildings*, uses this "failure prediction model;" however, it does not address glass with holes and notches.

Architects wanting to incorporate a point-supported glass façade or canopy in their design need to seek out engineers who are familiar with the use of glass as a structural material. These specialists have studied the experimental statistical analysis data and the breakage probability theories that form the basis for failure prediction models. They are then able to determine the glass thickness required for the size of glass lites, and the applicable code designated design loads, the usage of the glass, and its location on the building.

The safety factor issues and the breakage probability calculations necessary when designing a structure using a brittle material like glass must be understood by those designing point-supported structural glass canopies, skylights, guard rails, hand rails and façades. As a general guideline, an acceptable allowable stress at holes in glass is 9,700psi (67 MPa) for fully tempered glass, and 3,500psi (24 MPa) for heat-strengthened glass per ASTM C1048 *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass*. These values can be used conservatively for designing to a probability of breakage equal to or less than 1/1000 lites and are applicable for any load duration (short term and long term). These values apply for cylindrical holes or countersunk holes within the limitations of the diagram below. The holes should be free of unacceptable edge damage and/or imperfections such as, but not limited to, chips or shells. Higher stress values, alternate hole configurations, and alternate glass makeups may be used if validated by testing.

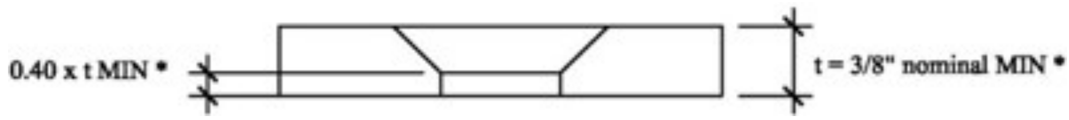

Figure 1: Diagram for Countersunk Holes

In addition to glass strength, deflection performance is an important design consideration. If the glass lite deflects laterally by more than half its thickness, large deflection, non-linear plate theory must be used when analyzing the performance of the glass. Finite element analysis is often required to determine the amount of stress and deflection of the monolithic tempered or laminated glass lite. The movement capabilities and limitations of each hardware connection system must be taken into account. Deflection of the glass lite under load causes the relative distance between the point supports to decrease. Allowance for this motion must be designed into the supporting fittings by using, for example, oversized holes or slotted connections.

The designer must limit the glass deflection under load by specifying thicker glass or altering the position or number of supporting points because the increased flexural strength of the glass does not change its stiffness. Accurate values for the interlayer properties are needed for analysis of point-supported laminated glass. These properties are dependent on temperature, interlayer type, and load duration.

Hardware

Point-supported hardware is supplied by several manufacturers. Typical hardware includes a simple bolt and patch plate system, a simple countersunk bolt, hardware with flexible washers and gaskets within the supporting structure, and hardware with articulated bolts. All of these hardware systems have been successfully used for façade and canopy structures.

Hardware manufacturers often do not make recommendations regarding glass thickness, distance from the hole to the glass edge, and maximum distance between point connections. The structural glass must be designed and fabricated properly to be compatible with the specific hardware system specified. The amount of stress in and around the holes in the glass will vary depending upon the location and size of the clamping hardware, as well as the load applied to and geometry of the glass lite. Glass holes and notches shall be designed and fabricated in accordance with the guidelines established in ASTM C1048 *Standard Specification for Heat Treated Flat Glass*. Loading requirements may dictate a more conservative approach to hole and notch locations than found in ASTM C1048. Design and fabrication processes should be coordinated.

Applications

Point-supported glass is used in two distinct applications: vertical glazing and sloped/overhead glazing. Vertical glazing can use monolithic or insulating glass units of fully tempered glass or heat-treated (tempered or heat- strengthened) laminated glass. Sloped glazing and overhead canopies require heat-treated laminated glass. The fundamental difference between sloped/overhead glazing (15 degrees or more from vertical, per the 2018 IBC) and vertical glazing is that sloped/overhead glazing is subject to a permanent gravity load from its self- weight and may be subject to a long-term snow load or maintenance activity load.

Vertical Façade Applications

The weight of vertical façades can be floor-loaded, stacked or suspended. The weight of the glass for high vertical walls can cause buckling of the lites if they are stacked too high. Façade systems above a certain height, as determined by the project-specific hardware and glass makeup, will need to be suspended from above.

It is most important that the façade designer has a clear idea of how the whole structure will behave under all imposed loads, including wind, seismic, and blast loading (if applicable). Because façade designers do not usually have the responsibility for the building structural design, the engineer of record (EOR) must be certain that the exterior loads imposed on the structure by the façade can be accommodated. Deflection and construction tolerances as defined by the EOR must be incorporated into the façade design and connections to the building structure. The differential deflection of adjacent structural elements to which the glass is attached should be taken into account to allow for this movement within the perimeter framing of the glass opening and to maintain adequate bite and engagement. Vertical downward deflection of roof trusses due to all environmental loads such as wind, snow or other dead loads and deflection due to building settlement or creep can transfer undesirable vertical loads to the edges of the glass façade if sufficient edge clearance is not provided in the perimeter design. Downward deflection of the floor supporting the system or upward deflection of roof trusses (especially in high wind areas) may cause a reduction or loss of glass bite, or failure of the weather seal.

It is very important to assess the safety implications of glass breakage and associated risk of injury from falling glass. Design redundancy must be used to avoid or greatly reduce the possibility of progressive collapse of the point supported system should one element fail.

Sloped and Oversized Applications

Glass canopies and roofs are more susceptible to impact from falling objects and thrown objects than vertical glass. Overhead glazing is more likely to fall from the opening when it breaks than is vertical glass. Most building codes require laminated glass for sloped glazing in order to retain the broken glass fragments or heat- treated glass with mesh screening beneath the glass to prevent the broken glass from falling on persons below in the event of breakage.

Dead loads and snow loads are examples of long-term loads that may be imposed on the glass. When designing laminated glass for sloped glazing, the interlayer properties for the appropriate load durations should be used. Snow drift loading must be included in the calculation as it can often be several times the magnitude of the ground snow load. Flat roofs or canopies may also be susceptible to water ponding if the glass deflection under gravity load is excessive.

Conclusion

The reduction or elimination of the visible barrier between the outside and the inside of buildings is a growing desire of architects. This trend means larger openings in a building and fewer impediments to the outside view. Point supported glass is one solution to this demand.

The National Glass Association (NGA) is publishing this information regarding point supported glass in order to educate glass suppliers and users about some of the design considerations necessary for assuring proper, safe use. NGA encourages architects, structural engineers, building officials, building owners, glazing contractors, and glass fabricators to become more aware of some of the limitations as well as the benefits of using point supported structural glass.

Consult the NGA website (www.glass.org) for additional information on glass and glazing applications and links to members providing additional technical resources.

Quick-Reference Guide to Point Supported Glass

- Do - use tested components.
- Do - use engineers familiar with structural glass design.
- Do - when using laminated glass, design the glass using interlayer properties for the appropriate load duration.
- Do - consider consequences if one or more lites should break.
- Do - understand the limitations of the system.
- Do - involve the glass engineer and glass fabricator early in the design stage.
- Do - review the deflection to ensure it doesn't exceed code and project requirements.
- Do - recognize the limitations of alignment of heat-treated laminated glass, both edges and holes, and the tolerances in all materials used in the system.
- Do - consult the laminated glass interlayer supplier for interlayer properties for use in calculations.
- Do - allow system to move with temperature and provide adequate room within or around the system for building movements.
- Don't - use non-rotational connection systems in applications unless fixity is considered in the glass analysis.
- Don't - approve engineered systems that you don't understand.
- Don't – allow direct contact between metal and glass.

References

- AS 1288 *Glass in Buildings – Selection and Installation*
- ASTM C1048 *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass*
- ASTM E1300 *Standard Practice for Determining Load Resistance of Glass in Buildings*
- Bength, Camilla, *Bolt Fixings in Toughened Glass*, 2005
- Cervenka, Jan, Schultz, Joshua, Stahl, Douglas, Knowles, John, *Strength of Point-Supported Glass*, 2016
- Eckersley, Brian, O'Callaghan, James, *Structural Bearings in Holes in Glass*, 2005
- EN 18-008 *Glass in Building – Design and Construction Rules*
- Schneider, Jens, Wörner, J.-D., *Glass Strength of Annealed and Tempered Structural Glass in the Area of Drilled Holes*, 2001
- Schultz, Joshua, Knowles, John, Morse, Stephen, *Glass Failure Prediction Model for Out-of-Plane Bending of Water-jet-Drilled Holes*, 2017

Visit www.glass.org/store for a complete list of Glass Technical Papers, as well as other glazing and glass building products industry reference materials. Most Glass Technical Papers are available free of charge to NGA members and for a small fee to nonmembers.

This Paper was developed by dedicated member volunteers and subject matter experts. The original version of this document was approved and published in 2005. This edition of the paper was updated and published in 2019.