Glass Informational Bulletin **GANA LD 03-0505**

Point Supported Glass

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 the buildings even more transparent, engineers have developed methods of reducing the size of the supporting structures.

In recent years, especially in Europe, it has been increasingly popular to attach the glass to the structure using bolted fittings directly connected through holes in the glass. These fittings allow improved transparency and offer additional architectural opportunities in the detailing of the bolted connections.

Glass Strength Theory

One of the more complex concepts for structural engineers to grasp when designing structural glass is that glass, as opposed to steel or another metal, 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 International document E 1300-02, *Standard Practice for Determining Load Resistance of Glass in Buildings*, uses this "failure prediction model;" however, it specifically excludes 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 the failure prediction models. They are then able to advise as to the glass thickness required for the size of glass lites and the wind load requirements of the building location. The safety factor issues and the breakage probability calculations that are necessary when designing a structure using a brittle material like glass must be understood by those designing point supported structural glass canopies, skylights and facades.

When designing point supported structures, it is often deflection and not the structural strength of the tempered glass that is the limiting criterion for determining the glass thickness. Most modern point supported structural glass designs involve large relatively thin lites of glass. However, if the glass lite deflects laterally by more than half its thickness, then large deflection, non-linear plate theory must be used when analyzing the strength and deflection of the glass. Simple four-sided plate theory does not take into account the membrane stresses that will occur, especially near the holes at the corners of the glass. If the point support connection to the structure or the

spider fitting has built-in movement potential, membrane stresses are not as significant when compared to bending stresses.

Finite element analysis is often required to determine the amount of stress and deflection of the glass lite. The movement capabilities and limitations of each hardware connection system must be evaluated by the structural glass engineer. Deflection of the glass lite also reduces the relative distance between the support points. Allowance for this dimensional reduction must be designed into the supporting fittings by using either oversize 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 tempered glass does not change its stiffness.

Hardware

Point supported hardware is offered by several manufacturers. Some are a simple bolt and patch plate system, some are a simple countersunk bolt, some have flexible washers and gaskets within the supporting structure and some have articulated bolts. All of these hardware systems have been successfully used for facades and canopy structures, but 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 hole in the glass will vary depending upon the location and size of the clamping hardware. Hardware manufactures often do not make recommendations regarding glass thickness, distance from hole to glass edge, and maximum distance between point connections. (Tight tolerances in the fabrication of the point support hardware system must be equally matched when drilling the glass in order to be within the hardware supplier's hole location tolerance specification.)

Applications

Point supported glass is used in two distinct applications, vertical glazing and sloped/overhead glazing. Vertical and sloped glazing can use monolithic or insulating glass units of tempered glass and possibly even annealed laminated glass, if there is no additionally imposed dead load on the holes in the glass. Sloped glazing and overhead canopies require heat treated laminated glass. The fundamental difference between sloped/overhead glazing and vertical glazing is that sloped/overhead glazing is subject to permanent gravity load from its self-weight and, possibly, to long-term gravity load from snow. The potential for and the weight of thrown or fallen objects may also need to be considered when designing the glass for sloped/overhead glazed applications.

Vertical Façade Applications

Vertical facades can be floor-loaded/stacked or suspended. If a façade with a height greater than about 10.7 m (35 feet) is desired, then it will probably need to be suspended from above. The dead load of the glass for high vertical walls can cause lateral buckling of the lites, if they are stacked too high. Suspended facades have been constructed over 30.5 m (100 feet) in height.

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. There is nothing unusual about this notion, as it applies as much to steel, aluminum, or concrete as it does to glass. Because the façade designer does not usually have the responsibility for the building structural design, he must be certain that the exterior loads imposed on the structure by the façade can be accommodated. Deflection and construction tolerances 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 so as to allow for this movement within the perimeter framing of the glass opening. Vertical deflection of roof trusses due to snow load or other dead loads can transfer undesirable vertical loads to the edges of the glass façade, if sufficient edge clearance is not provided in the perimeter design.

The reason that the effects of all imposed loads on the structure must be emphasized is that engineers inexperienced in glass design may not consider the importance of what will happen if one or more of the glass lites would break. It is very important to assess the safety implications of the failure of a lite of glass and what is the likelihood of persons being injured by falling glass. The concept of design redundancy must be used to avoid or at least greatly reduce the possibility of progressive collapse of the structure should one element fail.

Sloped and Overhead Applications

Glass canopies and roofs are more susceptible to impact from falling objects and thrown objects than vertical glass. Overhead glazing in most cases 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.

Snow loads may be imposed on the glass for long periods of time requiring that the lower long term strength of glass be used as the design strength, rather than the short term strength used for wind load. Snow drift loading must be included in the calculation as it can often be several times the magnitude of the design ground snow load. Flat roofs or canopies may also be susceptible to water ponding which can occur when the sums of all the deflections of all the components in the roof structure are subjected to a significant snow load. When sloped glazing is designed using laminated glass, the plastic interlayer offers little shear resistance in long term loading. Therefore, each ply of the laminated glass must be considered separately as a layered construction when determining the glass thickness.

Conclusion

An increasing desire on the part of modern architects has been the reduction or elimination of the visible barrier between the outside and the inside of buildings. This trend means bigger openings in a building and fewer impediments to the outside view. Point supported glass is one of the responses to this demand. Horizontally tempered glass with better dimensional stability, and modern numerically controlled cutting, edging, and drilling equipment, have allowed glass fabricators to respond with glass suited to fill this demand. Because the brittle nature of glass is

not as well understood by many structural engineers and code officials, point supported glazing designs have been slow to be adopted in North America due to building code restrictions.

The Glass Association of North America (GANA) is publishing this information regarding point supported glass in order to educate glass suppliers and users about the design considerations necessary for assuring proper, safe use of this popular means of achieving greater wall transparency. GANA 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 GANA website (www.glasswebsite.com) 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 systems. (The glass and hardware system should be tested to provide data as to its ability to withstand both vertical and horizontal loading as required by the application. Some systems have been tested only for vertical facades and some for both vertical and sloped applications. This information should be provided by the manufacturer to the design engineer for his use in the required structural calculations.)
- Do - use engineers familiar with structural glass design.
- Do - when using overhead laminated glass, design the glass as layers for long term loading when calculating the glass thickness
- Do - understand the limitations of the system
- Do - involve the glass engineer and glass fabricator early in the design stage
- Do - consider consequences if one or more lites should break
- Do - allow the glass to flex under load, but control the amount of deflection
- Do - recognize the limitations of alignment of heat treated laminated glass, both edges and holes

- Don't - use rigid interior connection systems in exterior applications
- Don't - approve engineered systems that you don't understand

The Glass Association of North America (GANA) has produced this Glass Informational Bulletin solely to provide general information as to identify issues related to point-supported glass applications. The Bulletin does not purport to state that any one particular type point-supported glass process or procedure should be used in all applications or even in any specific application. The user of this Bulletin has the responsibility to ensure the design, engineering and installation guidelines from the system supplier(s) are followed. GANA disclaims any responsibility for any specific results related to the use of this Bulletin, for any errors or omissions contained in the Bulletin, and for any liability for loss or damage of any kind arising out of the use of this Bulletin.

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