

The 'Glance' Sculpture: Safety Lamination for Architectural Cast Glass

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Abstract

Architectural glass designers these days are increasingly seeking unique forms and optical effects in contrast to the past few decades, when choices of color and reflectivity seemed sufficient. Many of the most sophisticated and unusual visual effects achievable in glass are found in the area of 'art glass,' but the techniques used to produce them have not heretofore seemed feasible for architectural applications. The following presents a project in which cast art glass has been designed and engineered for a large-scale, exterior application, suggesting that art glass may soon be more widely available to be used in architecture.

Project description

The Botanical Garden in Brooklyn, New York is the site of an ambitious new sculpture called 'Glance.' Simple in shape, yet imposing in its scale and transformation of light, it takes the form of a 50-foot (15.2m) high crystal cone with a base of only 5.5-foot (1.67m) diameter constructed from textured, 1-5/8" to 2" (40-50mm) leaded glass and lit from within. A number of technical challenges had to be met to realize this construction, not the least of which was the stabilization of such a slender form, achieved by the construction of a stainless steel armature within the cone. The other important challenges, more specifically related to glass technology, were:

1. Casting such a large complex shape using a lost wax ceramic shell technique to create accurately curved, tapering glass to form the cone.
2. Formulation of glass chemistry which would minimize the coefficient of expansion for exterior use, achieve maximum optical quality and chemical durability, and improve workability in hot and cold states.
3. Detailing of the glass attachments and geometry so as to remain safe in the event of fracture.
4. Addressing the clients' concerns of potential vandalism and safety by laminating free form cast glass elements.



Figure 1

Concept rendering of 'Glance' sculpture at the entrance of the Brooklyn Botanical Garden, designed by J. Jaroff, engineered by A. Chaszar.

In addition, a number of other technical features of the project are worth mentioning.

Glass composition

Alternative methods were explored for the production of the conical glass sections, including lamination of successive, thinner shells bent from flat glass stock, but the limitations on surface texture and geometry achievable by this means removed it from consideration. The desirability of lamination from a safety point of view remained apparent, however, and was revisited in a novel way as the project's design developed.

The optical quality sought for the sculpture favored the use of leaded glass, which was not available in sheet form. Too much lead in the glass formulation degrades its chemical durability and toughness. However, lead does facilitate the flow and casting as well as the cold working properties of the glass. Boric silica sand was used to decrease the coefficient of expansion of the glass. This was essential to ensure that the glass would not crack due to internal stress developed due to sudden temperature changes and freezing and thawing within its 40-50mm thickness. The final formulation resulted in a matrix

with far superior chemical durability, hot and cold working properties, a low coefficient of expansion, and far superior optics compared to soda lime float glass or other more typical options.

The sheer mass and pressure generated by such a large volume of glass, coupled with its highly corrosive nature when molten, made the mold making trials very challenging. The initial molds were not strong enough; resulting in the glass cracking the molds, and destroying the ovens. Subsequent trials had massive plaster and steel reinforcing mother molds over the ceramic shell. This resulted in uneven cooling during the annealing process, which caused further failures. In the final molds, a two-step process was employed. In the first phase, the molds cast the panels into flat textured slabs. Second, the slabs were slumped into textured molds, which afforded more control over the geometry and surface detail.

Glass detailing

A number of the project's features derived from decisions regarding the sculpture's assembly and maintenance. For example, although calculations indicated that the glass would be capable of bearing its own weight and

other compressive stresses over the full height, concerns over the possible need to remove and replace sections of glass independently led to the development of an internal armature that could provide individual support for each piece. The glass sections were apportioned, with those nearest to the base being the shortest in height, and those at the top being the longest. This achieved both a more uniform apparent spacing of the horizontal joints in perspective and a more even distribution of section weights for fabrication and erection. Each glass section sits along the ledge of a horizontal, circular stainless steel angle which forms the support for each level of the cone. The top of each glass section is restrained laterally by another curved angle, which is free to slide vertically in order to accommodate the movements resulting from thermal effects and 'bending' of the tower. Vertical pins project up and down from the circular angles into cavities in the glass. This supplements the structure with a mechanical interlocking connection, as opposed to depending solely on the silicone adhesive between the glass and the stainless steel angles for support.

Glass breakage and free-form safety lamination

The breakage characteristics of thick annealed glass, in combination with the mechanical restraints via the pins and structural adhesive, were seen as a precautionary measure in the event that a glass panel was to crack and fall. The pin placement was strategically determined, so that in the event a glass panel was to break it would fall into the internal void of the sculpture. This behavior was confirmed by the breakage tests; however, due to the



Figure 2

Detail photo of shatter-resistant coating with reinforcing mesh lamination clamped onto test frame.

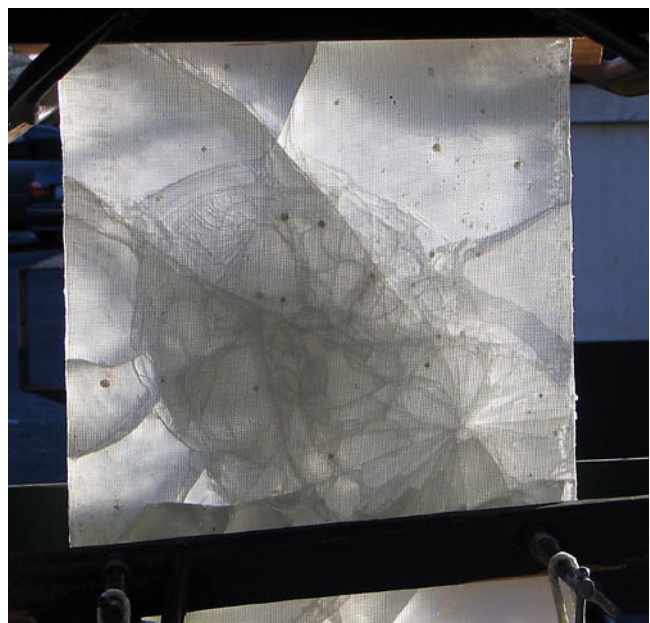
location of the sculpture in a high-traffic area, the possibility of vandalism was perceived as great. Therefore, we wanted to introduce additional protection without compromising the optical qualities of the cast glass.

The method we developed was to apply a liquid, shatter-resistant glaze that – due to the low viscosity of the coating – allowed it to conform well to the textured inner surface of the glass. Further strength was obtained by embedding glass fibers in the coating, resulting in a reinforced lamination 'film' which adhered completely to the glass. The success of this relied on good wetting of the fibers by the liquid coating. The fiber mesh was allowed to protrude at the ends, so that it could be

clamped to the structure. This afforded a secondary failsafe attachment of the glass to the armature. Break tests were performed on glass samples treated in this way in order to demonstrate the compressive and tensile strengths of the new composite material.

Testing

One 1-¾ inch (44mm) thick by 12 inch (305mm) wide cast glass sample was clamped to a frame structure, and 220lbs (100 kg) of weight was suspended from it. The sample was struck multiple times with a heavy, one-meter long steel bar. The glass broke all the way through but showed no sign of movement, deformation, or shifting.



Figures 3 and 4

Front and rear views of 44mm cast glass test panel with mesh/coating lamination and 100kg weight suspended from panel after heavy steel bar impact.



Figures 5 and 6

Destructive test of 1-meter large laminated glass sample, secured only at top and bottom with structural silicone adhesive and clamped to frame via mesh-reinforced shatter-resistant coating.

The second test was conducted on 12 inch (305mm) by 39 inch (1000mm) by 1- $\frac{3}{4}$ inch (44mm) thick slab of cast glass. The sample was adhered with structural silicone to top and bottom angles similarly to the sculpture installation, with the mesh being clamped to the frame structure.

The sample was set up on a 3-degree incline to emulate the slope of the glass cone. A 40-lb (18kg) cement block, swinging from a point 13 ft. (4 m) above the sample, was swung into the glass from 10 ft. (3 m) away. This was done multiple times with minimal movement and shifting in the glass. Several large shards were produced by the impact, but the panel's overall structural integrity was maintained.

These tests confirmed the desired outcome. By using a liquid coating in conjunction with a fiberglass mesh, we could achieve an enhanced safety precaution, in the event of breakage. This would allow any broken pieces of glass to stay in place while a replacement panel was re-manufactured.

An additional benefit of the mesh in the shatter coating is its light diffusing characteristics. Originally we were sand-blasting the interior of the glass to diffuse the light. The mesh in the coating ended up having superior light

diffusing characteristics, eliminating the hot spots created by the internal floodlights.

Summary

Cast art glass has far greater potential for creativity in the design process than flat glass. Standard industrial forms and variations of glass do not limit cast art glass. With the application of casting and blowing techniques, coupled with superior chemistries for exterior use, the horizons are limitless. The introduction of the painted-on, reinforced, shatter-resistant coating is the key element enabling these techniques to be safely used in our ever increasingly liability-conscious times. The concerns of lawyers and insurance companies, some of the necessary obstacles to innovation in our societies, can now be addressed without limiting our creative freedom. The application of shatter-resistant coatings will expand the potential uses for art glass in stairs, curtain wall and glass architecture.

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