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Glass Studio

Kerstin PULLER, Pascal HEINZ, Björn FRETTLÖHR, Werner SOBEK

Institute for Lightweight Structures and Conceptual Design, University of Stuttgart
Pfaffenwaldring 14, 70569 Stuttgart
Kerstin.Puller@ilek.uni-stuttgart.de

Abstract

The Institute for Lightweight Structures and Conceptual Design has for many years been actively engaged in the research and development of advanced glass structures and systems, including long-span glass arches, adhesively-constructed glass domes, switchable glazing elements, and reinforced glass.

In the summer semester of 2008 the institute held an interdisciplinary workshop for students from the faculties of Civil Engineering and Architecture, with technical guidance provided by the glass fabrication shop at the Stuttgart State Academy of Art and Design. During the workshop new possibilities were explored in the use of glass as a material. The students gained insight into the theoretical foundations of glass while simultaneously accumulating practical experience working with the material. Different fabrication approaches and technologies were used to create glass objects which reveal new design qualities beyond the aspect of transparency.

During the studio, lamination techniques were used to embed optical fibres between two glass panes, generating three-dimensional light images; glass rod structures were created with smooth, pure glass joints achieved through local heating; horizontal slats of glass were layered vertically to achieve a visual superposition of direct and reflected views; glass shards were fused at different temperatures to generate sharp-edged and fragile, or smooth-edged and sturdy objects; different thermal treatments were applied to produce flexible glass hybrid materials combining metal wires and glass shards, or slumped glass panes which recall the design vocabulary of lightweight structures. A detailed description of the different techniques employed and the various objects created follows in this article.

Keywords: glass, experimental, workshop

1. Introduction

At the Institute for Lightweight Structures and Conceptual Design an experimental teaching approach has been employed for the past several semesters. Instead of introducing only the theoretical principles and properties of materials to the students, the students have been given the opportunity to experiment themselves with various materials and to try to broaden the scope of their application. In the summer semester of 2008 the students dealt with the material glass. After learning the fundamental material properties and the basic material processing techniques, each student carried out an explorative study following a self-chosen theme. A variety of models were created with the aim of enhancing both the structural and the architectural qualities of glass – ideally simultaneously. The workshop can be thought of as a bridge between teaching and research, giving a glimpse of new and innovative glass design possibilities.

2. Description of the objects

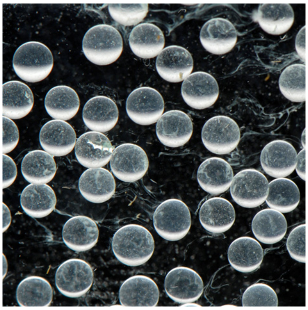

Figure 1: Glass laminate with embedment

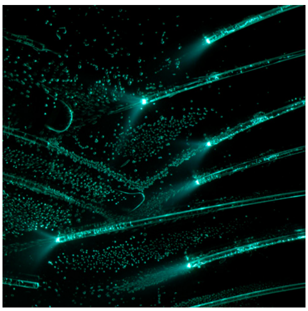

Figure 2: Integrated optical fibers

One group of students employed lamination to embed functional elements within the interlayer between two glass panes, and enhance the visual qualities of the glass. Previous studies have shown that the integration of reinforcement in the interlayer increases the load-bearing capacity of the glass pane after fracture (Feirabend and Sobek, [1]). Encapsulated phase-change materials (PCMs) within the interlayer may improve the heat capacity of the glass pane, while embedded optical fibres produce glowing images which are invisible when the light source is off. Optical fibres normally emit light only at their ends; but by intentionally scratching the surface of the fibres at specific points, distinct light-emitting pixels and regions were created. To generate a light image, the fibres needed to be embedded at predetermined positions within the interlayer. Grooves were milled into the interlayer material in the desired pattern, and the fibres positioned in the grooves to prevent them shifting during the lamination process. Unfortunately, the required lamination temperature was higher than the melting point of the fibre-optic material. The usual laminating technique using a vacuum bag could therefore not be carried out in an oven, where all of the components would be heated equally, but instead had to be conducted between heated plates, where the heat could be applied locally. Following several attempts, this technique was perfected, and a laminated glass pane with embedded optical fibers was produced, where illuminated designs could be created in any desired pattern.

Figure 3: Glass-glass joint

Another student began with the vision of realizing a pure glass-glass joint. To join glass elements, typically bolted or clamped connections are used. Glued connections with silicone have recently seen broader use, and connections using acrylate glues have been the topic of several recent research initiatives. But with all of these connection techniques at least one other material is introduced, and especially around elements such as drilled holes, significant stress concentrations arise. To avoid these issues and to generate clean, pure glass joints, the student used a technique which is frequently used in the manufacturing of glass instruments – the joining of glass through local heat application. While Soda-lime glass, which is regularly used in architectural applications, breaks when locally heated due to temperature-induced stress concentrations, Borosilicate glass has a significantly lower coefficient of thermal expansion ($\alpha_{T,\ Borosilicate} = 3.3\text{x}10^{-6}$ 1/K; $\alpha_{T,\ Soda\text{-}lime} = 9\text{x}10^{-6}$ 1/K) and is therefore much more resistant to temperature shock. At the laboratory for physical and chemical instruments at the University of Stuttgart the student bent and joined Borosilicate glass rods using local heating to create a three-dimensional glass structure with pure glass-glass joints. This project realizes, on a small scale, the idea of glass as a structural material and visualizes the potential of a fully transparent structure.

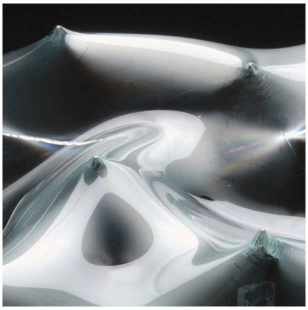

Figure 4: Deformed glass pane

While glass is seeing more and more use in contemporary architecture, it is almost always employed as a plane element. The aim of another student was to three-dimensionally deform glass panes using thermal treatment. Within a temperature range of 650-750°C the stiffness of glass is greatly reduced and the glass pane deforms between defined fixed points – this technique is called slumping. Simple materials like rounded stones and sharp nails were used to define highpoints, so that different curvatures of the glass pane could be achieved at different temperatures. A detailed study was performed to determine the optimal temperature range, thermal exposure duration and the best highpoint positioning pattern to achieve a desired shape. Through the three-dimensional deformation process, the geometric stiffness of the original plane glass element can be increased, and at the same time a unique visual appearance can be achieved. An improvement of the structural and architectural characteristics is achieved simultaneously. In this case the objects created also recall the design vocabulary of textile lightweight structures.

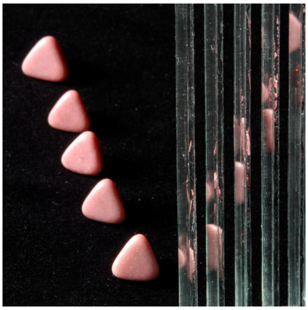

Figure 5: Reflection, refraction

Figure 6: and selective transmission

Glass is usually employed due to its transparency. Its appearance is, however, highly influenced by its surroundings, and characterized by its reflection, refraction and selective transmission of light. Two projects tried to take advantage of these inherent characteristics. Studies of horizontally and vertically oriented glass slats were performed, and the influence of different edge treatments, varying widths, and different angular orientation of the slats was investigated. One project dealt with the light distribution to the interior as light passed through different glass slat arrangements, while another project focussed on the visual effects of looking through various slat configurations. For some configurations of horizontally oriented glass slats, the normal horizontal field of vision is superimposed with reflections of objects located below or above the viewer's regular field of vision. Looking towards the ground, the sky is seen, while the view towards the sky shows the ground – an inversion of the expected perception.

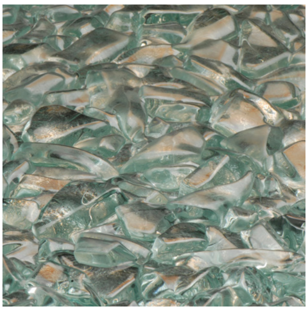

Figure 7: Glass shards fused together

The creation of continuous glass elements out of broken glass shards by thermally fusing them was studied in another project. A sequence of experiments was carried out using everything from regular float glass to thermally strengthened glass, from randomly arranged glass shards to intentionally laid configurations, from short to long thermal exposure durations, and from colourless to colourful glass. A manifold of shapes with diverse haptic qualities was created varying from sharp-edged and fragile to smooth-edged and sturdy glass agglomerates. Compared to regular plane glass panes a controlled diffusion of light is achieved, while the appearance of colourless glass is maintained.

Figure 8: Flexible glass hybrid

Another student investigated the idea of combining the fundamentally different material characteristics of glass and textiles with the aim of creating a flexible glass hybrid material. In a study, glass platelets, or sequins, were fused onto different wire filament meshes at high temperatures (around 800°C). Numerous studies were necessary to determine the best temperature range to completely embed the filaments but prevent the glass sequins from bleeding together. Unfortunately, most of the wire filaments lost their flexibility during this heat treatment and became very brittle. A durable flexibility was only achieved with a thin multifilament steel yarn. During this series of experiments an unexpected effect occurred: the coating of a silver-coated copper wire was burnt onto the underlying oven stones. When a glass pane lying on the residual silver-coating was later subjected to a heat treatment, parts of the residual silver coating fused to the glass pane, resulting in bi-coloured light effects depending on whether light was being reflected from or transmitted through the pane. A printing process for local dichroic coating was inadvertently discovered.

3. Summary

Through this experimental teaching method the students gain fundamental knowledge of glass as a material, and work following their own research initiatives. They are free to experiment with the material, exercise their creativity, and make their own discoveries. The objects created are not intended for direct architectural application, but rather to serve as stimulus for a new and innovative design approach for glass elements.

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[1] S. Feirabend, W. Sobek, *Bewehrtes Verbundsicherheitsglas*, Stahlbau, vol. 77, 2008, S. 16-22.