高等院校土建学科双语教材（中英文对照）

◆土木工程专业◆

玻璃构造

GLASS CONSTRUCTION

[德] 安德烈斯·艾奇里斯
黛安·娜维拉蒂尔 著

袁磊 许雪松 译

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责任校对：陈晶晶　姜小莲

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序

玻璃是最具魅力的建筑材料之一。它既连结空间又分割空间。玻璃种类繁多，从令人一目了然的全透明玻璃到隔绝外界干扰的立面反射玻璃，不一而足。玻璃的多样性使其在建筑设计中独树一帜。

玻璃形式纯净，却需要仔细斟酌。它可能意外地突然破碎，也不耐机械压力。不过，得益于科研的不断进展，玻璃展现出巨大的发展潜力及多样的应用可能——包括防弹玻璃和全玻璃承重结构之类的创新性技术，在这两方面其他建材望尘莫及。

一直以来，建材玻璃应用的发展都伴随着对其技术特性和可能性的认识的发展。建筑师只有了解各种玻璃的特性、玻璃构造的组成和组件及其材料局限性，才能开发出有创意的玻璃应用方法，并不断突破现有局限。

本书是国外高等院校土建学科基础教材系列丛书中的一个分册，从构造角度入手，向读者介绍玻璃的特殊性能及其作为建筑材料的应用可能。本书通过增进建材知识、解释复杂的构造和各种用途，使建筑学学生有能力构想具有个人创意的方案，而不仅仅是遵从建造行业已有的条条框框。玻璃构造的很多发展不只是从材料学实验室得来，而是来自建筑师富于创意、突破常规的设计，这些建筑师解决了难题，并促成了新的发展和应用。本书旨在启发学生运用玻璃方面的知识为设计增添创意，甚或开拓出新的创作思路。

套书编辑 Bert Bielefeld

FOREWORD

Glass is one of the most attractive building materials. It connects spaces to one another while separating them. The various types of glass range from complete transparency and openness to reflective glass that provides hermetic separation for facades. This diversity makes glass unique in architectural design.

Glass in its pure form is a material that needs to be carefully considered. It breaks very quickly and often unexpectedly and is sensitive to mechanical stress. Thanks to advances in research, however, no other building material offers such great potential for development or such a multifaceted spectrum of possible uses—including bulletproof glass and the creation of bearing structures entirely of glass.

The use of glass as a building material is always coupled with knowledge of technical properties and possibilities. Only by knowing the properties of various glasses, the components and elements of a glass construction, and the limits of the material can an architect develop creative solutions using this material and transcend the existing limits again and again.

The present volume, *Glass Construction*, is part of a subset of the series on construction. It begins by considering construction and conveys to the reader an understanding of the specific properties of glass and the possibilities that it offers as a building material. By increasing knowledge of the building material and revealing complex structures and applications, it enables students of architecture to consider their own creative solutions beyond the standardized offerings of the construction industry. Many advances in glass construction have resulted not only from laboratory research on the material but also from innovative and unconventional designs by architects who have met the challenges and provided stimuli for ever new developments and uses. *Basics Glass Construction* is intended to inspire students to use their knowledge of glass to explore the possibilities for their own designs and perhaps even develop new approaches.

Bert Bielefeld, Editor

INTRODUCTION

Like few other materials, glass possesses a symbolism that transcends mere function and exerts a particular fascination. The glass windows of the Gothic period already deliberately played with light in order to produce a feeling of transcendence. In the architectural visions of modernism, this transparent material took on central significance, although glass played different roles, depending on the theoretical approach in question. Glass was appreciated not only for its transparency, which permitted an almost dematerialized shell and hence flowing, open spaces, but also for its graceful, angular, and glittering qualities. The emancipation of glass from its role as a filler in relatively small windows to become an autonomous element would prove particularly forward-looking. Problems in terms of energy conservation and disregard of the physical requirements of construction put a temporary end to the euphoria over this material.

Today, thanks, among other things, to a turn to solutions that make sense for energy conservation, and the development of glass that provides effective insulation and solar control, glass has once again become a high-performance material. As such, it fulfills both functional and design requirements and opens up ever new areas of application.

For all the possibilities that glass offers, however, it should not be forgotten that it is a very brittle material. Glass breaks suddenly and without warning when it is overstressed in particular places. That calls for precise knowledge of the nature of the material and great care in planning and implementing glass structures.

This book introduces students step by step to the basics of glass as a building material and to glass construction. In the first three chapters, the reader learns the properties and diversity of today's types of glass, then the most important principles for constructing with it, and finally the different areas of application and their constraints. The technical fundamentals are explained intelligibly and in a structured way in terms of their principles and by means of simple examples. In this way, students obtain an overview of the current state of technology and are in a position to plan their own projects using glass as a building material and to make their own ideas reality.

THE PRODUCTION OF GLASS

Composition

Glass is produced by heating a mixture that consists largely of silica (silicon dioxide) and soda ash (sodium carbonate). Soda ash serves as a so-called flux to reduce the high melting point of silica (approx. 1700 °C). The melting that then takes place above 1100 °C is amorphous—that is, virtually no crystals are formed. Because the structure of glass resembles that of fluids, glass is sometimes called a "supercooled liquid." › Tab. 1

Types of glass

The most commonly used glass in architecture is soda-lime glass, the main components of which are silicon dioxide, calcium oxide, and sodium oxide. Borosilicate glass, which contains boron oxide rather than calcium oxide, is often used as fire-resistant glass thanks to its high chemical and thermal stability. Lead glass, which is produced from lead crystal, among other things, and special glass, which is used in optical devices, for example, have no significance for architecture. Glass ceramic, by contrast, has recently begun to be used to clad facades. Transparent synthetic glass such as acrylic glass and polycarbonate is lighter and easier to work than mineral glass, but because it has a lower surface hardness it is considerably more sensitive to scratching and thus not as durable.

BASIC PRODUCTS

Glass products that are formed during production in a "hot" state or immediately after cooling are generally referred to as basic products or basic glass. Various kinds of basic glass are employed in architecture. In addition to clear flat glasses with a smooth surface, glasses with specially designed surfaces or special shapes are also used. Basic glass is often further processed or finished. › Chapter Processing and finishing

Tab. 1:
Composition of glass according to EN 572, Part 1

Silicon dioxide	SiO_2	69-74%
Calcium oxide	CaO	5-12%
Sodium oxide	Na_2O	12-16%
Magnesium oxide	MgO	0-6%
Aluminum oxide	Al_2O_3	0-3%

We describe below the types of basic glass relevant to architecture and how they are produced.

Float glass

Float method

Float glass is the most commonly used form of basic glass. Its name derives from the process by which it is produced. The float method developed in 1960 was a milestone in the history of the production of flat glass, because it became possible for the first time to produce large quantities of clear, transparent glass with nearly flat surfaces.

Production begins by melting the raw materials, referred to as "batch," in a furnace. Next, the molten glass runs onto a flat bath of molten tin. Because it has a lower specific gravity, the glass floats on the tin, which gives it its flat surface. This produces an endless glass ribbon that slowly hardens; its thickness is determined by the speed with which it is pulled over the tin bath. After passing through this tin bath, or "float bath," the glass ribbon passes through a cooling zone, and finally is cut into plates. › Fig. 1

The standard format, known as ribbon size, is 600 × 321 cm. Its standard or nominal thicknesses are 2, 3, 4, 5, 6, 8, 10, 12, 15, and 19 mm.

Sheet or window glass

The term "window glass" is somewhat misleading, since float glass is usually used for windows these days. Sheet or window glass is now produced only individually in drawn glass facilities, in which the glass ribbon is drawn horizontally or even vertically from the furnace. Today this process is used to produce particular kinds of colored glass, or for special

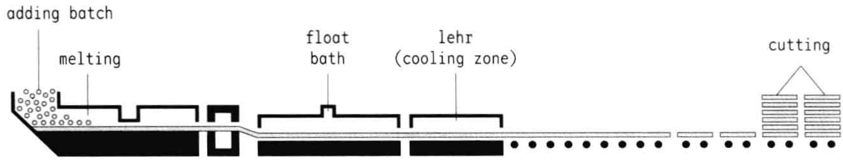

Fig. 1:
Diagram of the float process

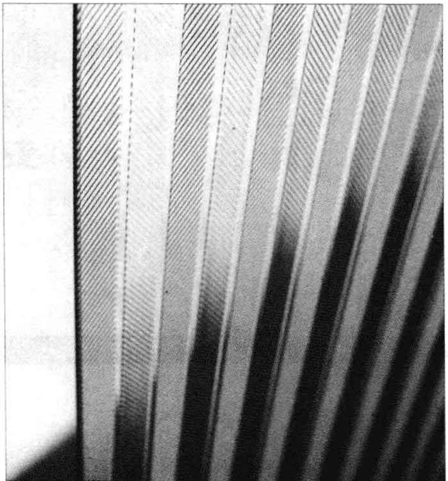

Fig.2:
Ornamental glass

Fig.3:
Various types of profile glass

glass such as very thin glass. The surface quality is somewhat poorer than that of float glass, as waves (called striae) are visible.

Cast glass

Rolling method

Cast or rolled glass is produced using the rolling method, in which the glass mass is formed into an endless ribbon between two water-cooled rollers. Decorations engraved into the rollers give the glass ribbon a surface structure. In order to produce wired glass or ornamental wired glass, a wire net can be rolled into the glass. Cast glass is also called ornamental glass because of its structure or ornamental surface, and its uses include partitions and facade openings where an open view through is neither desired nor required. › Chapter Design glass, Ornamental glass

Profile glass

Profile glass is produced using a process similar to that for cast glass. In addition to a surface structure, the glass is given a cross section (U-profile) that is structurally advantageous, so that considerable spans become possible. › Fig. 3

Because it is economical, profile glass has been and continues to be used for the facades of industrial buildings. Nowadays, profile glass is also a very popular building material in architecture generally. › Chapter Applications, Profile glass

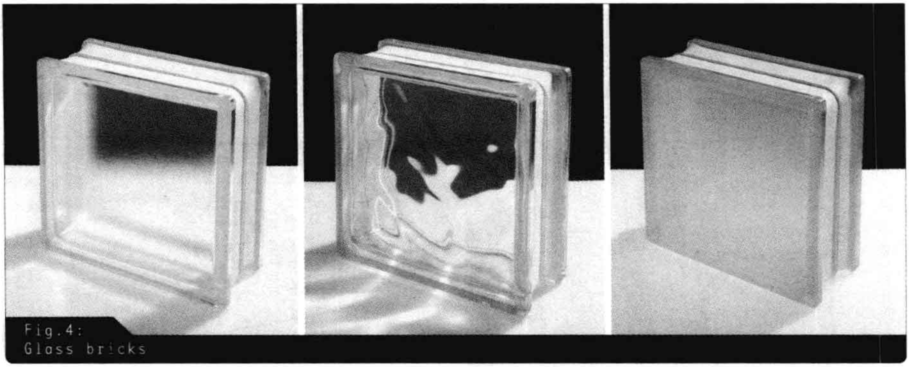
Fig. 4: Glass bricks

Pressed glass

Glass bricks

Pressed glass is the general term for glass bricks, glass ceiling tiles, and concrete glass. These are made by fusing two bodies of glass pressed in forms (pressing method). When cooled, the air in the hollow space within the glass brick is under low pressure, which makes it nearly impossible for condensation to form. Glass bricks are often used in interiors or as translucent elements in solid exterior walls. Architectural glass is used primarily in ferroconcrete construction, since it is also well suited to higher structural loads. › Fig. 4

PROCESSING AND FINISHING

Most types of basic glass are further processed and finished after manufacture, which offers an opportunity to influence not only its form and shape but also the physical and structural properties. The spectrum of finishing processes ranges from mechanical and heat treatments to coating and designing the surfaces.

Mechanical processing

Processing such as cutting, boring, grinding, and polishing are generally labeled mechanical processing or mechanical finishing.

Cutting

Glass is cut into its desired shape. It is not really a cutting process, since the cutting wheel or diamond merely scratches the glass surface, and then the glass is broken by gently bending it along the scratched line. The glass coming directly from the floating machine is cut to ribbon size (600 × 321 cm) and is then given its desired final size in the finishing process. Cutting down and further processing are usually done by machine. For example, complex forms can be produced very precisely using a water jet cutter. The cutting is done with the aid of high-pressure jet of water (with

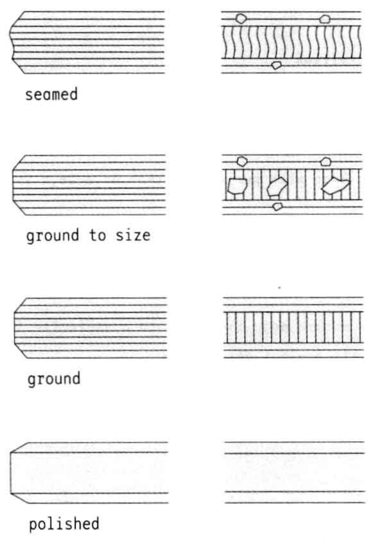

Fig.5:
Glass edges

a water pressure up to 6000 bar) to which a cutting agent (an abrasive) is added.

Edge treatments

Because the edges of the glass are still sharp after cutting, it is necessary to treat the edges both to prevent injury and for reasons relating to the production process. The treatments are distinguished in the following illustration and table. › **Fig. 5 and Tab. 2**

\\Note:
The edge treatment affects not only the optical qualities of the glass plate but also its stability. Inhomogeneous or sharp edges increase the likelihood of damage to the glass (cracks, shells). The type of edge treatment must therefore be determined before awarding the contract; in some cases the pattern should as well.

Tab. 2:
Edge treatments

Term	Definition
Cut	Untreated edge of glass with sharp perimeters as a result of cutting flat glass
Seamed	Cut edge with perimeters that have been smoothed with a grinding tool
Ground to size	Pane ground to the desired size. The edge may have shiny spots and shells.
Ground	The entire edge is ground to a semimatte finish. Shiny spots and shells are not permitted.
Polished	Ground edge is polished

Boring

Various applications in modern glass construction call for boreholes within the pane of glass. These boreholes make it possible to fasten the plates of glass at these points. Because glass is a very hard and brittle material, any mechanical processing must be done with an appropriate tool—boring, for example, should be done with a diamond-tip, water-cooled hollow drill. It should be drilled from both sides at once to prevent breaking through the opposite side. Because local tensions can be very high around the inner face of the hole, the panes are tempered after drilling to increase the strength of the glass.

Tempering

Bent

Bent or curved glass is produced from flat glass that is heated to approx. 600 °C to soften it and then brought into the desired form. Glass can be bent along one axis (cylindrically) or two (spherically), as for an all-glass domed ceiling, for example.

Tempering

Tempered safety glass (TSG) is tempered glass that has been heated to approx. 600 °C under controlled conditions in a tempering furnace and then cooled very quickly. The state of tension in the glass that this process produces can be "frozen," which considerably increases the bending strength of the material. › Fig. 6

In addition, TSG has a much higher thermal shock resistance than float glass. TSG can resist a thermal shock of as much as 150 K, whereas float glass can only withstand thermal shock of 40 K. TSG is considered safety glass, however, primarily due to the way it breaks. Because it is in