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Chronology of Historical Glass Constructions

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Abstract

Glass surfaces are characteristic elements of façades and make a significant contribution to the authenticity of architectural monuments. Glass as a material is considered an important testimony of its time. Depending on the manufacturing process, it differs both in surface and material composition. The period of high modernism (ca. 1880-1970) overlapped with the technical developments of the industrial revolution, which led from manual production to industrial production. The further development of manufacturing processes as well as the dimensions and qualities of the glass thus shaped the development of glass constructions, which had to be made increasingly slimmer over time in order to guarantee a high degree of transparency. Today, historical windows are often replaced by new glazing made of float glass, which can cause the authentic character of buildings to be lost. A team working on the research project at the Technical University of Dresden and the University of Bamberg has therefore set itself the goal of examining in detail the glass and its construction in the period from around 1880 to around 1970. The aim is to define the living character of industrially manufactured glass from the time before the introduction of float glass as an authentic and style-defining feature of the period. The present work focuses on the chronological presentation of the development of glass designs. Furthermore, the development and use of refined flat glass is analysed and presented. This includes wired glass, laminated glass, thermally toughened glass, insulating glass and curved glass. The significance of historical glass constructions for engineers and planners can be derived from the results and the evaluation.

Keywords

Historical Glass, Historical Glass Constructions, Development of Glass, High Modernism

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1. Introduction

1.1. Dealing with glass façades

Glass surfaces shape the appearance of façades. They achieve a high recognition value and also make an essential contribution to the authenticity of architectural monuments. The glass itself is a testimony to the materiality of its respective time. In terms of production technology, both the surfaces of the various manufacturing processes and the material composition itself differ. The reasons for the replacement of glass in the high modern era are rooted in several factors: Glass, both flat and hollow, is now a ubiquitous product that is abundant and cheaply available. The appreciation of today's civil society towards glass as a product is therefore rather low. The material therefore receives little attention in the public perception and is treated as a subordinate product. Currently, there is no set of rules with which glass from the period of industrialisation can be recognised and assigned to the different manufacturing techniques. It is generally known that glass from the period of industrialisation has a wavy structure and optical disturbances, such as bubbles and streaks, but today this is interpreted as a defect rather than as a testimony to technical progress.

Due to the technical possibilities, the increasing use of glass in architecture, especially in the 20th century, has produced a completely new architectural language. The increasing dissolution of opaque wall surfaces led to a new feeling of openness and lightness in façade constructions. This gave rise to the first daredevil glass constructions in the era of high modernism, which sought to satisfy the increasing desire for transparency. The first glass façades increasingly developed from the classic wall openings. The further development of manufacturing processes and the availability of glass in the appropriate dimensions and qualities thus shaped the development of these glass constructions. In order to maximise transparency, the substructures and enclosures of the glass had to be as slim as possible. In addition, the structural design of glass constructions also requires a high level of safety and thermal insulation. Against this background, the first forms of safety and insulating glass were developed in the era of high modernism. The glass construction as such as well as the execution of the glass in the sign of the development of the glass production and the further processing to insulating and safety glass therefore also represent contemporary testimonies of the development of glass constructions, which are currently often not recognised and taken into account. Not least because of the requirements for the energy efficiency of buildings and the associated desire for glazing with the lowest possible heat transfer coefficient, the historical glass is often removed, deposited and replaced by insulating glass with float glass and, if necessary, additional coatings. This leads to a loss of authenticity of buildings and to an irretrievable destruction of contemporary witnesses of technical history.

1.2. Manufacturing process

In the past 200 years, a total of five manufacturing processes have been developed that have significantly influenced glass production and glass quality. For a clearer chronological classification of the various processes, Fig. 1 shows the four processes that play a role in the period under consideration in this paper, the 1920s. It can therefore be assumed that the variance of the glass panes installed in relation to the manufacturing processes is greatest within this period. With the introduction of the float glass process (line 1) from the 1950s in England and its increasing establishment within Germany in the early 1960s, the other manufacturing processes clearly lost importance (Jaschke 1997). From the 1980s onwards, the float glass process had a monopoly position on the German flat glass market

(Spoerer et al., 1987). Moreover, the start of a manufacturing process always represents the first production facility in Germany and not the patent or the first plant worldwide for this process.

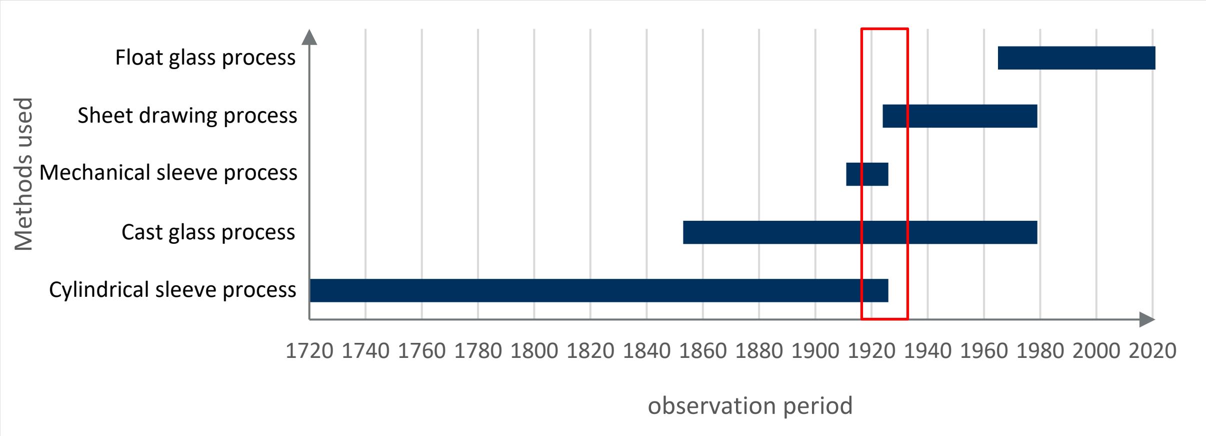

Fig. 1: Chronological classification of the manufacturing processes of flat glass. (M. Heinrich)

2. Development of new innovations

At the beginning of the new Weimar Republic, the demand for glass panes in Germany was very low due to the uncertain situation and the unwillingness of builders to invest, so that it was not until 1924 that the production of glass panes began again (Spoerer et al., 1987). By the end of the 1920s, the production of flat glass as a whole had changed a great deal. At this time, flat glass production using the traditional cylindrical sleeve process ended and the Fourcault, Libbey-Owens and Pittsburgh drawn glass process were introduced. These innovations led to a much cheaper production of the product glass and at the same time made larger formats possible. Thus, glass production in this decade acquired a variety of manufacturing possibilities, which were used in numerous buildings.

At that time there was already standardisation dealing with the safe installation of glazing. However, the already introduced standards and guidelines were not or only very rarely used in residential construction (Reitmeyer 1951). The reason for this was the previously unrestricted design freedom of architects, who did not want to relinquish this privilege (Völckers 1954). In addition, there was also a lack of acceptance among the population to prescribe window sizes for design reasons (Reitmeyer 1951). The acceptance of the population increasingly arose from the rethinking of the lighting conditions in factory buildings but also in residential buildings. Health problems or accidents caused by insufficient light led to a rethink and ultimately to the acceptance of larger glass sizes. (Völckers 1939).

In addition, new types of metal building materials came into use. The profiles of the metal window frames could be made much slimmer than conventional wooden profile frames and led to a greater incidence of light. The resulting saving in dimensions between muntin windows and muntinless windows amounts to an average of 0.34 m^2 (Völkers 1939). However, this difference in the glazed area also influenced the thermal insulation. This is because thermal insulation does not depend on the thickness of the glass pane, but on the size of the glazing. Due to this, an improvement of the glass or the window construction was increasingly strived for (Knapp 1958). The first thermal insulation guideline, DIN 4701 of 1929, rated single glazing worse than box-type and composite windows in terms of heat loss (Völkers 1939). As a result, box-type and composite windows were preferred from a normative point of view.

In addition to DIN 4701, various regulations were created between 1928 and 1931 that regulated window constructions as fixed frame windows in DIN 1240 to DIN 1248. This is the reason for the three standardised basic types of pane dimensions A (32/30 cm), B (44/30 cm) and C (56/30 cm) for the most commonly used fixed frame windows (Reitmayer 1951). Basically, a general glass standard developed from the work of DIN in April 1930 as DIN 1249. This standard included types, thicknesses and test methods for window glass. As early as September 1932, the standard was revised and the term construction glass was introduced instead of window glass (Beuth 2021).

Safety glass developed as early as 1910 in France as the first laminated safety glass with a celluloid layer, which, however, yellowed when exposed to sunlight and thus led to further developments. Before World War I, this safety glass was marketed in Germany as "Triplex", later "Kinonglas" (Bodenbender 1933). At the end of the 1920s, the monopoly position of Nikolaus Kinon for single-pane safety glass was ended by the expiry of the patent and technological progress, and new companies became involved in this development (Möller 2001). Accordingly, laminated safety glass was partially further developed in Kunzendorf in 1928 / 29. Until 1930, the variant with a celluloid layer was manufactured by the company Sigla GmbH in Kunzendorf with an edge sealing to protect the interlayer. In the same year, the PVB film was developed, which is the intermediate layer of today's laminated safety glass (Glocker and Gerheuser 2017). In principle, this laminated safety glass was mainly used in the automotive industry as windscreens, and less frequently as glazing in the construction industry.

Another representative of safety glass is called toughened safety glass (ESG). This is also generally referred to as "tempered glass". This is thermally toughened glass, which is also used today. The first attempts to thermally post-treat glass panes after cooling were made as early as 1874 (Glocker and Gerheuser 2017). However, it was not until the advent of the automobile and the associated serious accidents caused by broken glass that the development of safety glass was pushed forward (Bodenbender 1933). The first product on the market was the tempered safety glass "Sekurit" by Saint Gobain, which was manufactured near Aachen from 1930 onwards (Möller 2001). The starting material for the production was mirror glass, which was also used in shop windows (Bodenbender 1933). However, the maximum dimensions of such safety glass of 1.10 m x 1.10 m or 2.50 m x 0.50 m, which were not compatible with the intended muntin-free constructions (Völkers 1948), proved to be a disadvantage.

Before this development of such shatter-proof glass, grids were attached on the outside or also on the inside for protection, which were lowered like roller shutters (Schuhmacher 1951). In addition to the protection of separate grids, it was also possible to use wired glass, which had been known since the 1890s. The wire mesh inside the glass pane provides a similar injury-proof behaviour as toughened safety glass. The disadvantage of reduced transparency due to the mesh, which was particularly important in shop windows, suggests that this glass was rarely used in shop windows. In order to increase the burglary protection in shop windows nevertheless, the wire mirror glass with a higher transparency through silver-white inlaid wire mesh or also the special form as "Chauvel glass" with parallel inlaid wires could be used. All three types of wired glass are considered fire-safe or fire-retardant, as they contain the spread of smoke and fire due to their non-failure (Knapp 1958). This is also confirmed once again by the ministerial decree of 12.03.1925. Wired glass can also be produced in large dimensions due to its manufacture as cast or rolled glass (Knapp 1958) and can thus theoretically also be used in shop windows. Following on from the developments in safety glass, the Sigla GmbH company in Kunzendorf also developed a wide range of flat glass finishing. The first patent for a double pane (Kunzendorf double pane, "Ku-Do") was registered in 1934 (Spoerer et al., 1987). The structure of this pane is similar to that of today's insulating glass.

The invention of insulating glass marks the end of innovation for the time being. The development of this glass pane is probably due to the similar thermal insulation effect compared to a laminated window with a far less complicated construction. These windows were therefore probably the precursor of insulating glazing, as the distance between the panes was also only a few millimetres.

In the following, industrial buildings as well as residential buildings will be explained in more detail. These two categories still have quite a large number of buildings today and are therefore of particular value.

3. Flat glass application in the 1920s

3.1. Exemplary buildings

Classical Modernism developed into ubiquitous architecture in the 1920s after the economic situation stabilised. Even before the First World War, the first ideas for this striking epoch emerged and were applied in the buildings of work and transport, industrial buildings and railway station halls. The Fagus-Werk in Alfeld/Leine was designed by Walter Gropius and his collaborator Adolf Meyer in 1911 and stands as one of the first icons of architectural modernism. In the 1920s, these ideas manifested themselves and numerous architects designed industrial buildings, residential buildings and, not least, department stores. Important buildings of this period include the Bauhaus Dessau from 1925-26, the Sidol-Werke in Cologne-Braunsfeld from 1926-28, the Weißenhofsiedlung in Stuttgart from 1927, the Schocken department stores' chain (Stuttgart 1928, Chemnitz 1930), the Herpichhaus in Berlin from 1929 and the German Pavilion at the international exhibition in Barcelona from 1929.

However, the construction method of the skeleton building was only transferred to residential construction with the onset of economic growth in the 1920s. This is due to the more demanding design in terms of social, technical and hygienic as well as residential requirements compared to commercial buildings. The first executed designs were created in connection with the Werkbund exhibition in Stuttgart in 1927, the complex now known as the Weißenhofsiedlung. The approaches of modern building design led to a dematerialisation of the outer shell. The wall was no longer perceived as a load-bearing component; instead, the cross-section was to be reduced to a minimum (Schulze 1929).

3.2. Constructive aspects of industrial buildings

The continuing technological progress and the need for industrial buildings required the construction of new factory facilities, especially after World War 1. Examples from this period are the Bauhaus Dessau (built in 1925) by Walter Gropius and the Fagus-Werk (built in 1911) in Alfeld/Leine. The Fagus-Werk is one of the first buildings in the constructive design of a glazed steel skeleton building. It symbolises a certain lightness and transparency that could not have been more radical and, at the time, stood in contradiction to the hitherto traditional architecture. The modern skeleton construction as a new technique offered Gropius and his staff the possibility of forming the outer shell of the narrow structure as a large-scale curtain wall made of glass. Not only the main building, which mainly contains offices, but also the three-storey workshop building presents itself as a light-flooded working space.

In addition, the almost weightless character of the building is emphasised by the support-free corners of the building, which are also formed with glass. Dark yellow clinker bricks were also used for the plinth area and the upper wall of the workshop building, Fig. 2.

Fig. 2: Left: Fagus-Werk, front. Right: Fagus-Werk back – view from southeast. (F. Rehde)

Both Benscheidt as an enlightened factory owner and Gropius as a socially and health interested architect were committed to a people-friendly working environment, which was anything but a matter of course at the time. Glass subsequently became for Gropius the promising building material of a new age, both architecturally and socially. This material will find its peak in application in Gropius' work with the Dessau Bauhaus building (Kimpflinger 2011). The glass façade of the main building is almost completely dissolved into glass fields, which are suspended between a load-bearing and supporting framework of brickwork and steel girders. This is structurally reduced to a minimum and gives the building its striking lightness and transparency. The supporting pillars are inclined inwards. Each glass field is further divided into 16 smaller fields, where the horizontal side is almost twice as long as the vertical side. These fields are suspended from a cantilevered concrete arm and joined in an iron frame. These frame structures are made of metal and framed with a dark putty-like material, Fig. 3 left.

Fig. 3: Left: Window frame construction. Right: Pivoting window for ventilation. (F. Rehde)

The entire glazing is single glazing, which, however, caused problems in terms of building physics with regard to winter and summer thermal insulation. Fig. 3 right shows the so-called pivoting sashes. They are used for ventilation along the façade. These pivoting sashes enable draught-free ventilation thanks to their construction, in which the pivoting axis is located centrally in the window frame. At ceiling level, there is steel cladding instead of the glass panes; this sheet metal skirt runs around the corner to the stairwell.

3.3. Constructive Aspects of the residential buildings

The Weißenhofsiedlung is a settlement of various residential buildings, some of them single-family houses, which was built by renowned modernist architects for the Werkbund exhibition in Stuttgart in 1927. The designs do not focus on economic efficiency, but on the principles of modern architecture. The architects' central theme is the combination of skeleton construction and residential buildings. Compared to traditional masonry construction, this method of building allows for a faster construction time and can function as a mass production method for small flats. In only 21 weeks, 21 houses with a total of 63 residential units were built.

According to Schulze (Schulze 1929), all the buildings in the estate have in common the adoption of well-known techniques from industrial construction, as a basic idea. They consist of a reinforced concrete construction either as a frame construction or skeleton construction, in which masonry openings provide light. These openings are becoming increasingly important. They are designed as wide windows or, by lining them up to form window strips, as long windows with subdivisions by window mullions. The parallelism to industrial buildings becomes more obvious through the use of metal frames. The skeleton construction method also makes the increasingly large glazing areas possible due to the relatively slender supporting structure. The two following pictures in Fig.4 each show a building by Le Corbusier and Ludwig Mies van der Rohe from the Weißenhofsiedlung of 1927.

Fig. 4: Left: Residential House-Doppelhaus, Le Corbusier P. Jeanneret. Right: Residential Block, Mies van der Rohe (F. Rehde)

It can be seen from the two illustrations that the glass panes used are large-format and, in relation to the year of construction, were made from the panel-drawing method or by means of expensive mirror glass. Furthermore, it can be seen that the windows are set flush with the outer edge and usually completely fill the area between supporting pillars or columns. In this way, the cubature is emphasised and not dissected by windows, as was the case 20 years earlier. Furthermore, the narrow metal frame constructions are recognisable, which were one of the first applications in housing construction at this time. In order to continue to reinterpret modernism in housing construction, Walter Gropius designed two residential buildings for the exhibition in two different construction methods. On the one hand, the semi-dry assembly method, which was based on handicraft construction methods. The other was a completely dry assembly method, in which industrially prefabricated individual parts were assembled. These two variants characterise the essence of modern housing construction as a completely new type of dwelling made of rationalised standard goods. The requirement arising from this building was to influence standardisation in the glass industry with regard to window sizes (Schulze 1929).

In addition to the modern residential buildings of the Weißenhofsiedlung, the constructions of the perforated façade as well as the mullioned windows continued to be used as traditionalism or Heimatstil. In contrast to the previous highly rectangular installation of the glass panes, the 1920s and 1930s saw a horizontality of the windows in both rural and urban areas. Accordingly, the glass panes were installed transversely, see Fig. 5, using the standardised pane size of 30 cm x 42 cm as well as wooden glazing bars with a maximum width of 25 mm.

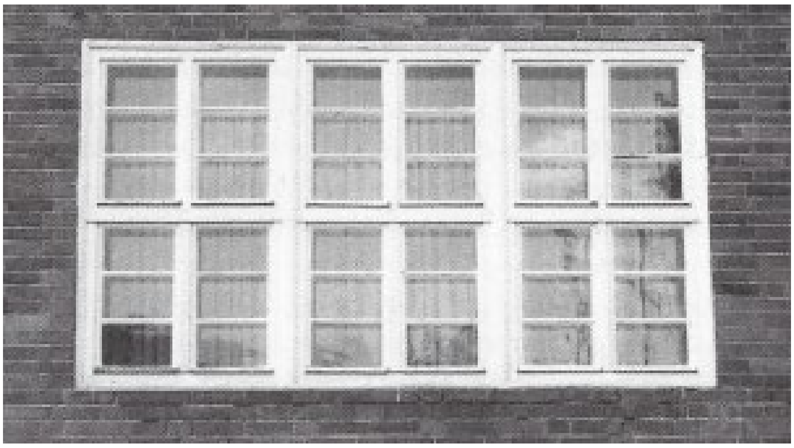

Fig. 5: Horizontality in the mullion window of the 1920s/1930s (Schrader).

Due to the first thermal insulation standard adopted in 1929, these muntin windows tend to be designed as box and composite windows instead of single glazed units. The heat loss through the windows in the normatively preferred variant is about half compared to single windows (Völkers 1939). As an example about the construction can be given by a residential building in Dresden Trachau from the 1930s, Fig. 6.

Fig. 6: Left: residential building Dresden Trachau. Right: Horizontality in the muntin window in the upper part (F. Rehde)

4. Summary

The window constructions used in this period of observation can be fundamentally summarised. Both industrial buildings, here in the example of the Fagus-Werk, and the residential buildings of the Weißenhofsiedlung or the residential buildings in Dresden Trachau show parallels in the supporting structure. This is shown as a reinforced concrete skeleton, which represents a technological improvement compared to the iron trusses of the previous period. In addition, the cubature of the residential buildings shows a change. The simplicity established as a principle in modern architecture is practically implemented by the flat roof and the cuboid shape of the buildings. This is also an innovation compared to the previous, mostly sloping roofs. The glazing in the buildings, which are determined by practicality, increases in area, so that the window widths are only limited horizontally by the supporting columns and pillars. The architecture of the 1920s and 1930s places a strong focus on the openings in buildings and the associated light yield and light penetration into the rooms. In order to be able to implement the large-scale glazing, it is necessary for the frames to be made of metal in order to be able to span larger spans with slimmer profiles.

However, wooden frames were still used in residential buildings of the so-called Traditionalism, the adherence to familiar construction methods, in the form of the transverse glass panes. In addition, window putty was used in various material compositions to avoid hard contact between the frame and the glass. In principle, it can also be said for the glass architecture of the 1920s that window glass to a large extent originated from the newly developed panel-drawing methods. Only shop windows in the 1920s are made of mirror glass from the cast glass process due to their large dimensions.

In the current DFG-funded project "Materiality and Authenticity of Glasses and Glass Constructions of High Modernity", questions about historical glasses and glass constructions are being investigated and discussed. Many historical glasses and also glass constructions are currently present in the building stock, but have not been mapped. Among other things, this represents one of the next tasks in the project. Here, the mapping of the Dresden district of Trauchau to the existing building stock in its installed state will be carried out using a geographic information system (QGIS). The results obtained from this represent an important part of the reappraisal of the history of technology.

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