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MANKIND AND ARCHITECTURE

Mankind as the focal point of architecture: interior views of a corresponding relationship.

# GLASS IN ARCHITECTURE

PHOTO BY RUPERT TRUMAN

***Above*** **The Palm House at the Royal Botanical Gardens in Kew/London was built between 1845–1848 by Richard Turner and Decimus Burton.**

**In the large greenhouses of the 19th century, glasshouse architecture took on a unique, engineered style quite different from classical archetypes.**

Text by Michael Wigginton.

**Glass in architecture means light and life, power and spirituality, utopia and ideology. Michael Wigginton tells the story of a material whose potential has by no means been exhausted yet.**

About 4000 years ago an extraordinary new material was discovered which was to change the nature of architecture. When and how this discovery was made is a matter of pure speculation, but we may imagine a craftsman sitting by a kiln on the shores of a river in Mesopotamia noticing a brilliant sparkle where the hot coals from the kiln had fallen on the sand beneath. From this discovery flowed centuries of technical experiment from which has evolved one of the most important materials known to mankind: a material made from one of the most abundant materials in the Earth's crust, silica, which has the remarkable property when melted and carefully cooled of transmitting the radiation from the planet's giver of life, the sun. The material was glass.

Discovering the true nature of the material, and methods of forming it, was an extremely slow process. From its earliest form as beads, the discovery that it was viscous when very hot led to the development of the core method of making pots (in which threads of molten glass were wrapped round a core). By 1500BC there was a glass industry in Egypt, which created vessels, and decorative products of enormous richness and diversity. This was consolidated by Alexander the Great in 332 BC when he founded the glass industry in Alexandria.

By around 750BC it was found that glass could be blown using a pipe, and the real adventure began. Blowing glass meant that it could be made very thin, and comparatively even in thickness. The basic technique for making the modern window was in place. This extraordinary material, hard, transparent, and capable of being formed, could act as a material to keep the weather out of buildings whilst at the same time admitting light and view.

It is remarkable that the evolution of the window itself then took nearly 3000 years to mature. The Romans, who conquered Egypt and used glass as tribute, lived in the same Mediterranean climate as the Greeks and Egyptians before them. Although they used glass in openings, and developed ways of growing plants out of season using what are now called "cold frames" (rudimentary conservatories), the climate did not create the functional imperative needed to create what we call windows.

Then, a thousand years ago, the need arose in France for a new kind of architecture. European architecture up until this time had been essentially derived from the massive forms of the southern Romanesque, itself derived (as the name implies) from the powerful precedents of Rome.

Romanesque was an architecture of massive walls, great vaults and small windows: an apparently inevitable result of the need to create large rhetorical volumes in a warm climate. The volumes provided the powerful statements concerning the importance of God and the technical prowess of man. The structures stabilised the temperature. The small windows modulated and controlled the often overwhelming light.

### THE FIRST GLASS AGE: GOTHIC CATHEDRALS

For the abbots and bishops of northern Europe at the turn of the first Christian millennium, this was not enough. They wanted to build bigger, both to accommodate more lay congregations (an essential source of funds as well as of spiritual allegiance) and to exploit the glories of Gregorian chant. In a slow, empirical progress, ways of spanning space with stone, a material only structurally effective in compression, were evolved, and geometries developed which could generate space free from the constraints of the Romanesque barrel vault. The development of the Gothic frame and the need to create walls to fill the huge resulting openings generated the need for light-providing, and lightweight, membranes. The first glass architecture in the history of the human race was born.

Transparency in the sense of providing visibility was not a prime objective to the church and cathedral builders of the Middle Ages. Their idea was to give light to the interiors of their huge volumes, and to use the richness of colour which glass had always been able to deliver. Stories from the Bible were told with vast images, much greater and more powerful than could be delivered by mere painting, lit from behind by the vast source of the sky.

From the rose windows of France, to the huge nave windows of the English, the skills of the Roman empire and their imported Mediterranean glass makers and glaziers evolved a new form of architecture, characterised by enormous expanses of stained and painted glass. The east window of York Minster is the size of a tennis court, and comprises thousands of pieces of glass producing, not transparency (there was no requirement to see in or out), but a shining painting. The Sainte Chapelle

PHOTO BY MARGHERITA SPILUTTINI

in Paris, built between 1243 and 1248, represents an extraordinary refinement of the Gothic glaziers art, with stone mullions almost as thin as metal.

Medieval cathedral architecture was essentially a northern European adventure, and it is not surprising that it continued to be built, and evolved, well after the inhabitants of the sunnier climates to the south had created new architectural paradigms. In the 11th century, Proto-Renaissance architecture was emerging in Florence at the same time as Gothic in Northern Europe, and Bramante was working on St Peter's in Rome in the early 16th century at the same time as Henry VII was building King's College Chapel in Cambridge, and Westminster Abbey, two of the last great Gothic glazed structures in England.

As soon as the Renaissance arrived in northern Europe a new generation of clients saw a way of using glass to celebrate their wealth in architecture. Whilst transparency was not needed in most Gothic churches, the great houses of the northern European aristocracy of the 16th century required view, and buildings such as Hardwick Hall ("more glass than wall"), designed by Robert Smythson and built in the 1590s, were the secular inheritors of the great Gothic glass architecture. Hardwick Hall, like most of the English "Prodigy Houses" of the Elizabethan period, was extremely uncomfortable to live in. Too cold in the winter, and far too hot in summer on its south elevation, the only way the occupants could survive in such a building was by moving around the house from season to season. The aesthetic considerations of glass architecture were far more important than the environmental, which in any case were only vaguely understood.

How to make glass, and particularly how to make it strong, was an abiding preoccupation for glass makers, and the 17th century saw an important new development in glass technology. Blown glass had dominated the industry for centuries, but the product was intrinsically thin and weak. The French gvernment initiated the search for a new stronger glass in 1676, and the result was plate glass, made by grinding and polishing cast glass. This was very expensive, but provided the basis for the extraordinary use of mirrors in the Palais of Versailles, completed in 1685. The great windows in the Hall of Mirrors, which the mirrors literally reflected, were characteristically poor in thermal performance, however, and wine and water froze on the dining table in the cold winter of 1695.

It was an acknowledgement of the thermal performance of glass in the late 16th century which led, by an accident of history, to the development of the conservatory. The exotic plants imported by the European explorers were recognised as requiring protection, and glass houses, including the great orangeries of the time, began to infiltrate the world of architecture, albeit as adjuncts to the houses and institutions they served. It was the conservatory which, over the subsequent 250 years, was to form the basis of the evolution of the next great flowering of glass architecture, the second glass age, growing from utilitarian buildings serving horticulture into the status of a great architectural type.

### THE CRYSTAL PALACE AND ITS PREDECESSORS

By the 19th century glass conservatories had developed from unpretentious buildings built by gardeners into great pieces of architecture. In England, the Palm House of 1845 at Kew by Richard Turner is one of the greatest of these, but fine and elegant conservatories were built all over Europe. The designers and their clients competed with each other to produce the biggest and the grandest, traversing the continent to look at the work of predecessors and rivals. It was this rapid evolution in the 19th century, and the travelling which fed it, which led to the design of what is undeniably the greatest glass building of the time, built in London in 1851. It was a visit by Joseph Paxton to Rohault de Fleurie's Jardin des Plantes in 1834 which was to plant one of the seeds for the Crystal Palace, home of the Great Exhibition of 1851. Hailed by Konrad Wachsmann, the great 20th century engineer, as the first modern building, the Crystal Palace combined innovation in technology, manufacture and space to create a masterpiece, created by a gardener, an engineer, and a fabrication company, constructed off-site as a prefabricated structure, and then, when its original use was complete, dismantled and moved to a different location, all without an architect in sight.

The Crystal Palace was one of an evolving type, growing out of the demands of the industrial revolution. If the Crystal Palace was the home of a celebration of the industrial revolution, railway stations, arcades (such as the Galleria Vittorio





"Everyone knows the wonderful properties of glass: it is transparent, hard, colourless, indestructible by acids and most liquids, and at certain temperatures more ductile than wax, ..."

Justus von Liebig, German chemist (1803–1873)

PHOTO BY HENRI PARENT

***Opposite*** **With the construction of the main hall of the Postsparkasse (Post Office Savings Bank) in Vienna between 1904–1912, Otto Wagner created one of the pioneering works of early Modernism, a model for modern office halls. Even the basement floor receives natural light, thanks to glass blocks laid in the floor.**

***Above*** **Gothic style breaks up the formerly solid cathedral wall into a ribbed framework, with the spaces in between filled by large glass windows. The large rose window of the Cathedral of Strasbourg clearly illustrates how the windows were constructed: the precast lead-encased panes were inserted into the stone tracery as a complete unit.**

Emmanuele II in Milan, built between 1865 and 1867) and market halls were the building types which were demanded by the requirements of industry in the railway age. Railway stations and the great central market buildings demanded large open spaces with long spans to be protected from the rain, and daylit at the same time. The great Victorian industrial buildings, able to rely on iron and steel, not stone, were the cathedrals of their time. These buildings had no basis in history, and defied the imaginations of contemporary European architects, leaving the challenge to be met by engineers.

The USA did not carry the same sort of cultural "baggage" as the Europeans, and it was in the USA that a new type of architecture emerged. The regeneration of Chicago after the great fire of 1871 led to the evolution of the skyscraper, with its steel or iron frame, and its glazed façade. Buildings such as the Gage building by Holabird and Roche of 1898 (with Louis Sullivan creating a next door neighbour) were virtually unthinkable by the "academic" architects of Europe. These buildings used the potential of plate glass, invented in France in 1687, and the origin of a great French industry set up in the Chateau de St Gobain in 1693.

### FROM INDUSTRIAL HALLS TO PUBLIC BUILDINGS

Although American architecture in the second half of the 19th century saw the creation of new building types, Europe was the home of the third great age of glass architecture, and its theoretical basis. Otto Wagner's Post Office in Vienna of 1904–12 demonstrated how to move the industrial technology of the industrial halls into a public building, with its wonderful glass roof and floor, but it was German architects and theorists in the second decade of the 20th century whose obsession with glass was to become the most significant influence both on architecture as a whole, and of its relationship with glass in particular. The writings of Paul Scheerbart, the author of "Glasarchitektur" of 1914, and the buildings by Bruno Taut, and later by Walter Gropius and Mies van der Rohe, changed the perception of the role glass could play in architecture. Mies van der Rohe's competition designs for Berlin in 1919 and 1922 represented a huge change in architecture, and he became one of the guiding figures in the modern movement who adopted glass as "their material"; a group

***Below*** **Unaffected by climatic building considerations, Walter Gropius used single glazing to construct the minutely detailed three-storey façade of the Dessau Bauhaus in 1926. The so-called 'curtain walls' are an exemplary realisation of the separation of the skeleton and façade of a building, an ideal of classical modernism.**

PHOTO BY CHRISTOPH KOCH

within the movement even took the work "Glass" as part of their name (Die Glaserne Kette). Glass was the material of socialism (with its transparency and openness), and was seen as the light and "modern" replacement for the weight and pomposity of previous ages.

The great Europeans were not the only architects who exploited the beauty and potential of glass. Frank Lloyd Wright's passion for stained glass led to its incorporation in many of the important houses and other buildings which he designed at the run of the 20th century.

In the years between the two world wars, the enthusiasm for the material developed on both sides of the Atlantic. America was the birthplace of the curtain wall (starting with the Hallidie Building in San Francisco of 1918 by Wills Jefferson Polk), and the work of architects such as Fred Keck in the American mid-West in the 1930s gave a hint of what was to come 40 years later, the evolution of the high-performance glazed façade, addressing issues such as energy conservation. Le Corbusier had tried to address these issues in his Cite de Refuge in Paris of 1931 (in the same year, and in the same city, as one of the greatest of all glass buildings, Chareau's Maison de Verre). However, technology was not yet well enough developed to sustain this sort of experiment.

In the USA, Frank Lloyd Wright enunciated what he saw as the theoretical and aesthetic problem related to glass and architecture in a lecture he gave at Princeton University in 1930: "Glass has now a perfect visibility, thin sheets of air crystallised to keep air currents outside or inside.......Tradition left no orders concerning this material as a means of perfect visibility". Working with characteristic innovative individuality, he went on to design the Johnson Wax Administration Building in 1936. This building used a membrane constructed from borosilicate glass tubing, creating a unique and wonderful translucency.

## A HOUSE WITHOUT WALLS: MIES VAN DER ROHE AND FARNSWORTH

In the years after the Second World War, the enthusiasm for the material remained, particularly in the USA, home of many European emigres, including Mies van der Rohe and Eero Saarinen. Mies van der Rohe designed what remains perhaps the greatest single example of the architecture Wright claimed to be seeking in 1930. The Farnsworth House, designed in 1946, is the classic paradigm of an architecture where the wall disappears. Postwar architecture in the USA saw the construction of some great glass architecture including Eero Saarinen's masterpiece for General Motors of 1948–56 (which remains an exemplar of technical virtuosity in glass, with one of the earliest uses of gasket technology), SOM's Lever House of 1951, and the Seagram Building by Mies van der Rohe himself, built between 1954 and 1958.

It is a tragedy of architecture that the geometrical simplicity of classic modern architecture proved so easily cheapened and copied. The technique of producing thin, bland, and poorly performing skins, with their huge need for environmental controlling systems including air conditioning, was exported round the world to produce a generation of devalued glass architecture, using the mass-market curtain wall, which became one of the most despised aspects of postwar architecture. It took the importing of another essentially American invention, the passive solar glass wall, and the oil crisis of the early 1970s, to consign this sort of architecture to history. The idea of using the radiation transmission characteristics of glass to capture solar energy had been studied in the USA in buildings such as the Peabody House by Maria Telkes in 1947, picking up ideas which were decades old. The Europeans followed with buildings like the Wallasey School in England by A E Morgan of 1961, and Michel and Trombe's work in France of the mid-1960s.

***Opposite*** **The possibilities of modern glassmaking are demonstrated in the "Dichroic Light Field" installation by engineer James Carpenter in New York. The light reflexions and shadows which the dichroic glass "fins" cast onto the glass façade change their colour according to the position of the sun.**

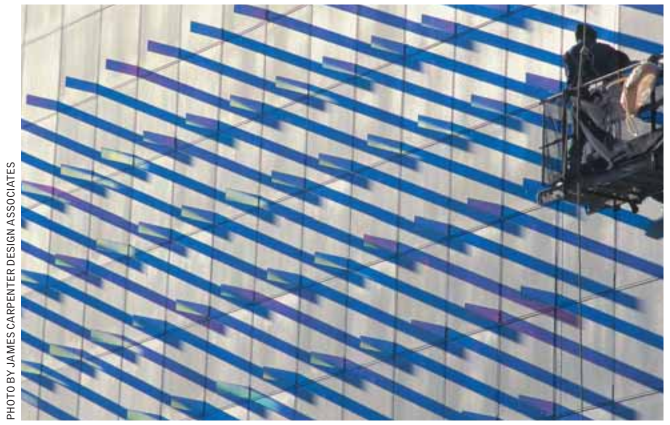

PHOTO BY JAMES CARPENTER DESIGN ASSOCIATES

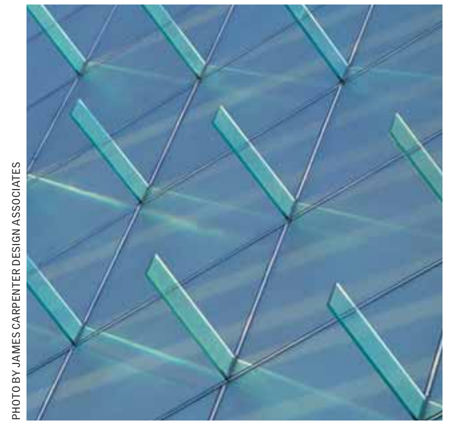

PHOTO BY JAMES CARPENTER DESIGN ASSOCIATES

## ENVIRONMENTAL ISSUES AND INTELLIGENT SKINS

Thus, although the curtain wall retains an unfortunate hold across the planet, as a phenomenon which blights our cities, a new generation of architects, with different priorities, produced a new flourishing of glass architecture in the 1980s and 1990s, building (perhaps sometimes unconsciously) on the theoretical principles of Wright, Mies van der Rohe and le Corbusier. What we might call the fourth age of glass architecture draws together the strands of the previous 60 years, liberated by the invention of the float process by Pilkington in the 1950s, and the development of a large number of technologies related to coatings and treatments. Glass is now one of the predominant constituents of architecture across the world, from climate skins to wonderful displays of structural ingenuity. Structural glazing is exemplified in the work of Tim McFarlane in the UK, of Mick Eekhout in the Netherlands, and of the Paris firm RFR. Many of these are effective realisations of the visions of work produced 50 years or more previously. Willis Faber Dumas, product of Foster Associates in the early 1970s, makes real the idea of a suspended wall seen in Mies van der Rohe's 1922 competition entry. The Lloyd's building by Richard Rogers Partnership, built 10 years later, saw the final realisation of le Corbusier's "mur neutralisant". Architects became interested in refined chemistries and new ways of fixing, exemplified in the glazing of the Pyramides in the Louvre in Paris, by IM Pei and Partners, designed and built between 1983 and 1988. Here "water white" glass, with most of the iron removed, produced glazing which did not distort the colour of the stone in the Cour de Napoleon when viewed through it, and the use of silicon bonding permitted a completely flush exterior. Other work used the emerging thin film technologies. Gunnar Birkert's Corning Museum of 1980 used thin film coating, to transform the hard and brittle visual nature of glass architecture into a soft appearance, as smooth as satin. For the last 20 years glass has become the favourite material for architectural essays in transparency, ambiguity and energy.

A fifth age is now on the horizon, with new materials, and new perceptions of use. Smart glass has been developed in the area known as "chromogenics" which change their performance at the flick of a switch. Insulating materials which produce U-values close to "0" have been developed using aerogels, and stronger materials resisting fire are all infiltrating the catalogues. Dichroics and beam splitting glasses can deliver or block tailored frequencies of the spectrum. Light bending glasses using Total Internal Reflection, such as Serraglaze, are also coming on to the market. These will transform the ability of the window to draw in daylight, and enable solar shading to operate using transparent materials.

If one aspect of this fifth age is clear, it is that we cannot easily imagine what it will have delivered in 50 or even 20 years' time. We can be sure that it could be magical, beautiful and wonderful. We can be equally sure that it is exploited properly, and not used to create universal blandness. We still suffer from all pervasive nature of the curtain wall, but the potential richness of the multifunctional intelligent skin, responding moment by moment, and season by season to the vagaries of climate and the needs of the occupants has the potential to give us the transient beauty of the butterfly's wing, with a material as hard as steel.

**Michael Wigginton** holds a chair in architecture and design at the Plymouth School of Architecture in England. His main research interests are intelligent façades, glazing systems and ecological studies. He has published several books on these subjects, including *Glass in Architecture* (Phaidon, 1996) and *Intelligent Skins* (Butterworth Architecture, 2002).