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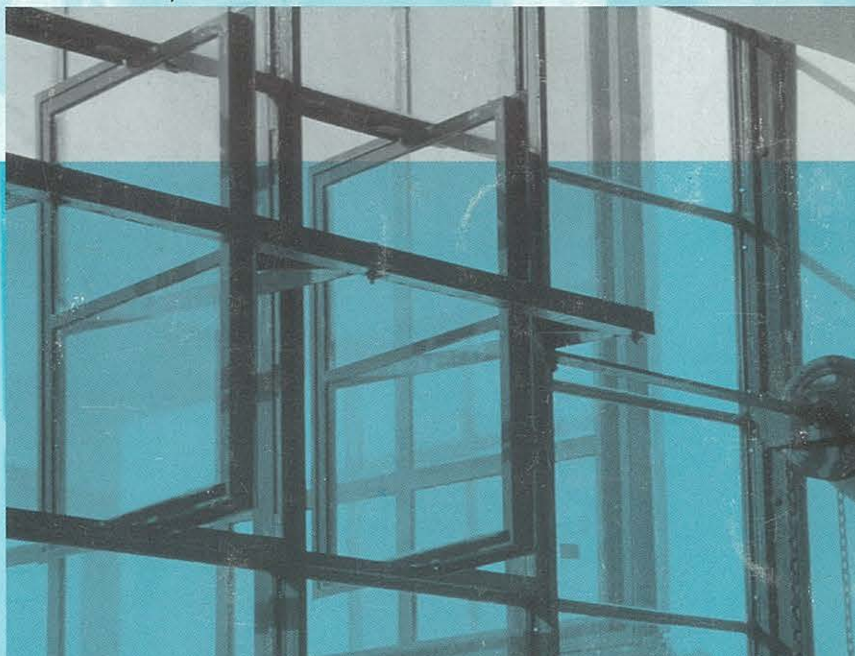
Reframing the Moderns

Substitute Windows and Glass



preservation technology
dossier 3
april 2000

THE NATIONAL FOREST AND NATURE AGENCY OF DENMARK
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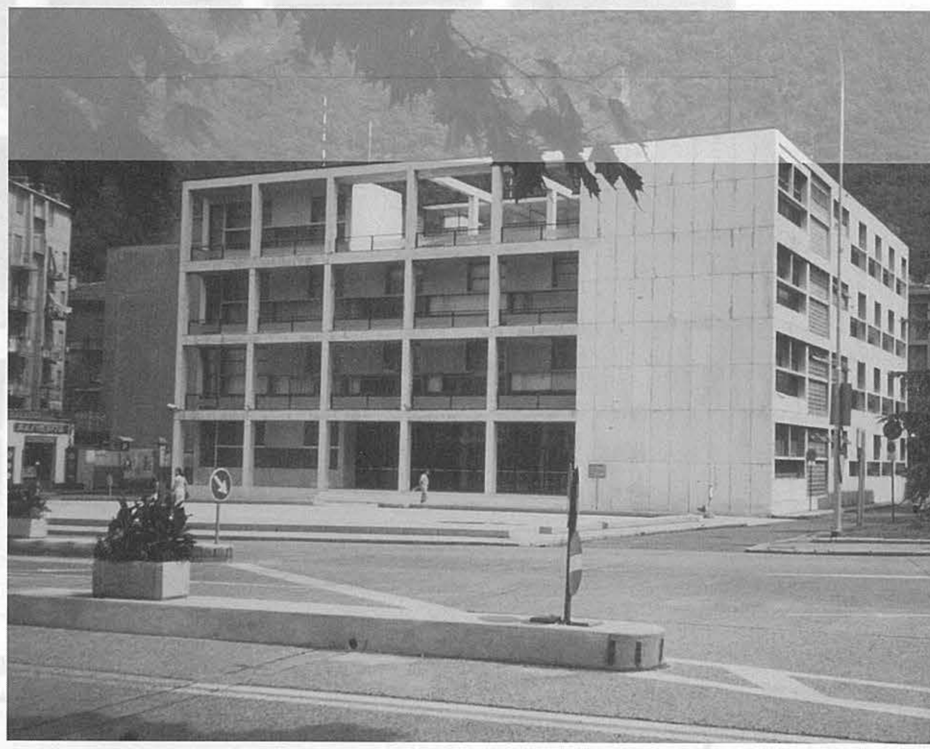

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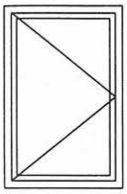
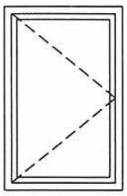
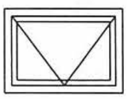
Vocabulary



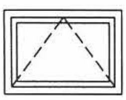
side-hung
casement or projecting window



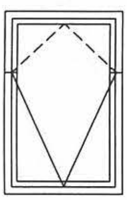
side-hung
inward-opening window



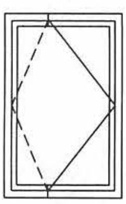
top-hung
outward-opening window



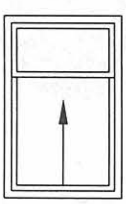
bottom-hung
inward-opening window



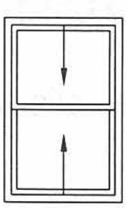
horizontal
pivot window



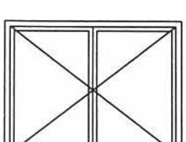
vertical
pivot window



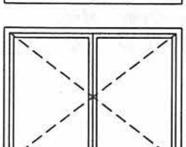
sash window
with fixed toplight



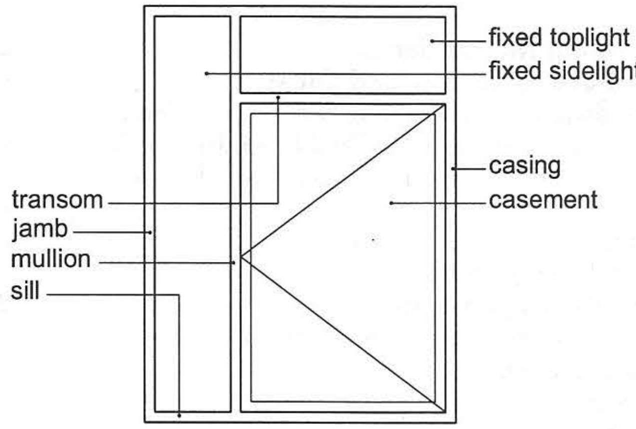
double-hung
sash window

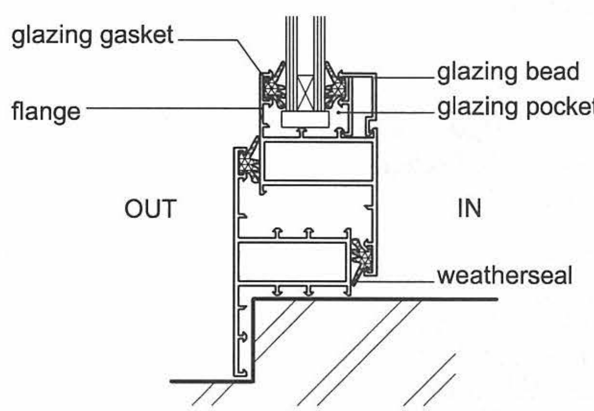


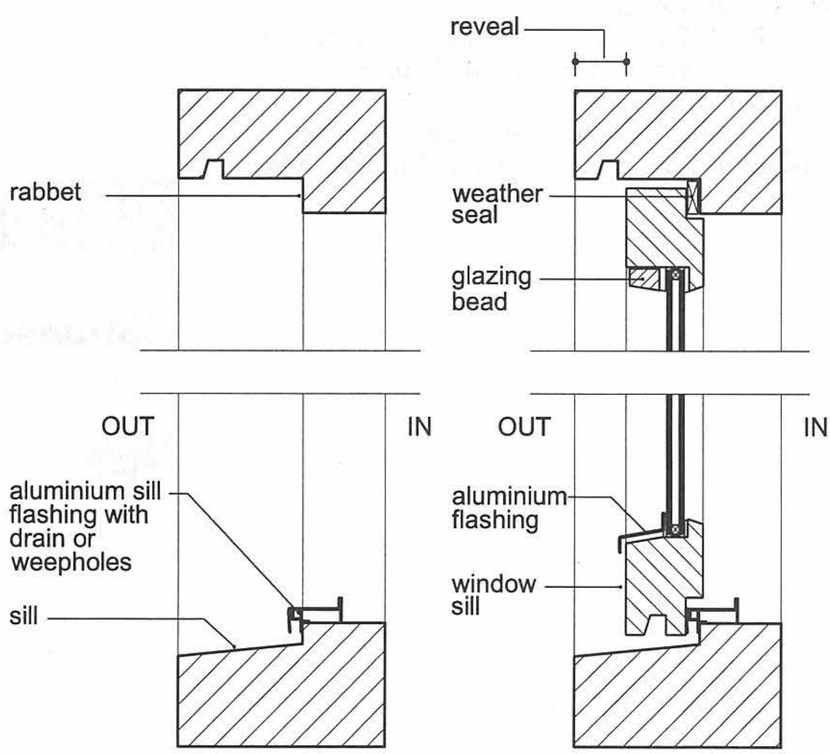
double projecting
window



french window







Colophon

Reframing the Moderns
Substitute Windows and Glass
Proceedings International DOCOMOMO Seminar, May 20, 1998, at the Royal Danish Academy of Fine Arts, School of Architecture, Copenhagen, Denmark

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Cover: The 1926 curtain wall of the Bauhaus Dessau was reconstructed in aluminium in 1976.
Photo: Ola Wedebrunn.
Title page: The Casa del Fascio in Como was conceived in 1932 as a glass house. Photo: A. Artioli.

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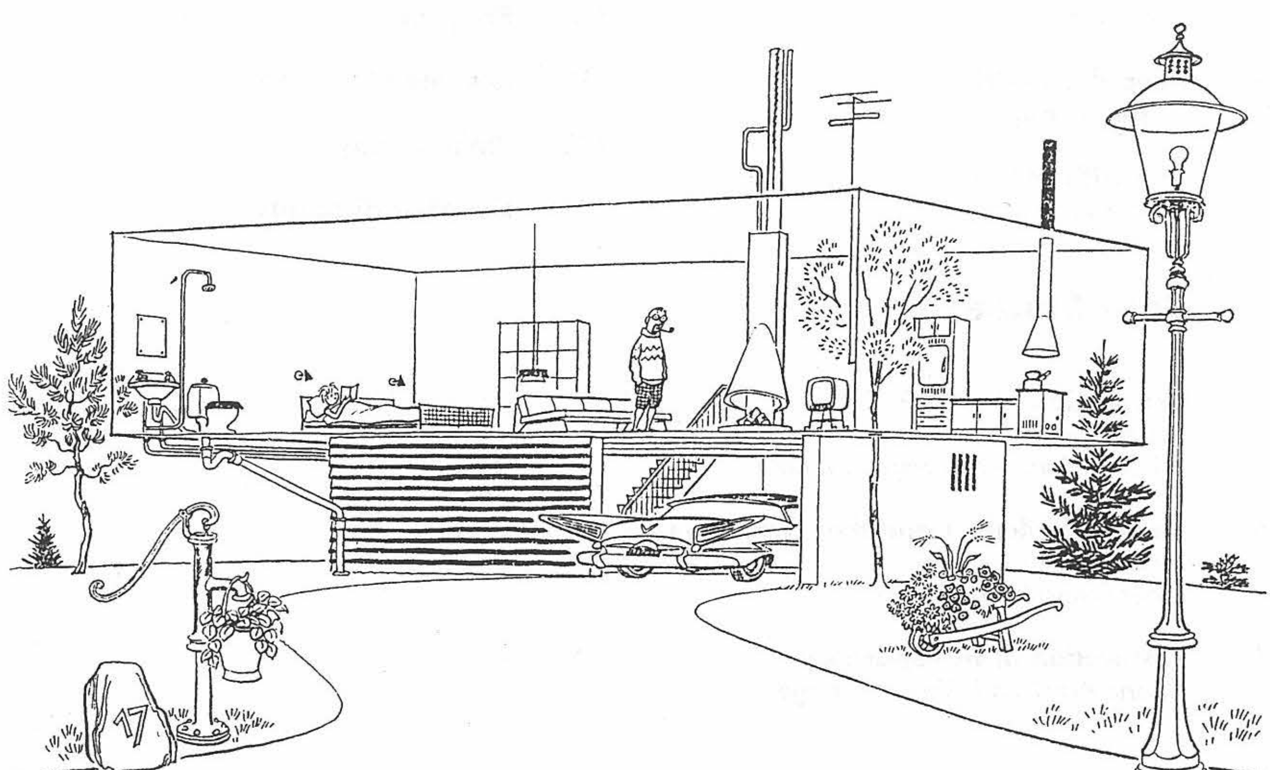
The transparency of Modern Movement architecture as seen by cartoonist Bo Bojesen.



Preface

The careful details of Modern Movement architecture rarely involve ornaments or decorations but are mostly the result of the thorough design and proportioning of building elements. Among these, windows are often of major importance.

The International DOCOMOMO Seminar 'Reframing the Moderns - Substitute Windows and Glass' took place in Copenhagen on May 20, 1998. Attended by about 55 researchers and professionals from 10 countries, it has been a great success.
In general terms, the seminar has contributed to the growing interest in the problems concerning the restoration of Modern Movement architecture. More particularly, it has of course drawn our attention to modern windows, which are increasingly recognized as precious and important features, both for technical reasons and for their expression of aesthetic values. Furthermore, the case studies presented at the seminar illustrate how practical problems with window restoration have been solved with great insight, sometimes demanding an integral development of substitute units, and sometimes involving practical and tailor-made on-site solutions.

The National Forest and Nature Agency of Denmark is in charge of the care for listed buildings in Denmark. With great interest, our institution has taken part in DOCOMOMO activities already for several years, and it has been a pleasure to support this international seminar as well. I am convinced that this interesting book will contribute to the international exchange of know-how and experience. Moreover, I am sure that further debate on the careful repair and replacement of modern windows will be stimulated by the papers presented in this publication.

Ane Vium Olesen
Head of the Division for Listed Buildings
The National Forest and Nature Agency of Denmark

Introduction

To maintain a creative dialogue, conceptions that are based on absolute values have to be reconsidered in order to remain as an open and tolerant vision of all kind of possible realms. Not in the least, this is of major importance when assessing the silent but sensual dialogue with the mute reality of architecture.
In this aspect it could be argued that Modern Movement architecture constitutes a reality of a renewed sensibility. As the Modern Movement distanced itself from the automated repetition of formalized themes, it even seemed to recognize and suggest a possible reality within architecture and materials themselves.

Glass, steel and concrete not only became quantitative means of the Modern Movement but were just as well regarded as characteristics of technical and aesthetical expression. Today the Modern Movement does not distance itself from tradition, but it creates its own heritage of rich range. This heritage provides us with the possibility to develop a vital language - a dialogue based on experiences with Modern Movement architecture. Experiences of both technical and aesthetical nature are therefore invaluable sources not only for conservation purposes, but also to fuel the ongoing process of understanding matter, architecture and all kind of possible counterparts of our reality.

Among the various activities of DOCOMOMO International, the strain on acknowledging Modern Movement technology is instrumental.
The DOCOMOMO International Specialist Committee on Technology started an international register of specialists on modern technology, the first results of which are now accessible through the website of the Architecture School of the Royal Academy of Fine Arts in Copenhagen[1]. The Committee's working program has also resulted in a series of seminars.
The DOCOMOMO Technology Seminars have been organized annually since 1996, starting with 'Curtain Wall Refurbishment - A Challenge to Manage' followed by 'The Fair Face of Concrete - Conservation and Repair of Exposed Concrete', both at the Eindhoven University of Technology in The Netherlands, and now 'Reframing the Moderns - Substitute Windows and Glass' at the School of Architecture in Copenhagen. The results of each of these seminars have been published in post-conference dossiers, with the present publication as the result of the third seminar of 1998.
A fourth seminar on 'Wood and Modern Movement' has meanwhile taken place in Helsinki in June 1999, and a fifth seminar on colour in Modern Movement architecture is scheduled for the year 2000.

In the Modern Movement, windows and glass are considered of central importance, respectively as building components and as a key material itself. The avant-garde visions of Paul Sheerbart, Bruno Taut and others were not the first ones that were reflected by a transparent and coloured dream of a crystalline glass architecture. It was in fact the culmination of a long history, in search of an architectural ideal as clear and bright as the Holy Grail.
For Bauhaus director Hannes Meyer, windows and glass provided the means and the material to create a vision of a new head office for the National League in Germany: an open glass building to avoid lobbyism and to ensure a transparent and honest dialogue - stressing the same characteristics of the material as Mussolini did when proclaiming the *Casa del Fascio* in Como to be a glass house and a materialisation of what he said was the transparent and open attitude of fascism.
This new understanding of windows and glass went along with a new appreciation of daylight and fresh air as preconditions for a physical improvement of living conditions - a combination of ideas that inspired Le Corbusier to formulate his five points for a new architecture. His *fenêtre en longeur* became a hallmark for the so-called 'International Style'.
The appreciation of windows and glass as particularly modern features appeared as a result of two distinctive developments. New construction technologies transformed the loadbearing wall into a non-loadbearing partition. Window openings were no longer limited to holes in the wall, but could be made anywhere and of whatever size desired. Instrumental technological developments include as well the rationalization of steel and glass production, and the invention of an operational method to produce plate glass by the Belgian inventor Emile Fourcault in 1913. Apart from technological developments, the changing attitude towards aesthetics in the arts provided a second prerequisite for architectural transformations. Not in the least the abstract and transparent spatial conceptions of cubism must be recognized as a decisive turn to new values.
The traditional window was thus transformed into a functional unit that responded to the needs of the Industrial Age. It became a symbol for the permeability of the skin - dissolving the borderline between inside and outside, both virtually and physically. Integrated as building components new window types became emblematic features of Modern Movement architecture, as well as of the actual expression of new spatial conceptions.

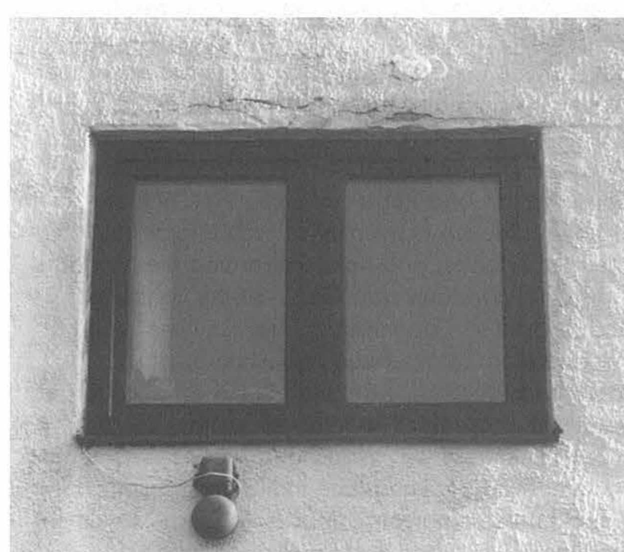
Today, windows - and facade systems in general - are among the most vulnerable building components of modern buildings. When buildings are renovated - either for functional reasons, to transform a building's

image for commercial reasons, or to improve its thermal, hygrical or acoustical performance - windows are easily subjected to change. Such interventions commonly concern the replacement of the original windows by units made of another material, like PVC instead of timber, or aluminium instead of steel. Frame dimensions are commonly increased to compensate for the lower strength of such substitute materials.
To accommodate multiple glass panes and to improve the overall physical performance of the units, window frames are further enlarged, resulting in a loss of the original proportions and bulky detailing.
New types of glass with coloured and reflective coatings may be applied to meet present energy performance standards, especially in commercial buildings. In this respect it must be emphasized that glass is certainly not an invisible material. Glass has highly distinctive material properties - not in the least when it comes to its colour, surface structure and reflectance.

The materials, details and dimensions of substitute window frames and new types of glass have a tremendous impact on a building's architectural qualities, particularly when dealing with an architecture that involved minimalist aesthetics that called for minimal dimensions. With the appreciation of Modern Movement buildings on the rise, the need for appropriate conservation techniques and substitute products has become critical.
Therefore, the third international DOCOMOMO Technology Seminar focused on the preservation and replacement of modern windows and glass.
International experts addressed key issues regarding the repair and replacement of steel framed windows, timber units and glass. International case studies presented examples of repair and substitution of window units and glass in modern buildings to illustrate that an improvement of performance does not necessarily imply a significant change of a building's architectural characteristics.
The papers published in these seminar proceedings cover a wide variety of aspects related to Modern Movement windows and glass, ranging from material properties, proportions and forms, to the contextual meaning of window design; from general technical and aesthetic considerations to concrete case studies; and from the impact of large-scale window

Original window at Emanuel Olesens Vej, Frederiksberg, architect Hans Dahlerup 1923. Photo: Ola Wedebrunn.

New window at Emanuel Olesens Vej, Frederiksberg, reducing the opening by 28 %. Photo: Ola Wedebrunn.



replacement on modern townscapes, to specific one-off solutions for the restoration of single windows and glass constructions.

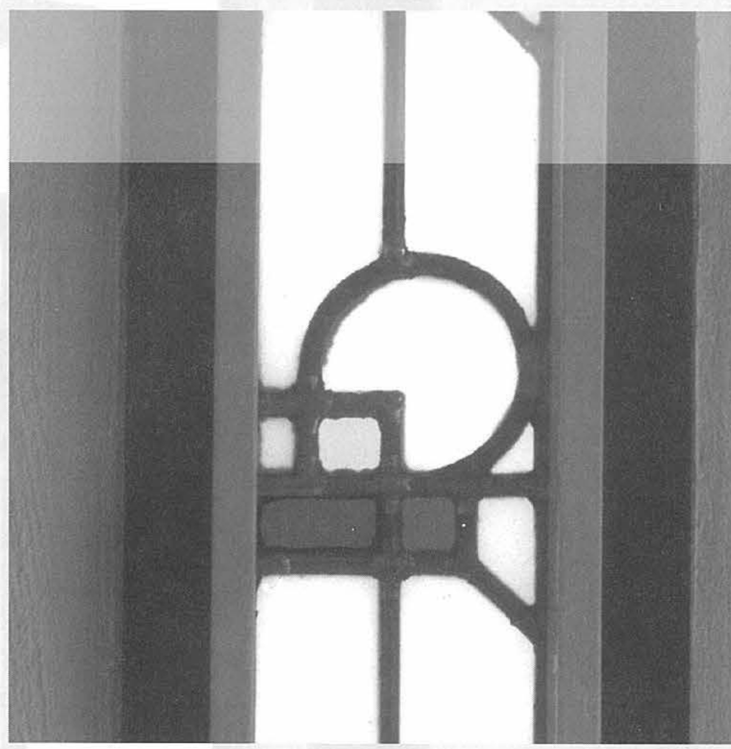
The documentation of modern windows as architectural features and of the problems related to their conservation greatly assist in understanding the qualities of the Modern Movement and the challenges we face when dealing with the preservation of this type of architecture. Not only does it inspire the careful restoration of modern windows and the appropriate conservation or replacement of glass, it also emphasizes the importance of a continuous involvement of Modern Movement conceptions in the present architectural dialogue.

Ola Wedebrunn, seminar organizer
Chairman of the DOCOMOMO International Specialist Committee on Technology

Note:
1. at www.karch.dk

Advertisement from *Kritisk Revy*, August 1928: 'See chimneys and houses like jelly...The normal glass is lying...What you see is not there. What is there you can't see!...Plate glass speaks the truth...See how all the lines are sharp and clear'.

History and Development



Opening

by Hubert-Jan Henket

The Third International DOCOMOMO Technology Seminar is dedicated to windows and glass.
The previous seminars dealt with the preservation challenges posed by curtain walls (1994) and exposed concrete (1996).
I am very pleased that the Danish DOCOMOMO group has decided to take over the responsibility to organize this seminar, as it debates a very valuable part - if not the Achilles heel - of the Modern Movement's architectural expression.
As many speakers will point out today the window, with its architectural, functional, technical and climatic properties, was made by modern architects into a symbol, expressing the permeability of the skin, the inter-relationship between inside and outside, and the liberation of convention.

Due to weathering, the dynamics in requirements, and developments in production technology the authentic windows of a building often disappear after a few decades and are replaced by new windows with totally different visual qualities. This is a problem that not only involves the frames but also the types of glass, that were often characteristic for the period.
For this reason, the present seminar is of extreme importance. You will be informed about small projects, large-scale housing estates, utilitarian buildings and office high-rises, by speakers from the USA, Germany, Sweden, Finland, The Netherlands, England, and Denmark.
All the cases being presented today will demonstrate that the building industry should not only concentrate on solving maintenance requirements and energy efficiency, but should also pay equal attention to the architectural appearance of their products.
Unfortunately, this attitude is still largely lacking.
The result is that both in cases of refurbishment and restoration too many visually unsatisfying solutions occur.

I sincerely hope that the proceedings of this seminar, that will be published in due course, will also reach the public at large. Public awareness is the key to improve on an undesirable situation.

I wish you a very informative seminar.

Hubert-Jan Henket is the chairman of DOCOMOMO International, and chaired the Reframing the Moderns seminar.

Windows

As a child, I often sat by our large living room window, peering into the garden and daydreaming. I can still remember the view in detail, the large willow with its hanging branches that almost hid the garden gate. The gate that might open at any minute - who is coming now?

by Boje Lundgaard

I can also clearly remember the window itself. It was top-hung and opened with a special stay bar that was screwed into the chipped and peeling, white-painted wooden sash that held a single layer of glass. Below the window, there was a window sill of smooth, reddish-brown terrazzo. Here there were always potted plants, my father's pipes, an ashtray, and usually our cat, a gray ball of fur called *Pjevs*, who loved to stretch out in the sun, which was often here as this window faced west.
The warm sun streaming through the window felt refreshing most of the time, and was only a problem on late summer afternoons. One could ease any discomfort by simply opening the window and closing the thin curtains. The curtains were always thin in the summer. Part of my mother's spring-cleaning ceremony involved replacing the heavy, yellow winter drapes

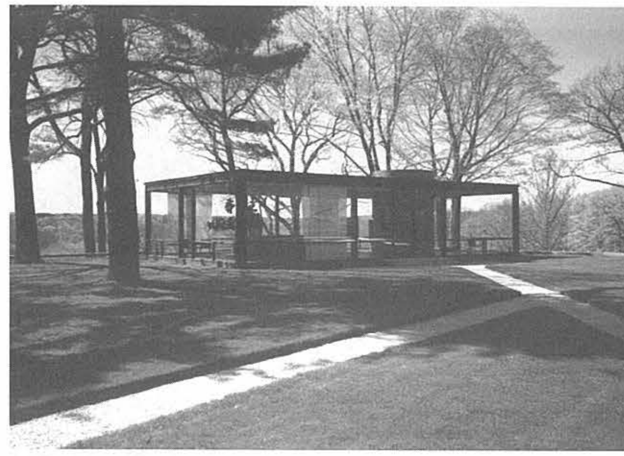
Photo: Peter Sørensen.

with pale, thin summer curtains.
The professional will by now have realized that I grew up in a house built in the postwar years, when top-hung windows and terrazzo sills were common. If I had lived in a house from the turn of the century, or a house from the 1930s, my window memories would be quite different. This change in the character of the window during the last thirty years has, for some, fostered different kinds of experiences and memories, or perhaps even a lack of them.
There are not many building elements that affect one's experience of a building, as windows do. The choice of a building's outer form, its interior spaces, structure and materials are all important factors for the final result, but the window is the only place in a building where the interior and exterior meet, where light makes its entry and where views are created. The window lends character to the facades and the spaces behind them.
The placement and proportioning of windows are thus extremely important for the total quality of a building. The art of fenestration, in terms of a hole or light opening in a facade, requires attention to both the facade expression and the character it gives to the space behind. However, there are other important considerations to be made, such as the integration in the wall structure, the design of the window construction as well as its detailing.

The window in the facade

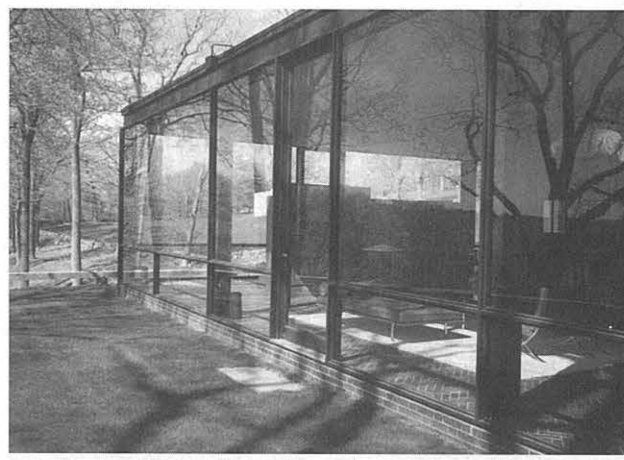
In most buildings, windows are placed with a decided rhythm and uniformity. Often only one type of window is employed, and repeated both vertically and horizontally. In such cases, it is not an easy task to express the building's functions, as all spaces, both large and small, have the same type of fenestration. This implies great variations in daylighting conditions with excess light in the smaller spaces and often insufficient daylight in the large spaces.
In classical architecture, fenestration was usually a rhythmic, modulated repetition of uniform elements, and if necessary, with certain variants to emphasize different building sections, or with respect for varying ceiling heights. It is this variation in ceiling heights, with the accompanying change in window heights, that often gives older buildings a supple, stepped rhythm despite the uniform window width. It also expresses the natural logic of employing larger areas of fenestration

Kay Fisker's Hornbækhus, Copenhagen, 1922-23.
Photo: Boje Lundgaard.



Glass House by Philip Johnson, 1949. Photo: Boje Lundgaard.

in the lower floors of the building, and small areas above where there is more light.
This orderly way of organizing a facade also reflects a building's structure. In older buildings, the vertical loadbearing elements are often of brick, as supporting walls in the inside, and with the facades broken down to brick piers between the windows and brick parapets below. One can see the variations of wall thickness from the interior, but the facade appears as a smooth surface of uniform thickness.
Thus, the structure's measured rhythm of piers creates a similar order in fenestration and the resulting Danish expression: *pille/vindue* (pier/window) architecture.
It is thought-provoking when one considers the fact that most older buildings, with their reasonably varied facade expression, are generally built of brick with relatively uniform windows. The difference from one facade to another, despite architectural quality, lies primarily in the way a few, well-known elements are treated. It is a question of proportioning, that is the mutual weighing of the sizes of the windows, the walls and the total expression. It is a question of texture, that is the surface character of the brickwork and window elements. And it is a question of the quality of detailing, in terms of brick notations, cornices, bands,



Facade detail of the Glass House. Photo: Boje Lundgaard.

Radio House by Vilhelm Lauritzen, 1936-42.
Photo: Boje Lundgaard.

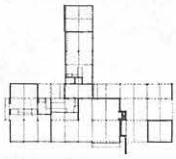
or the heads, sills, frames and lintels bordering the windows.

Modern windows

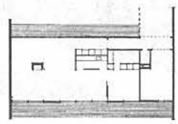
At the beginning of the 20th Century, the Modern Movement in architecture altered the organization of the classical facade. Again, the structure was a decisive consideration. New building methods in concrete or steel allowed the creation of non-bearing facades, or facades with a minimum of loadbearing elements, which suddenly offered a greater freedom in fenestration.
Le Corbusier described it as a revolutionary event. For the first time in history, architects had the freedom to design facades with no other restrictions than those imposed by oneself in terms of daylighting and proportioning.
Soon, this resulted in new facade expressions with continuous horizontal bands of windows, corner windows or windows with varying proportions and position following free artistic conceptions. At the same time, the surface area of windows increased considerably, and in some cases covered the entire facade.
During a period of fifty years, from the end of the

Jørn Utzon's house, 1953. Photo: Boje Lundgaard.

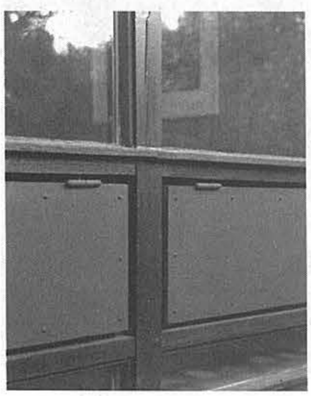
Plan of Utzon House. Drawings: Boje Lundgaard.



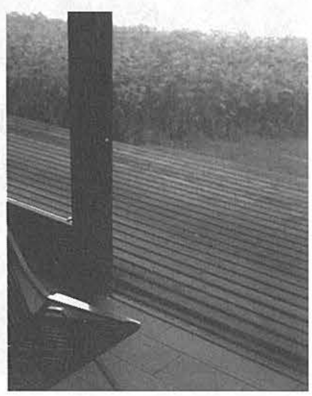
Plan of the Sørensen House.



Plan of the Gunnløgsson residence.



Erik Christian Sørensen's glass house, 1958. Photo: Boje Lundgaard.



Haldor Gunnløgsson house in Rungsted, 1959. Photo: Boje Lundgaard.

1920s up until 1970, new approaches to fenestration were developed in which technical advances allowed larger window sizes with new mullion systems, while still offering the freedom to place windows without structural restraints. In fact, it was now possible to live and work in buildings made entirely of glass; something previously reserved for botanical gardens and greenhouses.
Architect Mies van der Rohe, in a number of projects, was among the first to express what these new facade expressions could imply. One of his disciples, Philip Johnson, had the financial means to realize these dreams in several houses for himself. One of them came to have a great architectural significance. Johnson's glass house of 1949 consists of a single-story, rectangular building with floor-to-ceiling windows on all sides, with the roof appearing as the only closed surface, supported solely by columns in the facade. Apart from being a classic example of an almost ascetic, disciplined way of living with a deliberate, stationary furniture plan, the house today is still an archetype, one that greatly influenced an entire generation of architects throughout the world.

The unquestionable beauty of this house lies in the marriage of a simplified, minimalist formal expression with the richly varying and versatile qualities of glass. One can grasp the concept at a glance, yet it still changes character as one moves around it. One can see through it yet at the same time see the shifting reflections of the surrounding nature in the glass. The building thus alters its character in a chameleon-like fashion according to the sun and light as well as the changing seasons.

Postwar Denmark

In Denmark during the 1950s and 1960s, houses were also built with large glazed facade surfaces. Of the single-family homes, I would like to mention three examples, which have been milestones in Danish housing, and were built and designed for the architects themselves.
In 1953, Jørn Utzon built a house in the Hellebæk forest with a dissolved, open plan that linked the interior and exterior together by a combination of large windows, brick walls and flat roofs. This marked a break with the traditional housing plan and the opportunity for new spatial expressions. It was the first time that windows of this size were employed in housing and it resulted in completely new facade articulations.
In 1958, Erik Christian Sørensen built a house in which the facades were also primarily of glass. However, he deliberately exposed the supporting post-and-beam structure to frame the house's functional and spatial organization. The glazed areas are subordinate to the structure and at the same time emphasize it. A detail worth noting is the use of operable spandrel panels below the windows in the glass facades. These are raised above the floor by a narrow band of glass and contribute to the lively, refined appearance of the facades, while beautifully framing the radiators on the inside.
In 1959, Haldor Gunnløgsson built his own home in Rungsted as a large horizontal roof supported by a few columns, and tied together by two brick end slabs and two longitudinal, floor-to-ceiling glass walls.
The house, with its open plan, lies between a recessed, sheltered garden space and the *Øresund strait.* Here the glass walls, as in Johnson's house, serve the dual purpose of marking the border between inside and outside, and bringing these areas together. An important, refined detail should be mentioned and that is the way the glass meets the floor in a recessed sill, which allows the floor and the exterior deck to merge as a visually coherent surface.
During the 1950s and 60s, a number of houses were built, modelled on these private homes, with large glass facades. This happened not only in Denmark, but throughout the industrialized world. One can almost say that the glass facade at that time was the epitome of 'the modern architectural expression'.

Glass architecture

The non-bearing 'glass skin', that enclosed a supporting structure, was further developed under the term 'curtain wall'. In the United States, this system was first widely used in the design of a number of skyscrapers in which the entire facade consisted of windows.
In Denmark, this was manifested in Arne Jacobsen's Royal Hotel. In his refined masterly fashion, he introduced this new 'International Style' to the Copenhagen urban scene. In addition to the Royal Hotel, Arne Jacobsen employed the non-bearing glass facade in his designs for the Rødovre Town Hall, the office building on Nyropsgade, a housing scheme in Vangede and the glass facade of the National Bank. In each case his precise, almost minimalist detailing still maintains a rare and highly aesthetic quality. In his final years, Jacobsen became an advocate for the international, non-vernacular architectural generalism based on the anonymous, glass skin facade. Very few architects had his ability to give these vast expanses of mullioned glass a spiritual quality. This was evident already in his early water colour competition sketches of the delicate, reflective glass facades, and in his ability to retain his primary visions in the finished projects. This glass architecture was not always well received. In terms of the city structure, critics maintained that this concentration of glass surfaces created a shiny, cold and alienating urban environment. As for the indoor climate, the large glass facades often created serious problems, with excessive heat loads in the summer and cold and drafts during the winter.
In 1972, as a result of the so-called energy crisis, a radical rejection of glass architecture occurred. The threat to our energy resources had to be considered, and the building sector was brought under scrutiny. Calculations showed that almost half of a building's heat loss occurred at the windows. As in many other countries, in Denmark this led to a significant revision of the building codes requiring an increase of insulation and a reduction of window areas. The total surface area for windows was limited to a maximum and this implied a serious reduction of windows and glazed area, not only in relation to the curtain wall epoch, but also compared with the traditional pier/window facade architecture.
In practice, this politically based legislation has led to almost twenty years of building activity based on poorer window solutions, with thicker walls and smaller windows. This has had a negative effect on facade proportions, daylight conditions and spatial quality. Thus the hard-earned architectural freedom to work with windows and daylighting was curtailed almost overnight. It is for this reason that in recent years there has been a sudden bloom of unheated glass bays and greenhouses in order to provide at least one area where a sense of daylight quality could be experienced.

The 1956-61 Royal Hotel in Copenhagen.
Photo: Wessel de Jonge.

The curtain wall of the Royal Hotel in Copenhagen by Arne Jacobsen. Photo: Boje Lundgaard.

The window in the room

The relation that a window has to a room is primarily a question of incident daylight. The way in which light and sun enter a space is of great importance for its spatial character. Most people have experienced poorly lit rooms, yet not many complain when there is excess light, and if they do it is more a question of overheating as a source of discomfort.

In the Nordic countries, there is a special awareness of light, and the changes in weather and season. The long, dark winter days bring a longing for the return of spring and sunlight. We prefer to sit in areas of daylight or open a window to admit fresh air and outdoor sounds. During the summer, everything is opened, and we prefer to sit outside. Light has a great influence on our well being and recent research has proven that depressions can be treated with intensive exposure to light.

The typical Danish window appears as a hole in the wall, surrounded by panels and bordered at the bottom by a window sill, a popular place for plants and other items to absorb and reflect light in a fashion we find pleasing. Personally, I prefer the French window, which is common in Southern Europe. It runs down to the floor, admits more light, gives the room a feeling of an outdoor space, and often implies harmonious facade proportions.

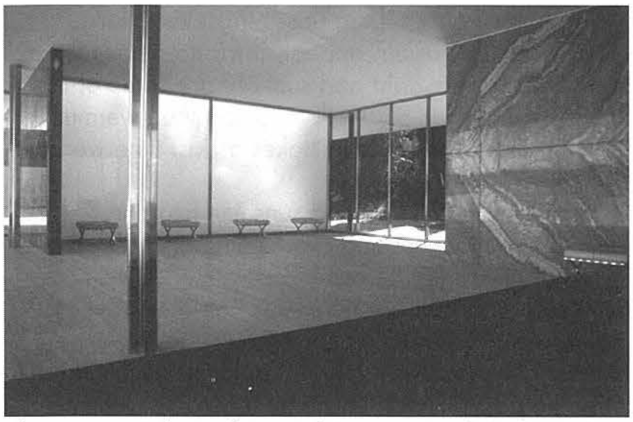
An allergy specialist recently stressed the importance of window sizes, such as in the bedroom. He maintained that the typical Danish window, with its potted plants and knick-knacks, prevented the proper airing of bedclothes. However, a French window would radically improve the situation, with a considerable reduction in the presence of dust mites. It is hard to believe that a window's form can be a decisive factor for indoor climate and the airing of bedding, but it is precisely on the climatic level that the changes in window form and size will have the most obscure consequences.

As I mentioned earlier, by freeing the facade from its structural function, the use of non-bearing, floor-to-ceiling glass facades was a reality. One of the firsts to demonstrate this was Mies van der Rohe in his Barcelona Pavilion in 1929. The consequences of this, in terms of the spatial experience, were a shock to many. At a time when houses were still seen as 'blocks' or 'boxes', he built a pavilion that completely altered the mutual relationship between spaces and between the interior and exterior, and offered the opportunity for new visual continuity while still defining space - in another way than if there would have been no glass at all. Even though glass is transparent, its reflective features make one aware of its presence, and provide a sense of being inside and out at the same time. Mies was very aware of these phenomena in his pavilion design and also demonstrated the special characteristics of plate glass, as well as tinted, frosted, and translucent glass.

The Barcelona Pavilion was torn down at the end of the exhibition, yet few buildings have had such a great influence on the development of modern architecture. The open plan and the beautiful, black and white photos of the new spatial concepts went around the world and influenced several generations of architects. The pavilion has now been recreated and still has a deeply compelling effect as the masterpiece it is, although many architects were shocked to experience in reality how different the materials and colours were as opposed to the well-known black and white photos.

And the message still applies: after Barcelona, the window is no longer just a hole in the wall. In principle, the modern window can be anything from a properly placed hole in a surface, to the surface itself, and the choice of how this is treated should be carefully considered from project to project and from room to room. To a much greater degree than previously, architects should design windows and daylighting as perceived from the inside of a building, they should build models that they can stick their heads into, and evaluate the effects of daylight in a broader sense. One could even imagine, that to obtain a building permit, it would be necessary to illustrate the effect the windows have on the interior in the same way one must illustrate the facades. One must also be aware of the climate adjustment features offered by the window. The sun should be utilized without creating problems, light should be invited in but regulated according to seasonal differences, just like a natural air change should be assured without employing complicated mechanical means.

Drawing by Ib Andersen.



The reconstructed Barcelona Pavilion, Mies van der Rohe, 1929. Photo: Wessel de Jonge.

The window itself

A window normally consists of glass and muntins. With one to four layers of glazing, the muntins can be of wood, metal or plastic in widely varying dimensions. In the old days, a window was something to be opened. That is not necessarily true today.
The traditional Copenhagen casement windows consist of a cruciform frame that carries four outward opening sashes with thin, puttied glass. They were made of a timber quality that is no longer available. The frame, sash and muntin sections are finely profiled on the inside, which gave slender dimensions and a beautiful, graduated change in light.
Millions of these windows were produced, which is understandable, as they satisfied almost all of the most important considerations. They are beautiful both from the interior and exterior. They function well and the entire area can be opened to varying degrees.
They can be cleaned from the inside, and if maintained can last for centuries. In addition to all of this, they become more beautiful over time.
The typical window of today is quite different. With double or triple thermal glazing, coated or gas filled, there are bold muntins in aluminium, plastic or timber, that is often quickly grown and of poor quality.
The method of opening can be as a casement window, top or bottom-hung, or a combination of these, but seldom with any real functional qualities.
The placement of windows in the facade construction is also important. As the walls are normally thicker than the window frames, it is crucial where the window is positioned in the opening. In the old area of Stockholm, *Gamla Stan*, the windows are flush with the facade. In the old Copenhagen area, they are recessed about five centimetres. In Southern Europe, where it is normal to retreat from the sun, the window lies even farther back in the opening. This gives a great difference in appearance both from the interior and exterior.
Depending on the window's position in the facade, it is necessary to plan how it is to be joined to the surrounding wall. The traditional Danish window in a brick outer wall usually has mortar joints on three sides and a protruding sill to lead off rainwater.
The form of such features can have a major aesthetical influence on the total facade expression.
In the interior of older buildings, the edges of the window opening are often lined with finely made wooden panels and window sills with refined mouldings and surface treatments. Today, many of these important window subtleties have disappeared and are often replaced by shoddy, cheap solutions, which imitate what once was, but have little value in terms of aesthetics or durability.
In recent decades, there has been an extensive, technical development in window design but typically, this has been based on the manufacturers' needs. Architects or designers have rarely been consulted. The result is an enormous range of window products, yet it is almost impossible to find a window that has the aesthetic, functional and technical qualities inherent in all windows a hundred years ago.
It seems as though the manufacturing and energy resource limitations totally govern the market. Complicated glazing systems are developed, which one can hardly see through, just to save energy. Clumsy and costly mullion and muntin systems are developed in order to minimize a meaningless thermal bridge. One should learn from tradition instead of forgetting its values. There are some architects, however, who have shown other ways of approaching the problem.
The Swedish architect, Sigurd Lewerentz designed a completely different window solution for Church of St. Mark, in Björkhagen, Stockholm. He used a new, highly advanced insulated glass, but mounted it without mullions, outside the brick facade, and fastened it with a few heavy hook nails and had it weather sealed.
By doing this he created an entirely new effect. From the interior it appeared as a hole in the wall, as though there was no window. From the exterior one saw the window as it was: a piece of reflecting, insulated glass as an independent glass surface, mounted on the wall. However this construction does not allow the window to be opened.
Utzon has worked with a similar solution in several of his projects. However, the glass is installed in a sash before being mounted to the wall. In this way he achieves the same effect in the interior, but the window can be operable, for example as a sliding sash, and a textural effect is added to the facade due to the protruding sashes, tracks and necessary flashing.
In recent years structural glazing has been introduced in Denmark. The system allows large expanses of glass without visible mullions. It consists of a slender, structural filigree work on top of which the glass is mounted or glued. Thus the exterior joints appear only as silicon weather seals. These silicon sealants are so waterproof that they can be used on completely flat glass roofs, although our national quality assurance standards would have trouble accepting bold solutions like this.

A window to the future

As explained, the design of the window has altered character throughout the 20th Century. From the rhythmic size, the hole in the surface, to the entire wall or combinations of these, freely formed.
After having been bound to window surface area restrictions for over twenty years, during which time the window has been reclassified primarily as an energy consuming element, the situation seems literally to be brightening.
Technical advances in recent years have resulted in substantially improved insulated glass units, and it appears that in the near future the level of thermal insulation will be as effective as a traditionally insulated wall. The so-called 'air-glass' units are already available in Germany as translucent elements with a high insulation value.
Concurrent with this, the importance of passive solar heating is being widely recognized. This heat gain can be achieved through properly oriented windows.
If they are also provided with movable insulation at night, the window suddenly becomes a source of energy rather than a reason for energy loss.
This will again allow the use of large expanses of glass in buildings. And it is high time! Not that we are to live in glass houses, but because it is important to give the architect the freedom to form daylight and proportion windows in the best possible fashion for a specific project.

I am quite sure that if the possibility exists, large glass areas will again appear, if for no other reason than because daylight and sunlight are some of the basic qualities for our wellbeing. But then we must avoid making the same mistakes as last time we built with glass.
We must invite daylight and sunshine into our buildings without causing overheating or drafts. Large areas of glass must be combined with effective solar screening and ventilation systems. We must develop new glazing systems that combine the desire for slender dimensions, with high insulation quality, and offer the possibility of functional, operable elements such as the horizontally sliding sashes as used in England. We must also demand glazing that complies with sustainability principles without rendering colour to daylight. If these requirements can be met we, in the light craving northern countries, will experience a new architectural epoch, in which light once more is treated properly. The tendency is already evident.

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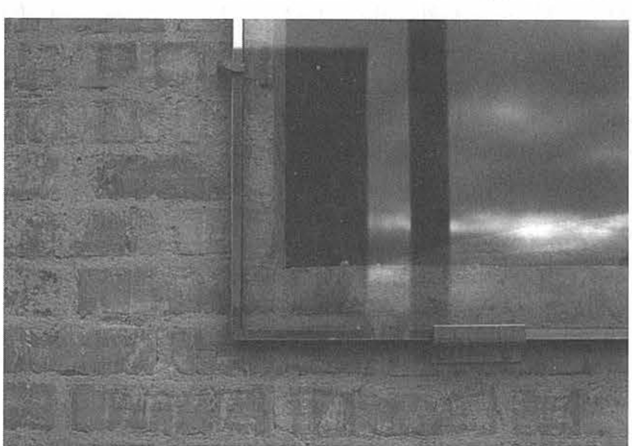
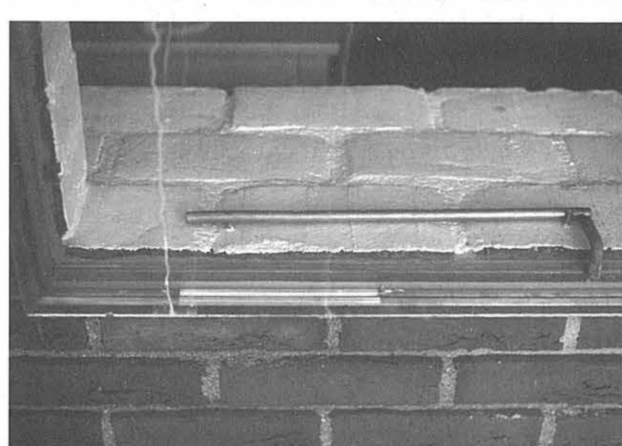


Double glazing unit at Tinggården, similar to technique used by S. Lewerentz. Photo: Peter Sørensen.



Hinged double glazing unit without casing.
Photo: Peter Sørensen.

Maison de Verre by Pierre Chareau and Bernard Bijvoet, 1929.
Photo: Boje Lundgaard.

Steel framed windows of the 1930s

Metal window industry in Finland

In Finland, steel framed windows became common in the 1930s with the spread of the Modern Movement. Though metal windows are a key feature of Modern Movement architecture, guidelines for the preservation of such windows are still relatively rare, as compared to timber windows. As preservation problems are often related to thermal efficiency, replacement is an easy strategy. If priority is given to the preservation of the concept of modern architecture rather than to its material aspects, will the utilization of new construction systems instead of a faithful reconstruction be an option?

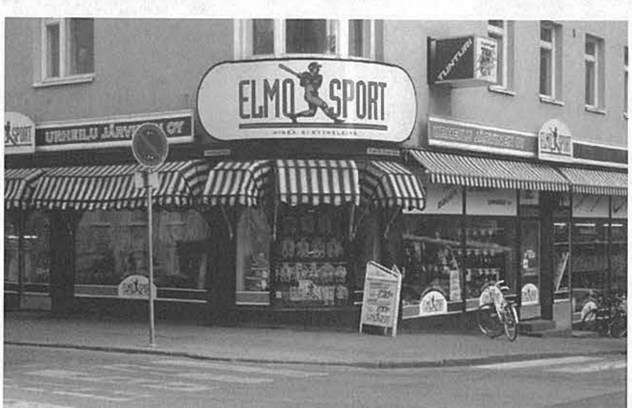
by Marianna Heikinheimo

In recent decades, a lot of attention has been paid to the renovation of timber windows, and the Finnish National Board of Antiquities, for example, has compiled instructions for assessing their suitability for renovation. However, the situation is quite different with regard to metal windows, which are still in most cases replaced by new windows when a building is being renovated. Yet it is precisely the applied materials that often serve to characterize modern architecture: reinforced concrete, glass, and various metals. Hence metal windows, mostly made of steel, are a key feature of modern architecture.

Corner entrance of a 1930s commercial building in Tampere with rounded steel windows, probably assembled from imported profiles at the Pietarsaari machine workshop.
Period photo: Pietarsaari City Museum, PeKo archives.

Emblematic

In Finland, steel framed windows became common in the 1930s with the spread of the Modern Movement, which is commonly referred to as 'functionalism' here. Many of our best known architects used them, including Alvar Aalto, Erkki Huttunen, and Väinö Vähäkallio. Steel windows were often used in factories, public buildings, and shops on the ground floors of residential buildings. Various transport related buildings also featured steel windows as early as the 1930s, including Shell service stations, Helsinki airport, and Tampere railway station. Steel windows were regarded as emblematic of the new era.
Another, less poetic reason for the growing popularity



The same corner today with aluminium replacement units, straightened windows and the entrance moved to the side of the building. Photo: M. Heikinheimo.

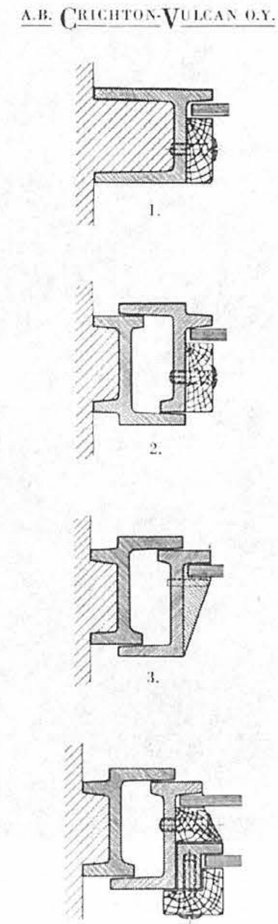
The SOK cooperative warehouse in Viipuri, designed by Erkki Huttunen (1932) featured steel windows.
Period photo: PeKo archives.

of steel windows was the technological innovation in producing such building components industrially. After the invention of the Siemens-Martin process already in the 1880s it had been possible to use steel for the construction and shipbuilding industries, as it guaranteed both homogeneous quality and large quantities.
For the window manufacturing industry however, the spread of welding in the 1930s has been instrumental, as windows could thus be assembled without the need for riveting.

Steel window manufacturing

In Finland, steel windows were mainly made from profiles that were imported from Germany, Britain, or Sweden. Though there were a number of machine workshops which manufactured steel windows, it was rarely regarded as their core business. The Crichton-Vulcan company in Turku for instance, was primarily active in shipbuilding, while the Pietarsaari company produced mainly agricultural machinery. Steel windows were a side product and very susceptible to fluctuations. Production figures at Pietarsaari for example varied by up to several hundreds of percentage points annually.
As for most companies, for Pietarsaari the golden years of window manufacturing were in the middle of the 1930s. At that time, the window department had its own draftsmen and designers who produced production drawings on the basis of architect's proposals.
The large majority of metal windows concerned those made of steel profiles. More expensive metals, such as copper and bronze, were used for more exclusive projects. Hollow core sheet metal windows were produced as well, with profiles folded from cold steel sheet at the workshop. Another common practice was to order metal windows directly from abroad. The German firm Anton Schultz, for example, had an agent in Finland who advertised complete systems in the construction handbook published by the Finnish Architects' Association in 1937.

The assembly of a large window at the Pietarsaari window-and-door department. Period photo: PeKo archives.



Drawing: Masa Yards Oy archives.

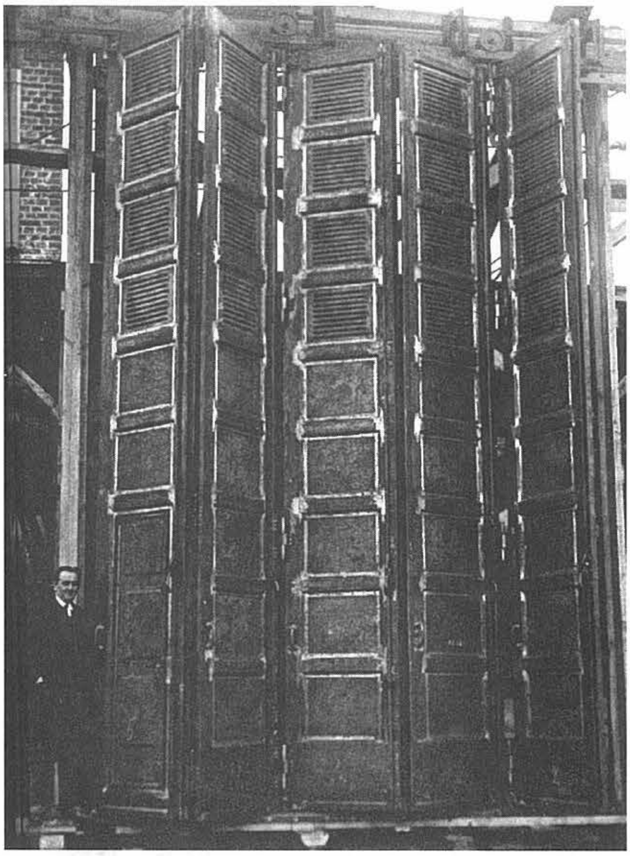
The first Modern Movement buildings in Finland had steel windows which were ordered directly from abroad; these include Aalto's Turun Sanomat building (completed in 1930), whose windows arrived from the Crittall-Braat factory in The Netherlands.

Window types

Within the range of readily available steel framed windows four basic types can be distinguished, that are illustrated here from the Crichton-Vulcan manufacturing company in Turku:

- Fixed single glazed windows with timber beads. Professor Kreuger, a Stockholm expert in building technology, recommended single glazing particularly for production facilities;
- Outward opening single glazed windows with timber beads;
- Inward opening single glazed window with putty sealing. The window pane was fixed by dowels;
- Inward opening double glazed window with the two glass panes separated by timber beads.

Permanent weathersealing was considered an advantage with steel windows, as were the absence of thermal variations, the large light openings, the adequate soundproofing and thermal insulation even with coupled casement windows, and the satisfying



The folding doors of the Helsinki Abattoir.
Period photo: PeKo archives.

The windows of the Helsinki Abattoir production facilities opened simultaneously by operating a horizontal bar.
Period photo: PeKo archives.

architectural appearance.
In this period, new types of windows and doors were developed, including special products such as folding doors, aluminium sliding doors, and fire doors. Other innovative developments concerned operation systems and window furnitures. To meet hygiene requirements for particular production facilities such as abattoirs for instance, special devices were designed to allow a series of windows to be opened centrally at the same time, by use of a horizontal bar. Similar systems are found for example in the Bauhaus Dessau.
The Swedish Allanco-Kawneer firm introduced a metal glazing bead, thus avoiding the use of short-lived organic compounds such as putty. Large windows were provided with thick mirror glass, which had better wind resistance, and so on.

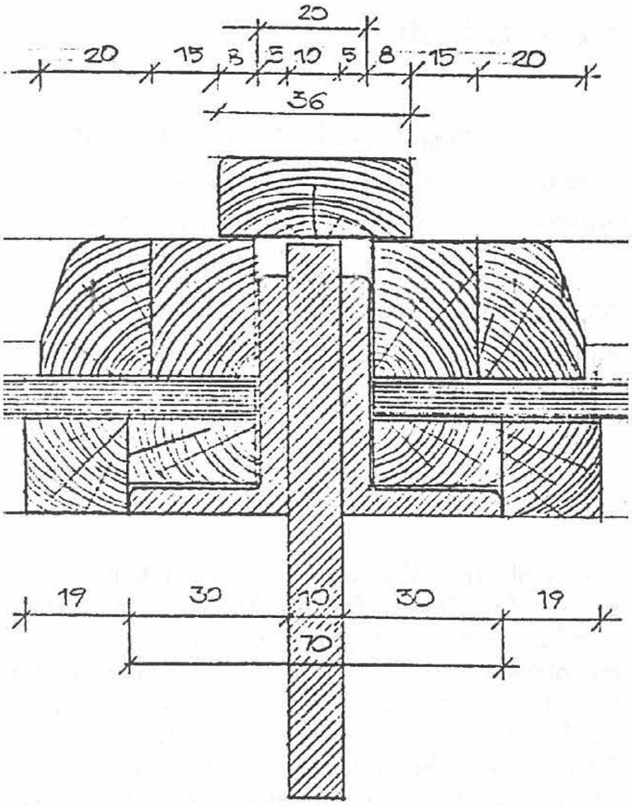
Two cases

In order to bring the restoration problems with steel framed windows to a more concrete level, a window type is introduced here that is used in the Glass Palace in Helsinki. A similar solution was used in Alvar Aalto's Library in Viipuri. Both buildings were completed in 1935, and both feature steel windows manufactured at the Pietarsaari workshop. The present window type concerns a large fixed window, single glazed with timber beads. Structural mullions of steel plate provide the required strength. Apparently, both originally had thick sheet glazing (8 mm in Viipuri).
The problems in restoration are often related to thermal efficiency. A single glazed window fails to provide sufficient insulation for all-year-round use. The dimensions of present day insulated glass units are quite different from the original glass panes. In addition, the modern float glass of which insulated glass units are made reflects light more effectively than the original glass types. Consequently, the original transparency is compromised by a mirroring effect.
An inventory of the library in Viipuri learned that the original large window still exists, but that its profiles are entirely enclosed by timber. If the frames and sash would appear not to be entirely corroded, in my opinion they should be preserved when the restoration of this building will eventually become a reality.
At the Glass Palace the windows are already replaced as part of a refurbishment project by Alli architects.
In this case there was also a structural problem to respond to. The steel profiles had been deformed due to the combined weight of the glass itself and wind loads. Hollow rectangular tubes now replace the structural steel plate mullions, to provide the additional strength required for the heavy insulated glass units.
This construction, however, still fails to meet contemporary requirements imposed on insulated glazing systems regarding ventilation of the glazing pockets, for example.

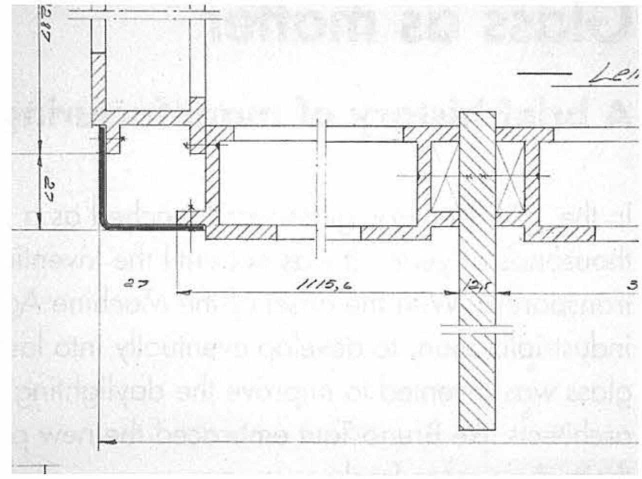
Strategic approach

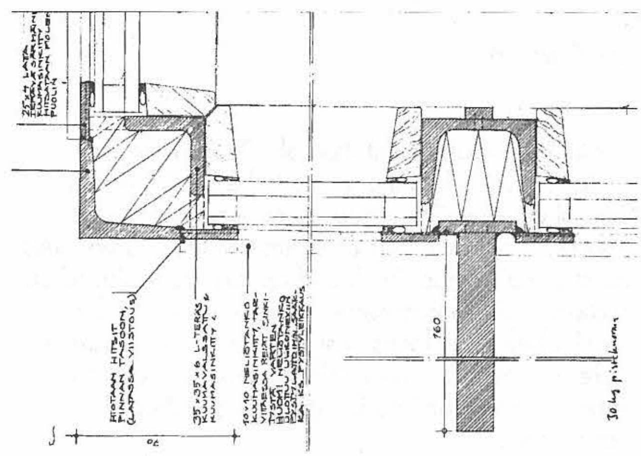
In principle, there are a few alternative solutions:

- Truthful restoration, without any alterations, which would sustain the problems with thermal efficiency, i.e. compromise user requirements;
- Replacement of the single glazing by insulated glass units, which would create the problem of the increased dimensions, the insufficient stiffness of the structure, and the change in material properties of the type of glass;
- A redesign of the profiles to accommodate double glazing, which may allow the concept to survive, but the question remains: What will be lost?
- Innovative additional solutions, like secondary inside glazing and a warm air cavity between the windows.



An inventory drawing of the existing situation of Viipuri Library's windows. Although the old frames still exist, they are rusted through. Photo: Alvar Aalto Association.

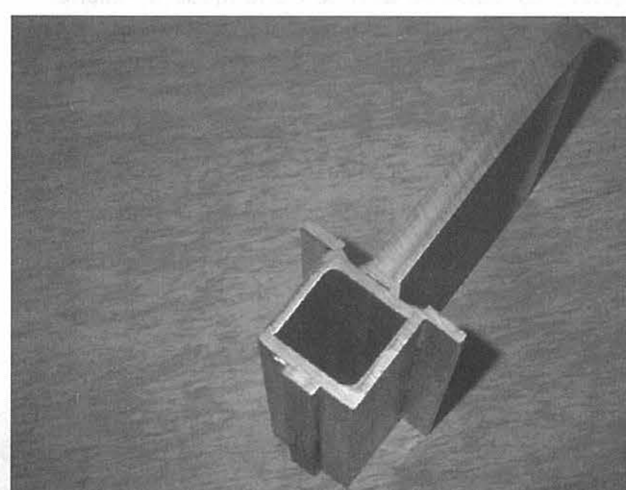




Top: Tender drawing for the Glass Palace's windows, from: PeKo archives.
Bottom: Detail of the Glass Palace replacement glazing design. Drawing: Alli Architects.

These are problems that I have personally encountered in my work as an architect. A database and repair instructions might contribute to the preservation of at least some 1930s steel windows. There are a lot of data available on traditional timber windows and their care, but this is not yet the case with the slender metal and timber window units of Modern Movement architecture. Replacement is too easy a strategy, merely a shortcut. Not all old facades should be replaced by new ones. If, in case of renovation, we give priority to the preservation of the concept of modern architecture, the utilization of new construction systems instead of the reconstruction of the original parts and details might be an option.
The key question is: can we accept the (partial) renovation of modern architecture using contemporary technology, if this would allow the conception of the original architecture to survive with the structure itself?

Marianna Heikinheimo is an architect (SAFA) and a researcher at the Helsinki University of Technology.



Tubular mullions strengthen the window to hold double glazing, keeping the exterior appearance of the profile in an attempt to retain the original architectural conception. Photo: Alli Architects.

Glass as matter

A brief history of manufacturing and application

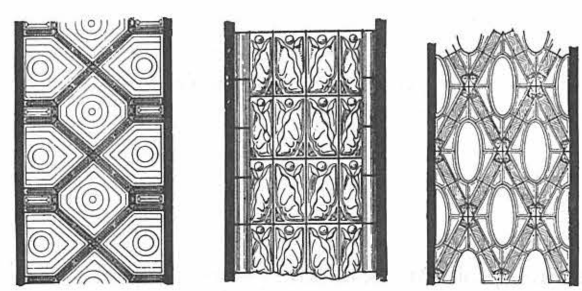
In the 19th Century, glass was launched as a new material though it had existed already for thousands of years. It was not until the invention of the blow-pipe that glass became transparent. With the onset of the Machine Age, window glass manufacturing moved to semi-industrialization, to develop eventually into large scale production. Around 1850 prismatic glass was invented to improve the daylighting of basements and deep spaces. Modern architects like Bruno Taut embraced the new possibilities offered by the glass industry to express their ideas more freely.

by Anne Beim

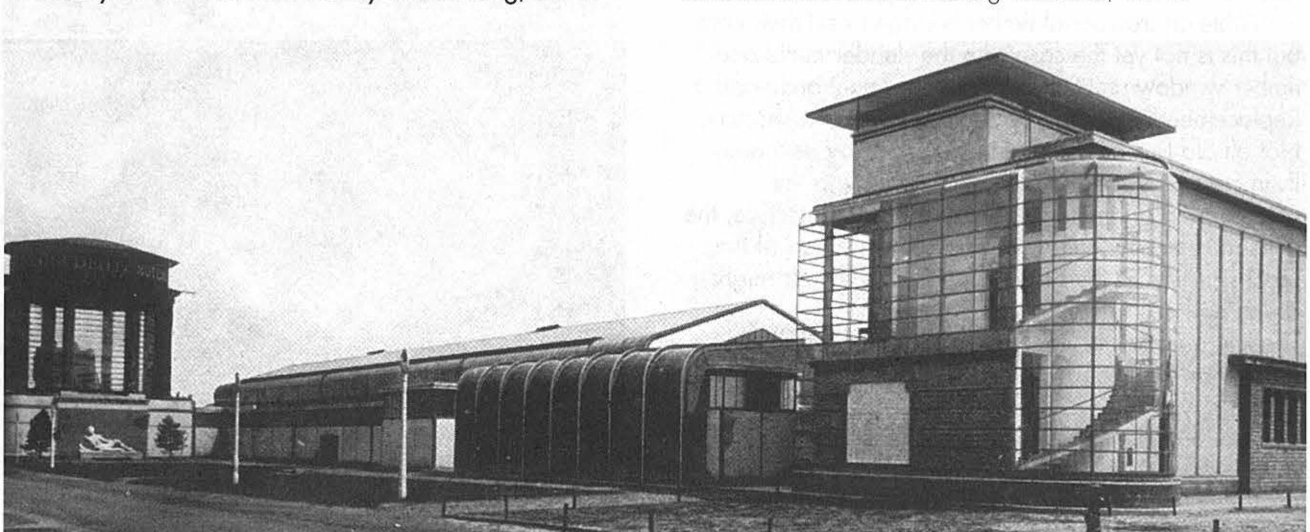
For the *Werkbund* exhibition of 1914, Bruno Taut designed a pavilion that came to be known as the Glas Haus. The *Glass House* was among the most extraordinary buildings of its time, as it featured walls constructed of glass brick and double walls glazed on two sides with polychrome panels, and was lit by series of glass balloons. Inside, opaque glass screens were employed to project slowly changing abstract images, giving the interior spaces a psychedelic appearance.
However, besides being a phenomenal and esoteric experience, the Glass House was designed as a showroom for the Luxfer Prism Glass Company[1], with the explicit purpose of displaying the firm's products. These presented glass in every form and for any purpose: mirrors, prismatic blocks, bricks, tiles, mosaic and balloons, in opaque, coloured and clear glass.

Ancient matter

Glass was launched as a new and modern material though it had existed already for thousands of years. Its history of constructive use may not be long, but in its natural form - *obsidian* - it was known to man as early as 75.000 years BC, mainly used in small sharp tools for domestic and hunting purposes.[2]
Etymologically, the English term 'glass' originates from the natural occurrence of amber and resin, which in Old English and Old German was termed *gläre*.
The expression characterized a shiny golden, light reflecting substance, and the term also relates to words like 'glaze' and 'glow'.

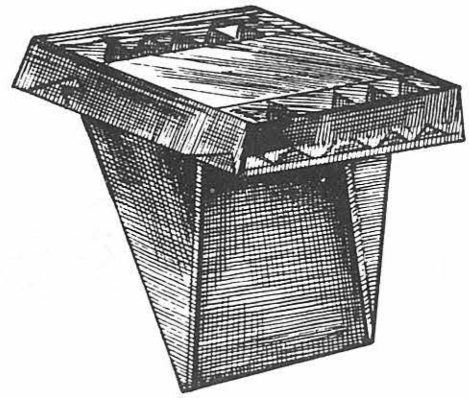


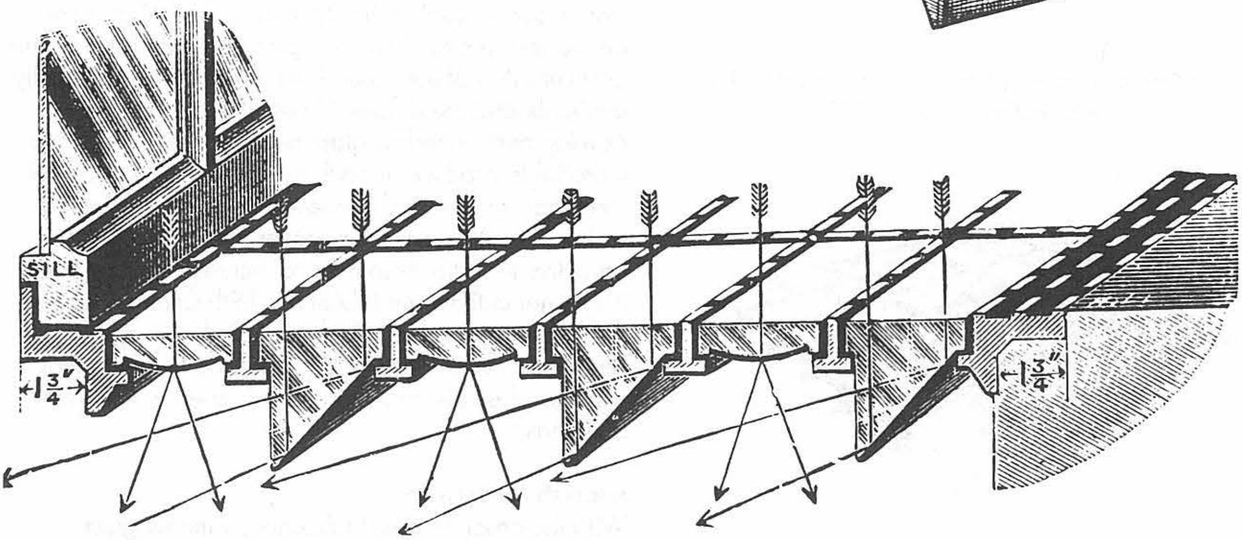
Examples of Luxfer crystal ceiling elements as presented in an advertisement. From: Bouwkundig Weekblad, 1912.



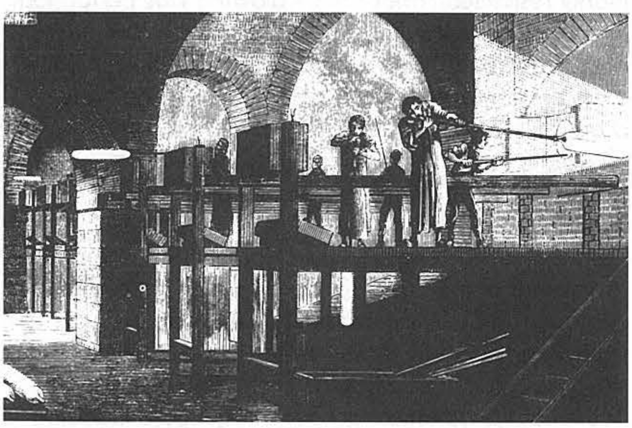
The 1914 Werkbund Pavilion by Bruno Taut was a showpiece of architectural applications of various types of glass. Photo: unknown.

The Latin etymology reflects a different perception of this phenomenon. The Latin term is *vitrum*, which can be translated as 'a greenish hue', while in Medieval Latin the word referred to the notion of 'defectively transparent'.[3] The latter probably relates to the material appearance of glass in Antiquity and the fact that if one looks through a thick pane of glass it appears green.[4]

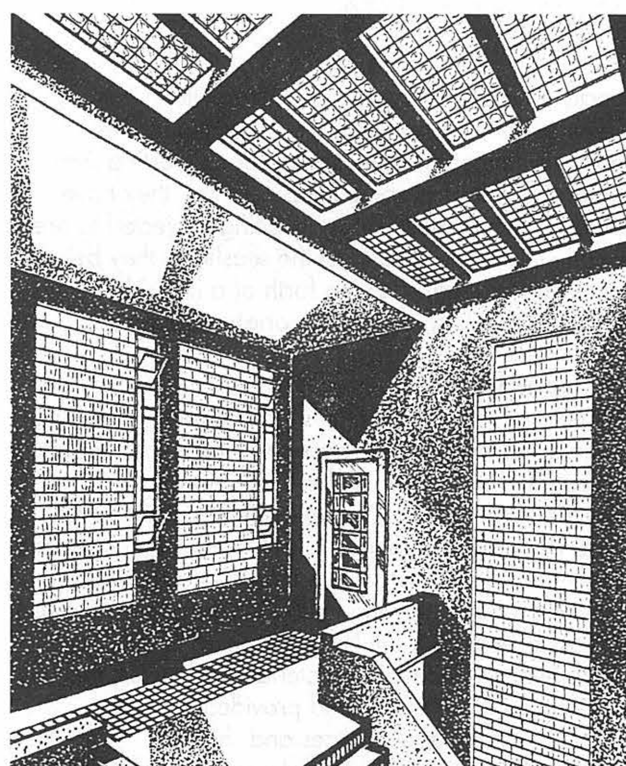




Prismatic glass block to light basements trough the sidewalk. From: Verhage, Onderhoud en verbetering van woonhuizen, 1917.



Despite semi-industrialization glass manufacturing still reflected the craftmanship of the glass blower. From: E. Peligot, Le Verre, 1877.



Various applications of glass brick as illustrated in the catalogue of the Cristalleries du Val St.-Lambert, Belgium in the 1930s: Skylights, facades with steel framed vents, and glazed risers in the stairs.

The earliest man-made glass originates from ceramic glazes in pottery making, which is one of the most ancient arts dependent on fire. The Egyptians manufactured glass both by casting and pressing processes. They considered glass a precious material that was used along with gold and jewels in the necklaces of the Pharaohs.[5]
The craft was later passed on to the Romans and descriptions of its manufacturing and application are found in the encyclopedia of the Roman officer Pliny the Elder, who lived until 75 AD. He describes the first making of glass taking place at a river delta in Syria, when a ship carrying nitre landed at a shore where a

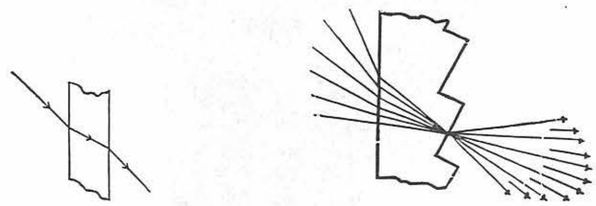
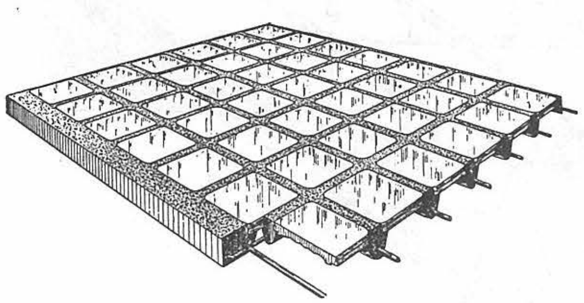


Illustration of the migration of light through normal window glass and prismatic glass. From: Luxfer catalogue, 1910s.



The Keppler system of glass brick framed in concrete. From: Luxfer catalogue, 1910s.

special kind of sand was found. He writes, 'The merchants while preparing their repast upon the seashore cannot find any stones for supporting their cauldrons and used some lumps of nitre, they have taken from the vessel. Upon its being subjected to fire, in combination with sand of the seashore, they beheld transparent streams flowing forth of a liquid hitherto unknown, this is said, was the origin of glass.'[16]

Transparency

Up until and during the time of the Romans, glass was primarily something one *looked at*, rather than *looked through* and it was not until the invention of the blow-pipe that glass became somewhat transparent in the sense we recognize today.[7] Glass technology developed slowly from casting processes through a combined semi-casting and blowing method to the proper method of glass blowing we still know today. Through experiments with different materials and mixes, the product could be refined and provided in a large variety of stains, appearances and shapes.
Actual mass production of window glass begun in the early Middle Ages and Venice, in Italy, became one of the most significant centres for glass making. Glass was a very expensive material to produce due to the vast amount of fuel (wood) required for firing the ovens. As such, the precious material was only affordable to a wealthy clientele, primarily the churches and nobility.

The objective of window glass making remained primarily to make larger units and to achieve a greater transparency of the material. Even when, in 1688, cast glass was rediscovered in France, it was therefore not considered of great interest.

Process

In the late Middle Ages the skill to make window glass spread to other parts of Europe, such as France, Germany and England. About the same time, glass manufacturing was revolutionized by the change over from wood to coal to fire the ovens. From that point on, various regional technologies developed due to the particularities of the natural resources that were locally available and the different levels of technological development. Window glass became a less expensive material to produce, though during the 17th and 18th Centuries, glass - and windows - were still regarded as luxuries. As such, many governments found them attractive to indicate sources to increase their revenues. It was not until the middle of the 19th Century, when the heavy tax laws on glass and windows were repealed in countries like England and Belgium, that window glass became more widely used in common buildings.[8]

Industrialization

With the onset of industrialization, window glass manufacturing moved from small workshops, where the highly respected craft of glass blowing was performed, to a phase of semi-industrialization where methods and technologies still mirrored the craftsmanship of the glass blower, eventually to develop into large scale production in actual 'factories'. This development allowed as well for an improved control of the processes, the material composition and the homogeneity of the final product.[9]
Besides this technological development, the fashionable *orangeries* of the late 18th Century also created a demand for thinner, more homogenous and transparent window glass. These slender, large-span structures, that later developed into the great palm houses of the botanical gardens, required a cladding that would be thin in order not to become too heavy and highly transparent to allow for a maximum of daylight.[10]
In the late 19th Century, the developments in window glass manufacturing accelerated and various innovations were introduced for commercial and scientific purposes as well as for new building constructions. This development has continued to our century, where glass fibers have revolutionized our communication systems and both float glass and laminated glass are essential to contemporary glass construction.

Glass block

In the history of glass manufacturing, cast glass products such as prisms and glass brick are fairly new construction materials. Around 1850 they were

invented and developed, mainly to improve the daylighting of dark basements and ship holds, by concentrating and redirecting the daylight.
As construction technology changed by the end of the 19th Century - through the introduction of steel and reinforced concrete - the average building volume of factories and office blocks increased, and the need for improvements in daylighting arose. This architectural challenge was responded to by the industry.
In a competition in 1898 the Luxfer Prism Glass Company succeeded in fitting glass prisms - with their translucent qualities - in masonry and concrete constructions. In American high-rise buildings and large department stores, glass prism became a common and successful feature, especially in the buildings by Sullivan and Frank Lloyd Wright. However, glass brick could initially only be used in small areas because the common construction method lacked in loadbearing properties and tensile strength. Typically, glass block was held together by mortar only[11]. But at the 1914 *Werkbund* exhibition, the Luxfer Prism Glass Company introduced the new Keppler System to Germany. This construction system for glass block was developed shortly before and involved heavy prismatic glass tiles framed by thin reinforced concrete members. The Keppler System appeared to be a much more flexible and dynamic construction method and created new construction potentials. With his design of the Glas Haus, Bruno Taut welcomed glass block and its new constructive possibilities through which he could express his utopian ideas more freely.

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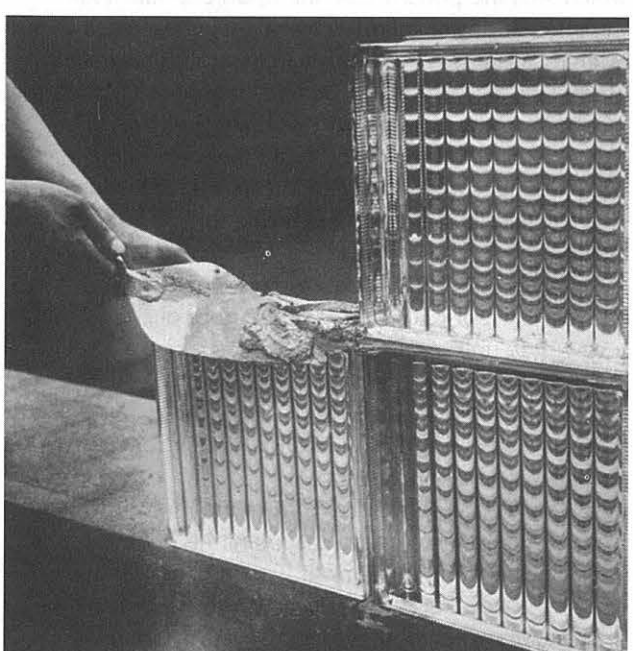

Glass block held by mortar. Photo: Anne Beim.

Notes:

1. Neumann, D., ' "The Century's triumph in lighting": The Luxfer Prism Companies and their contribution to early modern architecture'. *JSAH*, vol. 54, no.1, 1995, pp. 24-54. Neumann's article contains detailed accounts about the development of the Luxfer Prism. He traces its history through the competitions held by the companies and describes its application in early works of Louis Sullivan and Frank Lloyd Wright. Neumann's intention is to bridge the gap between rational technological development of a material and the intuitive aesthetic architectural production. The article describes the architecture through the technical development of the material.
2. Philips, C.J., Glass - *The miracle maker, its history technology and applications.* Pitman Pub. Corp., New York/Chicago, 1941.
3. Partridge, E., *Origins - A short etymological dictionary of modern english.* The Macmillan Co., New York, 1958.
4. This particular colour is due to the presence of ferro-oxide.
5. Phillips C.J., Glass - *The miracle maker, its history technology and applications.* Pitman Pub. Corp., New York/Chicago, 1941.
6. Caius Plinius Secundus, *The natural history of Pliny,* Book XXXVL, chap. 65, p. 379. Translated by Bostock, J., Riley, H.T. and Bohn, H.G., London, 1857.
7. Pittsburg Glass Co., *Glass - History, manufacture and its universal applications.* PPG, Pittsburg, 1923.
8. Elliott, C.D., *Technics and architecture - The development of materials and systems for building.* MIT Press, Cambridge Massachusetts, 1986, pp. 127-129. Elliot's book, 'Technics and Architecture' provides an elaborate description of the development and application of materials and construction technologies. He describes this historical development in Europe and North America from the Industrial Revolution to the present.
9. Elliott, C.D., *Technics and architecture - The development of materials and systems for building.* MIT Press, Cambridge Massachusetts, 1986, pp. 129-130.
10. Kohlmaier, Georg, *Houses of glass; a nineteenth Century building type.* MIT Press, Cambridge, Massachusetts, 1986.
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Window glass technology in the 20th Century

Glass manufacturing in the United States

The technological advances in the glass industry during the 20th Century have made the problem of matching window glass in historic structures built before 1960 a very difficult task. With the inevitable ageing of buildings built between the World Wars, this will continue to be a challenge for many years to come. This paper aims to try and explain why a material such as plate glass, which was so widely used in the first half of the 20th Century, is no longer available. While it will not make the job of finding a replacement any easier, it is hoped it will spawn a better appreciation of this near extinct building material so that more attention will be given to its preservation and conservation in the future.

by T. Gunny Harboe

One of the most vexing problems when embarking on any restoration project is trying to match an original material that is no longer available. The solutions will be partially determined by the scale of the project, the material to be replaced, the availability of people or facilities to reproduce the missing elements, and the construction schedule and budget. Given the numerous limitations, more often than not, compromises must be made. The real challenge is to find a solution that brings the greatest overall benefit to the project while making the smallest compromise.

Buildings constructed since the end of the 19th Century are often found to contain archaic materials both as exterior cladding and as interior finishes. Sometimes, when the material that makes up a major component of the building's visible historic fabric is changed, the way the entire building is perceived can be effected. This is certainly the case with window glass. The history of the development of glass technology is long and complex, but little has been written about it since the first half of the 20th Century. The purpose of this paper is not to serve as a definitive description of the glass industry, but rather to try and explain why a material such as plate glass, which was so widely used in the first half of the 20th Century, is no longer available. While it will not make the job of finding a replacement any easier, it is hoped it will spawn a better appreciation of this near extinct building material so that more attention will be given to its preservation and conservation in the future.

What is glass?

Before describing the different technologies used to produce glass in the 20th Century, it may be helpful to explain the basic physical make up of the material itself. Glass is made up of three basic ingredients that are fused together at a high temperature of approximately 1350-1650°C (between 2500-3000°F) and has such high viscosity that it is rigid in the normal temperature range in which it is used.[1]

The three ingredients are: silica (SiO_2), usually in the form of sand, sandstone, or quartz; soda (Na_2O), usually in the form of sulphate of soda (salt cake) or carbonate of soda (soda ash); and lime (CaO), usually in the form of limestone, burnt lime, or dolomite.

The proportions of these basic ingredients vary depending on the exact properties the glass is to have, but for modern glass are typically about 73% sand, 17% soda ash, 10% lime. Often other ingredients are added to give the glass certain desirable qualities, but these are usually in minor amounts.

Glass manufacturing in the United States

The manufacturing of window glass in the United States can be traced back to the first settlement at Jamestown in 1608. However, this and many subsequent attempts to establish a glass industry failed, which was the pattern until the middle to late 19th Century. During this time domestic window glass manufacturing was carried out by small family run businesses that produced smaller quantities of glass for local or regional use. Most window glass was still imported and there were virtually no large-scale domestic operations until the end of the 19th Century. This was claimed to have been due to several factors including:

- An acute shortage of skilled tradesmen;
- Poor transportation between the natural deposits of raw materials, fuel, and the market place;
- And perhaps most significantly, the competition of foreign producers.[2]

Foreign glass was readily available, of good quality, and very cost competitive.

In reviewing the various texts from the mid-20th Century that attempted to document the beginnings of the domestic glass industry, it is difficult to get a complete and exact chronology. It is even difficult to differentiate whether they are discussing common window glass or plate glass, which was a more expensive process. However, in general it appears there was difficulty raising sufficient capital to build a plant large enough to make production cost effective. This was particularly true for plate glass, which required large expensive machinery for the grinding and polishing processes. The end result was that until the 1880s, virtually all attempts at establishing a large-scale window glass manufacturing operation in the US failed.[3]

The revolution that was to make glass the common building material that it is today had to wait until the late 19th Century when technology and capital combined to completely change the glass industry.

Window glass

There were basically two types of domestically produced glass used for glazing in the early 20th Century: window glass, which was blown, and plate glass which was rolled, ground and polished. These were different processes carried out in separate factories by separate manufacturers.

Blown window glass was made by either the crown or cylinder method. Although these pre-20th Century methods fall out of the scope of this paper, it is useful to understand the basics of how they were made to put later developments in context.

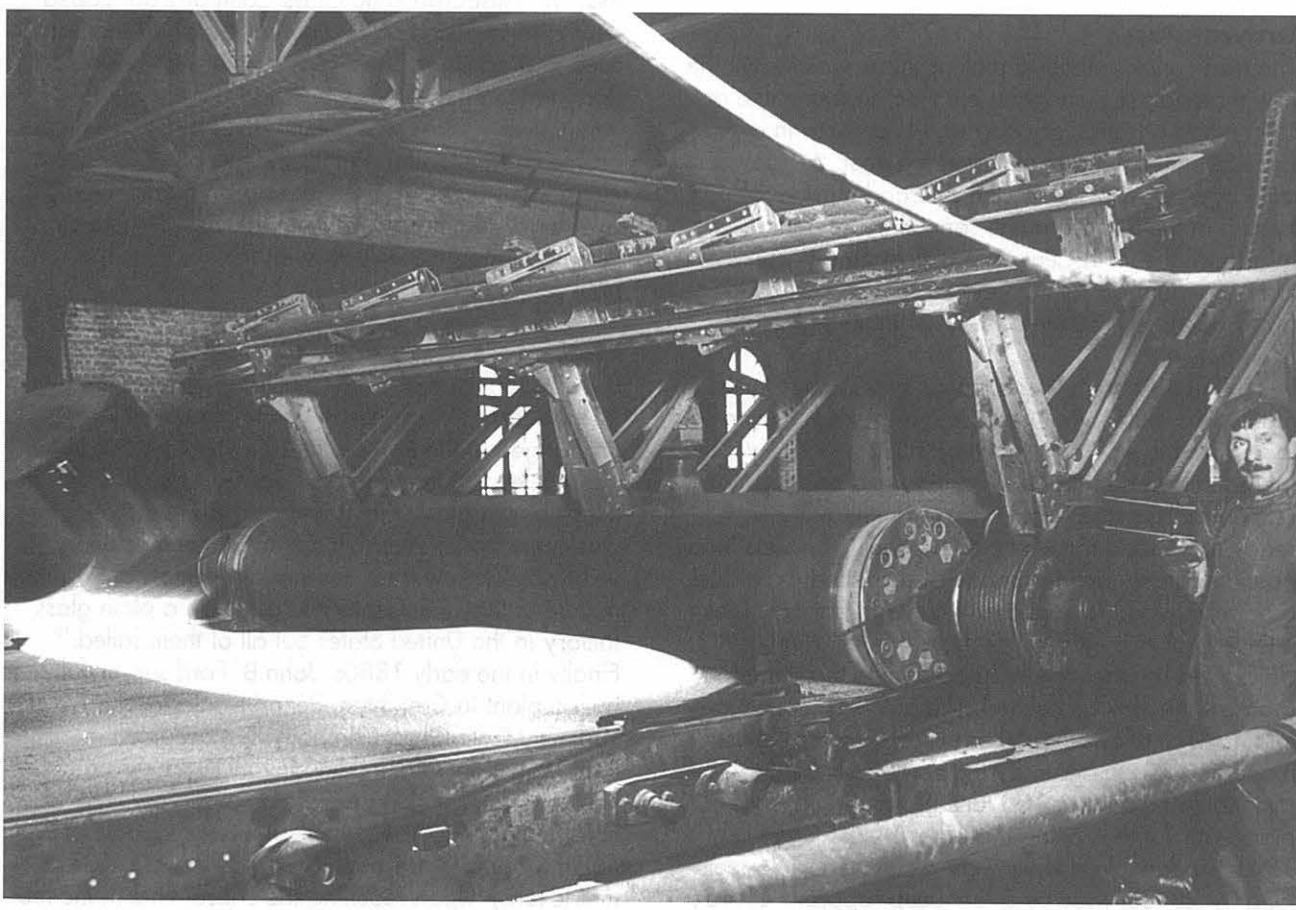
The crown method started with a large sphere of blown glass. One end was then opened up and the sphere was repeatedly heated and spun until a large flat disc of glass was produced. The disc was then cut up into small sheets with the 'bull's-eye' in the middle often being used for decorative lights such as in a transom.

The cylinder method started with a cylinder of blown glass about 4 or 5 feet long and up to 30" in diameter (about 1.22 - 1.52 m long and 0.76 m in diameter). The two rounded ends were cut off, and the cylinder was split down the middle and flattened out into a rectangular sheet.

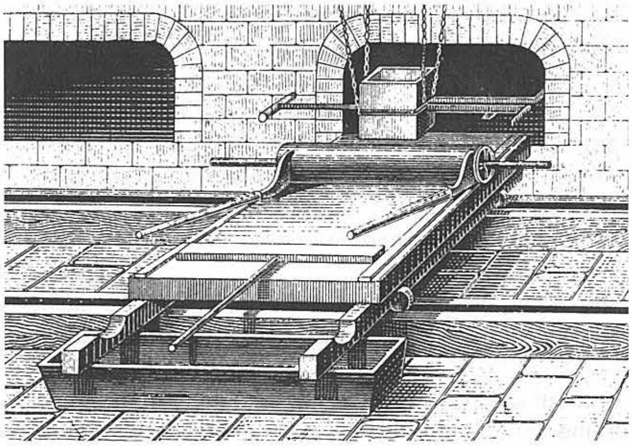
The quality of glass produced varied, but both methods resulted in quite a bit of distortion. The crown glass had tell-tale swirls from the spinning action, and the cylinder method left ripples that could not be removed in the flattening process. Both methods had limitations as to how large a sheet could be produced. Crown glass began to fall out of use in the early part of the 19th Century, and by the end of the century almost all common domestic window glass was made by the cylinder method.

Cylinder glass in the 20th Century

In 1903, J. H. Lubbers invented a machine which employed carefully controlled compressed air that could blow a cylinder of glass 30" - 40" in diameter and a length of 40 feet (over 12.19 m, with a diameter of 0.76 - 1.02 m) while maintaining a consistent thickness of material. The long tube of glass was then lowered and cut into smaller lengths and then split down the middle into 'shawls'. Then in the same



Molten glass on the casting table of a Dutch factory.
Photo: Rijksarchief Zeeland, Middelburg.



A European engraving of the glass rolling process.
From: J. Smal, De nijverheid aanschouwelijk voorgesteld, 1899.

manner as the hand cylinder method, the shawls were repeatedly heated and flattened out by hand in an annealing oven with a charred block of wood. The flattening process tended to polish the glass, but could not remove all of the waviness or ripples caused by the differential between the inside and outside surfaces of the cylinder.

Lubbers' machine quickly came to dominate the American window glass industry, but it too was about to be eclipsed by a radically new method: drawn glass.

Drawn glass

The traditional method of making glass was to mix the raw materials dry and then put them in a crucible or 'pot' made of refractory clay and heat them in a furnace until the materials fused together. As factories got larger, they increased the size and number of pots heated in the furnace at the same time. By the last quarter of the 19th Century a typical glass factory furnace would contain ten pots with between 2500 - 3000 pounds (1.36 metric tons) of molten glass in each pot.

In 1879-1880 the first continuous tank in the United States was built in Poughkeepsie, New York.[4] Invented in England in 1870, this method allowed the dry ingredients to be introduced at one end and the refined molten glass would come out the other end ready to be used for whatever purpose. This was made possible largely by the change over in the type of fuel used from wood to coal and finally natural gas. Gas allowed either a very concentrated or an evenly distributed heat source to be applied to the different areas of the tank as needed. The gas fired continuous tank is what allowed truly large-scale window glass manufacturing to occur. By the early 20th Century, a tank could hold up to 100 tons (90 metric tons) of glass with 12 tons being melted every 24 hours.[5] By 1941 window glass tanks were as large as 136 feet long by 28 feet wide by 5 feet deep (approx. 41.45 x 8.53 x 1.52 m) and could hold over 1000 tons (900 metric tons) of molten glass.[6]

Although there had been early attempts to draw a flat sheet of glass directly from a pot as early as the 1857 in Europe[7], it was to take another 60 years before anyone could develop a system that actually worked. After almost two decades of failed attempts Irving W. Colburn, with the financial backing of the Libby-Owens Sheet Glass Company, perfected the first American machine to draw a continuous sheet of glass from a tank in 1917. Initially the sheet was 72" wide, but was increased to 84" (about 2.13 m) by 1920.[8] This new method totally revolutionised the window glass industry. Previously about 5 man-hours were required to make 50 square feet (about 4.65 m^2) of window glass by hand. Colburn's machine could produce the same amount in a little over one tenth the time.[9] This led to the virtual elimination of the cylinder method by 1930.[10]

With the Colburn method, the glass was drawn out of the tank vertically 2 or 3 feet (about 1 m) and pulled over a large roller and then down a long annealing oven or *lehr* where the glass was slowly cooled to room temperature. The difficulty in perfecting the machinery was to get it to draw a ribbon of glass of consistent thickness.

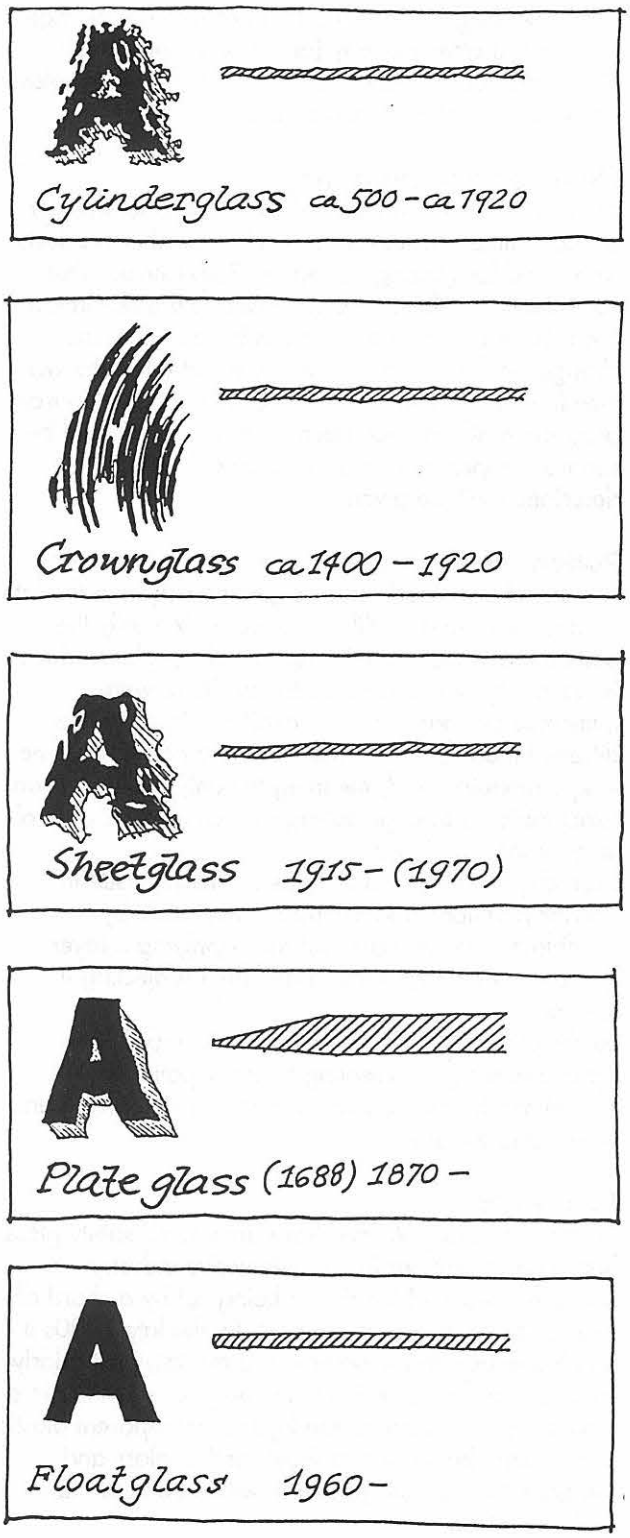
A similar method, invented by a Belgian named Emil Fourcault, was introduced in the United States in 1923.[11] It was similar to the Colburn method, except the glass was drawn vertically up through a lehr of only about 23 feet (about 7 m), and then cut off at the top. The Pittsburgh Plate Glass Company developed their own variation of the Fourcault method that was used to produce its sheet glass until it was replaced by float glass in the 1960s.

While drawn glass was inexpensive, it still had the problem of distortion. Rather than ripples there were elongations, which looked like stretch marks, created by the glass being drawn from the tank. Where clarity was important, the only way to achieve it was to use polished plate glass

Plate glass

Perfected in the mid-17th Century in France, the method for making polished plate glass was largely unchanged at the turn of the 20th Century. Although the skill level of the workers involved was not as high as for blown glass, the making of polished plate glass was very capital intensive due to all the machinery involved. There were a number of attempts during the middle of the 19th Century to establish a plate glass factory in the United States but all of them failed.[12] Finally in the early 1880s, John B. Ford successfully built a plant in Creighton, Pennsylvania for the New York City Plate Glass Company that became the Pittsburgh Plate Glass Company in 1883.[13]

The process of making plate glass was very time consuming.[14] Glass was melted in pots capable of holding about 3000 pounds of glass (about 1,36 metric tons). Upon reaching the critical time in the melt the pot was removed from the furnace by a large crane and the impurities were skimmed from the top

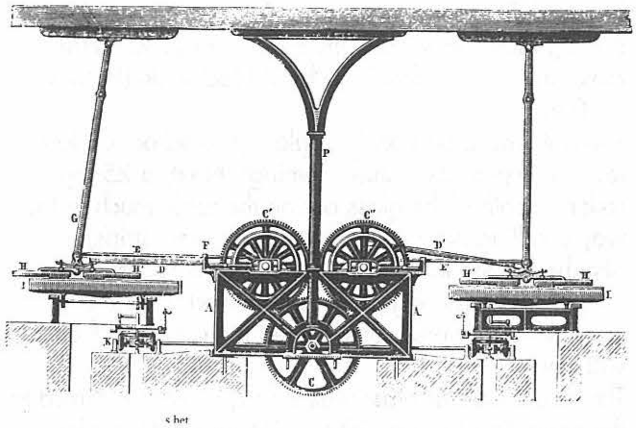


Identification key to five glass types. Top to bottom: Cylinder glass, crown glass, sheet (or drawn) glass, plate glass and float glass. Drawing: Søren Vadstrup.

by hand. The pot was then carried over to a steel casting table, which weighed 200 tons (180 metric tons) and was 32 feet long by 20 feet wide (9.75 x 6.10 m).
The pot was tipped and the glass poured out on to the table in a process called 'teeming'. Next, a 25-ton roller smoothed the glass out on the table much in the way a rolling pin makes a pie crust. Steel strips, attached to the table, served as gauges to insure the proper thickness of glass was achieved. Both the table and the roller were water cooled to keep them from warping.
The large sheet of glass was then quickly transferred to the annealing oven or *lehr*, which was 800 feet long (over 240 m). If the glass cooled too quickly, it would develop stresses and crack. It took about five hours for it to cool down to room temperature at which time it was cut up into the desired sizes. Great care was taken to identify flaws or other imperfections that would be cut out. In this state, the glass was known as 'rough stock' and was often used for skylights, or in other situations where light but not transparency were needed.
Next came the grinding and polishing operations. The large pieces of glass were lifted by crane onto a large circular table covered with wet plaster of Paris, which held them in place. These large tables weighed 70 tons each (about 64 metric tons) and rotated underneath iron runners of about the same weight, which were lowered down onto the glass. Water and sand were fed under the runners and the glass was ground. Finer and finer grades of sand were introduced until finally emery was used. When the grinding operation was complete the surface of the glass had a satin finish.
While still on the table, the glass was washed off and inspected and then moved over to the polishing machine. This time felt covered disks were lowered on to the surface with a paste of red iron oxide or rouge used as the abrasive. Once the polishing was complete, the glass was removed from the plaster of Paris, flipped over, and the entire grinding and polishing process was repeated. Grinding and polishing reduced the thickness of the sheet by about 50%. When finally completed, the glass was stripped from the plaster of Paris, cleaned with muriatic acid, given its final inspection, and cut to size.
Improvements such as electric powered cranes and grinders and continuous *lehrs* reduced the time required to make a sheet of plate glass from ten days in 1889 to 36 hours in 1923.[15] However, even bigger changes were on the horizon.

The continuous process

In the 1920s several steps were taken to create a continuous process for the manufacturing of plate glass.
The Bicheroux process, developed in Germany right after World War I, poured glass between two rollers to create a continuous sheet that was then cut up into



A French machine for grinding and polishing of plate glass.
From: E. Peligot, Le Verre, 1877.

manageable sizes and ground and polished as previously described. In the early 1920s, both the Ford Motor Company and Pilkington Brothers Limited of England developed processes by which a line of continuous grinders ground and polished the cut sheets on both sides simultaneously.
In 1938 Pilkington Brothers Limited took it one step further and developed a truly continuous process. The sheet was rolled to a rough-cast ribbon, annealed in the *lehr*, and then ground and polished on both sides while remaining one long continuous ribbon.[16]
The maximum size of plate glass available in the 1940s was approximately 126" x 284" (10'-6" x 23'-6", or 3.20 x 7.20 m).[17] Today, the largest standard size of flat glass available is 130" x 204" (10'-8" x 17'-0", or 3.30 x 5.20 m) although it is possible to get it as long as 400" (almost 10.20 m).[18]

Float glass
In 1959 Pilkington Brothers Limited again revolutionised the glass industry with the introduction of the float glass process which dominates the industry today. Starting in a similar fashion to the continuous plate glass process, the glass is melted in a large tank and a ribbon of glass is formed by passing the molten glass through two rollers. Then, rather than being ground and polished, the glass is drawn over a bath of molten tin with additional heat applied from above. Today, a typical tin bath is about 60 m long and the molten tin is from 5-10 cm deep.[19] This 'fire polishing' replaces the grinding process in attaining a flat polished surface.[20] The quality of this glass is regarded by the industry as being on par with the polished plate of the past. It is clear, flaw free and virtually flat. Any slight variations that occur are imperceptible when measured using ASTM[21] Standards. However, when installed in a building, there is a perceptible difference in how 'flat' the glass looks. When double glazing or heat strengthening is used the visual distortion is often greatly accentuated.
Today, virtually all flat glass is made by the float glass process. It is estimated that there are 120 float glass lines operating in the world that produce on average 550 tons of glass per day (about 500 metric tons). That comes out to about 20 billion square feet of glass per year (almost 186 million m^2).

Other glazing products
Along with the advances in the basic technologies of window glass production, a number of other products were used for glazing during the 20th Century that could have an effect on current and future restoration projects. Many of these products have undergone changes in the way they are made that effect the way they look, or in some cases have eliminated them from production all together. Each of these topics could be a separate paper in its own right, so only a brief description will be given.

Patterned glass
The use of patterned glass as glazing began in the late 19th Century and is still in use today. Typically the pattern was rolled into the surface of the glass, which is essentially how it is made today. There were numerous standard patterns available from several different manufacturers. Most of these patterns are no longer manufactured, meaning the only way to get an exact match is through salvage which involves a lot of time, money, and luck.
Glue chipped glass, which was commonly used in interior partitions and transoms, was made by sandblasting plate glass and then applying a layer of glue to the rough surface and then subjecting it to heat.
As the glue dried, it peeled off and 'chipped' the surface of the glass creating feathery patterns. Sometimes this process was repeated twice giving an even richer texture.

Safety glass
Developed during World War I, laminated safety glass first became popular in the automotive industry because it reduced the risk of being cut by a shard of glass in the event of an accident. By the late 1920s it had found uses in the architecture market, particularly for doors and glazing in mental hospitals.[22] Made in a similar fashion today, a thin layer of transparent plastic was layered between two sheets of thin glass and subjected to heat and pressure, which bonded the sheets together.

Tempered glass
Like laminated glass, tempered glass was used in locations where the danger of injury from broken glass was greatest, such as doors, display cases, etc. It was considered a 'new' product in its description in the 1933 Sweet's Catalogue. Tempered glass was made from plate glass that was heated and then cooled rapidly which gave it great additional strength.
When a strong impact exceed the strength of the glass, it would shatter into thousands of tiny pieces, thus reducing the risk of being cut on a sharp shard of glass.

The earliest method of tempering glass involved hanging a sheet of plate glass vertically from a set of tongs, heating it to a high temperature, and then quenching it with cold air. The tongs often gave the edge of the glass characteristic indentations and the sheets were prone to warp, which sometimes made it difficult to glaze.
There is also a chemical method for tempering glass, which is used in very special situations but is quite expensive and limited in the sizes that can be treated. Although there are still a few plants that use the tong method, it has generally been replaced by the horizontal method whereby a sheet of glass is moved through an oven on a set of ceramic rollers, heated to a near molten state, and then quickly cooled. The rollers give a very characteristic 'roll ripple' texture to the sheet which is quite visible when installed. Any quick visual survey of buildings built within the last ten years will reveal this common distortion.

Tinted glass

Already in the 1920s tinted glass was being used to try and reduce glare. The 1925-26 Sweet's Catalogue includes an amber tinted glass called 'Actinic' glass which claimed to 'exclude 85% of the ultra violet rays and 55% of the radiant energy rays of the sun' and was sold primarily as an anti-glare glass.[23]
By the 1930s polished plate was available in a number of colours, including several shades of blue and green, a 'peach' violet, and a few others. These were primarily intended to be used for making mirrored interiors, but were also used for glazing. The heat absorbing qualities of some of the tints began to be noticed and some of the tinted glass was marketed in the 1940s as 'heat absorbing plate glass'.
Tinted glass is still available today, but the selection is limited to what the different manufacturers have as standard colours. The colours are achieved by adding various colouring agents to the tank of molten glass. Due to the large scale of glass production today, especially as it relates to the amount of glass in a tank, the cost to make a custom colour tinted glass for even a large-scale restoration project would be prohibitive.

Coated glass

Coated glass[24] began to be used in the 1960s.
The earliest coating method was vacuum evaporation. In this process a metal powder was vaporised in a vacuum which then condensed on the glass surface forming a nearly transparent metallic film. Cheaper wet chemical coatings replaced this method in the 1970s. The wet coatings processes were based on the same principles used to make mirrors. However, the coating was soft and susceptible to damage and therefore it was used almost exclusively on the inside surface of an insulated glass unit. There was also some difficulty in achieving a uniform distribution of the coating on the glass. This 'sputter coat' method has been refined with the addition of magnetic enhancement so that a more uniform coating using a variety of oxides is possible. This method is still being used today although the colours of the end product may be different than they were fifteen years ago, which could create a problem when replacements are required.
Today, chemical vapour deposition (CVD) methods are the industry standard. These pyrolitic coatings are applied in the float bath or at the start of the *lehr*. They have the advantage of being extremely durable and the coated glass can be tempered or bent.
Low emissivity (Low-E) coatings that reflect infra-red wavelengths but leave the glass appearing clear, have been under development since the 1980s and can now be found in both sputter coat and CVD forms.
Although some of these developments have been so recent as to not appear to be a restoration concern today, it is quite possible to be confronted with a building from the late 1960s that needs to have glazing replaced that can't be matched. Some of the gold reflective glass that was so popular in the late 1960s and early 70s would be very difficult to match today.

Conclusion

The technological advances in the glass industry during the 20th Century have made the problem of matching window glass in historic structures built before 1960 a very difficult task. If the history of the industry is any indication, the problem will only get worse. Production methods continue to get larger and more sophisticated, and are completely geared toward new construction. The glass industry is primarily interested in expanding their markets by developing new products to replace old ones. This is particularly true with glazing products geared towards creating better energy efficiency. Unfortunately there is currently no economic incentive for any large glass manufacturer to offer the custom products that restoration projects typically require. There is at least one positive exception to this. Within the last few years, a European made cylinder glass has become readily available in the United States.
This product has the distortions commonly associated with cylinder glass and makes a good match for any project in which this material was originally used. However, this is of no help if one of the many other 20th Century glazing products is required.
The problem is especially troubling in the case of polished plate glass. Due to the large amount of infrastructure and capital required to produce polished plate glass the majority of this product was manufactured in only a few locations. When float glass came to dominate the industry, all the plate glass plants were converted or abandoned, and the machinery scrapped. The author was unable to learn of any place where any of this machinery is still extant. Obviously, without the machinery to grind and polish the glass, replication is impossible.
Although the industry claims that today's float glass is virtually the same as polished plate, there does appear to be a difference in how the glass looks when used in

large sheets over an entire building. The difference is a subtle one but it is perceptible. When the building being restored is a skyscraper that is virtually defined by its glass skin, the issue becomes one of the utmost concern. With the inevitable ageing of buildings built between the World Wars, this will continue to be a challenge for many years to come.

The problem will continue not only because of the need to replace broken or deteriorated glass or even entire curtain wall systems, but also due to pressure from building owners who want to 'modernise' with new insulated glass units to make their building perform better economically. When used in large lights, the reflective qualities of the two (or three) sheets of glass make the distortions even more pronounced. Add to this the 'roll ripple' effect caused by heat strengthening so commonly used today, and the problem multiplies.

Every building has its own story, and economic realities, which will dictate the final solution to its window restoration problem. However, just as with buildings from before the 20th century, a higher priority should be placed on conserving the existing glass and finding other ways to achieve better thermal performance.

At the onset of the 21st Century the materials and technologies preservation professionals will be dealing with may change, but the basic challenge will be the same; to find creative and cost effective solutions that meet the clients needs while preserving the integrity of the building to the fullest extent possible.

Gunny Harboe AIA is an architect and the director of the Preservation Group of McClier architects, Chicago.

Acknowledgement

This paper would not have been possible without the generosity of Neal Vogel, Rolf Achilles, and Steve Kelley, who made numerous volumes on glass available from their personal libraries.

The editors have converted the American measures given by the author in the original text to metric measures.

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international working party for
documentation and conservation
of buidings, sites and neighbourhoods of the
modern movement

Strategies and Policies

Framing Opinions

English campaign to conserve windows

English Heritage began a national campaign to protect the country's heritage of traditional windows in 1991. The endeavour has been a huge propaganda exercise to raise the public's awareness of the importance of windows.
Though primarily aimed at 18th and 19th Century timber sash windows the campaign will now be rejuvenated so as to include windows and glazing from modern buildings. The question raised by Chris Wood is, how much of English Heritage's conservation principles is relevant to the issues concerning modern windows.

by Chris Wood

Framing Opinions was a national campaign to protect England's heritage of traditional windows and doors. This means all windows of historical interest in England, but the campaign concentrated mainly on timber sash windows of the 18th and 19th Century, as it was these that were most threatened. Therefore this paper focuses on examples from this period before looking at examples from the 1930s.
English Heritage began the campaign in 1991 and it ran for 3 years. It sought to raise awareness about the importance of windows in historic buildings and areas and to show how damaging most modern replacements were. It is still continuing and has been reactivated in 1998. The rejuvenated campaign will also include windows and glazing from modern buildings of the later 20th Century and, as we will see, a slightly different approach to their conservation may be required. However, it is necessary initially to briefly explain about English Heritage and the processes of control over historic windows in England.

English Heritage
English Heritage is an independent public agency set up by government and principally funded by it. It has an annual budget of £ 120 million, 1,200 staff and is probably best known for maintaining over 400 historic sites on behalf of the nation, including Stonehenge and many famous ruined abbeys and castles.
It gives grants worth £ 45 million to help repair historic buildings, is formally involved in the country's development control process, advising all local planning authorities and the relevant Secretaries of State on everything concerning the historic built environment.
English Heritage is also responsible for drawing up the statutory list of buildings considered to be of architectural and historic interest and worthy of protection. New additions to the list are approved by the Secretary of State. Currently there are over 500,000 listed buildings, the vast majority of which were built before 1840. In towns and cities classical terraced dwellings such as these from the 18th and early 19th Century are perhaps the most common types.
Listing interwar buildings is now far less emotive than it used to be and over 600 are included. However, extreme scepticism amongst politicians and the public about the value of postwar buildings has led to resistance to list them. Buildings that are included have to be at least 30 years old, but in extreme cases where an outstanding building is threatened it can be added, provided it is at least 10 years old. In response to this hostility towards the protection of modern buildings, English Heritage has carried out rigorous research on different building types (e.g. hospitals, schools and factories) and has identified the best examples of each. These broadly define a standard against which proposals for further additions are judged.
The increasing use of public consultation to propose modern buildings has allowed the government to feel more easy about adding them to the list. Nonetheless there are still less than 200 postwar buildings included, representing 0.1% of the total listed building stock.
Once listed, consent is required for demolition and alterations affecting a building's architectural or historical character. Removal or alteration of windows needs listed building consent, which is dealt with by local authorities. Such applications are usually resisted especially if the windows are original and/or intrinsically important for architectural reasons.
Although controls do exist over the removal of windows from most types of non-listed buildings the powers are far less effective and often not enforced by local authorities. Finally, it is important to stress that listing does not prevent change taking place. It allows time of fully consider a proposal and investigate alternatives. The aim is good conservation, not preservation.
English Heritage's principles governing change are found in established charters, such as ICOMOS, Burra

and Venice. These include: minimum intervention; conserve as found; where replacement is needed it should be carried out on a like for like basis; change should be reversible; and restoration is only justified where clear evidence survives of the original. These principles are relatively easy to apply on proposals to remove 18th Century windows - but not always so easy to apply on modern buildings.

Framing Opinions campaign

So how did English Heritage get involved with Framing Opinions which was really a huge propaganda exercise dealing with a great number of issues? As stated earlier, it was principally aimed at raising the public's awareness of the importance of windows.
It started as a response to criticism in the press that huge resources were being spent on the conservation of cathedrals, castles, country houses and very little to sort out the problem where unlisted buildings, mainly single family dwellings in the country's 9,000 conservation areas, where having their period windows removed and replaced with wholly inappropriate alternatives.
Most of these conservation areas contain attractive groups of historic buildings that are characterized by a strong unity in appearance, of which the windows form an essential part. However, this unity and character can be destroyed by such changes.

Establishing alliances

The campaign started by establishing alliances with like-minded groups and individuals in the public, voluntary and commercial sectors to add more weight and resources to the campaign. Local councils hosted conferences and exhibitions and published technical guidance based upon the Campaign's messages. Civic societies also helped by producing advisory notes, running seminars and finding volunteers to deliver leaflets.
Links were set up with relevant trade associations and their member companies who contributed money and help on behalf of traditional joiners and carpenters. The draughtproofing/weatherstripping association

A typical conservation area whose appearance and character is marred by the replacement windows on the left. All photographs by courtesy of English Heritage.

and steel fabrication companies throughout the UK became involved. Crittall, the biggest manufacturer of steel windows, helped with the advisory leaflet on metal windows.
Designers, specifiers and architects gave advice and help to individuals and local communities. National and local TV, radio and newspapers were also very keen to report the issues.

Demonstrating importance

The next stage was to explain the value of period windows to the public at large. It was important to show that windows were: generators of style; usually designed within the overall proportions of the facade; important as markers for time and change in history of building technology; mostly well-made, using durable and sustainable building components; and should be seen as assets not liabilities.
The rich variety of window types and the value of historic glass were stressed - particularly crown glass which is no longer available. Pattern books from the 18th and 19th Century were used to illustrate the architectural importance of sash windows and show that the range of designs were deliberately related to the general proportions of the facade.
Sashes were shown to be quite ingenious devices with wide variations and subtleties - and we showed where collections of old windows of different dates could be viewed. This assisted consumers, specifiers and those in the repair and fittings industries.

Explain the threats

The threats to existing windows were explained by showing that:

- Replacement was often unnecessary (the original timber being sound);
- Unsuitable replacements were often poor quality (e.g. timber of today could not replicate the quality of the original and PVC did need to be maintained despite claims to the contrary);
- Alternative materials could not replicate the originals (in terms of fine detailing and the way that they aged);
- The alteration lead to the loss of a significant part of the buildings special architectural, historic and archaeological interest;
- The long term impact of changing details on the facades of individual buildings contributes to a decline in character of historic areas.

Ultimately there could be a serious risk to craftsmanship in joinery, carpentry and glazing.

Explain the causes

Why were old windows threatened with replacement in the first place? Consumer demand for new windows was created by the availability of cheap loans for modern replacements and the heavy marketing by the replacement industry which tried to create the image that old means worn out and rotten and propaganda from the replacement industry - often providing

COMPARATIVE COSTS OF DOMESTIC ENERGY SAVING MEASURES

Type	Installation cost (£)	Annual savings (£)	Pay-back period (Years)
Draughtproofing (DIY)	30-50	15-40	1-3
Loft insulation (DIY)	120-150	60-70	2
Loft insulation (contractor)	170-250	60-70	3-4
Interior wall insulation* (DIY)	200-300	50-80	2-4
Draughtproofing (contractor)	100-200	15-40	3-10
Thermestatic radiator valves	108	13	9
New condensing boiler for central heating	200-400 (overprice of standard boiler)	100-150	10
Interior wall insulation* (contractor)	1,500-3,000	50-80	15-20
Secondary glazing	1,000-1,500	20-23	15-20
New double glazing	2,000-3,000	23-30	15-25

(From work by de Building Research Establishment)

Independent data has been used to illustrate that the pay-back period for new double glazing fares badly in comparison with other energy saving measures.

misleading information e.g. replacements were cheaper than repair, more energy efficient and maintenance free.

In comparison there was very little 'marketing' on behalf of existing windows, partly because of the limited number of repair specialists.

As replacements were usually unsuitable on visual and historic grounds we challenged these perceptions by:

- Showing that most heat loss occurred through walls, floors and roofs and not necessarily through windows;
- Producing independent information to challenge the claims made about energy savings;
- Producing literature with others to show that simple methods of repairs were readily available;
- Giving wide publicity to joinery firms and publicizing the by now widely available supplies of fittings;
- Showing that inexpensive methods of draughtproofing existing windows were available.

Independent research was used to demonstrate that the pay-back period for double glazing was 20-25 years, compared with other methods of fuel-saving measures, such as draughtproofing (1-3 years), loft insulation (2 years) and condensing boilers (10 years). Even with the reduced maintenance requirements, PVC double glazing was more expensive than repairing and upgrading even the worst maintained timber windows.

Provide the solutions and spread the word

So how did we get the message across? We produced videos, numerous leaflets and travelling exhibitions.

With our allies we held meetings, seminars and conferences. We issued news press releases, magazine articles and items for TV and radio. It was estimated at its peak that the campaign reached over half the population through one source or another.

It is impossible to say how successful the campaign has been. At its height it resulted in a general demand for greater powers of control. There was certainly a dramatic increase in technical publications for home owners, specifiers, contractors and window manufacturers, as well as improved contact between heritage bodies and the building industry over these concerns. In fact, the British Plastics Federation Windows Section and Glass and Glazing Federation advised members that they were unlikely to win a public battle over replacement windows in historic areas and advised members not to sell there. The campaign was praised by government ministers for its balanced, cost-effective and educative approach.

It has to be said that the Framing Opinions campaign has not necessarily reduced demand for changing windows in historic buildings. However it has effectively publicized the issues and made it easier to resist such proposals. It has demonstrated how an effective campaign can exert commercial and political pressure in the market place, which is normally outside English Heritage's sphere of influence.

20th Century buildings

The application of English Heritage's conservation principles is fairly straightforward when applied to

No 2, Willow Road, where the original ungalvanized steel windows have been sympathetically repaired in situ leaving the original glass in place.

buildings of the 18th and 19th Century. The question is how much of this is relevant to the issues confronting modern buildings? The next few examples illustrate where windows have been changed or proposals made to do so. These show some of the main issues which an expanded campaign will need to deal with and indicate where a different philosophy and approach may be needed.

Ernö Goldfinger designed and built 2 Willow Road, Hampstead, London, which he occupied for over 40 years. As a result of its architectural importance and its association with one of the 20th Century most important pioneering architects, it has now been acquired by the National Trust.

The existing ungalvanized steel windows were badly corroded but these were repaired in situ, rather than being replaced. This avoided the risk of damaging the glass when removing it. The Trust are primarily concerned with authenticity and detail and carry out five-yearly reviews and regular maintenance, so the fact that the repairs may need to be done again soon was accepted.

Obviously, in many ways, such a sympathetic owner, together with a museum use should ensure the ideal conservation solution. However, for most buildings, once change to the windows is inevitable the usual request is to allow some form of upgrading or improvement.

The White House, Surrey

The White House, Grayswood, Surrey, built in 1932 and designed by Connell Ward Lucas was originally pink with the window frames painted green. Change was needed because the ungalvanized steel windows to the staircase tower had corroded. The architects and Crittalls (who supplied the original windows) agreed that there was no economical prospect of saving the originals.

The problem here was the scale of the glazing and the limited opportunity to improve thermal insulation by means other than double glazing. Replacement was carried out in W20 galvanized powder-coated sections which maintained all fenestration details. Double glazed 14 mm, low emissivity units were incorporated reducing U-values from 5.4 to 2.6. The change in appearance was quite subtle. The apparent slight thickening of some sections is caused by the beading and the reduction in depth of the steel sections that two panes of glass creates.

Boots Factory, Nottingham

Philosophical considerations played an important part in the consideration of the replacement of the curtain wall glazing by a double glazed system on Owen Williams' D 10 building of 1932, designed as part of the Boots factory at Beeston, Nottingham. The existing glass had suffered wind damage and been replaced by hardboard, louvres and ventilation grills. The requirement to change the glass resulted from new Euro standards for pharmaceutical production and the need to withstand the wind loads.[1]

Owen Williams used Crittalls' standard range of medium universal steel window sections with 20 mm flat glazing bars to the external face which gave minimal sight lines. The original glazing was inserted with every third mullion performing a structural function.

A secondary glazing system was proposed which would have formed a corridor creating a visual connection with the machinery and not appearing as part of the structure. This would have allowed the original windows to have been kept and therefore the 'conserve as found' principle could be implemented. However, for D10, although this would have kept the original surviving glass it would have also included the repairs, alterations, blank panels, extract fans

and blinds.
A very important characteristic of the building is its simplicity of structure and transparency of glazing. This posed something of a philosophical dilemma, although for a number of reasons this approach was rejected.
A second proposal to use similar section mullions and thicken the horizontal structure by incorporating a handrail would in many ways have created a more delicate and perhaps more minimalist solution. Arguably this would have been more in the spirit of the original intention of Owen Williams. However, after much deliberation and the construction of a series of mock-ups it was agreed to go for an 'as built' solution, which comprised a composite with a steel plate at every third mullion and at the high transom with double glazed W20 steel sections, galvanized and polyester powder-coated to match the original.
The completed scheme is best seen at night with the lights on - the only disappointment being the slight obscuring caused by the toughened glass.
The important point about this case is that a very full exploration of philosophies and ideas was allowed, with a considerable amount of time and effort spent in research and development to let the final solution evolve slowly.

The Curzon Cinema, Central London, where the proposal to replace the aluminium framed secondary glazing with a tilt and turn PVC system, would have severely damaged the appearance of this listed building and meant the loss of a rare survival of a pioneering glazing system from the early 1960s.

The Boots building before repairs were carried out, showing the original glazing and replacement hardboard, louvres, extract fans and blank panels.

The timber double glazed windows at Balfron Tower on the main elevation, which are likely to be replaced with PVC unless some research and developments is undertaken to either repair and adapt the originals or design new timber modules which replicate the originals and allows for the necessary improvements.

Curzon Cinema
The three cases looked at so far all involve buildings where change was unavoidable. Both involved the use of steel where original manufacturers are still producing the same sections, or have been prepared to innovate in order to try and satisfy the desire to conserve or comply with the original design intent. The case of the Curzon Cinema involves a now redundant glazing system in aluminium which cannot sensibly be reproduced.
The cinema, in central London was designed by Sir John Burnet Tait & Partners and built between 1963-66. The proposal was to remove all the existing windows above the cinema and replace with PVC double glazing. The building was listed while the application was being considered.
The existing frames are made in aluminium with secondary glazing. Architecturally, the importance of the windows lies with their simplicity, where they appear as horizontal bands only broken by bay divisions. Minimal vertical emphasis is given by the seals around each pane, creating these very thin vertical lines. The sliding windows and sills are flush with the facade, with no projections. It is important historically because it is a rare survival in England of a very innovative system.
The proposal to change the windows was made to solve the problems of thermal inefficiency; panes ratt-ling in the wind; secondary windows making cleaning difficult; apparent failure of acoustic lining; the applicants need for greater flexibility in internal partitioning of the office; and the fact that anodizing will continue to deteriorate.
Admittedly the original system contains faults. The height to width ratio of each pane results in tipping of windows and binding of the sliding gear and these rollers may well be worn. Little attention was originally paid to thermal performance.
The applicants wanted to replace with a new tinted double glazed tilt and turn system using thick sections forming bold mullions and transoms which would have destroyed the original design concept and appearance. Extensive inquiries were made but no one manufactures anything resembling the original system - indeed only the rollers are still made. Alternative materials were examined including steel, but nothing was currently available that could be done satisfactorily in double glazing. However, the existing window system was in reasonably good condition and the local authority are continuing to resist the application. Obviously we hope that maintenance is followed and small-scale repairs carried out to overcome some of the current faults in order to make the most effective use of the existing windows. In this case, it would seem that at present we do not have the technology to reconcile the applicants and the conservation requirements at a reasonable cost.

Balfron Tower
The case of Balfron Tower is a completely different scale of problem involving a major public housing development where there are a great number of different interests to satisfy. Balfron Tower is situated in East London, in a particularly deprived inner city borough. It was designed by Ernö Goldfinger in 1967 and thought by many to be one of the best tower blocks in England. It has now been listed and the whole estate designated as a conservation area.
One of the two main elevations faces one of the busiest roads in England which the Highways Authority needed to widen. This meant that the flats facing the road would need additional sound proofing.
The original timber framed double glazing had not fared well, because of its exposure, minimal storm detailing and the changes required under health and safety legislation. So it was suggested that another frame was placed inside, creating triple glazing - this was rejected because it would interfere with internal arrangements of the flats. The building was listed when standard PVC units were proposed.
The standard units were rejected, but new specially designed PVC windows were felt to be acceptable.
A timber alternative was considered but the sections were too bulky to replicate the originals.
The ideal solution would have been to take away an original and carry out some research into repairing or adapting the existing window, or try to copy them

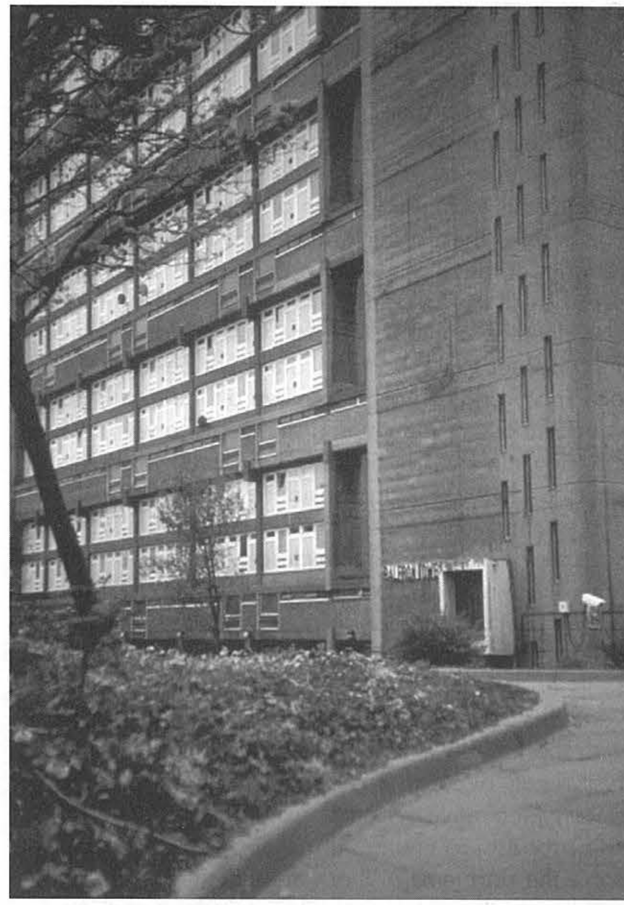
Original timber double glazed windows in situ shown against proposed PVC replacements which were rejected at Balfron Tower, East London.

in a way that would overcome original 'flaws'. However, this was not possible because of pressure from the tenants and the limited amount of money and time available.
Listing this building was unpopular in some quarters because leaseholders have to pay more for insurance and the Council, as owners of the building, will incur greater costs for alterations and repairs. This is a problem that affects many of the best examples of large postwar public housing developments in England, very few of which are yet listed.
A new problem will arise when the rest of the windows on the other main elevation need to be changed. Should we use timber bearing in mind half the building is now clad in a different material? Currently there is no funding anyway for the research and development work that is necessary to come up with an alternative solution in timber. The scale of this problem may also require a solution which is capable of mass production in order to ensure that costs are reasonable. A lot more thought and action will be needed and time may not be on our side.

Conclusions

So what is the relevance of a renewed Framing Opinions campaign to modern buildings? Clearly there is a need to explain why these buildings merit listing or form an important contribution to a conservation area and emphasize why windows are so critical. In order to reduce people's worries about listing, examples of good solutions which successfully incorporate change need to be publicized.
The conservation of modern buildings often presents new challenges due to their use of short term or redundant materials and their flexible design. Established conservation principles will need to be adapted to address these, however we need to show that these existing principles still form the basis for considering change and that each case should be treated on its own merits.
Encouragement needs to be given to the repair sector and to technical advances as well as supporting individuals and groups battling to conserve windows. The overall aim with Framing Opinions is to make people aware of the importance of windows and glazing to the architectural and historical heritage of the nation. The rejuvenated campaign will have to clearly show that it is not merely limited to the 'traditional' window but can embrace modern ones as well.

Chris Wood is a senior architectural conservator working in the Architectural Conservation Team of English Heritage, and now coordinating the Framing Opinions campaign.



PVC windows that were finally agreed and inserted.

Note:

1. The case of the Boots D 10 factory is more fully written up by James Strike in DOCOMOMO Preservation Technology Dossier 1, *Curtain Wall Refurbishment - A Challenge to Manage,* January 1996.

Keep the spirit!

Window replacement in Rotterdam's 1900-1960 districts

Large-scale window replacement in some of Rotterdam's famous social housing areas triggered an active approach by the city's Review Committee. Their concern was not primarily the listed buildings, but rather to sustain the particular architectural quality of ordinary neighbourhoods. Information campaigns and consultancies now suggest solutions that bring benefit to such projects while making less compromise to the streetscape. The necessary data were provided through a market survey for replacement windows. The present research also spawned a dialogue with the industry to result in an increase of appropriate replacement products.

by Wessel de Jonge

Professionals that are dealing with the preservation of recent heritage will often run into the problem that building materials and components that were common only three or four decades ago, are no longer available today. Innovative developments in the building industry speeded up considerably since World War Two, partly through the introduction of new materials such as aluminium, plastics, and various types of glass, and partly through the industry's endeavour to respond to stricter building codes. The other side of the medal is that building products become outdated almost at the same pace. This appears to be the case also for windows, one of the oldest and most traditional features of buildings.

Typical 1900-1920s ring housing in Rotterdam after careful renovation. All illustrations by W. de Jonge except where stated otherwise.

Detail of a 1900-1920s timber window with stationary top light and recessed sash.

Typical 1920-1940s housing in Blijdorp, featuring horizontal timber windows with quite bold details.

Ongoing innovation in the industry and the increasingly strict regulations make earlier editions obsolete and, soon, in need of upgrading.

Historic windows

Windows are more than just a construction that closes off the interior from the exterior. A window is an element of contrast. It separates inside from outside, and connects them at the same time by allowing daylight and fresh air to enter when desired. It is also our window to the world, an intermediary between public and private, light and dark, and sometimes even between heaven and earth.

Windows are vital to the character of architecture in the widest sense and therefore decisive to our appreciation of a streetscape. A simple technical intervention such as window replacement can completely alter the character of a neighbourhood, and mostly for the worse. Over the 20th Century, the technical and architectural innovations regarding windows have been radical. Within a hundred years we have witnessed a development from relatively small custom made timber windows that had remained largely unchanged for ages, to ever larger units in timber, steel, aluminium and PVC.

This development has resulted not only from ongoing progress in the design and production of windows and larger glass panes. The introduction of the loadbearing structural frame to architecture, which is an essential achievement in Modern Movement technology, allowed for a light infill of the facades that was free of structural limitations. Large expanses of glass allowed the ingress of daylight and ventilation in unprecedented quantities. This eventually resulted in the industrially produced metal-glass curtain wall, a development that continues until today.

Rotterdam is a striking example of a city where this architectural development can be recognized in the faces of the buildings in the city's extensions, which followed each other at intervals of sometimes less than five years.

Rotterdam

Until the mid-19th Century, Rotterdam was a middle-sized town on the north bank of the river Meuse. With the Industrial Revolution the ever growing demand for affordable housing triggered new areas to be developed, which resulted in the urbanization of consequent rings around the centre of the city. All of these rings have a specific architectural character that is defined largely by the type, proportion, detailing and colour of the windows.

1900-1920 saw a continuation of traditional housing, though now for low-income families. Commonly it concerned individual, multi-family houses, sometimes grouped by two to five houses at a time. These city houses mainly involve traditional constructions with loadbearing walls at right angles to the street, with relatively heavy brickwork facades, and therefore with vertical windows.

The proportions of the windows are inspired by the Golden Section and are typically about two-to-one, commonly about 1.25 m wide and 2.5 m high.
The upper third part is mostly a recessed, stationary top light. The lower part is a vertical sash that is set back even further. As a result, these windows have a deep reveal, i.e. the depth of the jamb is relatively large.
As the window reveal plays an important role in the way that light is reflected, it lends depth to the window as well as to the facade as a whole. This type of window was inherited from previous centuries, though much smaller than the stout windows of the large 18th and 19th Century houses in Amsterdam, The Hague and the prewar centre of Rotterdam. Before 1900, these windows were typically painted in a cream colour, as continued to be the case in Amsterdam and The Hague. In Rotterdam the typical colour scheme changed to dark green for the top light and the sash, lined by a cream coloured window frame itself.
1920-1940 was characterized by a growing interest in new and modern construction methods. Although building structures remained largely traditional in their loadbearing function, architects became increasingly interested in modern innovations. According to the agenda of the Modern Movement, large windows served the ingress of daylight and fresh air. The residential blocks in neighbourhoods like Blijdorp are characterized by big, horizontal windows with large areas of glass, over horizontal brick spandrels.
In these areas a slightly traditional flavour can as well be traced, particularly in the many brickwork housing blocks where timber window frames have been used. The units typically feature double-hung sash windows in the proportion two-to-three or one-to-one, with a large vision panel in the middle. Timber posts and sills are mostly rather heavy, and relatively rich in details and decoration so as to match the expressionist tendency in many of these blocks. Such windows are often fully cream coloured, though the dark green can be found as well.
In the same neighbourhoods, more straightforwardly modern architecture features steel framed windows, thereby optimizing the ingress of daylight to a maximum. Steel windows are more often asymmetrical with top and side-hung casements, again with a large vision panel as a central part. Steel framed windows are found in a variety of colours, though dark green or blue, black and beige are most common. Mostly the casements are painted so as to hide their presence.
1945-1965 was marked by the introduction of mass production to housing. Industrial building methods were employed to produce loadbearing structures with light infills. Facades were developed that consisted of floor-to-ceiling timber fronts, featuring top and side-hung casements, large vision panels, and spandrels of wired glass or coloured panels. Timber quality was mostly poor, the detailing very simple, the glazing single. The use of colour is mostly restrained, often white, beige or sandy-gray, though casements are

Detail of a 1920-1940s steel framed window.

Typical 1920-1940s modernist housing in Blijdorp featuring horizontal steel framed windows.

commonly painted in a contrasting colour. This architecture is found for instance in the famous Pendrecht development by Lotte Stam-Beese of the late 1940s, the Netherlands entry for CIAM 1949 in Bergamo.

Replacement problems

When in a bad condition, the repair of windows may be considered, especially when listed historic buildings are concerned. Still, in case of ordinary public housing renovation, replacement is much more common practice. It is often less expensive, comes with a full guarantee, allows for technical and physical improvements, and meets present day quality standards. By the way, this implies that in case of replacement we also have to stay alert for additional ventilation inlets (sometimes with bulky 'mufflers' for soundproofing), safety railings, reflective glazing and so on.

In most cases the economic arguments are decisive. Sales employees in the replacement window market are known to be rather aggressive. Especially in PVC sales, outdated windows are sometimes dumped on the market, which means that any architectural argument is immediately overruled. We see this happening now in the former socialist countries in Europe, which are completely overrun by the German PVC industry, victimizing the historic neighbourhoods of Poland, Hungary, Czechia and even the former Eastern Germany.

When analyzing the main problems with window replacement in Rotterdam's housing districts, the following issues can be identified.

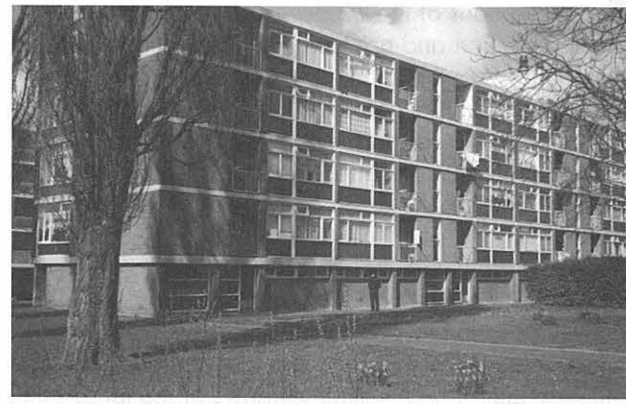
1900-1920s neighbourhoods have been the stage of the majority of window replacement until recently. Because these city houses were typically designed individually, single solutions for each house do not conflict with each other as easily as is the case with the large 1930s blocks with individual apartments.

Still, the timber or PVC replacement products that are typically applied here are mostly completely different from the original windows. One of the most apparent differences is that, regardless of the material used, the rabbet and bite are typically deeper to accommodate multiple glazing units, resulting in heavier profiles.

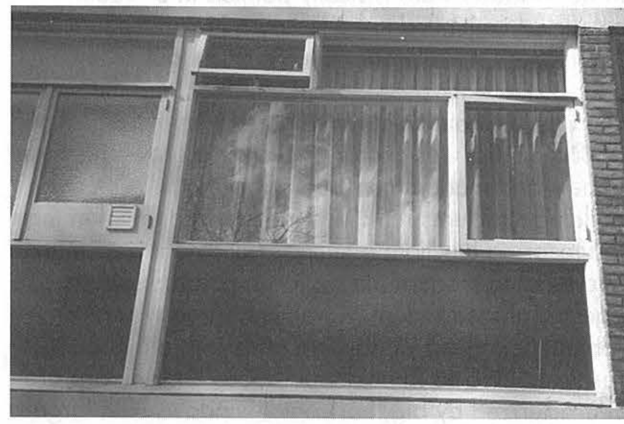
A problem with the first generation of PVC windows, which are glazed from the inside, is that they lack a proper reveal so that the glass is set almost flush with the surface of the window frame, causing a dull and expressionless face. These mostly German products do not match with the architectural characteristics of traditional Dutch architecture.

About five years ago, a new generation of plastic windows with a proper reveal - that reminds the original detail of timber frames - has been introduced to the Dutch market. It is significant that the primary reason for the development of these more appropriate products has been a continuous and persistent crusade against PVC windows by some of our municipal Review Committees for Architecture[1]. Responding to their complaints about the flush appearance, some manufacturers introduced PVC windows with a top light more in front over a recessed lower part - more or less like the original timber windows, although the lower part is now mostly a German type *dreh-kip* window instead of a sash.

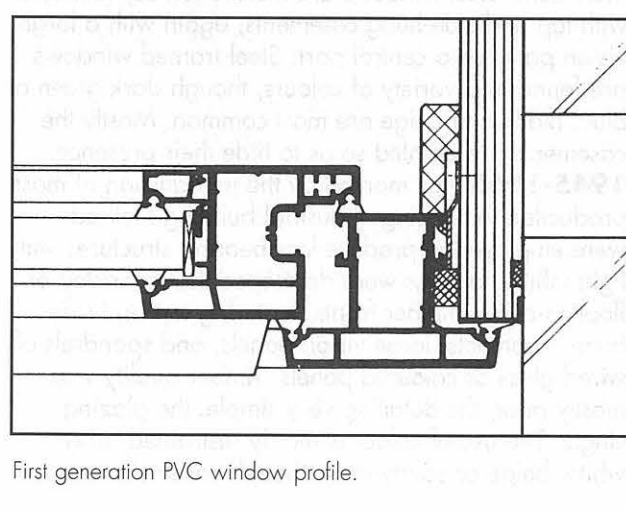
Another pain was the initial choice of colours. The basic tone is a brilliant white with a blue shade, while sash were also available in bright red, yellow, blue, and green, and in a variety of wood prints. This selection was not only incredibly limited, but also totally inappropriate for the Dutch market. To counter the increasing resistance against PVC windows, a few



Typical 1945-1965 housing in Pendrecht with floor-to-ceiling timber fronts.



Detail of a Pendrecht timber front.



First generation PVC window profile.

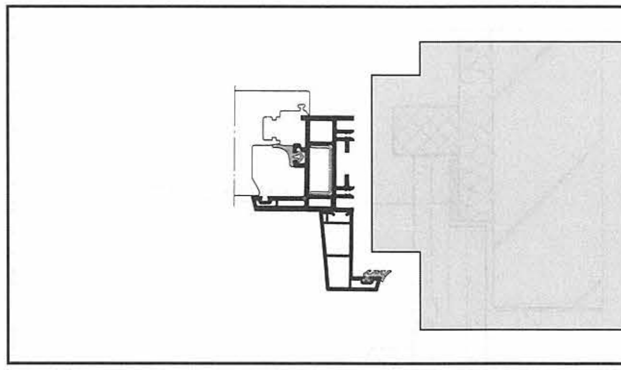
manufacturers started to produce cream-coloured PVC windows, which unfortunately looked more like 'butter' than 'cream' - to stick to the dairy range.
1920-1940s areas saw things go wrong also for another reason. The spacious apartments in the large blocks have often been sold out individually to the former tenants. At random interventions by private owners of single apartments created a patchwork of repair and replacement on the basis of individual preferences. The overall architectural consistency, which is so highly characteristic for these blocks, has consequently been lost. Though a full-scale intervention of such buildings is no guarantee to a better result, some degree of consistency is more likely to be achieved.
In the 1920-1940s areas similar problems regarding timber windows occur as found in the earlier 'ring'. Remarkably, the replacement windows that appear heavy in turn-of-the-century housing, again look too light when applied in these expressionist blocks.
The apartment blocks with steel windows represent a particular challenge, since such windows are not easily replaced in a way that is architecturally respectful and responding to present performance standards at the same time.
1945-1965s postwar areas were the next to be taken up. Because timber quality in those years was typically extremely poor, window replacement is almost inevitable when postwar public housing renovation is considered. Larg-scale intervention in some of Rotterdam's famous postwar areas was due, and the municipal Review Committee decided to change tack from reviewing individual permit applications to a more active approach by information campaigns and consultancy.

Review Committee

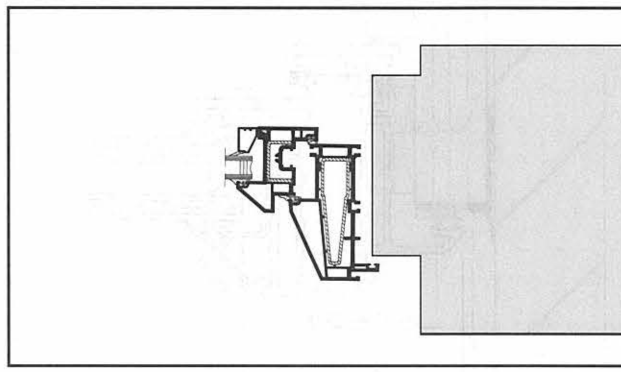
The new approach of the Review Committee was to respond to three main issues:

- To obtain an insight in the variety of replacement units available;
- To obtain an insight in their technical, financial and aesthetical qualities, in order to suggest alternative solutions for unfavourable proposals;
- To promote full-scale window replacement for apartment blocks rather than individual interventions, by stimulating concerted action from owners' associations.

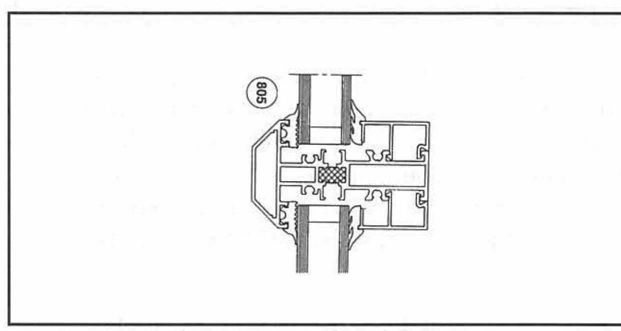
The Committee decided it was essential to them to understand economic arguments as well, and how to balance these with architectural values and general performance standards, in order to respond properly to the questions emerging from the field. This was a slightly delicate policy in legal terms as the Committee is of course not authorized to act as a consultancy, or to promote certain products over others.
Also, the municipality had been rather easy on window replacement so far and a more strict interpretation of law could not be enforced overnight. As long as the general lay out of a window and its proportions were



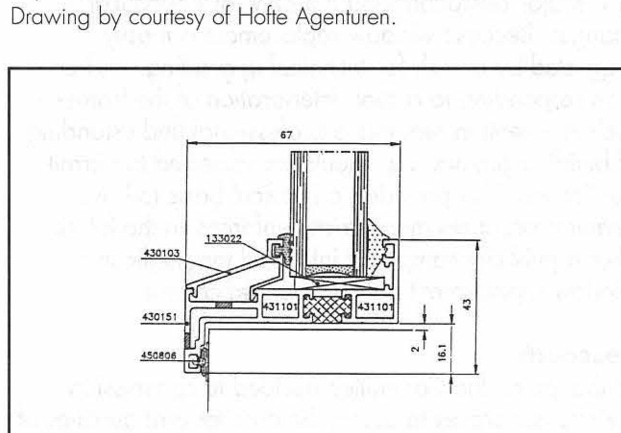
PVC window profile with 'added reveal'. Kömmerling Eurodur VS. Drawing by courtesy of Kömmerling Nederland.



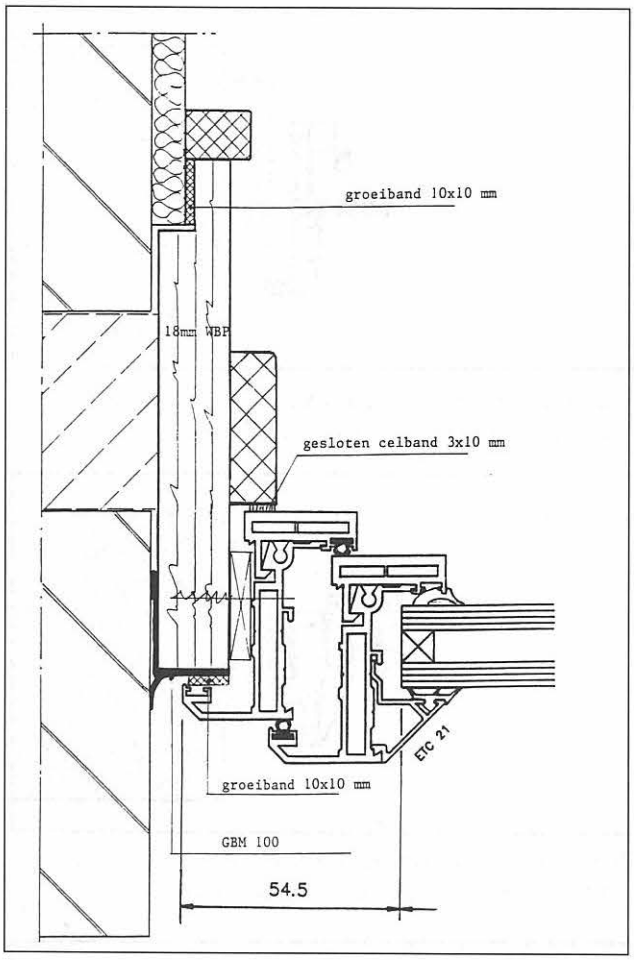
PVC window profile with 'integrated reveal'. Forbo-Helmitin 2000 KS. Drawing by courtesy of Forbo-Helmitin.



With inward opening aluminium systems, a bevelled part is typically added on the outside, producing a greater overall depth. Schüco Iskotherm S, a 40 mm wide series.
Drawing by courtesy of Hofte Agenturen.



With most outward opening aluminium system, bevelled glass beads remind the putty setting and still allow for a minimal overall depth. Alcoa 43 series. Drawing by courtesy of Alcoa Systems.



This outward opening Duotherm window has very slender features, as the thermal insulation is provided through the PVC flange on the inside. In other insulated aluminium profiles a thermal break in the core of the profile affects their static performance, that has to be compensated by a greater overall depth. Drawing by courtesy of Geerdink Bouwspecialiteiten.

not altered - even if the materials and details changed - window replacement had often been allowed without a permit, although the Building Act requires a permit for any 'major alteration' and not only for aesthetical changes. Because window replacement is mostly suggested by a wish for technical upgrading - rather than responding to actual deterioration of the frames - such intervention requires a professional understanding of building physics and should be subjected to permit application. This provided a juridical basis to have permit procedures more strictly enforced in the future, after a publicity campaign informed the public that window replacement policies were to change.

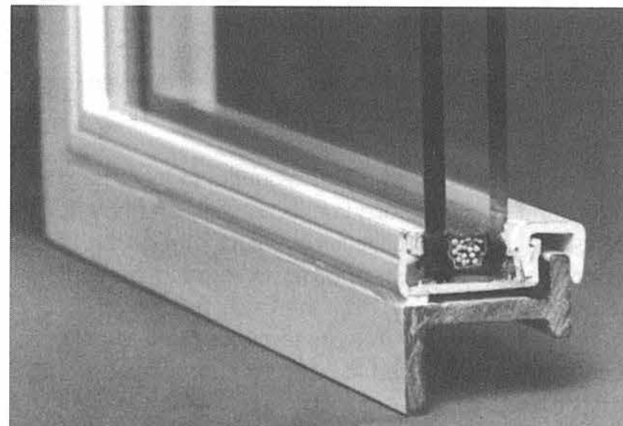
Research

At that point, the Committee decided to commission various researches to assess the architectural qualities of the major neighbourhoods. The findings of such surveys might lead to a future designation of these neighbourhoods as architectural heritage.
Closing the net from two ends, the Committee invited our firm to set up a market survey for replacement windows. Our proposal elaborated on a 1990 research for the National Department for Conservation on modern heritage in general, and the replacement of steel framed windows in particular[2]. An inventory was made of window units that, beforehand, were considered more or less suitable to replace old windows. Four groups of products were distinguished on the basis of the material: steel and aluminium, both to replace steel framed units, and wood and PVC to replace timber windows.
Though many severely oppose plastic windows for various reasons even for contemporary buildings, the Committee's brief was clear. We had to be pragmatic and recognize the massive preference of house owners for PVC windows for maintenance reasons.
The Committee's concern was not primarily the listed buildings, but rather to sustain the particular architectural quality of some ordinary neighbourhoods. The manufacturers of all 36 products were asked to complete an extensive enquiry form, arranged according to eight entries that were relevant to the Committee: Environment, Strength and Building Physics, Surface and Colour, Glazing and Rabbets, Door and Window Furniture, Installment and Maintenance, Guarantees, and Aesthetics. Their answers and the units themselves were then reviewed, assessed, calculated, turned upside down and inside out. The information was processed in the form of matrices to allow the officers easy access to the large amount of information, in order to reply efficiently to questions like:

- Which steel replacement products have inside glazing and are yet available with outward opening top-hung windows?
- Which competitive PVC products come in dark green with a ten year full guarantee and a side detail of 110 mm or less?

Trial projects

In coordination with the Committee, four facades were selected for a theoretical trial project. For each of these models four products of various nature were selected,



The French Confortglace system provides minimal double glazing units for salvage steel framed windows. Drawing by courtesy of Grona B.V.

that - within their category - appeared from the enquiry as most suitable for the given situation. Each of the trials was designed so as to clarify specific questions.
For the 1900-1920 facade, four products were selected that were specifically developed for the replacement of timber windows with vertical sash. The trial for the replacement of 1920-1940 horizontal timber window involved some new PVC profiles with a reveal, to explore their suitability for the expressionist' apartment blocks of the 1930s as compared to a timber alternative.
For the 1920-1940 horizontal steel window a trial was drawn up involving four slender contemporary metal products, compared to the retention of the original windows and fitting them with a French system for double glazing that is particularly marketed for salvage steel frames.
For the 1945-1965 floor-to-ceiling timber fronts, three specific products for the replacement of such fronts were compared with a certified timber-repair system.
In simulated practice, a number of window systems appeared unsuitable to respond to some essential features of the original units. For instance, French windows are a problem for almost all current window systems[3]. With aluminium systems it appears impossible to combine inside glazing with outward opening casements and doors, or vice versa, in an architecturally satisfying manner. Similarly, the combination of inward opening casements with outward opening (balcony) doors is a problem for many PVC systems, but a common feature in Dutch architecture.
With this part of the research, also the way the units were to be installed into the facade could be evaluated. It appeared that some of the most elegantly detailed units could not be installed properly, resulting in rather bulky side details.

Results

The research resulted in an extensive report, which is now used by Committees nation-wide to evaluate window replacement proposals. It serves municipal officers as a source of background information that enables them to provide a more professional response, and to counter arguments of technical and financial nature.
A free brochure has been based on this report to inform building owners about the new policy, and to support the Committee's information campaign.
Equally important is that our research appeared a rare and well-appreciated opportunity for the window industry to obtain information from the professions. Many manufacturers mentioned that finding out what architects, planners and heritage officers really wanted was one of their main marketing problems.
Also they realized that the Committees were becoming stricter, and something had to be done to secure their market. Surprisingly many aesthetic improvements appeared relatively easy to realize. Some improvements were even introduced within a few months after our initial inventory, well before the research was completed and reported. The majority of PVC manufacturers for instance changed their cream colour from RAL 1013 (butter) to RAL 9001 (light cream, more or less according to the traditional colour) within four months time. More manufacturers introduced particular profiles with a deeper reveal to the Dutch market.
Coincidentally, several new sash window systems were introduced - some in PVC, some in timber - that were designed to satisfy present performance standards. Some of these appear of great help in restoration planning also for older historic buildings.
Aluminium window manufacturers continued their efforts to further minimize the section of their replacement series, which mostly involve bevelled window profiles. Various new series have been introduced in the past years. Schüco is now[4] the leader of the pack, with their inward opening 40 mm wide Iskotherm S series, while the most slender outward opening system is Alcoa's 43 mm series. Still, their overall suitability also depends on their respective depths, which is typically larger for inward opening systems.
This dialogue with the industry resulted in a major increase of the number of options for respectful window replacement. It triggered a general improvement of the architectural quality in public housing renovation in Rotterdam, since the municipal authorities are now better equipped to retain the spirit of Rotterdam's 1920-1960s districts.

Wessel de Jonge is an architect in Rotterdam, the Netherlands. He is a member of the DOCOMOMO Specialist Committee for Technology.

Notes:

1. According to the Dutch Building Act each project submitted for a building permit, whether new construction or renovation, has to be considered for its merit by a Review Committee for Architecture, with reference to the architectural qualities of the surrounding buildings. In some cases, like in Rotterdam, the municipal Heritage Committee has merged with the Review Committee. The Committee is an advisory body to the mayor and aldermen, who formally submit an eventual permit. They may decide not to follow the Committee's advice in case of other important interests.
2. 'The Modern Movement and Restoration. Determining the Impact of Various Restoration Options', research report for the National Department for Conservation, Dutch text with extensive English summary, Zeist 1990.
3. French windows involve two side-hung casements opening from the middle, without a central post. With this type of windows, the central joint between the casements is difficult to make draughtproof.
4. At the time of the seminar in May 1998. Since then, other window manufacturers came up with aluminium products with similar dimensions.

An artificial look

PVC replacement windows in Tallinn

For years, the PVC industry swept Western Europe with inappropriate replacement windows while heritage authorities were desperately trying to prevent their instalment to historic buildings. Since then, the window industry has been successful in improving the aesthetic performance of their products in terms of styles and colours.
But the earlier series are now dumped at Europe's new markets, destroying the streetscape of many historic cities in Eastern and Central Europe. A field report from Tallinn, Estonia.

by Andri Ksenofontov

The first large facade where PVC windows were installed in Estonia was that of the hotel 'Viru', a 23-floor rectangular Niemeyerian building in the centre of Tallinn, in 1992. However, the Nordic sun produced an unwelcome surprise: the material swelled up in the heat of the sun, making it impossible to open the windows in summer.
After 50 years of Soviet rule wooden windows were dismissed as being 'all rotten', largely because of poor quality repair work done by state companies in the past. The windows had just accumulated layers of dirt and paint. When a friend of mine had her Art Nouveau wooden windows repaired, people thought they were plastic because they again looked clean and sound.

Tasteless bureaucrat

With current building technology it is as easy to replace windows as it is to sew on new buttons on a garment. As a result, glaringly white units of different design often appear on the same facade.
Manufacturers and customers do not care, not even in the case of listed buildings admired by other citizens. The market's interest in PVC windows may be explained by their low cost.
One might ask in whose interest it was to change sound oak windows for PVC ones of poor design in the Tallinn City Government building, the most outstanding Art Deco masterpiece in town, in 1994. Although the uniformity of the facade has been retained, there is no sense in the division of its tall windows into two with a vertical bar, instead of the original six-pane design. The building has acquired the boring face of the tasteless bureaucrat who divides his own front in two with a tie just because everyone else does so.
When the officer in charge was asked why he had allowed such a change to a building listed by city government, he explained away by saying he did not know it was listed, sorry. Someone involved in the case later reported that this 'ill-informed' city officer had his own house refurbished soon after.

A simple house of the 1920s by Herbert Johanson now displays a doubtful demonstration of progress. The PVC units to the left contrast sharply with the old wooden windows to the right. All photos: Andri Ksenofontov.

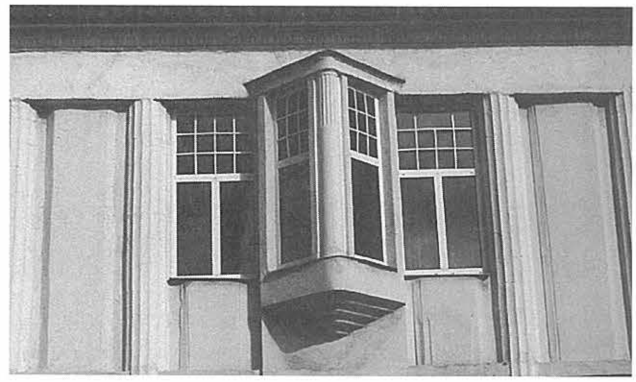
Bad examples

The PVC business may attract many progressive-minded people. One marketing agent has suggested that building technology has always come to Estonia from Germany and now Estonians again had to follow the German fashion. Visiting St. Petersburg last July, I wondered what might have been the examples for the PVC windows in the facades lining the historic canals Fontanka and Moika, and crawling along the river Neva towards the Winter Palace.

If PVC units are acceptable as building components in new architecture, they cause great damage to Tallinn's traditional wooden buildings. Unlike the old windows, PVC units do not breathe and totally change the microclimate of a building.

In the previous edition of the DOCOMOMO Journal, Wessel de Jonge quoted my comparison of PVC windows to whistling lollipops, made at the Copenhagen window seminar. I believe that however well designed the lollipop may be, it will never replace the whistle. Likewise, in historic facades PVC windows will never be anything more than cheap plastic imitations of their wooden predecessors.

Andri Ksenofontov is a architect inspector with the Central Board of Antiquities of Estonia.



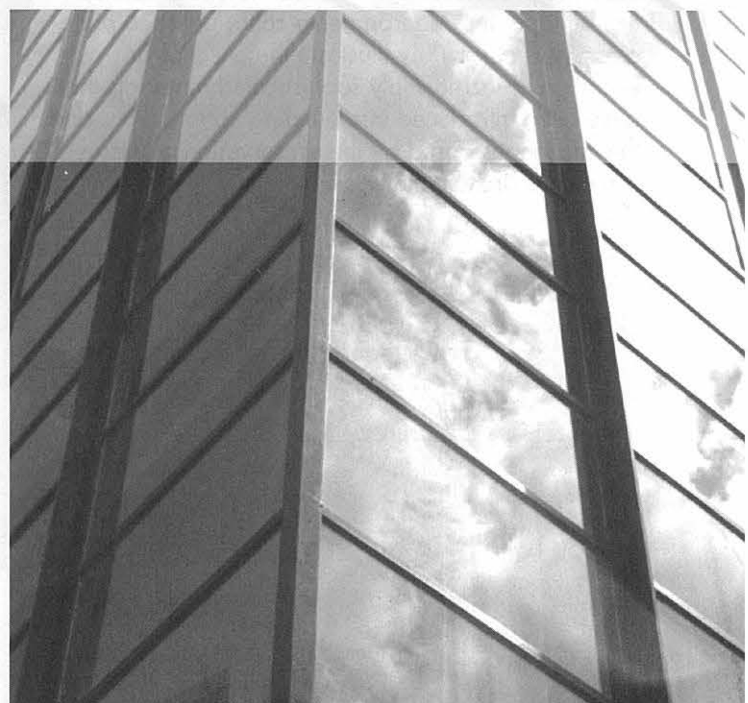
The Art Nouveau architecture of the Tallinn Power Station (H. Schmidt, 1910) is compromised by new PVC windows (top). The technical quality is poor as is clearly visible from the top light details (left).

PVC windows aesthetically compromise this 1912 traditional building in Tallinn's Koidula street.

A sad sight in Tallinn's Old Town. Bright and white when new, today dirty and ugly, and culturally out of place.

The front of the Tallinn City Government building, an outstanding example of Art Deco, changed into an expressionless face when PVC units were installed in 1994.

Case Studies



Restoration of a 19th Century curtain wall

The Reliance Building of Chicago, USA

Restoring the windows of any historic building presents numerous challenges that require creative and sometimes unique solutions. The differences between the original materials and details, and today's construction standards and code requirements often conflict. Restoration solutions are also limited by the technology available at the time the restoration work is undertaken, such as the way glass is made. The case study described below offers a snapshot of the state of preservation of early curtain walls with emphasis on glass, presenting the restoration of one of the most important early skyscrapers in the United States, the National Historic Landmark Reliance Building in Chicago.

by T. Gunny Harboe and Stephen J. Kelley

The Reliance Building heralded an era when construction technology made the change from hand craftsmanship to standardization and reliance upon machine processes. Curtain wall materials applied in this building include iron, terra cotta, polished plate glass, and putty. They illustrate the onset of an evolution of increasingly sophisticated materials that have been introduced into building construction, and the challenges posed by the preservation of these sometimes archaic materials.

Historic view of the Reliance Building ca. 1896.
Period photo, collection McClier, Chicago.

Unique envelope

Of the Historic Landmark Reliance Building, Carl Condit wrote, 'If any work of the structural art in the 19th Century anticipated the future, it is this one.' Siegfried Giedion referred to the Reliance Building as the 'swan song' of the Chicago School. The 15 story skyscraper in the heart of Chicago's loop was completed in 1895 according to the designs of Charles Atwood of D. H. Burnham & Co. With its extensive use of glass and minimizing of exterior masonry, it was a precursor of the post-World War II glass curtain wall.

North facade before restoration, 1994.
Photo: T. Gunny Harboe.

Using the most advanced construction technology at the time, the structural frame and exterior envelope above the previously completed first floor was erected between May and November of 1894 and the upper floors were occupied in early 1895. A unique feature of the exterior envelope was the use of a system of cast iron vertical mullions spanning from floor-to-floor and rails spanning between mullions. This gridwork formed frames into which all the fixed glass elements were placed. The terra cotta was connected directly onto the gridwork thus eliminating the need for much of the masonry back up. The exclusive use of glazed terra cotta as cladding was unprecedented in Chicago and considered to be innovative because it could clean easily. The result was the minimizing of the terra cotta mullions and the concealment of the window frames within the terra cotta mullions.

Rehabilitation

The history of the Reliance Building through the 20th Century is that of unfortunate alterations and lack of proper maintenance. In 1941 the base of the building was altered when the bottoms of two of the three projecting bays, were removed to accommodate signage. By 1950, the cornice at the top of the building had also been removed. Many of the large windows had cracked and were replaced with smaller panes of glass with vertical mullions of aluminum that bisected the once magnificent windows. Most of the large and delicately proportioned double-hung wood windows had deteriorated to a point beyond repair and the building had become noticeably darkened by soot. By the mid-1980s, the building posed a danger to pedestrians due to falling terra cotta and its future was in question. After a number of failed attempts to rehabilitate the building by the private sector, the Reliance Building was purchased by the City of Chicago in 1994 and funds were allocated for its restoration and rehabilitation.

North facade after restoration, 1996.
Photo: T. Gunny Harboe.

Exterior restoration

Phase I of the project discussed below was the restoration of the Reliance Building's famous exterior that was completed in early 1996. As part of Phase I, an extensive Historic Structure Report was prepared which discussed the history of the building, technical issues regarding its construction, conditions observed, and preservation approaches. Special emphasis was given to the building's curtain wall which required extensive investigation. This included visual inspection of all of the more than 14,000 units of terra cotta, selective disassembly, material testing, testing of cleaning techniques, and survey of the windows. While only a handful of the original architectural documents were available for review, details of the facade did exist in architectural drawings and in historic publications.

The investigation revealed that the terra cotta portions of the curtain wall were under a tremendous build up of compressive stresses. The three factors contributing to this condition were: the foreshortening of the steel frame under the weight of the building, the expansion of the terra cotta masonry due to environmental forces, and a lack of means within the curtain wall to accommodate these contrary forces. It was also determined that terra cotta units could not be removed from the wall for replacement or repair without causing damage to adjacent panels, until the stresses within the wall were addressed.

Reliance Building after restoration, 1999.
Photo: Jon Miller of Hedrich Blessing.

Terra cotta

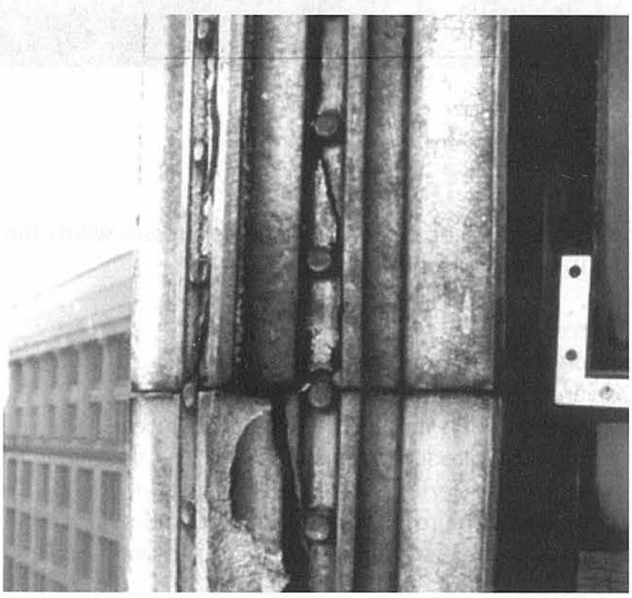
To address the stresses within the curtain wall, it was determined to introduce temporary horizontal expansion joints through the wall at each level. The joints were introduced continuously below floor line relief angles, starting at the top level and working downward. The result was a graduated relaxation of stresses as the expansion joints were installed floor by floor.

A contemporary curtain wall features a means at specified floor levels to transfer the wall loads into the

building structure. The Reliance Building curtain wall was transitional - shelf angles are located in most but not all areas.
It was decided by the project team that shelf angles would not be added where none had originally existed, thereby respecting the original technical features of the curtain wall as defined by its period in history. Therefore, once the expansion joints were completed and the stresses were relaxed, the joints were again filled with mortar to reinstate the originally intended integrity of the curtain wall. Stresses will eventually re-appear in the curtain wall, but they will never achieve the same level as before the restoration. Once the stresses were relaxed, restoration of the terra cotta curtain wall could proceed. Approximately 3,000 units were removed, 1,000 of these were conserved and reinstalled and 2,000 were replaced with newly fabricated terra cotta. In addition, about 500 terra cotta units were repaired *in situ*.
In addition to the terra cotta, the original cornice was reinstalled. Rather than make it out of the original terra cotta material which was cost prohibitive, it was decided to make it out of cast aluminum. This material is lighter, more durable, and easier to maintain than terra cotta, and it was possible to get a very good color match. The reconstruction of the cornice brought the building back to life in a way that could not have been achieved without it.

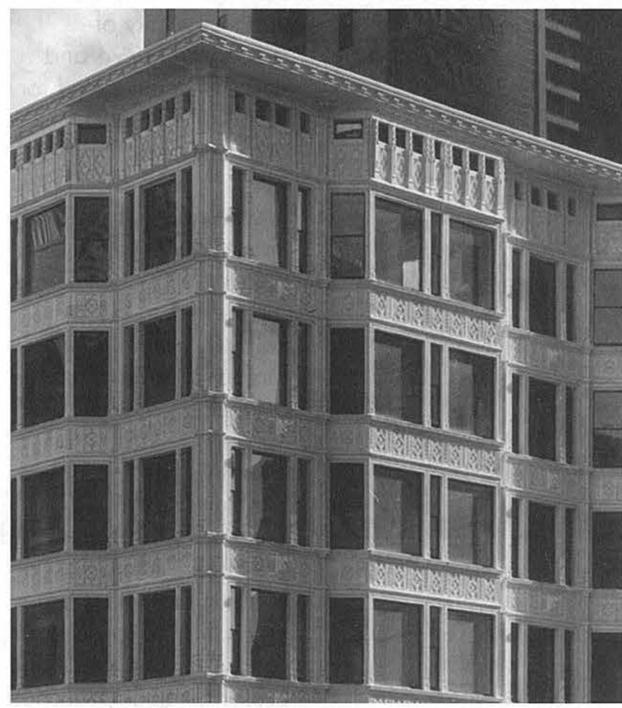
Windows

In addition to the terra cotta parts of the curtain wall, the large 'Chicago' style windows had to be addressed. Chicago style windows are characterized by a large, inoperable picture window flanked by double-hung windows. The original picture windows were composed of large polished plate glass set within the cast iron gridwork. Many of them had cracked over the years and had been replaced with two smaller



Deteriorated terra cotta mullion piece, 1994.
Photo: T. Gunny Harboe.

Reliance Building cornice before restoration, 1994.
Photo: T. Gunny Harboe.



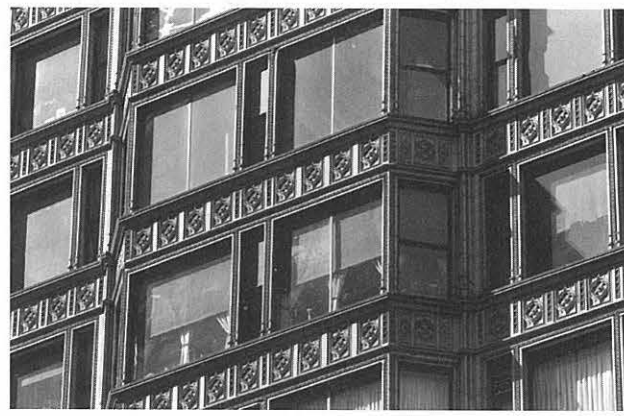
The new cast aluminum cornice, 1996. Note reflections on the new windows. Photo: Jon Miller of Hedrich Blessing.

panes bisected by an aluminum mullion. The flanking wood double-hung windows were set behind the terra cotta cladding hiding much of the exterior wood frame. They had also suffered terribly from the lack of routine maintenance, and were severely deteriorated.
The client had specified that insulated glass be used in the restoration to make the building more energy efficient and comfortable for future users. In addition, the proposed mechanical system was designed as a 'closed system', meaning that the window systems would be rendered inoperable. Therefore natural ventilation was not an issue.

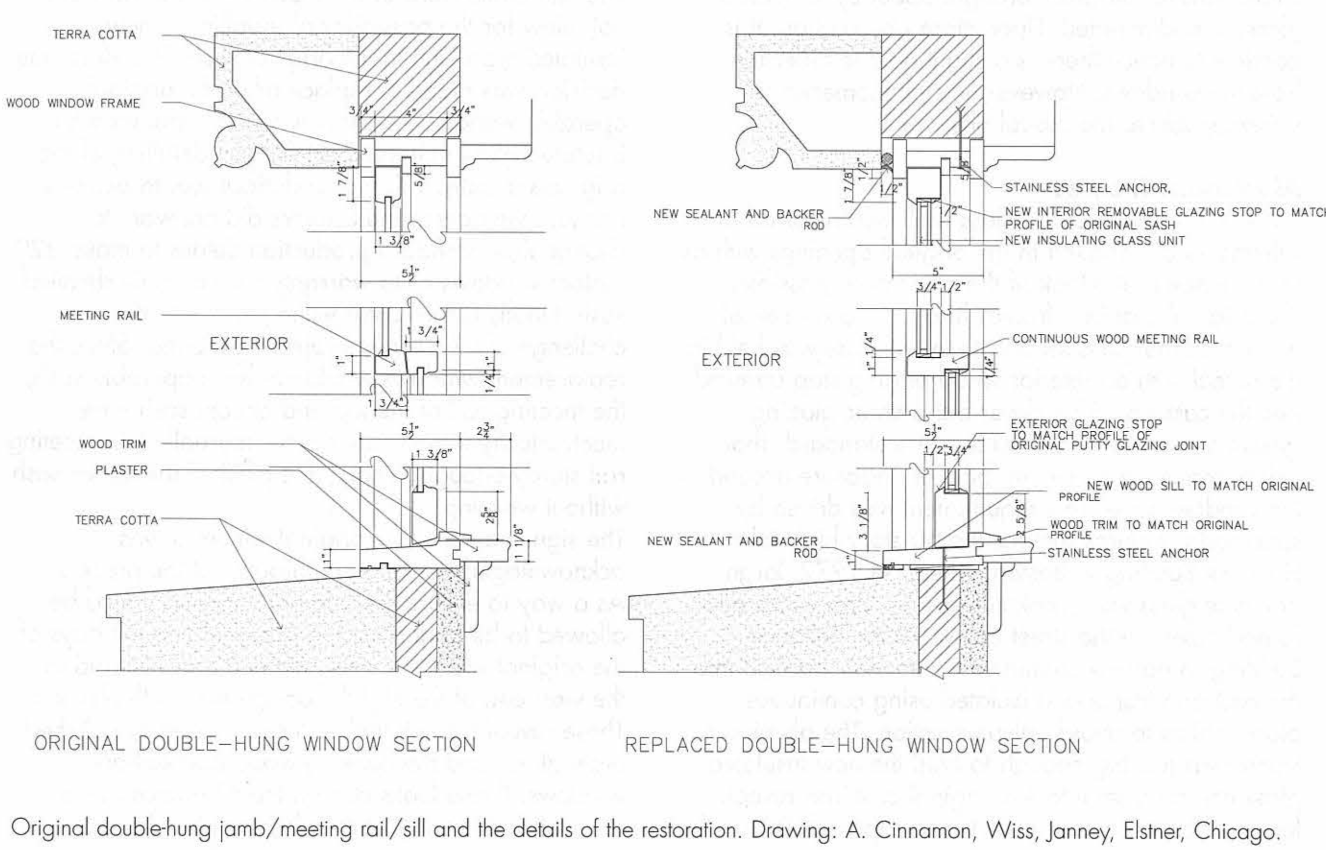
Picture windows

The large fixed windows set in the cast iron frames presented a series of challenges, defined by replicating

appearance while meet industry standards, building codes, and energy requirements. The first issue was that polished plate glass, such as that in the original building, was no longer commercially available in the United States. With the widespread acceptance of float glass in the early 1960s the costly process of making polished plate glass was abandoned. Although float glass appears relatively flat to the untrained eye, it is not as flat as polished plate. This difference between the two is apparent by the way the two glasses reflect light and shadow.
Commercially available plate glass has a flatness that is closer to polished plate glass, but the criteria established for the project ruled out its use. Because so much of the original glass in the building had been damaged or replaced, reuse of the remaining original glass was not feasible.
The next challenge was that, though the building code and engineering analysis allowed for the use of annealed glass for the large windows of the Reliance Building, the United States glass industry typically requires glass lights of this size to be tempered or heat strengthened. This is primarily for protection of the workers as they fabricate, handle, and install large panes of glass. Tempering of glass, by running it through an oven after it has set, increases its strength dramatically and makes it harder to break. This will increase its wind-load carrying capacity, always a concern with skyscrapers. However, tempered glass is noticeably warped compared to annealed glass.
In addition, the rollers upon which the glass is set within the tempering ovens can leave distinctive and unsightly distortions in the glass that appear as stripes under certain reflective conditions. This 'roll ripple' effect was not acceptable to the team. Fortunately, a glass manufacturer was located who was willing to meet the challenge of fabricating the large panes of insulated glass without requiring tempering.
Another challenge was that of the double reflection given off by the insulated glass. Being composed of two panes of glass separated by an air space, insulated glass will give two closely interposed reflections rather than one. The effect from afar is that of a soft, slightly out-of-focus reflection relative to a sharp reflection given off by a single pane of glass. The final product chosen was an insulated glass unit

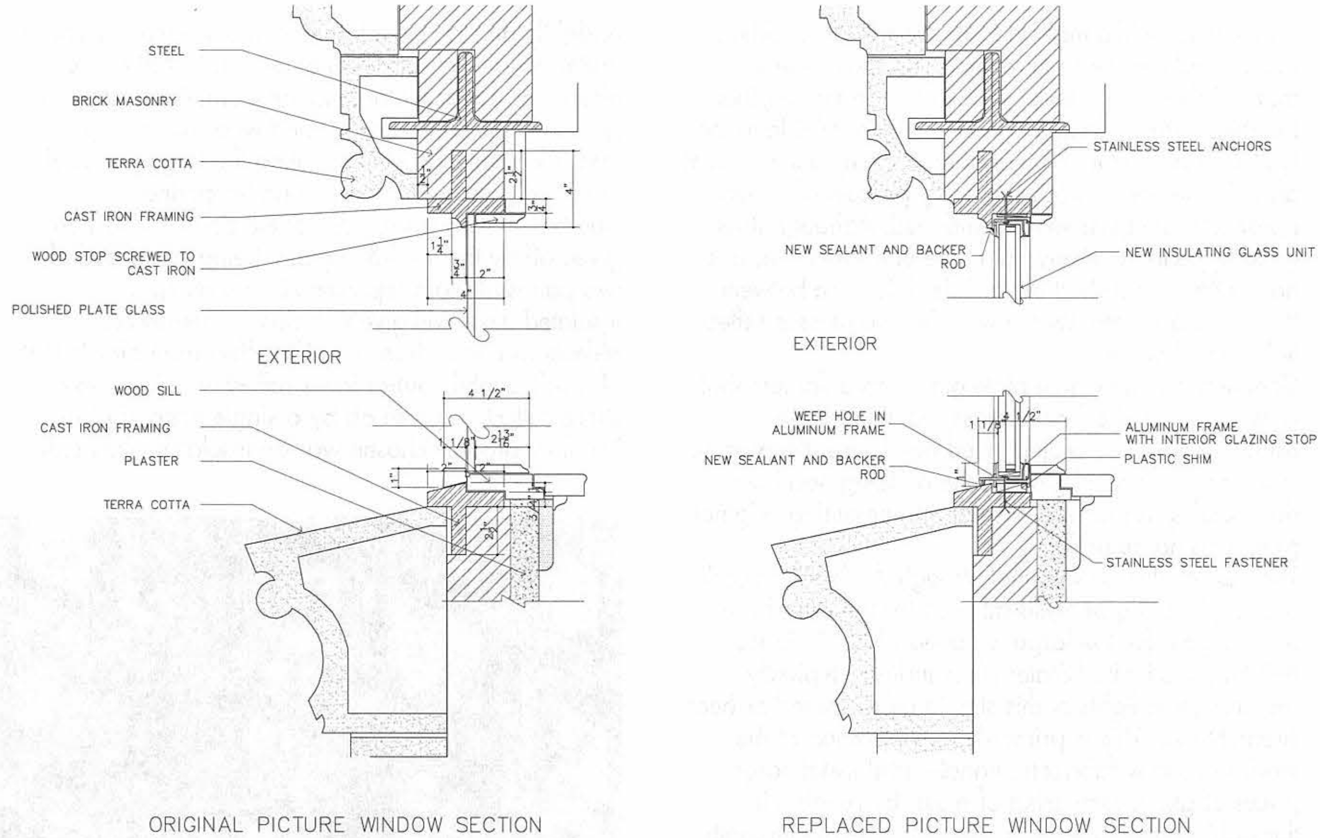


Windows before restoration. Note the aluminum mullions added to windows where large panes of glass were replaced. Photo: Richard Nickel.



ORIGINAL DOUBLE–HUNG WINDOW SECTION REPLACED DOUBLE–HUNG WINDOW SECTION

Original double-hung jamb/meeting rail/sill and the details of the restoration. Drawing: A. Cinnamon, Wiss, Janney, Elstner, Chicago.



Original picture window jamb and restored jamb. Drawing: A. Cinnamon, Wiss, Janney, Elstner, Chicago.

composed of sheets of annealed (and not tempered) glass. It was not possible to totally eliminate the change in reflectance brought about by the installation of this glass, however the most objectionable characteristic, 'striping' brought about by tempered glass, was eliminated. Upon close observation, it is possible to notice there is a slight double reflection from the windows. However, this phenomenon is imperceptible to the casual observer.

Aluminum frames

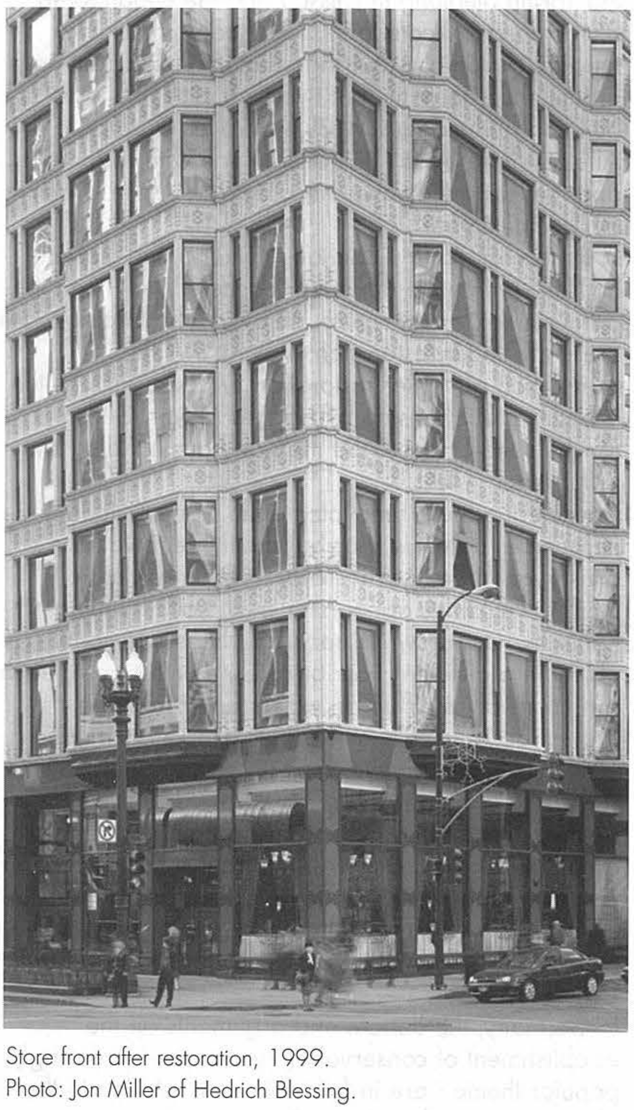
Once the problem of the glass itself was resolved, it still had to be installed in the original openings with as little change to the look of the original as possible. The original cast iron frames had a 1.25 cm reveal into which the glass set and then the glass was held in the reveal with an interior wood parting stop screwed into the cast iron. This clever but archaic glazing system did not meet current industry standards that strictly require a minimum 'bite' of enclosure around the window pane. This requirement was driven by spectacular failures such as the 60-story high John Hancock Building in Boston, where, in 1972, large panes of glass were shaken loose by high winds and rained down on the street below. At the Reliance Building, a narrow aluminum frame was installed into the cast iron frame and isolated using continuous plastic shims to avoid galvanic action. The aluminum frame was just big enough to hold the new insulated glass unit and, set into the original cast iron reveal, leaving about 1.5 cm of the frame exposed. Due to the large size of the windows it is impossible to see the aluminum frame when observed from the street.

Double-hung windows

The thin dimensions of the wood stiles and rails did not allow for the possibility of installing a new insulated glass unit in the original sash. Therefore, the decision was made to replace all of the original operable wood sash with new wood windows with insulated glass that matched the thin detailing of the originals exactly. This was a difficult feat to achieve because window manufacturers did not want to change their standard production details to make 220 custom windows or to warranty such a thinly detailed sash. Finally a fabricator willing to rise to the challenge of this unique project was found. Since the replacement windows would not have operable sash, the meeting rail of the top and bottom sash were mechanically joined making the unusually thin meeting rail sturdy enough to carry the glass of the upper sash without warping.

The significance of the original windows was acknowledged by the team throughout the process. As a way to ensure the original windows would be allowed to be understood, a group of two full bays of the original windows were retained and restored at the west end of the eighth floor on the north elevation. These reveal the original picture windows of polished plate glass, and the flanking wood double-hung windows. If one looks closely, the difference in the color and reflectivity of the glass can be viewed.

Store front before restoration, 1994. Photo: T. Gunny Harboe.



Store front after restoration, 1999.
Photo: Jon Miller of Hedrich Blessing.

The elevator lobby after restoration, 1999.
Photo: Jon Miller of Hedrich Blessing.

Conclusion

Phase II of the rehabilitation was started in 1997 and was just completed in the fall of 1999. The former Reliance Building has been reborn as the Hotel Burnham. It is a small boutique hotel that is already extremely popular with visiting architects from all over the world. As part of this phase of the restoration the original granite and bronze filigree storefront was reconstructed exactly as it had looked in the 1890s. The original first floor elevator lobby was completely reconstructed, with its multicolored marbles and elaborate ornamental metal elevator grills and stair. On a number of the upper floors, many of the original storefronts of the original doctors' offices survived and were restored to serve as the hotel corridors. The restored features include Carrara marble wainscot panels, mahogany doors and trim, original door hardware and a beautiful ornamental metal stair. The completed exterior restoration has received numerous preservation awards.

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Modern buildings and their windows

Some restoration experiences in Germany

The fenestration of modern buildings continues to require special care when conservation or replacement is considered. In Germany, a relatively large amount of buildings of the modern era have already been renovated or restored in the last decades, including the Weissenhof estate in Stuttgart and some of the so-called Bauhaus buildings in Weimar and Dessau. Three recent restoration cases illustrate the experiences with modern window conservation in Germany in theory and practice.

by Berthold Burkhardt and Dieter Rentschler-Weissman

In recent years in Germany, the restoration or renovation of a great number of buildings of the modern era has been undertaken. In the last decades especially, housing estates, such as the *Weissenhof Siedlung* in Stuttgart, the *Dammerstock Siedlung* in Karlsruhe, the *Rothenberg Siedlung* in Kassel, and not the least the *Taut Siedlungen* in Berlin, have been fundamentally renewed and renovated. Briefly disregarding the current backlog in urgent housing renovation projects like Taut's housing in Magdeburg, the *Törten Siedlung* in Dessau and the endangered *Blumenlaeger-Siedlung* in Celle, today the single-function buildings requiring renovation are gaining prominence. To name but two examples, the main building of the *Fagus-Werk* by Walter Gropius in Alfeld, where a start has been made with restoration, and the less well-known *Haus auf der Alb* in Urach by Josef Frank.

Bauhaus building in Weimar by Henry van de Velde, main facade with atelier windows.

In Dessau alone, the Bauhaus building, the master houses - where the Bauhaus' teachers lived - and the former employment centre, all by Walter Gropius, are presently under restoration. This follows the completion of earlier restoration projects, such as the access gallery housing by Hannes Meyer, Georg Muche's Steel House and the Kornhaus building by Karl Fieger.

Considering these renovated buildings individually, no general agreement or basic attitude towards conservation goals in the preservation of classic modern buildings appears to exist. Each building naturally has its own history, and is an individual object in a different state of repair. Furthermore, each project involves different owners and architects (though sometimes none) as well as local authorities with clearly different views. It is therefore not surprising if the procedures and results of such renovations not only differ, but also appear to be of greatly different quality. All too frequently, renovation results in more loss of original substance than had occurred over decades of use, change or neglect.

Confrontation

In Germany, the debate and arguments on the establishment of conservation goals - an increasingly popular theme - are in full motion. In relation to the above mentioned projects, they have gained an even sharper edge. Awareness of the problem is clearly increasing, initiated by a relatively small group of art and architectural historians, architects and conservationists, perhaps also fueled by the relatively recent inclusion of the Bauhaus buildings in Dessau

and Weimar - as the first classical modern buildings in Germany - on the UNESCO World Heritage List. It is of principal importance in this context to realize that the physical object itself raises the questions of conservation. Not only must the problems be solved, they first need to be recognized. That means that from now on there will be an increased confrontation between considerations as to art and architectural history, and those concerning physical and technical building problems. In the context of change of use, as is often the case in single-function buildings, or of changed user requirements as in housing projects, simple solutions are not to be expected.
The development of technical preservation measures that meet conservation standards is not nearly complete. Most of all, they are still not free from subjective directions and individual views on conservation. Three technological aspects have a close relationship to conservation issues:

- The use of current and/or historical technical processes in connection to questions of durability;
- The desires and demands of current and future users;
- The built original and the way of dealing with readable traces of history, on the basis of a technical and historical documentation of the building or projects' life history.

Through the example of three modern buildings, these problems and related processes are being documented and brought up in a book series in Germany[1]. The series will start in the autumn of 1999 with a volume on the Einstein Tower by Erich Mendelsohn in Potsdam, the restoration of which has recently been completed. This will be followed by the Muche/Schlemmer masters' house in Dessau by Walter Gropius, and the Villa Schminke by Hans Scharoun in Löbau (Saxony), both of which will be restored over the next two years, and then published, with support from the Wüstenrot Foundation. These are three exemplary models, in which the interrelation between art and architectural history, and technical and functional conditions will be shown.
The basis and direction for these projects are conservation issues including technical repair and the consideration of former and future usage. The existing buildings and the traces of their life histories are to be understood as originals, even if what was lost remains lost. Buildings as 'monuments', which are witnesses to material and immaterial as well as social history, cannot be renewed, rebuilt or improved, but must be repaired, even when this means that, in technical terms, they may remain 'patients' for an undefined lifetime.

Windows

Fenestration occupies a special place in the restoration and maintenance of modern buildings. Windows are more than just building elements or details. In architectural, technical and functional contexts, they are actually the most difficult building elements. The arrangement and effect of the window in the facade and the interior, its shape and type of application, its operating hardware, its materials, details, colour and physical performance, ventilation, heating and humidity as components of building physics, day and night time transparency, sun shading, and in some cases, safety: these are all aspects that circumscribe the complexity of a window's role in a building.
In contrast to the massive heat-accumulating building elements, the window is flexible, variable and light. Like the whole building, windows must be operated to adjust correctly to interior and exterior conditions, and finally to provide comfort. Much damage and unnecessary costs were created in buildings through the replacement of windows whose climatic context was not respected. Reduction of heat loss in order to save energy is, for instance, only a partial aspect.
In no other period in building history there have been so many and such short lived developments and experiments in building construction as in the first decades of the 20th Century. New materials were tried out and combined, with clear goals of acceleration, technical improvement and economic rationalization of building processes. Without restriction, this also applies to windows as building elements, although the technical and artisan methods of the 19th Century continued for wood and steel windows, as for example with traditional timber lights or casement windows, and steel framed windows with single glazing and typical T, U or L profiles. Almost without exception, the development and patenting of windows and window furnitures was primarily geared toward standardization. At first it had little to do with the profiles as such, and it was only much later that the integral relationship between glazing, frame and casement in terms of building physics was acknowledged.

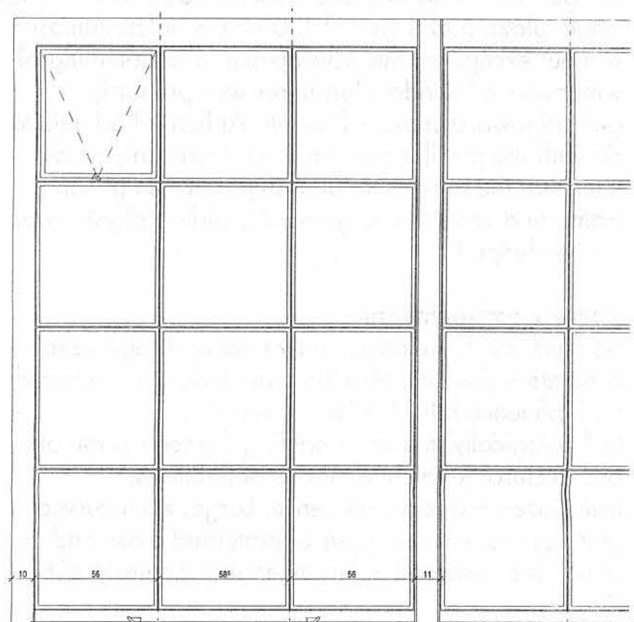
Törten experiment

As much as the relatively new steel and reinforced concrete industries, also the glass industry supported and influenced the Modern Movement technologically, thereby enabling the realization of architectural ideas and visions of lightness, transparency and translucence. Large, even curved glass panes, various types of patterned glass and glass block were all achievements of the early 20th Century.
A special experiment with new window systems in housing construction practice in Germany was tried out in the *Törten Siedlung* in Dessau.
The contemporary financier, the *Reichsforschungsgesellschaft* (State Research Society) in Berlin, supported and aided in the construction of different window types in timber, steel and concrete. The requirement from the financiers to monitor the functional and technical performance of the various window types over a longer period in order to collect

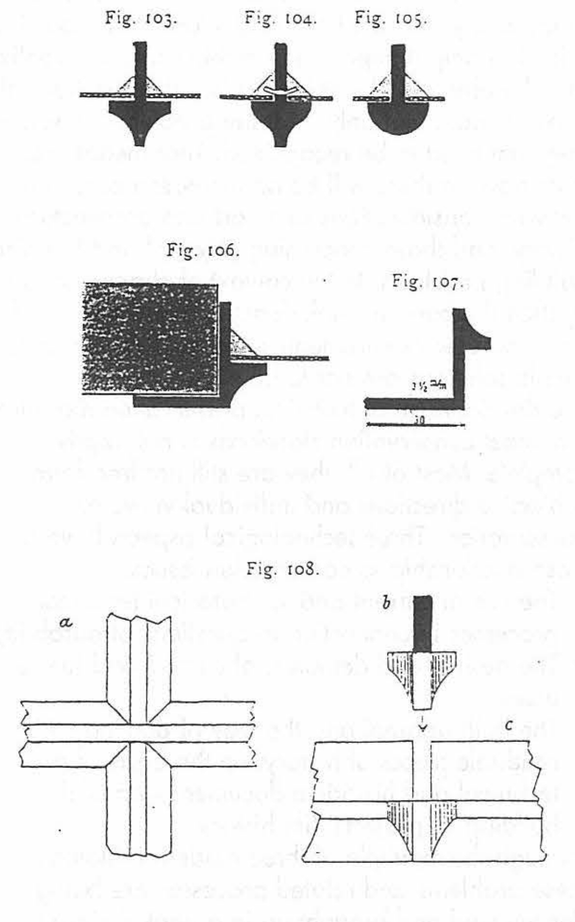
practical experience was abandoned after the National Socialists took power in Germany.[2] Steel windows with single glazing preponderate in window repair of modern buildings. Numerous windows have demonstrated a lifespan of more than seventy years, even in certain cases of lack of maintenance. However, with recent renovations earlier repairs have been found that seem to rely on doubtful analysis as to building physics.

Bauhaus Weimar

The Arts and Crafts School in Weimar was built between 1904 and 1911 by the Belgian painter and architect Henry van de Velde. This school and its buildings were the birthplace of the Bauhaus, directed here by Walter Gropius from its inception in 1919 to its move to Dessau in 1927. The main building, built in 1911 in a sculptural organic form, nevertheless already has elements that would reappear in buildings of the classical modern of the 1920s. After 1945, the group of buildings accommodated the *Hochschule für Architektur und Bauwesen (HAB)*, and then, after 1990, the Faculty of Architecture of the newly founded Bauhaus University in Weimar. The programme and influence of both the Weimar and Dessau Bauhaus buildings were decisive for their inclusion in the World Heritage List two years ago. A necessary and comprehensive renovation is planned by Van den Valentien architects

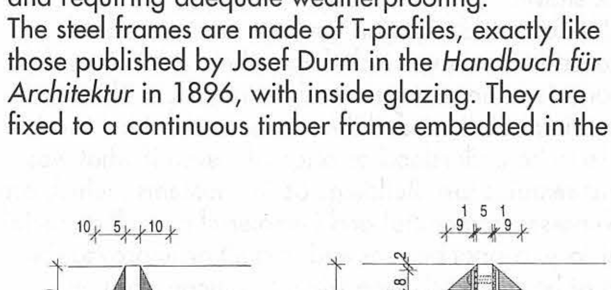


Drawing of a single glazed atelier window in the Bauhaus Weimar with top hung vents in a large steel framed window over a lower row of operable timber casement windows.

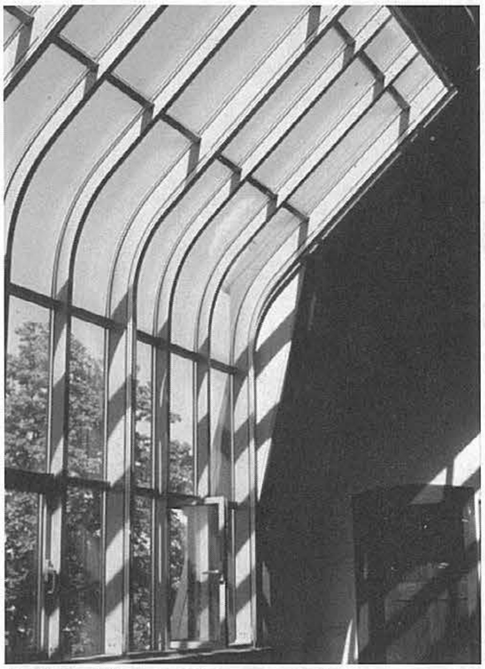


Standard steel window details with pin joints.
Drawing: Handbuch für Architektur, 1896.

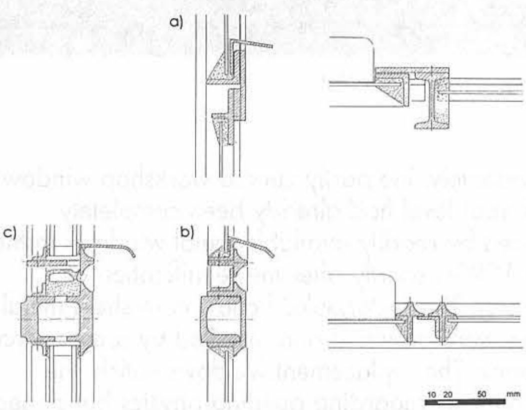
from Cologne and expected to be completed in 1999. The windows of the workshops and ateliers in the ground, first and roof levels are striking elements of the main facade. The fact that the lower row of windows is made in timber - as opposed to the steel framed vents of the top row - may be explained from the fact that these were designed to be operable casements with a particular use for service purposes, and requiring adequate weatherproofing.
The steel frames are made of T-profiles, exactly like those published by Josef Durm in the *Handbuch für Architektur* in 1896, with inside glazing. They are fixed to a continuous timber frame embedded in the



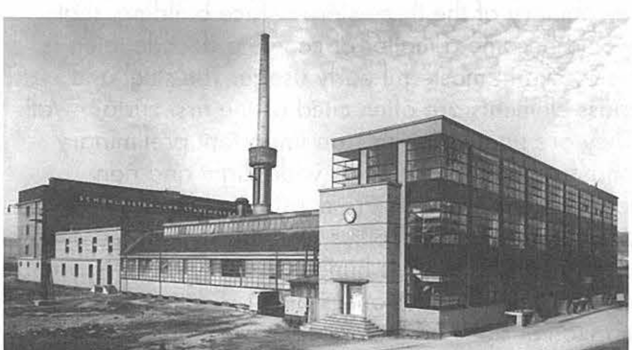
Bauhaus Weimar. Window details, showing the existing condition and renovation proposal with insulated glazing.



Bauhaus Weimar. Clerestory window renovated after 1990, with commercially available profiles.



a: Fagus factory. Steel window profiles from the first building phase, commercially available I, L and T-profiles.
b: Fagus factory. Window profiles by the Fenestra Co. from the second building phase.
c: Fagus factory. Window profiles of the 1985 renovations with insulated glazing, with similar profile width and outside appearance as those from the second building phase.



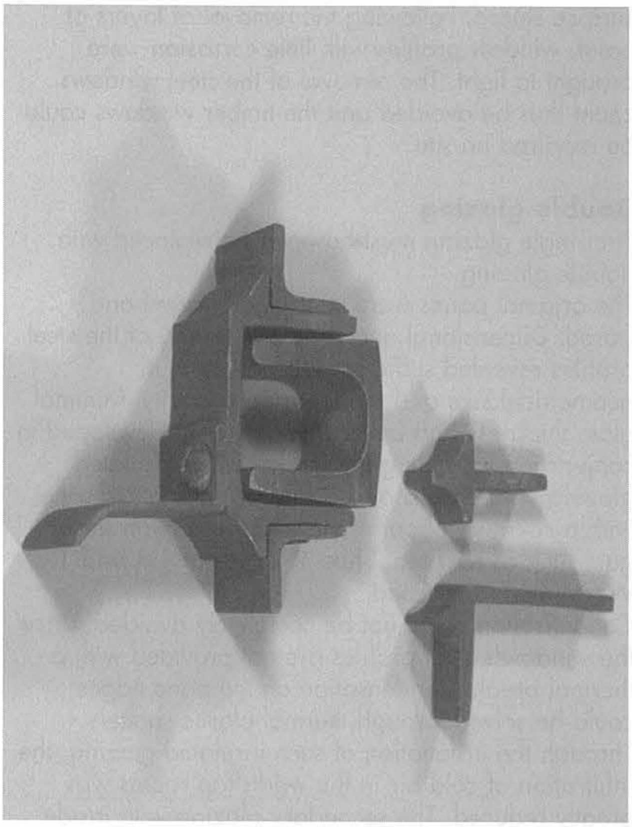
The Fagus factory in Alfeld, Germany.

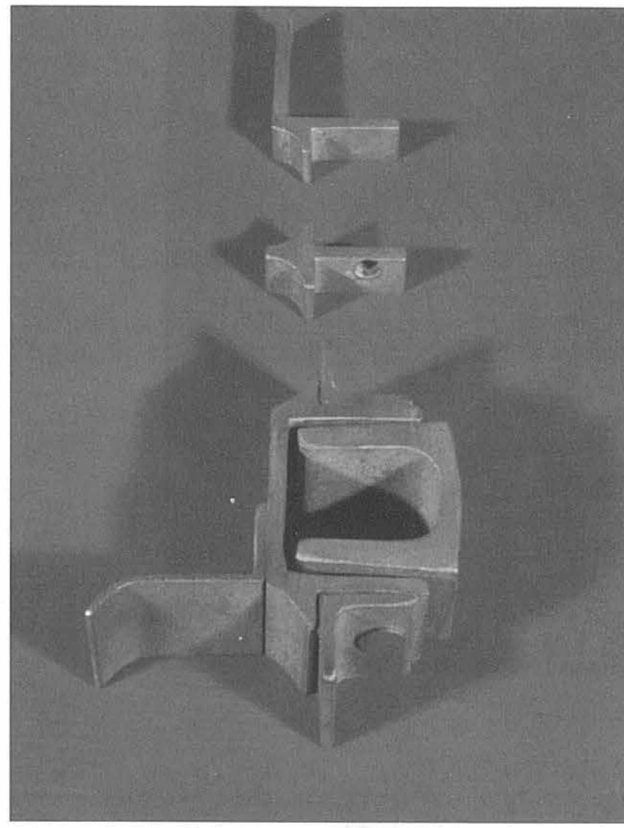
surface stucco. Following the removal of layers of paint, window profiles with little corrosion were brought to light. The removal of the steel windows could thus be avoided and the timber windows could be repaired on site.

Double glazing

The single glazing must however be replaced with double glazing.
The original panes were carefully removed and stored. Dimensional and structural testing of the steel profiles revealed sufficient sections, both in geometrical size and loadbearing capacity. Minimal glass thickness and better R-values were developed in conjunction with the glass industry. The insulated glazing units consist of a 3 and a 4 mm glass pane, with a cavity of about 4 mm to be filled with air or gas, such as Krypton. Thus, R-values of 1.4 and 1.8 W/m^2 K were reached.
Condensation could not be completely avoided, since the window's steel profiles are not provided with a thermal break. Condensation on the pane edges could be solved through thermal plastic spacers. Through the installation of such insulated glazing, the infiltration of cold air in the workshop rooms was greatly reduced. The secondary glazing with inside timber casements, that had been added to the windows in some rooms, could be removed. The exterior appearance of the windows was conserved,

Interior view of the staircase (second building phase) of the Fagus factory in Alfeld with single glazing, even after the restoration.





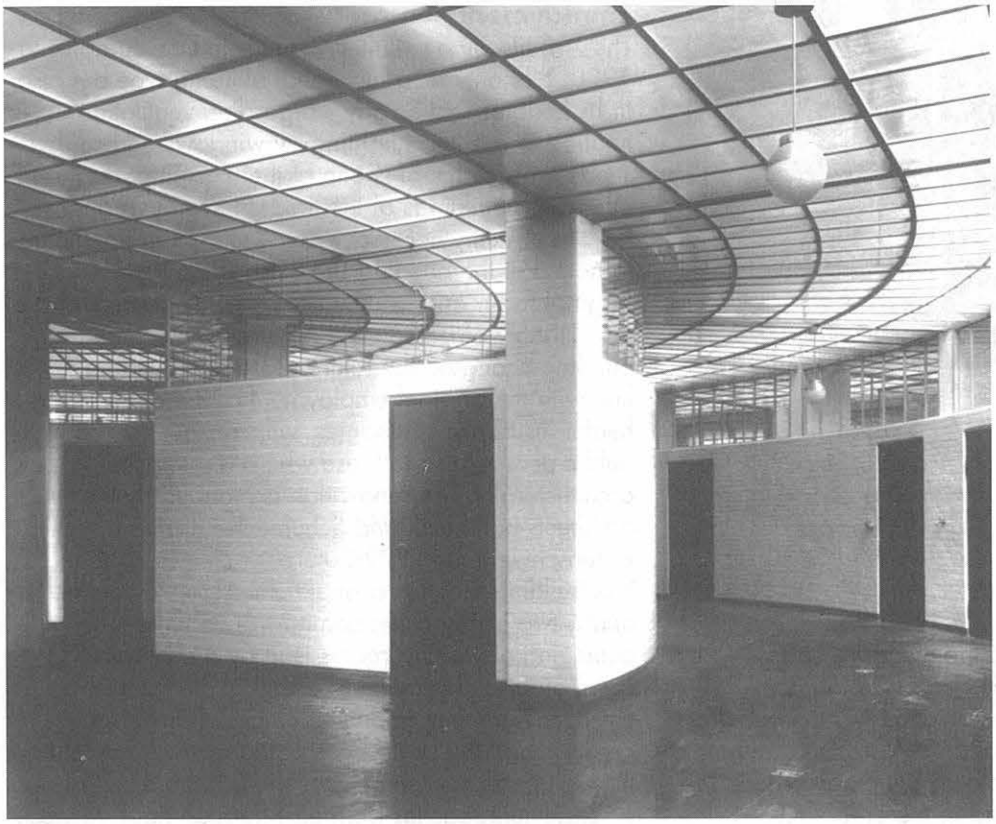
Fagus factory. Window profiles produced by the Fenestra Co. for the second building phase 1914.

or reconstructed.
The need to restore the outside glazing with a surface texture similar to that resulting from the original glass manufacturing process is questionable. The installation of 11 mm thick insulated glazing as opposed to the original 4 mm single pane greatly reduces the effect of the steel profile from the inside. The window is more flush, which is only particularly noticeable in diffused daylight or with interior lighting by evening. In the planned solution the exterior appearance and the preservation of the existing steel profiles are given priority.

Former employment centre by Walter Gropius in Dessau in 1928, with a view of the round building with the row of top lights in the exterior walls and the curved roof sheds.

Unfortunately, the partly curved workshop windows of the roof level had already been completely replaced by readily available metal windows in the early 1990s, shortly after the reunification of Germany. The rectangular hollow core sheet-metal frames were provided and installed by a commercial company. The replacement windows satisfy the requirements regarding building physics but appear as alien elements in the otherwise filigree character of the Van de Velde design.

Fagus-Werk
The Fagus factory in Alfeld was designed by Adolf Meyer and Walter Gropius between 1911 and 1914. This early project of Gropius is his first significant architectural work. The steel-and-glass architectural vocabulary of the three-storey office building, that would become a matter of course a decade later, is here seen in masterful early usage. The steel and glass elements are often cited as the first curtain wall. They are unquestionably an important preliminary phase-marker. The 4.35 m wide, light and non-loadbearing elements are constructed of prefabricated steel profiles, with an infill of glass or steel sheet panels. It is hung in front of the supporting columns, but the mullions, which are attached to the horizontal slabs of each storey, do not form an independent facade element.
There are great differences between the steel and glass facades of the two construction phases. In the first phase of 1911, Gropius made use of standard



Employment centre. Interior view of the round building with the Luxfer prismatic glass ceiling that is intended to be reconstructed.

steel profiles and had the elements constructed from narrow, loadbearing vertical mullions. In the second building phase of 1914 he resorted to window profiles from Fenestra GmbH of Düsseldorf. These profiles have concave bevelled edges. A wide loadbearing transom is arranged in the form of a horizontal casement profile. A group of four ventilation panels are centred in the middle of the sixteen-pane window element.
A first impression was that the facade was relatively intact. On closer inspection there proved to be a series of substantial damages, which led to a complete renovation starting in 1985. The primary issues of the works, planned by the architect Jörg Behnsen from Hannover, involved:

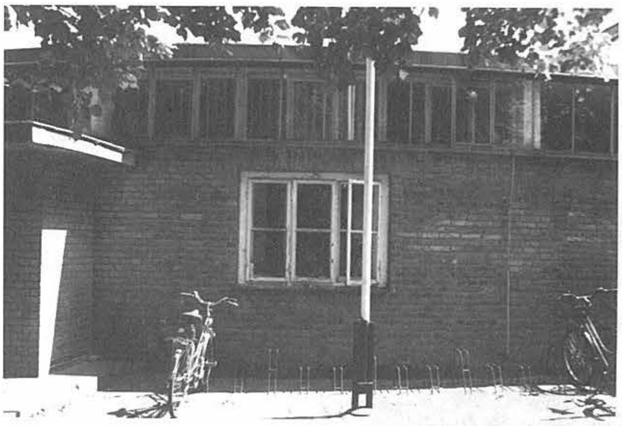
- The steel profiles were protected from corrosion by red lead primer and linseed oil lacquer. Rust had formed in the glazing pockets and at the profile joints that remained inaccessible with maintenance. The expanding volume of the corroding steel had pushed the profiles apart, leading to glazing breakage, and the window panels could no longer be shut tightly as a result of the corrosion splitting the steel;
- Further damage occurred due to tension between the black painted frames and transparent glass; in all, about 40 panes out of 856 were breaking each year;
- The steel profiles were inadequately dimensioned to properly carry the glass, causing deformations of up to 50 mm in windy conditions;
- Because of the single glazing and single steel sheet panels there was great heat loss and the interior was extremely uncomfortable in winter. In summer, the large expanses of glass lead to massive overheating in the offices, which could hardly be improved by airconditioning.

Employment centre. Window in the south facade of the administration wing. Original steel windows with single glazing and casement windows. In the background the timber windows added after 1935, that will be removed as part of the restoration.

Functional rearrangement

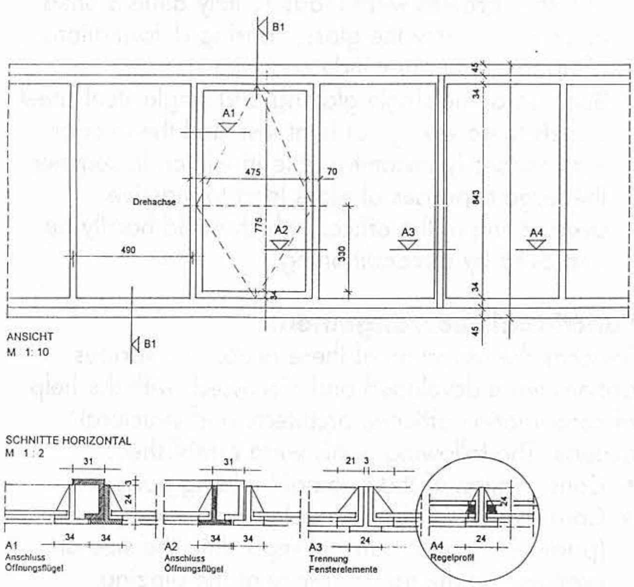
Towards the reduction of these problems, various options were developed and discussed, with the help of conservation officers, architects and structural experts. The following goals were established:

- Conservation of the original building parts;
- Conservation of the original visual impression (particularly from outside) regarding the size of profiles and the transparency of the glazing;
- Conservation of original principles of construction;
- Conservation of the office usage;
- Improvement of the interior climate conditions, both in winter and in summer;



Employment centre. Exterior view of the round building: Band of top lights with secondary timber windows added behind in 1935. The vision windows in the exterior wall were added at the same time.

• Justifiable investment and maintenance costs.
The chosen solution followed a test to establish whether functions could be rearranged in the building to establish zones with climatic standards of different levels. The result was that in both building corners, in the area of the staircases and in the area with conference rooms for occasional meetings, the original glass facade could be maintained. The remaining six bays, in continuous use as office space, were furnished with insulated glazing. In principal, there was agreement over a solution comprising a mixture of original, repaired and improved/replaced facade elements.

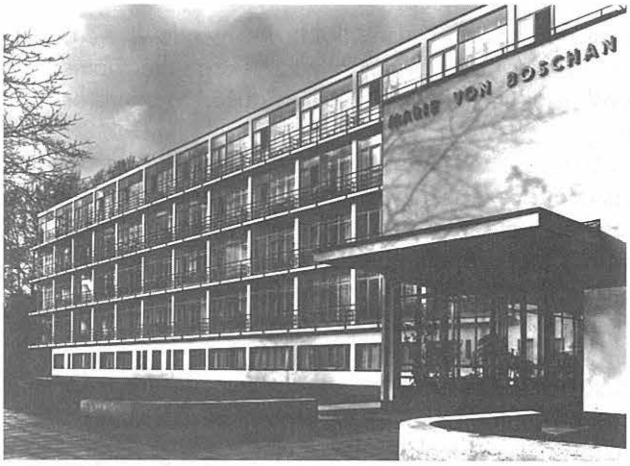


Employment centre. Window detail of the round building. Casement windows with single glazing in commercially available steel profiles.

Employment centre

The *Arbeitsamt* by Walter Gropius in Dessau dates to 1928. Not only as a functional building type but also in its building technology - regarding ventilation, heating and natural lighting by windows and roof sheds - this structure is one of the most important and interesting buildings of the modern era in Germany. For the urgently necessary renovation, it is significant to note that the building still exists in nearly its original form, and its new use by a department of the municipality of Dessau will require no essential building changes. The future use of the building, in line with the original employment centre and various health insurance companies, will continue to allow public access, also to those who are interested in it architecturally. The renovation is planned by the architects Burkhardt and Schumacher from Braunschweig for 1999-2001.
The building features a single-storey round volume and a two-storey cubic administration wing. The outer ring of waiting rooms is lit by a continuous band of top lights made of single glazed steel casings. The inner employee offices, the interior corridor and the central cash area receive daylight through three concentric roof sheds, whose radial arrangement reaches from east through north to west. The glazed sides of the sheds are made of steel frames and simple wired glass. By means of these sheds even the interior rooms - without vision windows in an exterior wall - are sufficiently lit. A further lighting effect is obtained in the round building through top lights in all the partitions. In this way, all rooms obtain extra light from adjacent

Employment centre. Projecting steel and glass windows with single glazing in the administration building.

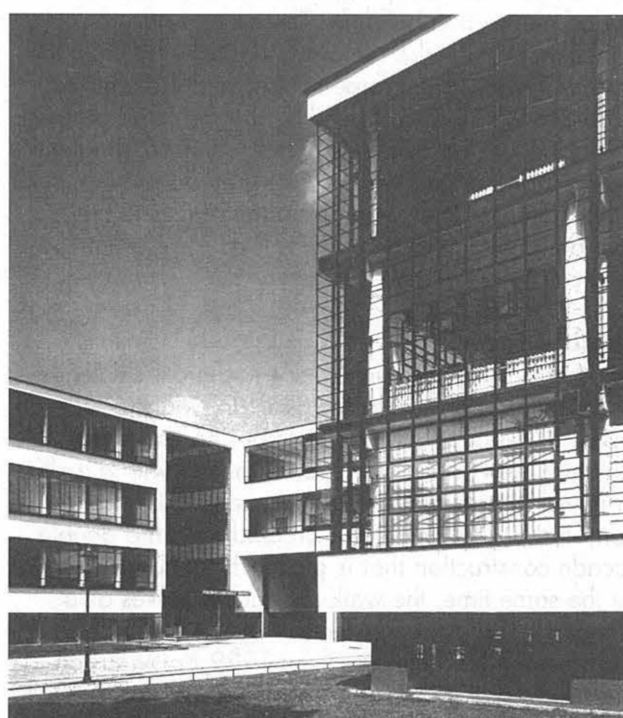


Ashrott seniors' housing in Kassel by Otto Haesler (1931-32). Main facade and interior view of a living room with walk-in flower windows in front of a narrow balcony. Sun shading is provided by curtains and an awning.

rooms, from their own windows and through the sheds.
A horizontal glass ceiling separates the inner rooms from the air compartment under the sheds. This light ceiling - formerly also called dust ceiling - prevented direct heat radiation through the sheds. The ceiling involved so-called Luxfer prism glass and the prismatic effect of the glass panels created a uniform distribution of the light throughout the room. This prism glass no longer exists, but if possible it is intended to reproduce and re-install it, to demonstrate this technical light effect on site, and to test it.

Renovation

The ventilation of the outer ring of rooms is provided through a casement window, while the interior rooms are ventilated by casements in the sheds. These are mechanically operated by cable and crank. At the same time these cable pulleys open a panel in the glazed ceiling, to permit cross ventilation. In recent planning for the renovation, it appeared that this type of ventilation would not be sufficient for the expected number of visitors to the building. Therefore an extra ventilation system for the winter months was planned and integrated. By means of an accessible canal in the basement, heated exterior air is drawn through a ventilator (made by Junkers in Dessau) and pumped through hollow steel columns into the rooms.
The administration building and its staircases also have large windows, which are mounted to secondary steel frames that project from the brick facade, similar to how Gropius had them made for the Fagus factory. For ventilation purposes two high casements are included in each field. The steel profiles of all windows, the top lights and sheds in the round building, as well as the large windows in the administration building, will as much as possible be kept in place, cleaned or partly replaced by similar new profiles.
For the future use, the thermal transmission through the single glazing is not acceptable. Therefore and despite the resulting loss of original panes of glass, new insulated glazing units will be installed. As is the case in Weimar, glazing units of minimal thickness - about 11 mm - will be used. A heat transmission factor of 1.8 W/m^2 K can thus be obtained.
Balancing heat, ventilation and daylight performance with running costs, it appears possible to maintain single glazing in the sheds and stairs.
In the mid-1930s the building - like modernity in general all over Germany - fell victim to the cultural terror of National Socialism. In 1935, it was even decided to demolish the building. Although this has never occurred, still some changes were made to the building. Most apparent are the timber vision windows that were added in the exterior red brick wall of the round building.



The Bauhaus building in Dessau after the 1976 renovation. Though not original, the present aluminium curtain wall represents the essence of the original architectural conception.

The Kornhaus building in Dessau by Karl Fieger (1929-30). The winter garden with single glazing curves around the restaurant.

At the same time, for reasons of building physics, secondary timber windows were added on the inside of the steel framed top lights and to the windows in the administration building. These secondary windows will now be removed, since they disrupt the intended transparent appearance, and the physical problems will now be solved by the insulated glazing. The added vision windows in the round building will be kept for the time being, since they do provide the advantage of direct vision from the offices to the outside and - not to be undervalued - preserve a trace of the building's history.

Double facade

Another particular example of a technical challenge as to building physics is the 'walk-in' window. For the 1930-31 Aschrott old peoples housing estate in Kassel, Otto Haesler designed a facade with a walk-in flower window for each apartment. The conservatory-like feature is created trough a double facade construction that is glazed from both sides. At the same time, the walk-in window serves as a climatic buffer zone between inside and outside. Karl Fieger, the architect of the 1929 *Kornhaus* on the shores of the Elbe river in Dessau, enclosed the round volume of the restaurant with a secondary construction that is largely glazed, as a kind of winter garden. Even if single glazing does not meet current technical standards, the principle is correct.

Unfortunately in Kassel, the flower windows were partly sacrificed, principally to enlarge the rooms, and insulated glazing was introduced to avoid heat loss.

In Dessau, the single glazing was kept during renovations, but only on the condition that the winter garden would be regarded as a thermal intermediary with a moderate temperature, with warm-air circulation to minimize condensation. Therefore such a space is only suitable for occasional use.

Bauhaus Dessau

The presented buildings indicate that although renovation of steel windows with single glazing may seem similar for most modern buildings, it has lead to different solutions. It has also shown that in only a few cases a complete substitution of windows and glazing, due to corrosion damage beyond repair, is necessary. In this context, tests are currently being carried out on different window profiles, to obtain information about corrosion occurrence and lifespan. Requirements in terms of building physics are met or improved upon with specially developed insulated glazing in steel profiles with or without a thermal break. In most cases, at least the exterior profile width and the size of the window pane can be maintained.

The upcoming renovation of the three masters' houses by Gropius in Dessau will be interesting and is sure to provide useful information. The atelier glazing and staircase windows are essentially all replacements, since the originals were violently removed in the 1930s. Three different functions, and three different architectural practices, with different conservation attitudes, will transform the Ebert Allee in Dessau into a teaching laboratory about the renovation of buildings of the modern era.

The Bauhaus building in Dessau by Walter Gropius remains to be mentioned. A solution to the glazed main facade of the workshop wing and the staircase windows does not yet exist. The physical and climatic building problems of the windows and facades greatly resemble those of the Bauhaus building in Weimar and the Fagus factory in Alfeld. One might timidly ask why Gropius, despite his experience with these earlier works, re-used the glass facade principle in the same stage of development without technical improvement.

Over the course of a year, the Bauhaus building will now be researched, measured and tested with regards to physical and climatic building conditions, including the effectiveness of the ventilation through windows and between storeys, and sun shading. The operation and regulation principle of windows, that allows proper ventilation and conditioning of the interior climate, is often disregarded by the users. When thinking of improvement through insulated glazing, the effect of an added structural load is surely a question. The Bauhaus facade presently features the aluminium profiles and single glazing of the main renovations of 1976. It thus has a quite significant value in the history of the Bauhaus. Moreover, the idea and symbolic power of the glass facade, including the transparent and lucid corners, is already present - even if it is only a simulation of the original construction. In evaluating all parameters, including the readiness of future users to use flexible spaces flexibly, the preservation of the existing facade must be seriously considered.

Berthold Burkhardt is a private architect and a structural engineer, a professor at the Braunschweig University of Technology, and an invited consultant for the conservation of various Bauhaus buildings. Architect Dieter Rentschler-Weissman, who contributed the chapter on the Fagus-Werk, was the Regional Conservator for Lower-Saxony, Hannover, until 1997. Text translated from German by Susan Ross, DOCOMOMO, Montreal-Berlin, and edited by the editors.

Notes:

1. The first volume of the Reihe Baudenkmale der Moderne der Wüstenroth Stiftung will be published by Karl Kremer Verlag in November 1999 on the Einstein Tower (ISBN 3 - 7828 - 1512). Future volmes will include the Schmincke House by Scharoun (ISBN 3 - 7828 - 1514 - 9) and the Muche-Schlemmer House by Gropius (ISBN 3 - 7828 - 1513 - 0).
2. With the support form the State of Saxony-Anhalt and under the supervision of DOCOMOMO Germany, a research project about Törten is set up, which considers, in addition to the estate's history, technical and physical data of the initial construction phase and subsequent changes.

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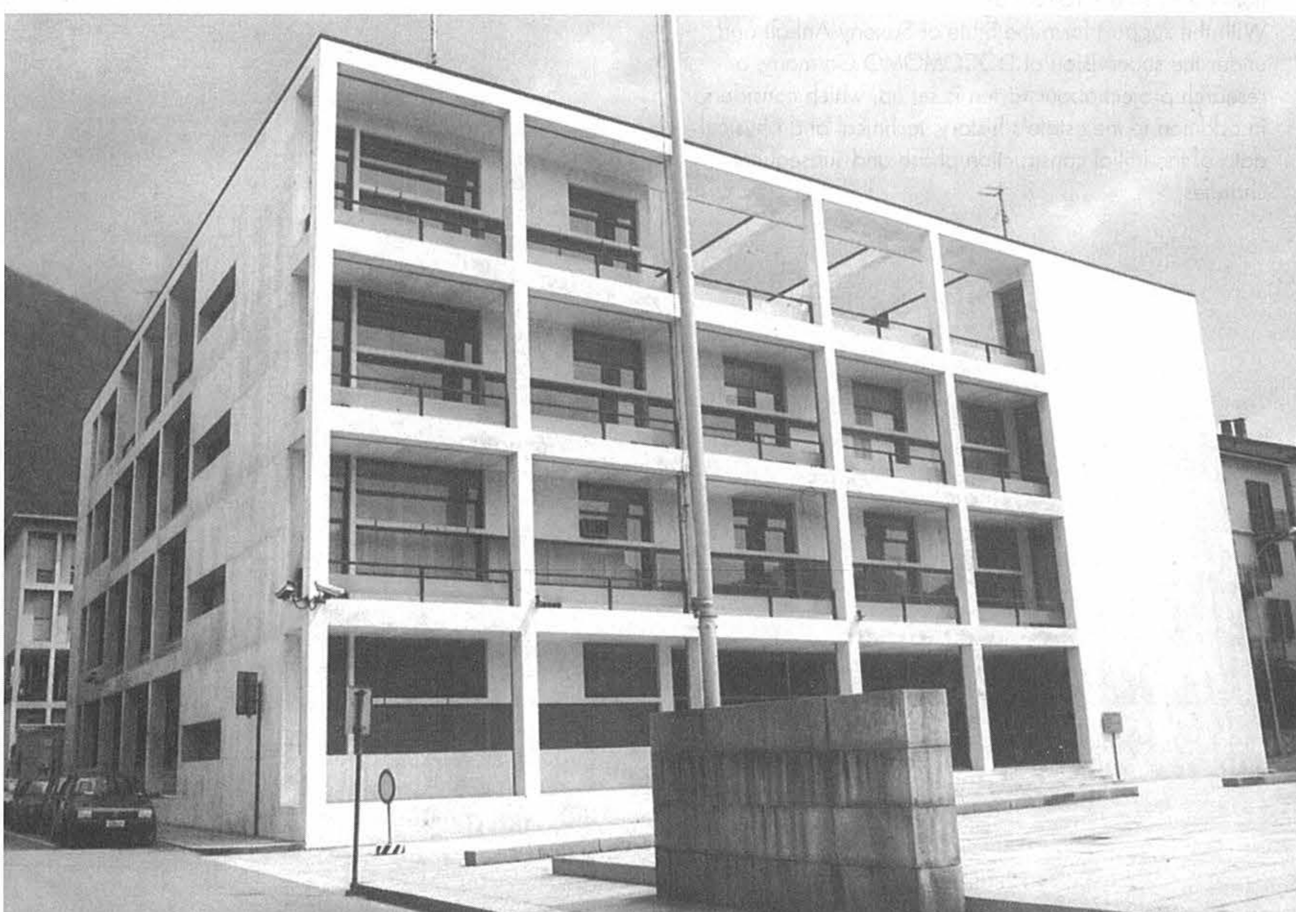
Restoration of transparency

The Casa del Fascio in Como (Giuseppe Terragni, 1932-36)

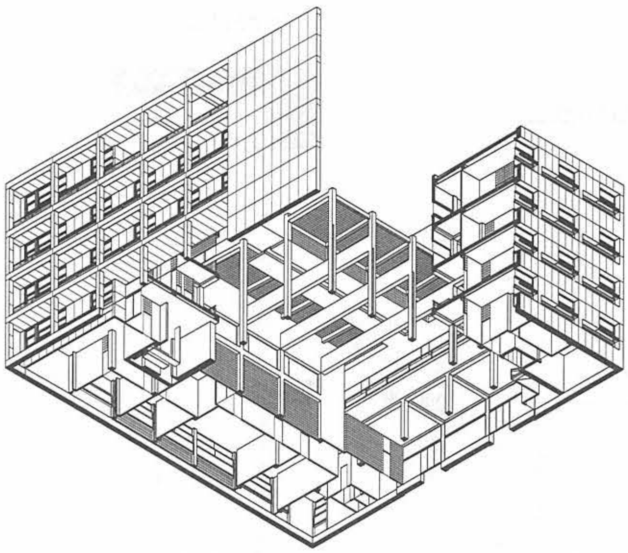
The Italian rationalist Giuseppe Terragni made extensive use of glass block to separate environments and, at the same time, connect them as an effect of transparency. The striking grid pattern of concrete-and-glass panels, both interior and exterior, enhance the strictly rational geometry and spatial concept of the *Casa del Fascio*. Careful restoration of deteriorated glass block was therefore required, but no easy job.

by Alberto Artioli and Wessel de Jonge

The *Casa del Fascio* in Como was designed by the architect Giuseppe Terragni and built between 1932-36. The strictly rational geometry of the building was manipulated by the architect so as to express the presence of an internal atrium. This is revealed by the geometric proportioning of the concrete superstructure, the strict pattern of the marble cladding, and the carefully measured infill of timber framed windows and glass block, further enhanced by the strikingly manifest grid of the glass-and-concrete panels.
About the connection between the geometry and the 'metaphysical spatial effects' of the building Kenneth Frampton wrote: 'The building is treated as though it were a continuous spatial matrix, without any particular orientation such as up or down, left or right, etc. Thus the mirror effects of the glass are used in the lining of the foyer ceiling to create the illusion of an infinite trabeated construction existing in volumes which are in fact quite differently occupied. At the same time the subtle implantation of the work in a historic urban core, its facing throughout with Botticino marble and its use of glass block to designate its honorific space, combine to create a work which is at once tectonic, meticulous and monumental.'[1]



Main facade of the *Casa del Fascio* after the restoration. Photo: Alberto Artioli.



Axonometric worm-eye view showing the internal atrium with glazed roof. Drawing: Tullia Iori, from *La Casa del Fascio di Como*, Sergio Poretti, Rome 1998.

The choice of materials for the *Casa del Fascio* represents a careful balance between poetry and technology. Although the building was almost finished when the Autharchy Act became in force in late 1935 - largely prohibiting the employment of foreign materials - a number of unusual materials were applied. The use of new materials - like prismatic glass, linoleum, and aluminium alloys for downspouts - was not only inspired by the wish to respond to functional requirements, but just as well to express the new spirit of the time. When particular materials were discussed and tested Terragni was often personally involved, frequently compelling the producer to resort to artisan manufacturing to satisfy his specific demands.

Glass

Glass played a particular role in many of Terragni's works. At least for the Casa del Fascio the aim for transparency can to a certain extent be explained from ideology, as Mussolini had defined fascism as 'a house of glass where everyone can look in'.[2]

In this building glass was used lavishly, not only for transparent surfaces but also as a decorative cladding, in furniture and fixtures. Terragni stressed the essential character of glass: 'The abundance of glass lends a sense of lightness, of modesty, a pleasant appearance, a satisfying harmony, that has the merit to show the observer the relation between the external elements and those inside, with a new and rich potency for the combination of movements, for simplification'.[3]

This statement appears fully underscored by the *Casa del Fascio* if the proportion of glass is analysed for each of the facades. Of the 572 m^2 total surface area of each facade, between 164 m^2 (back facade) and 294 m^2 (along via Partigiani) is glazed.

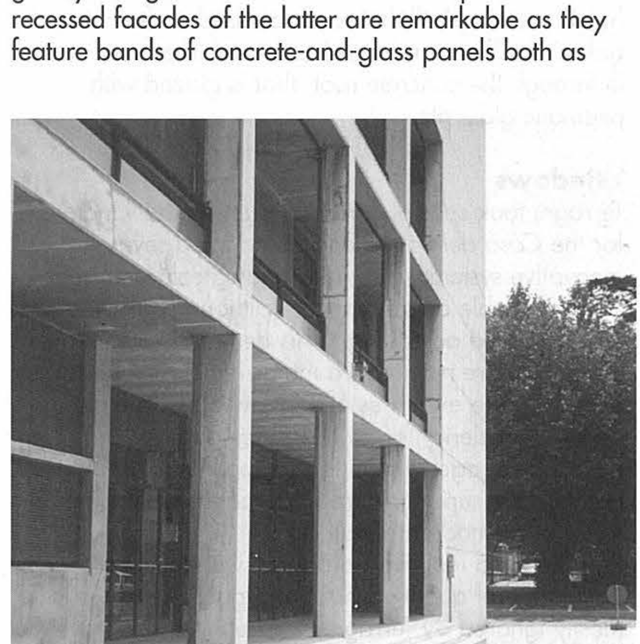
Despite progress made in window glass manufacturing in the decades before, the use of large windowpanes had until then been constrained by the materials' fragility and the consequent dangers thereof. This limitation was more and more overcome by new products like laminated and tempered glass. Such new technological conquests allowed for several innovative applications of glass at the *Casa del Fascio*, like the 7 m long and 10 mm thick crystal table top in the *Sala del Direttorio*, the glazing of the two main walls of the same room, the long slot in the soffit (a glass pane of 33 mm thickness), the 'extra strong' glass railings along the main stairs, and the 8 mm thick 'Securit' tempered glass panels at the entrance.

Vetrocemento

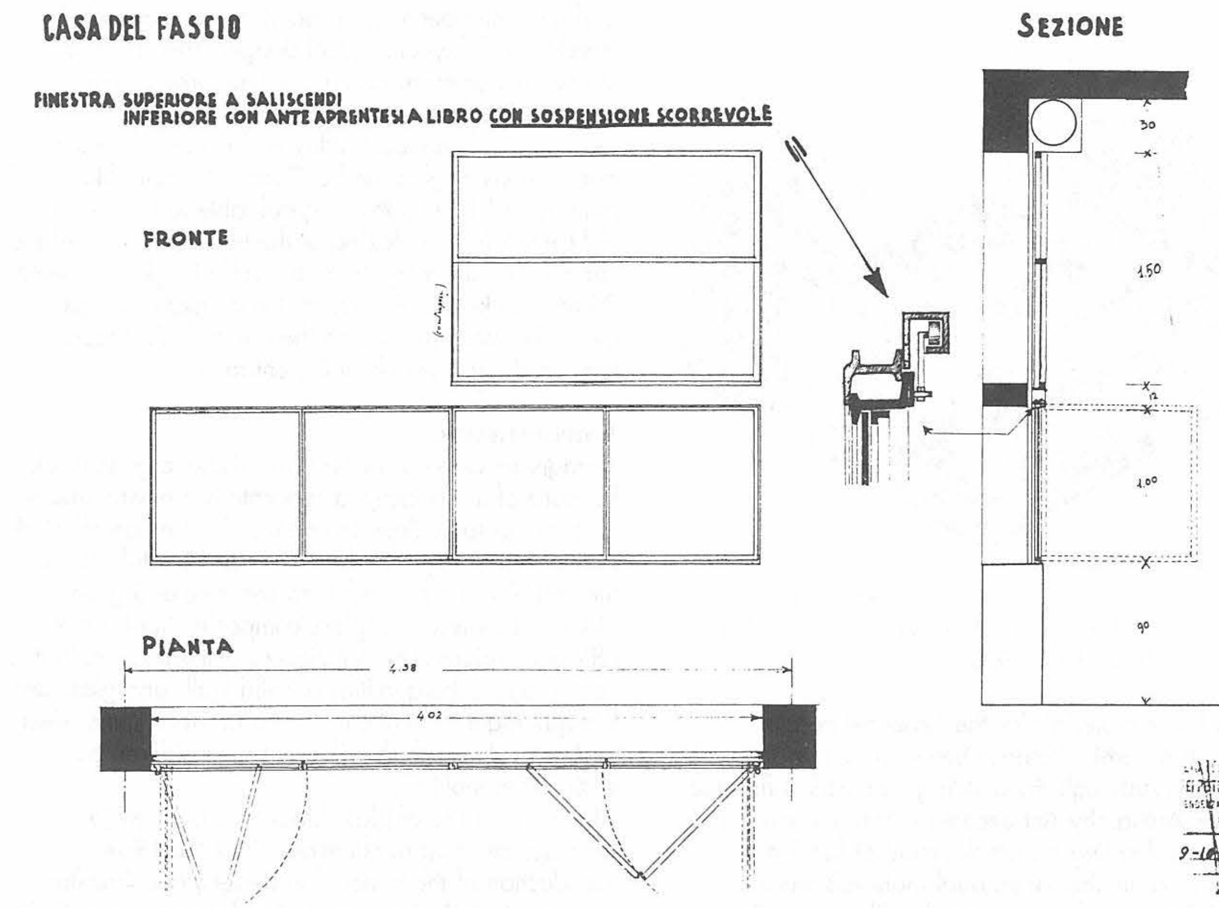
Terragni made extensive use of prismatic glass block because of its capacity to separate two environments and, at the same time, to connect them as an effect of transparency. A particular role must be attributed to the combination of reinforced concrete and glass block, a concrete-and-glass composite that is more efficiently referred to in Italian as *vetrocemento*. In this combination, the qualities of solid walls and glass are brought together, while the bond between glass, steel and cement is such that it may be considered as statically monolithic.

Although the use of glass block was not new to architecture, most applications since the 1904 introduction of the material in Perret's Rue Franklin apartments in Paris concerned a decorative use. Only in the 1930s the full architectural potency of the concrete-and-glass element was again recognized and many examples can be mentioned.

In the exterior of the *Casa del Fascio*, glass block is mainly used for spandrel panels for some of the larger offices and meeting rooms, at the main staircase and the adjacent bathrooms, and for the transparent gallery along the main terrace on the top floor. The recessed facades of the latter are remarkable as they feature bands of concrete-and-glass panels both as



The entrance with the 8 mm Securit tempered glass panels before restoration. Photo: Wessel de Jonge.

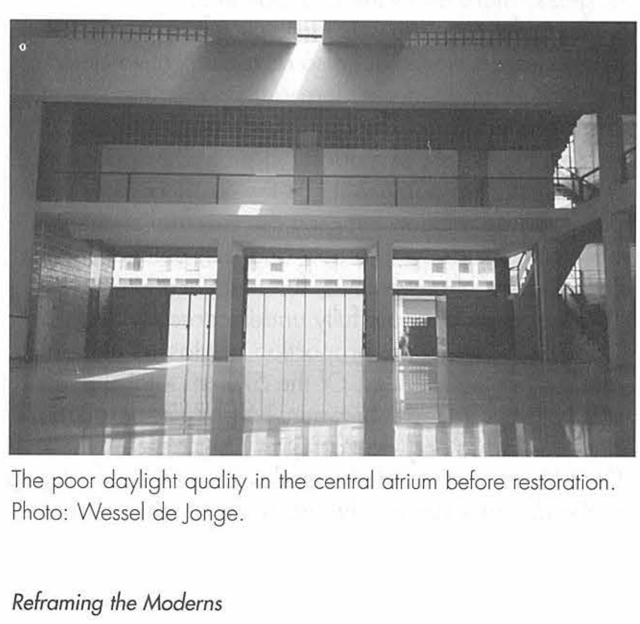


Original drawing of the timber windows. From: Terragni Archives.

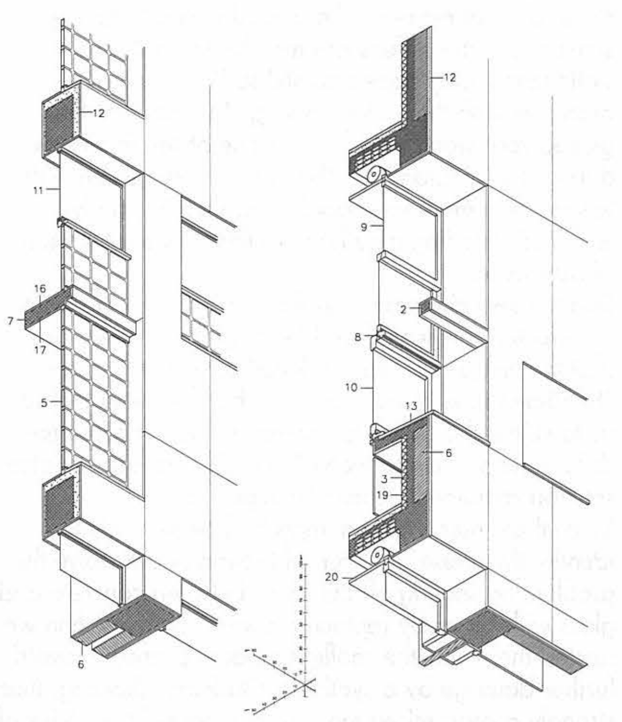
spandrels and at two-thirds of the gallery's height. Inside, glass block is used for many partitions, with steel framed openings for doors and internal windows. Most prominent in the interior is the central double-height meeting hall that is surrounded on four sides by galleries, offices and meeting rooms. The foyer is top-lit through the concrete roof, that is glazed with prismatic glass tile.

Windows

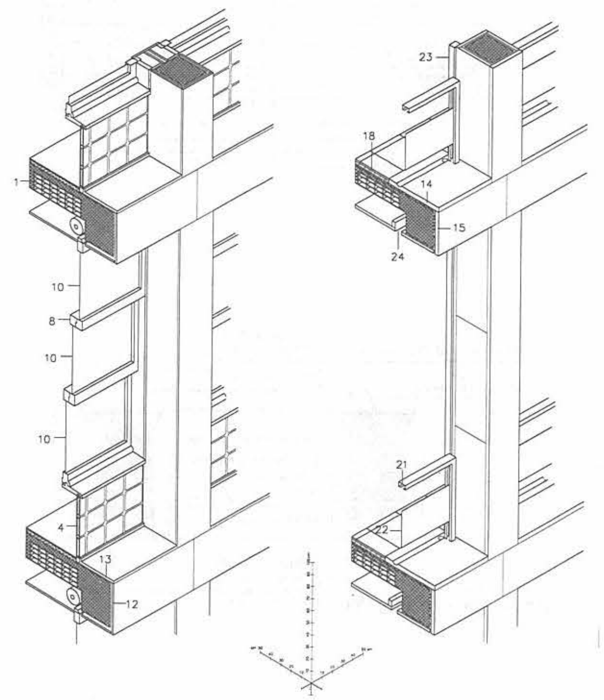
Terragni took special care in designing the windows for the *Casa del Fascio* and he adopted several innovative systems, also in technological terms, that were available on the market - although mostly he had them adapted according to his demands. Steel framed windows were regarded a major improvement as they allowed large expanses of window glass, a high daylight efficiency, great resistance against atmospheric agents (due to the application of anti-rust paints), and superior durability, that made them most suitable for modern architecture.
Prefabricated industrial products, with their supposed advantage of quality control and guarantees, were mostly ignored by Terragni, who preferred to have the metal windows handmade by a local company, offering him a maximum of design possibilities. Most steel framed windows in the interior, the horizontal pivot vents over the doors, and the windows of the staircase were produced this way. The sliding doors of the main entrance are locally made of 'alpacca', a copper-nickel-zinc alloy.
Still, Terragni did not reject the use of traditional timber windows for the major part of the facades.
Although the architect had considered to make ribbon windows at first, the deep and high rooms required additional lighting by a second light over the wide lower part. The double-hung timber sash were



The poor daylight quality in the central atrium before restoration. Photo: Wessel de Jonge.



Axonometric sections of the facade at via M. Bianchi.
Drawing: Tullia Iori, from Poretti, 1998.



Axonometric sections of the facade at via Pessina.
Drawing: Tullia Iori, from Poretti, 1998.

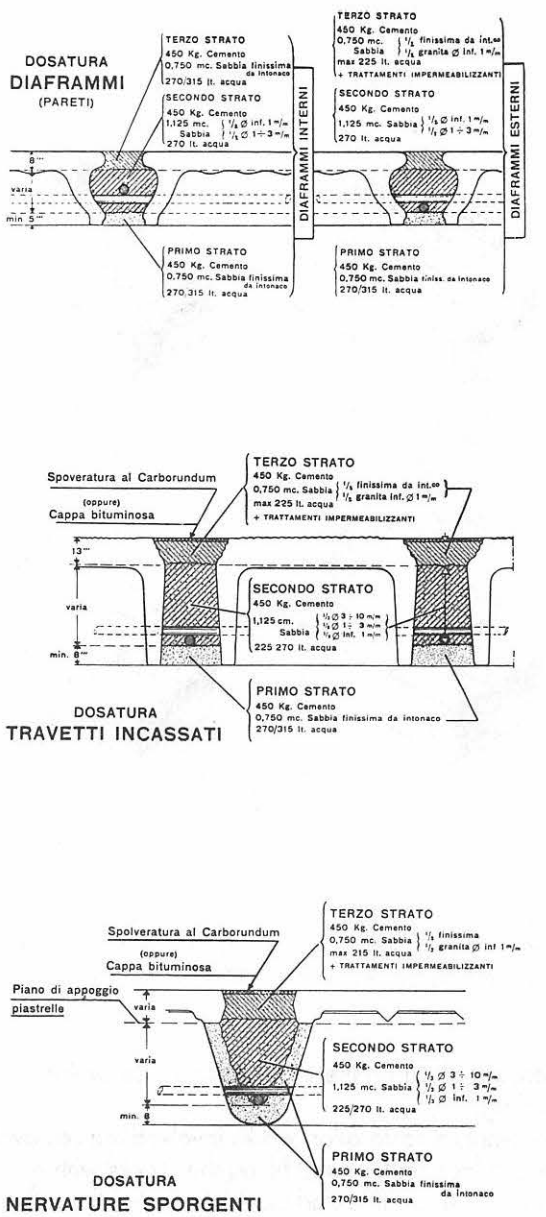
balanced by a system of counterweights that allowed even the large 4 m wide lower windows to be operated by one single person. The sophisticated mechanisms had worn out a little but had suffered most from neglect and could be repaired quite easily.

Restoration project

The late 1980s restoration project addressed in this paper was necessarily limited to some particular aspects, as an integral intervention would have required the building to be vacated. At the time this was impossible due to its function as a military head-quarter. Still, the restoration involved three interesting problems of modern preservation practice: the repair and partial substitution of the marble cladding, the renovation of the sanitary facilities, and the refurbishment of the windows as well as the concrete-and-glass units of the building's envelope.
Before any interventions occurred, the general condition of the white 'Botticino' marble cladding was not alarming, despite signs of sulphatation and micro cracks. Occasional slabs had warped, sometimes to such an extent that they had detached from the subsoil and some had fallen down. This condition had worsened after an earlier attempt to seal the cracks and joints between the panels with transparent silicones, that soon turned black and caused a typical blackish streaking effect on the once pristine face of the building.
The eventual restoration works involved the removal of the previous sealant and filling the cracks with a mortar of slack lime and marble powder, the refixing of stone where necessary with stainless steel anchors, the consolidation of damaged stone with silicon resin, and the replacement of stone that could not be salvaged.

Enamelled glass

Terragni kept full control of all aspects of the design, including every little detail as well as the furniture. Even the sanitary facilities were taken into consideration not only as a functional space, but as part of the overall architectural conception. Therefore, special care was given also to these rooms when the restoration project was set out.
The bathrooms are divided into several units by walls that were clad with 'Fontanit', a coloured glass that was produced by the firm Fontana, and that is found in many rationalist' buildings as it was appreciated for its pure and essential character. The bathroom floors were covered with glass mosaic tesserae.
As a great deal of the original materials had survived and full documentation was available in the form of period photos, it was relatively easy to obtain a



Three structural solutions for *vetrocemento* roofs taken from period documentation. From: Giuseppe Terragni. *La Casa del Fascio di Como*, Alberto Artioli, 1989.

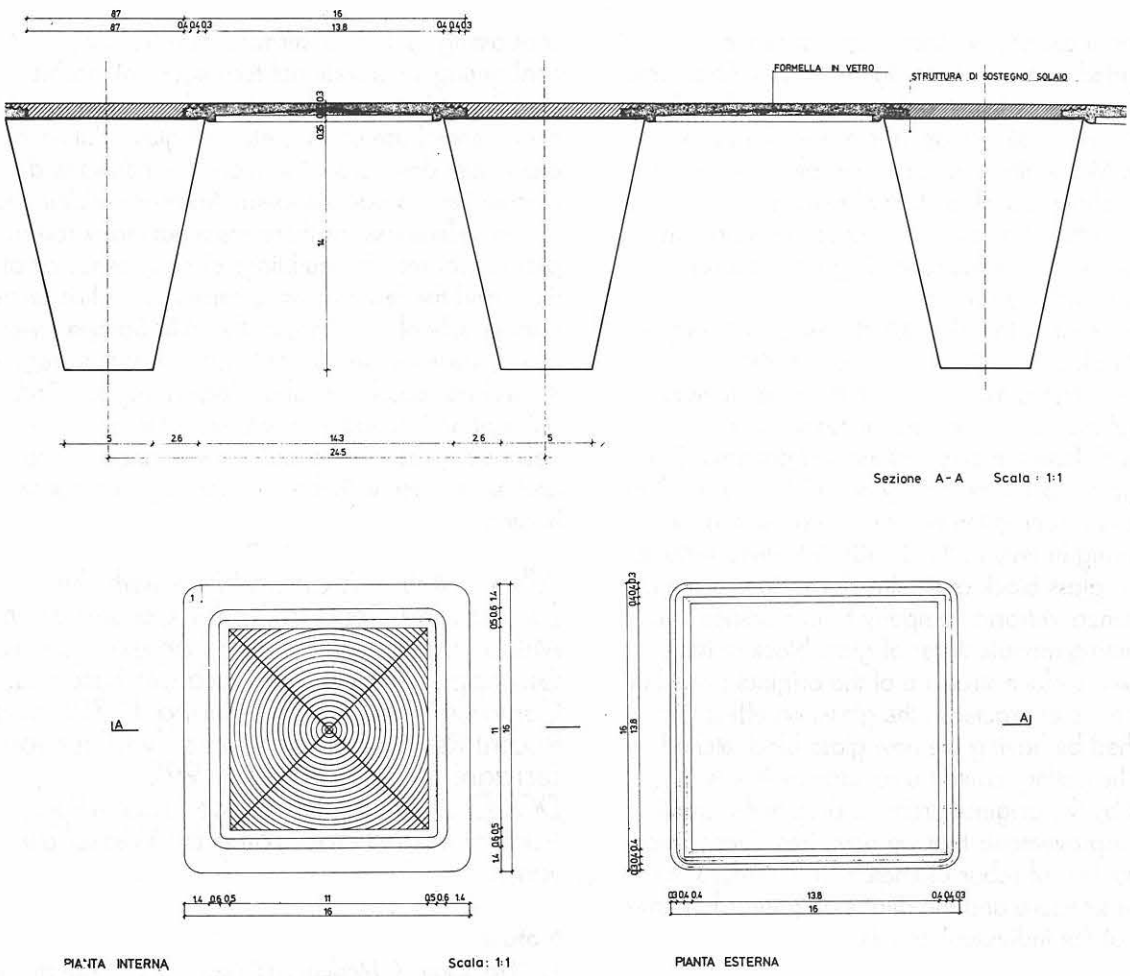
complete picture of the original situation.
To colour the substitute glass panels, car paint was applied on the panes after which they were enamelled in a furnace. To replace missing mosaic tesserae, 3 mm thick crystal was coated pale blue for the first floor and grey-green for the second floor, and then cut according to the various tile sizes.

Coffered ceiling

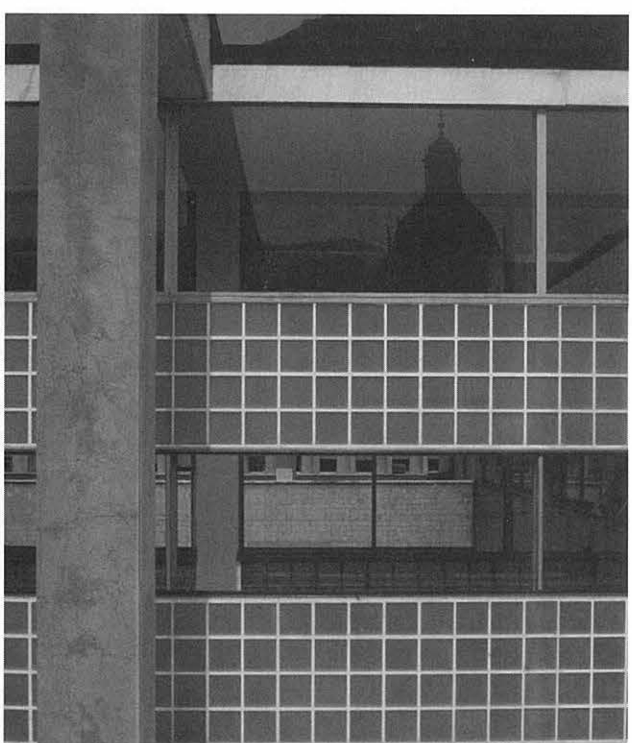
Right from the start, the best solution for the glazed concrete roof over the main hall would no doubt have been to use hollow glass block with an air chamber, buried flush in a concrete frame. Still, in 1935, it was decided, for economic reasons as well as the lack of experience with the above system, to adopt a roof structure with projecting concrete ribs (*nervatura sporgenti*, see illustration) with recessed translucent glass tile, in fact consisting of a coffered structure in reinforced concrete featuring thin prismatic glass tile. Although the thermal expansion coefficient of the three materials that make up the glazed concrete roof are similar, and the differences may be insignificant in static terms, they appeared still sufficient to cause problems with the waterproofing. The fact that the glazed roof was carried out as one of the first items during construction, and that lack of experience with this modern material probably resulted in poorly executed detailing may have furthered the infiltration of rain water.
Due to these circumstances the original *vetrocemento* construction presented problems right from the start and the entire roof was replaced almost immediately. The dimensions of the ribs were thereby increased so as to stiffen the structure. However, this improvement did not help to avoid water infiltration, as the adopted solution remained technically imperfect.
Since then, numerous attempts had been made to identify the cause of water infiltration and to solve the problem by sealing off the joints between concrete and glass with tar or by replacing several areas. When we started the works the rooflights were covered to avoid further damage by a synthetic 'Ondulux' sheeting, that strongly compromised the essential daylight qualities of the central foyer. As waterproofing remained problematic, the concrete structure that held the glass was affected by reinforcement corrosion, and showed occasional spalling.

Glazed roof renewed

Restoration planning confronted us with a principle choice. Given the fact that the concrete-and-glass composite must be recognized as monolithic it seemed inappropriate to replace individual glass tiles that were still buried in concrete, and the only way to deal with this correctly seemed to demolish the roof altogether and remake it.
This solution was abandoned for two reasons. The idea to salvage as much as possible from what was left of the original elements prevailed, but also the fact that the original tiles could no longer be found and that the reconstruction would inevitably display different characteristics as compared to the original roof was decisive. It was briefly considered to seal all the glass tile with a suitable resin but as it would be impossible to enforce quality control of this process for over three thousand elements the idea was dropped as well.
The only possible intervention that would guarantee a proper technical solution and be typologically correct, was to carefully peel off the existing roofslab from the coffered concrete structure, after removing all original glass tile, and to make a new glass-and-concrete roofslab with hollow glass block over the existing ribbed concrete structure. This was the only way to overcome the technical shortcomings of the glazed roof without modifying its daylighting properties and overall aesthetic effect.
The new 80 mm thick glass elements are filled with



Details of the glazed roof over the central atrium. From: Artioli, 1989.



The panoramic gallery along the roof terrace with alternating bands of glass and glass block, after restoration, reflecting Como's dome. Photo: Ola Wedebrunn.

conditioned air, and are readily available today. This solution guaranteed a perfect waterproofing and virtual absence of condensation on the inside. However, the mass of the new glass block caused an additional load of about 100 kg/m^2 and required static verification in advance.

Greenish and opaque

Apart from the glass tile roof covering the central meeting hall, the *Casa del Fascio* features numerous walls of glass block, mostly framed in reinforced concrete. While the internal separations remained in a good condition, those exposed to the exterior climate showed serious degradation.
Especially the two longitudinal walls of the panoramic gallery along the roof terrace, with alternating bands of glass and *vetrocemento* in steel frames, presented alarming damage. Corrosion and the consequent deformation of the steel frames had caused numerous cracks in the glass block, allowing rainwater to enter the construction particularly at the bottom end of the panels, and initiating reinforcement corrosion that further increased the pressure on the glass. In addition, grave fractures in the lower sections must be attributed to design failure, as the steel frames had insufficient capacity to carry the heavy concrete-and-glass panels. The same can be said about the lack of dilatations to

allow thermal expansion, that were just as well recommended by the industry in the 1930s. Over time, these walls presented such extensive technical problems that there was no other way than to remake them altogether. Many other concrete-and-glass panels in the facade showed such a state of extreme deterioration that it had become hazardous both in technical terms as well as regarding the working conditions in the interior.
The replacement of the glass block elements, however, appeared rather complicated as it appeared impossible to find glass block with the same features as the original elements, and current models are completely different in size, colour and patterns. The original glass block was slightly greenish as a result of iron oxides present in the types of sand used for glass manufacturing in Italy in the 1930s. We were fortunate to find new glass block of similar dimensions produced by the Fidenza Vetraria company from Florence, the only remaining manufacturer of glass block in Italy. The irregular surface structure of the original parts had lent an opaque character to the glass, an effect that was matched by having the new glass block etched. This way the gallery could be remade as it was conceived by the original architect despite the small technical improvements that we have introduced, such as the reduction of rebar diameters, the reinforcement of the steel structure and the dilatation joints along the perimeter of the individual panels.

Technological review

The restoration of the *Casa del Fascio* presented some particular issues of 'modern conservation'. We met two contrasting realities in terms of construction, confronting the traditional techniques of marble cladding - that was relatively well executed - and the experimental use of concrete-and-glass, flat roofs, aluminium downpipes, horizontal windows and mechanisms to operate them. Another problem was the lack of references, as there were not many restoration projects for modern buildings already executed at the time, and the few that were carried out - like Terragni's nursery school in Como, or the Villa Savoye - were merely reviewed in formal terms rather than regarding the technological or methodological aspects. This publication is therefore instrumental in advancing the debate on these issues and the exchange of know-how and experience with the conservation of modern heritage.

Alberto Artioli is an architect with the Lombardian Department for Conservation in Milan. This paper is based on excerpts from Giuseppe Terragni. La Casa del Fascio di Como *(Alberto Artioli, Milano 1989), and* Recent Restoration of Works by Giuseppe Terragni *(Alberto Artioli, 1992 DOCOMOMO Conference Proceedings), translated and elaborated by Wessel de Jonge.*

Notes:

1. Frampton, K. Modern Architecture. A Critical History, pp. 205-206. London, 1980.
2. Terragni, G., 'Il Vetro'. Quadrante 35-36, 1936.
3. Terragni, G., 'Il Vetro', Ibidem.

Transparent and translucent parts of the restored facade. Photo: Ola Wedebrunn.

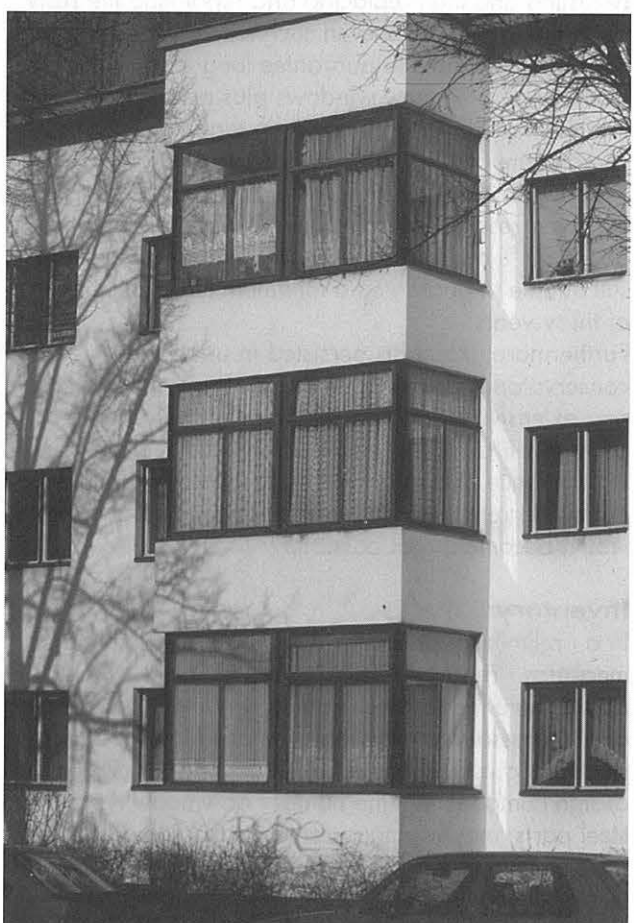
Preservation of steel framed windows

The Weiße Stadt Estate in Berlin-Reinickendorf, 1929-30

Windows are subject to a wide variety of pressures for change and modification both to meet new requirements from tenants and to keep in line with changed insulation regulations. Experience shows that renovating windows - and in particular steel framed windows of the 1920s - is no simple undertaking. The sheer scale of such works in the *Weiße Stadt* estate with no less than 1,300 housing units and ancillary facilities gives a good indication of the problems awaiting planners and builders.

by Winfried Brenne

The *Weiße Stadt* estate was built by the architects R.O. Salvisberg, B. Ahrends and W. Büning in Berlin-Reinickendorf between 1929-30. The estate involves no less than 1,300 housing units, shops, a central heating unit, and ancillary facilities such as communal laundry, health centre and nurseries, altogether featuring approx. 6,500 timber jointed windows ranging from single bathroom casements to six adjoining casements with a balcony door. Two thirds of the flats also have a conservatory with single steel framed windows. These figures are enough to give an indication of the scale of the project for the renovation or replacement of the windows as well as some idea of the cost involved for the housing association.
Until today, the estate has seen two substantial overhauls. The first, in the early 1950s, was primarily concerned with eliminating the damage the estate had sustained during the War and rebuilding bombed-out sectors, although it also included a comprehensive renovation of the exteriors. By the early 1980s a



Original (left) and new conservatory (right) glazing in 1996. All photos: Brenne Architects.

second renovation proved necessary and this was gradually implemented under the terms of a master plan for the preservation of historic buildings.
Work in the second renovation phase aimed at optimal conservation of the original buildings and their substance whilst repairing construction defects and technical inadequacies, and followed a fixed cost plan.

Timber and steel

Whereas creative input into plaster renovation is more or less easy to control (with the notable exception of rendering for thermal insulation walls), problems connected with the design concept for the renovation of windows are altogether of a different scale.
In Modern Movement architecture, the window as a design element assumed an unprecedented importance; in particular the conservatory, a body of glass with non-supporting corners, brought a hitherto unknown transparency into architecture and was the symbol of a new feeling for light, air and sunshine.
Even slight alterations to the design would disrupt a delicate equilibrium and substantially change overall proportions.
The many windows on the estate have up to present not been subject to renovation. This may be ascribed to the fact that, as sturdy timber-jointed casements, they still largely correspond to current building regulations.
However, after sixty years it has become apparent that maintenance costs, in particular for the steel framed conservatory windows, have become too high whilst changed patterns of tenant behaviour have led to an increase in damage to windows.
During the last comprehensive renovation of the estate in the early 1980s, it was noted that the conservatory windows were in very poor condition. Casements were warped as a result of the numerous coats of paint the windows had received over the years, causing them to stick. Severe corrosion of the frames had caused extensive and critical damage particularly on the weather side. Furthermore, as the conservatory windows were no longer a tight fit, water had seeped through causing damage to walls, floors and the main structure of the buildings.

Changed usage

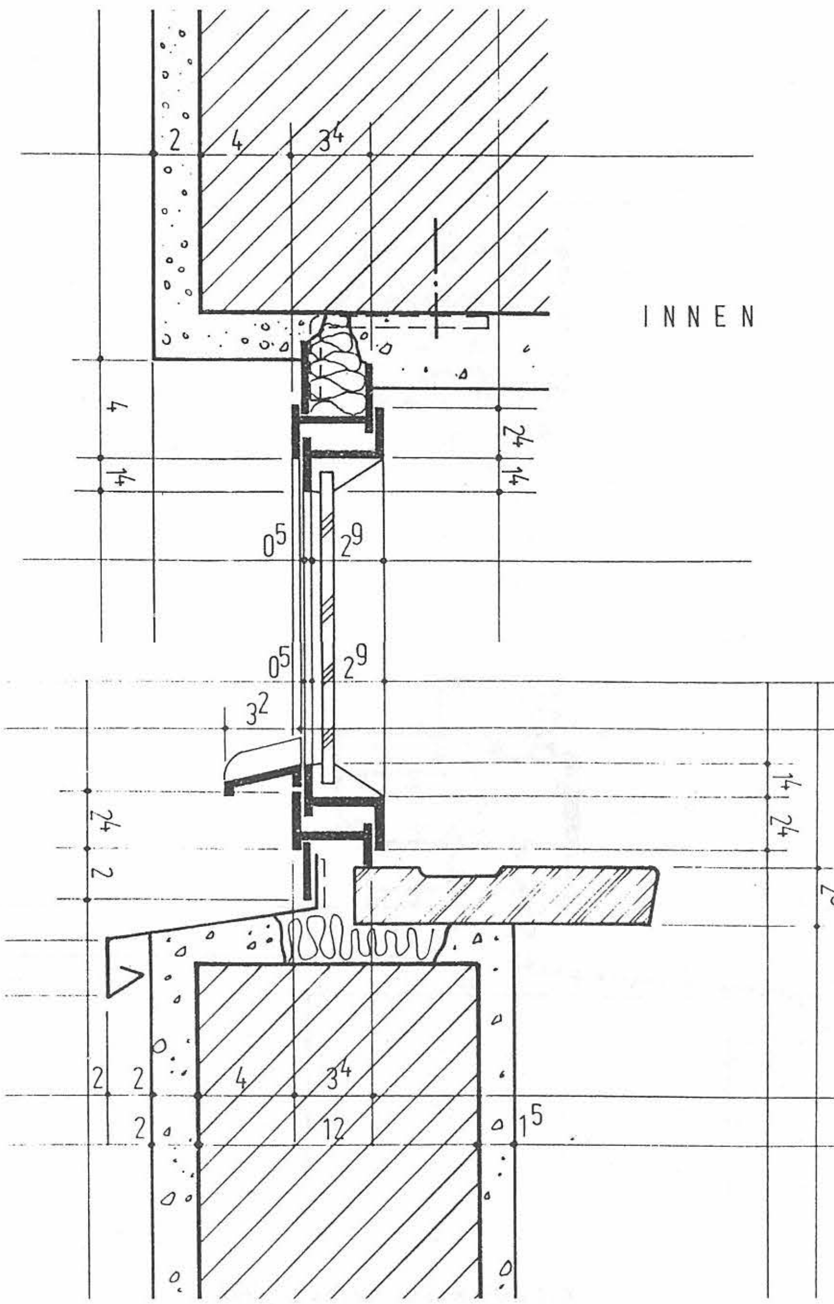
Why, we may ask, have the steel conservatory windows incurred greater damage than the timber-jointed windows? The conservatory was originally designed as a kind of buffer zone between indoors and the outside world. If it is not used in line with the original design but as a kind of extended living space - as is very often the case today - the conservatory envelope is subject to a number of stresses and strains for which it was not intended. This easily gives rise to major structural defects. A drastic increase of condensation during winter leads to damp which attacks both the steel construction of the window and the structural frame of the building itself, resulting in extensive mid-term structural damage.
The original architects considered a steel frame conservatory as a particularly functional design element, as steel was far more able to withstand the ravages of winter damp than conventional timber frames.
The conservatory fulfilled its original function as a climatic buffer zone until well into the 1960s when a change set in and tenants increasingly began to use it as heated living space.
The new kind of usage to which it was subject in conjunction with higher room temperatures caused higher levels of condensation on the windows and other parts of the envelope. Not only the windows but also the ceilings, walls and floors had all been designed without thermal insulation, in line with the original performance requirements.

Strategic decisions

Faced with an increasing number of complaints from tenants as well as downright rent cuts, the housing association had no alternative but to try and find a solution that would meet the new lifestyle requirements.
A plan to renovate the windows was considered but rejected after an inspection showed that the costs for even the simplest work such as realigning them for smooth opening and closing would be prohibitive.
Such a plan would have first involved removing the many layers of old paint to allow for a complete derusting and then replacing and repainting the rusty parts themselves. And even such extensive work would not have been able to guarantee long-term protection - only completely new windows plus an in-depth treatment of all surfaces could do that.
The amount of work involved in renovating the windows in this way stood out of all proportion to the expected results. Although the renovation costs were about 80 % of the costs of a new window, they were still unable to guarantee a minimum life expectancy of thirty years.
Furthermore, if tenants persisted in using the conservatories as extended living rooms, elaborate and extensive renovation would need the back up of permanent, all round maintenance with sharply rising maintenance bills for the flats. It would prove more difficult to rent them and the social decay of the estate would become a real possibility.

Inventory

In a preliminary phase for deciding just what kind of measures - renovation and/or replacement - were appropriate for the steel framed windows, it was first of all necessary to draw up a detailed inventory. This stocktaking established an exhaustive list of all window design components - the number of window types, steel parts, mounts, measurements and colours. It was supplemented by a report on the extent and amount of damage the windows had incurred, by exact cost accounting and by a survey of tenants' wishes.
The findings of this complex inventory made it clear



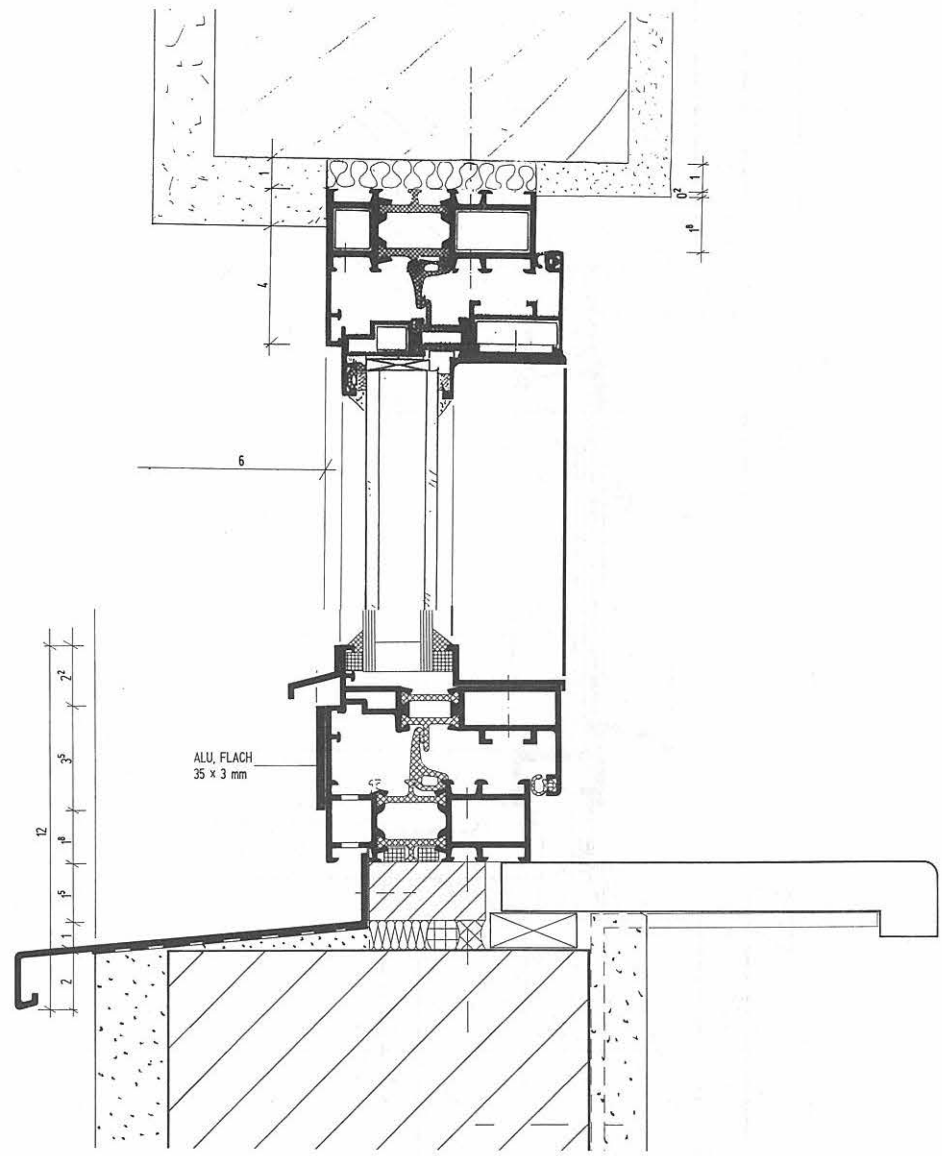
Inventory of original conservatory glazing, top en bottom details.
All drawings: Brenne Architects.

that only a complete replacement could come into question. With a view to working out an adequate solution, from the very early stages a coordination process was established involving conservationists, our client and the contractors to ensure that the final plan was in line with the stipulations regarding the preservation of historic buildings.

Alternative solutions

However, even when this goal can be safely achieved, in the last analysis it is the cost factor that decides the why and wherefore. In this light it quickly became apparent that the implementation of the new window project could only be carried out by using standard market products.
Engaging on this approach with no time to spare - for the time allocated to the planning stage was highly limited - meant that it was vital to locate a company producing windows that was prepared to cooperate in developing a range of alternative solutions. The main problem here was that the vast majority of companies in this field only work with producers of standardized parts thus ruling out the possibility of their engaging in alternative solutions.
Developing new prototypes or crafting them by hand were alternatives too costly even to contemplate; besides which the sheer number of window frames and the short time available meant that it was imperative to fall back on industrial products.
In order to fulfil minimum structural stipulations, these industrial products had to meet current building standards with regard to double glazing and thermal breaks. At the same time, they also had to be as exact replicas as possible of the original construction in order to meet preservation requirements, and they had to stay within the assigned cost limits.

Detailed plan for replacement of conservatory glazing, top and bottom details.



Redesign

The proposal put forward by the window manufacturer using standard material ruled all design considerations out of court. It involved widening the jambs by nearly 60 mm - from 140 to 220 mm - to allow for the instalment of double glazing. It was obvious that such a proposal would not obtain the consent of the conservationists.

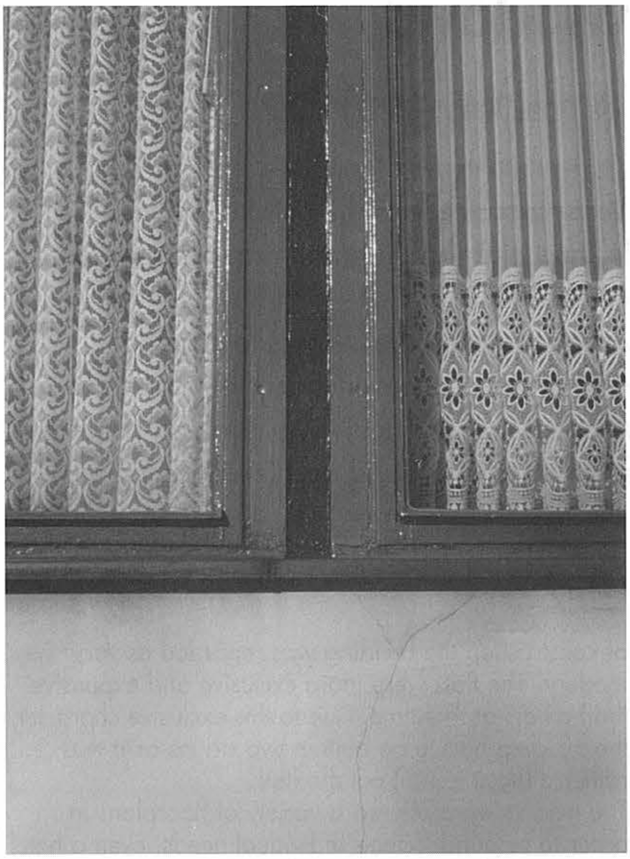
While working out the construction design in detail we also noticed that the width of the jamb is not the sole decisive factor. The gradation of the jamb levels also plays a significant part, as the windows are painted in several colours which need clear edges to delineate them.

We were able to maintain the original proportions of the casement and the frame by including fixed casements thus substantially reducing the width of the frame. We also investigated the feasibility of sawing off or removing shanks et cetera from standardized elements to achieve a design that would correspond as closely as possible to the original.

In many cases only a slight alteration in the standardized parts will bring about a substantial reduction in the visible surface of the casement element and thus dispense with the need for specially produced parts. And since the conservatory with its new windows would continue to be used as extended living space, it was also necessary to explore possibilities for improved window ventilation.

Our client expressed a wish for outward opening double casements in the lower conservatory windows. These windows involve two casements hung from either side of a window casing, opening outward without a central mullion. Installing such windows in the upper part was ruled out on grounds of cost. Also, our client calculated that this type of window installation would involve high maintenance costs.

As a compromise the conservatory side windows are now equipped with a double casement so that the front side remains true to the original design even when the



Original detail at separation wall between two conservatories.

New detail at separation wall.

windows are opened. Our actual window design also incorporates features to reduce indoor damp pressure levels to minimize condensation. The effect is reached through the omission of lip seal gaskets at the upper windows, resulting in slight continuous ventilation.

Architecturally faithful

Our collaboration with the contractor has led to the creation of a new type of conservatory window whose production costs lie within the tight limits of the budget we were assigned and which fulfils present day building requirements. Not all its design features do correspond exactly to those of its historic model. For instance the original rounded steel fixtures have now been replaced by sharp-edged fixtures and in some instances the fittings are 10 mm wider. Still, the overall architectural impression has been faithfully preserved. As a case study the conservatory window replacement project is clear evidence that solutions in line with preservation aspirations do not always need to rely upon elaborate and cost-intensive, tailored models. However, we should beware of generalising from a single case, as the approach we have adopted here might not be as suitable for an individual building as it was for a 1920s residential estate.

Winfried Brenne is a practising architect in Berlin and a member of DOCOMOMO Germany.

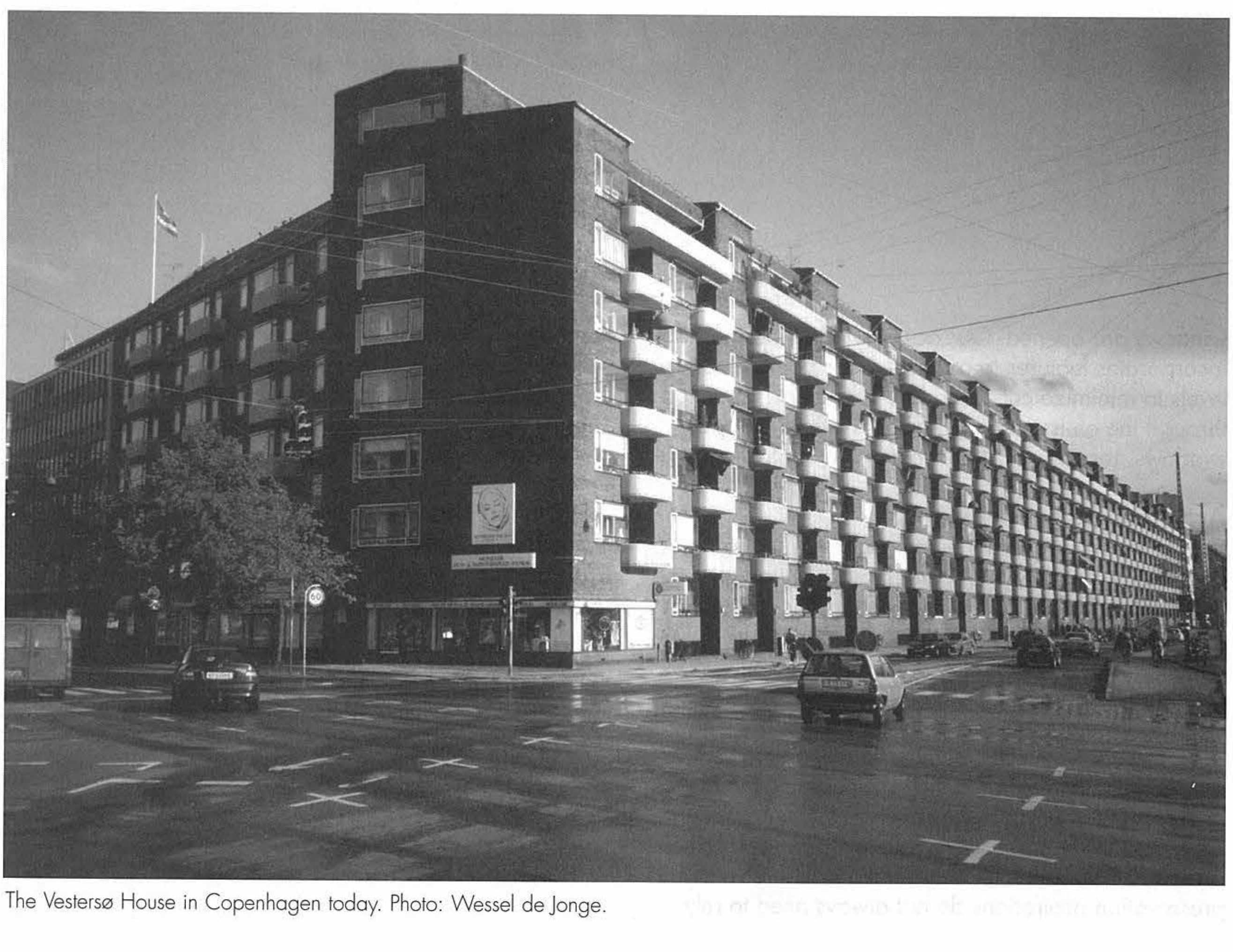
Modification of existing windows

Vestersø Apartment House (Fisker & Møller, 1937-39)

Kay Fisker's and C.F. Møller's window design for *Vestersøhus* reflects the spirit of its time, allowing plenty of daylight and fresh air to come in, and offering diagonal transparency through glazed corners.
The increase of traffic noise and energy consciousness compelled the owners to consider upgrading of the large timber framed window units, that were never intended to respond to such conditions. As a result of the conservation authorities' persistence, a painstaking process of trial and error led to a redesigned unit that satisfies both technical and aesthetical ambitions.

by Søren Lundquist

In 1935, the construction of a 7 storey high building at Vestersøgade in Copenhagen was initiated. *Vestersøhus* was to include 270 flats, with several shops on the ground floor facing Gyldenløvesgade. The architects were Kay Fisker and C.F. Møller.
The building was designed to provide many different sizes of flats and the house contained elevators, rubbish chutes, and a balcony for each flat. At the time of construction the building was regarded as very modern. The flats were more exclusive and expensive than others at that time. Due to this exclusive character, the building had to be built in two stages as it was rather difficult to rent out the flats.
The tenants were offered a variety of floorplans in order to respond to their individual needs. Even a hotel was included in the program for the house. This is still



The Vestersø House in Copenhagen today. Photo: Wessel de Jonge.

Facade detail of the Vestersø House. Photo: Ola Wedebrunn.

existing and its entrance is found in the centre of the facade along Vestersøgade.

Daylight

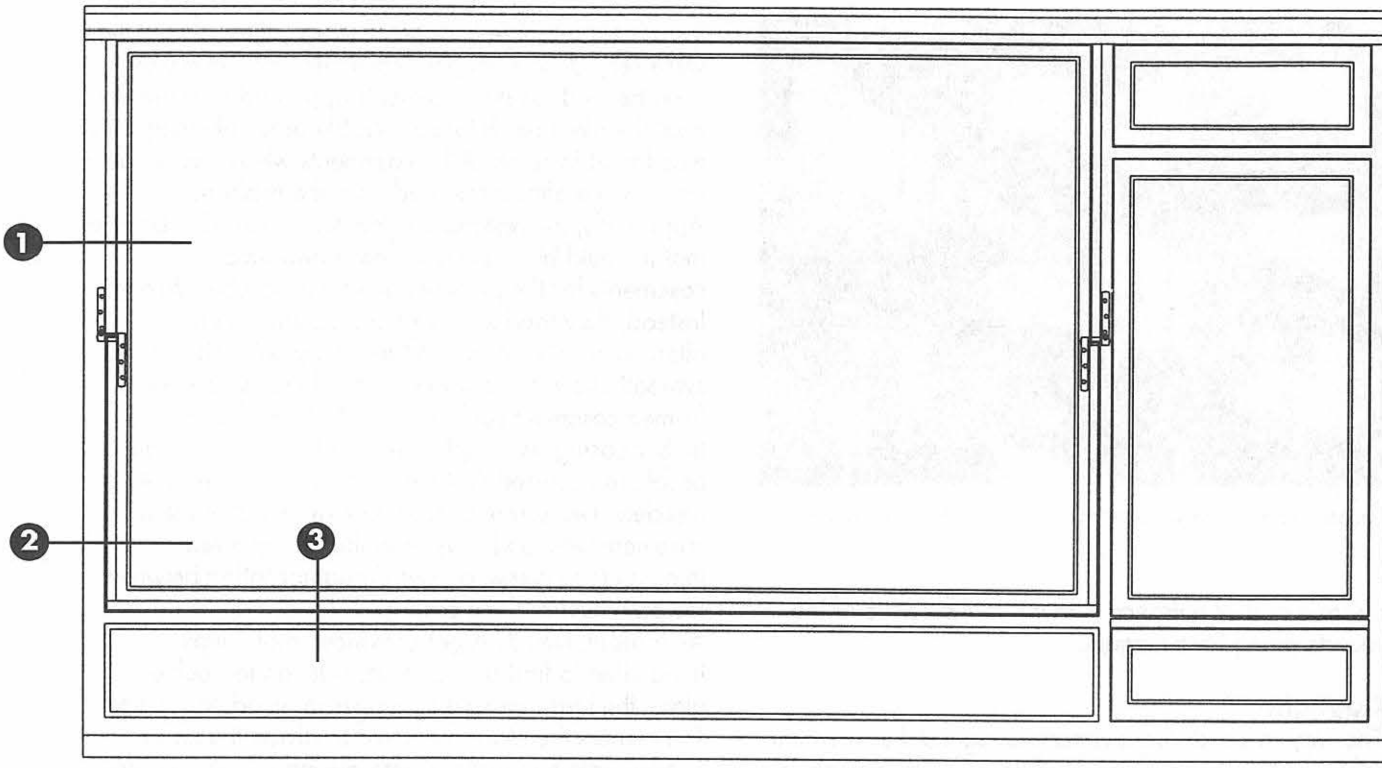
The way in which the architects designed the windows reflected the typical demand of that time to provide the flats with as much daylight as possible. The modernists' desire to substitute massive brickwork corners for corner windows was taken to the limit at *Vestersøhus*. At all the balconies there is a corner window providing the interior with daylight from two sides. The balcony windows were integrated with the doors, and a complex program of window varieties was created by the architects.
Except for the shop windows, all the window frames were made of timber. The sections of the casings and window profiles appear very minimal in dimensions, in relation to the large glass panes held by them.
The main architectural conception regarding the fenestration was to create a large vision panel in the centre to dominate the unit, with adjoining secondary elements that were either fixed sidelights or pivot windows. For energy efficiency, the smaller sidelights and windows featured a secondary glazing on the inside, but the large windows remained without insulation.
Over time the limited energy efficiency of the units as a whole became a problem for the tenants, who also developed a growing concern about soundproofing as traffic noise increased considerably, further fuelling their demands for additional insulation.

Emergency

DANICA, the owners of the building, asked C.F. Møller architects for a proposal to improve heat and sound insulation. Many of the large single glass panes were installed in fixed lights, that were not designed to be operable. Without many problems, the glass panes in these frames could be replaced by double glazing units by simply enlarging the rabbet. However, another part of the large glass panes was installed in horizontal pivot windows. The existing construction of these vast operable casements was so flimsy that it was were very close to its physical limits - and in a way even beyond, as the casements appeared insecure to hold the glass much longer. Visible proof of emergency was found in some of the casements where the window panes were almost released from the rabbets.
Apparently, the restoration architects refused to believe that it would be possible to make new timber casements for the pivot windows with double glazing. Instead, they tried to solve the problem with an alternative solution in steel. In a way, this solution was sympathetic to the original design because a steel framed casement could be installed into the existing timber casing. A sample unit was tried, but so many problems occurred that the proposal was eventually rejected. Two essential problems were that the steel casement was too heavy, and that it appeared impossible to create proper draughtproofing between the casement and the casing.
As a result, DANICA got convinced that it was impossible to find an adequate solution to double glaze the large casement, neither in wood nor in steel. The owners therefore proposed to divide the large window into two parts by introducing a bold glazing bar, that would make a characteristic change in the architecture of the building. Although the National Nature and Forest Agency, Denmark's listing authority, was not very pleased with this solution there seemed to be no alternative and they were almost ready to accept the division of the window.

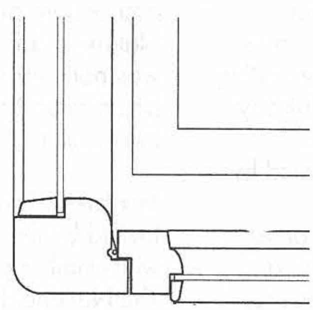
Timber alternative

Invited by the owners, C.F. Møller architects came up with another proposal. I was invited as a consultant to The National Nature and Forest Agency to participate in a meeting to discuss a proposal to replace all the window units by new ones made of aluminium. Even using this strong material it appeared impossible to elaborate the large casement as a horizontal pivot window. As an alternative the producer of the aluminium replacement units suggested to install top-hung casements. In any case, all the subtle details of Kay Fisker's window design would have gone lost, as it appeared also impossible to combine an aluminium casement frame with the existing timber casing.
Until then no serious attempt had been made to solve the problem using wood. When asking for survey data of the existing conditions I was kindly handed a set of detailed drawings from the time the house was built. The drawings were made for the first stage of construction and diverged from the second stage window design. Still, no one had surveyed the existing conditions until then and, consequently, no serious consideration had ever been made whether or not new timber casements could be fitted in the existing timber casings.
After the meeting when the aluminium replacement windows were proposed my conviction grew that a timber alternative should be explored. Fortunately, I was granted some time to elaborate a solution in

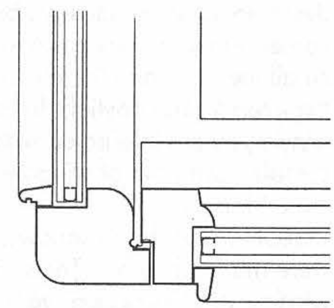


Details of original and replacement window. Drawings by Søren Lundquist architect.

1

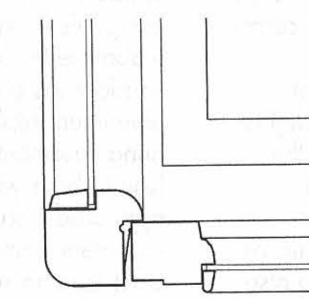


1. Original detail.

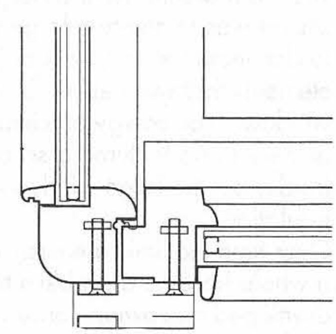


1. Replacement detail.

2



2. Original detail.



2. Replacement detail.

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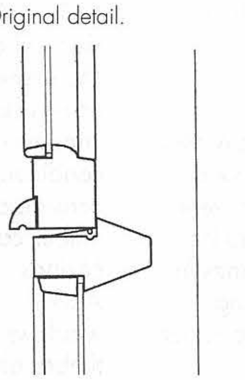
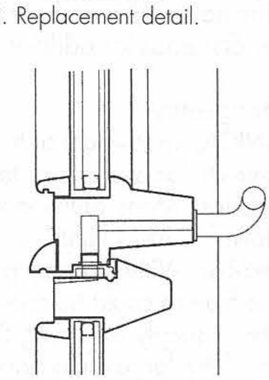


3. Original detail.



3. Replacement detail.

timber. It was agreed that if a timber alternative would turn out possible, a trial window would be made. As the owners already paid for an earlier test window they were reluctant to pay for another one, and the National Nature and Forest Agency decided to fund the second trial window.

Trial project

The trial project was based on an extensive survey of one existing window. Horizontal pivot windows are complicated due to the fact that the sections of the casement and the casing profiles above and below the hinges are different. In contrast to the other facade where the various windows are cleverly arranged around balconies, the windows above the shops at Gyldenløvesgade feature an open corner instead.
A corner post links the large pivot window with a little side window fitted with a traditional side-hung casement and an inside secondary glazing. Although it holds the hinges for the heavy pivot casement, the corner post is actually too slender to do so, posing an additional problem.
Even when taking into consideration that it only had to hold a 4 mm thick window pane, the frame of the 1.40 x 2.50 m pivot casement is very flimsy. When the window is opened to its horizontal position, the casement shows considerable deflection. Particularly at the top floors it felt uneasy to doubt whether the casement frames were sufficiently stable to secure the window panes.
The vertical post at the corner is flimsy too. The engineering company Rambøll, that was responsible for the technical calculations, would not accept the existing situation nor would it give its consent to a proposal to mount an even heavier frame into the existing casing.
The technical and aesthetical requirements were complex. The horizontal parts of the casement frame (the top and bottom sill) had to serve as structural members when the window would be opened, in order to avoid deflection and securely hold the glazing, and were to be dimensioned accordingly. The size of the jamb was not to exceed the dimension of the corner post to prevent it from being covered. The frame was to hold double glazing with asymmetric thickness for soundproofing. Finally, the casement should be mounted in the existing casing without changing the dimension of the rabbet. All this appeared possible without major changes in the proportions or the external dimensions, just by increasing the width of the frame profiles with only 5 mm.

Window fittings

The biggest problem, however, was to find a solution for the hinges. The large horizontal pivot windows were hinged with primitive hardware at the middle of the jambs. The hinges were fixed to the outside of the casing, which caused a displacement of the axis of rotation off the centre of mass. This displacement allowed the window to remain balanced in the

The rejected proposal for a division of the large window into two smaller units. Photo: Ola Wedebrunn.

horizontal position. However, a light person easily got the feeling of being drawn out of the window when opening it. It was an intelligible wish to provide an alternative solution with friction.
Only a few hinges for horizontal pivot windows are available in Denmark and the hinges found on the market were not available in suitable dimensions for such big and heavy windows. The hardware company Carl F. Petersen had already heard of our case when we contacted them, and they were despondent not to be able to find a new hinge to be used in the existing casing. A German hinge would still have been suitable to support such heavy windows, but it turned out that these were only to be applied in combination with inside glazing, which was inappropriate for the *Vestersøhus*. Also, the hinge would have required to cut a big part from the existing casing in order to install it properly.
It was decided that the existing hinges were to be re-used as supports for new and stronger steel hinges. These feature a metal screw that can be adjusted to tighten around the axle so as to provide the necessary friction. The first trial showed that there was too much friction which caused the hinge to bend. Therefore a lap was welded to the hinge that was then fixed against the casing. As screws were expected to be pulled out of the timber casing, a steel plate with threads was installed on the casings instead.

Soundproof

The windows were originally secured by use of a simple casement fastener. This type of fastener was totally inappropriate to press the casement frame against the mating casing rabbets tight enough for draughtproofing. The sill detail of the window presented a particular problem as this was actually a flimsy transom with another light beneath it. This subsill could easily be moved horizontally, inward and outward, with a serious sound leak as a result.
Two sliding pasquil fittings were mounted in the top and bottom casing, so that the top frame and bottom frame could be locked together with the transoms at


The replacement window after approval. Photo: Ola Wedebrunn.

four points. The thick casement profile provided an additional stiffness to the transom in the locked position, so that the joint is now soundproof.
After the trial of the new window in the workshop and the correction of the hinges, it was decided to try the sample unit on site. The new casement was installed to assess its soundproofing capacities. It was a success beyond expectation and today all horizontal pivot casements are substituted. All tenants are now provided with insulated and soundproof windows, and you have to be a sharp-eyed professional to see the difference from outside. The alternative solution developed for the Vestersø House windows fortunately was able to satisfy technical as well as aesthetical ambitions.

Søren Lundquist is an architect MAA in Hillerød, Denmark.

The window and the plane

The Central Post Office in The Hague (Bremer 1939-49)

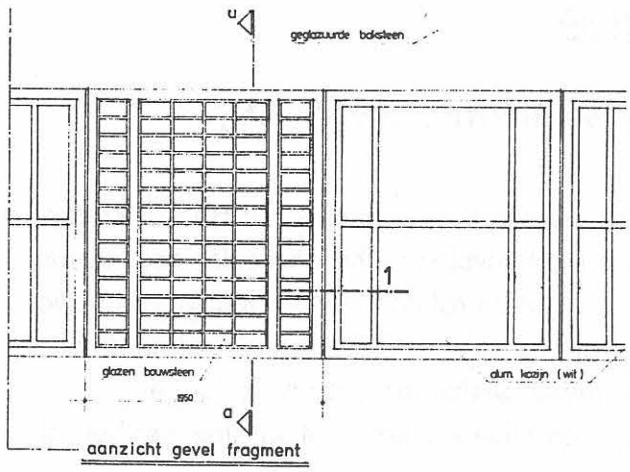
In contrast to most Modern Movement buildings, the Central Post Office in The Hague features a continuous skin rather than a permeable and transparent envelope. The particular application of glass brick elements has been key to the original architectural conception. Recent renovation required the replacement of the original elements that had suffered from the uneven thermal expansion of glass and concrete. With the original imperial-size glass brick no longer available, the renovation architects had to develop a creative solution that satisfies aesthetical as well as technical requirements.

by Dirk Jan Postel

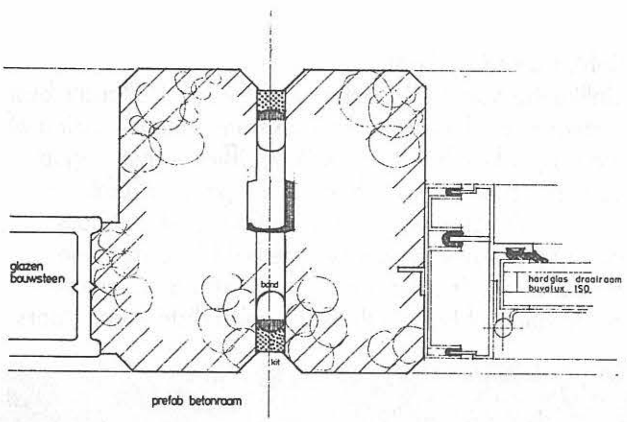
By origin, the window is an exception to the solid wall of relatively minor dimensions. By the virtuosity of Gothic architecture, the walls dissolved into a bone-like structure, holding crystalline windows of stained glass. Only during the 19th Century, fully glazed buildings became a reality. The Modern Movement demonstrated completely new oppositions of open and closed, of transparent and translucent. In some instances the window was, in turn, made part of a glass facade: light, framed by light.

Unlike the Van Nelle factory (1926-30), Holland's best known icon of the Modern Movement, the obsession of the original architect of the Post Office in the Hague does not seem to have been with light and lightness, but with the expression of a continuous skin. Glass brick and glazed masonry together blend into one single plane. The glass brick facilitates a maximum penetration of light to the large mail distribution floors;

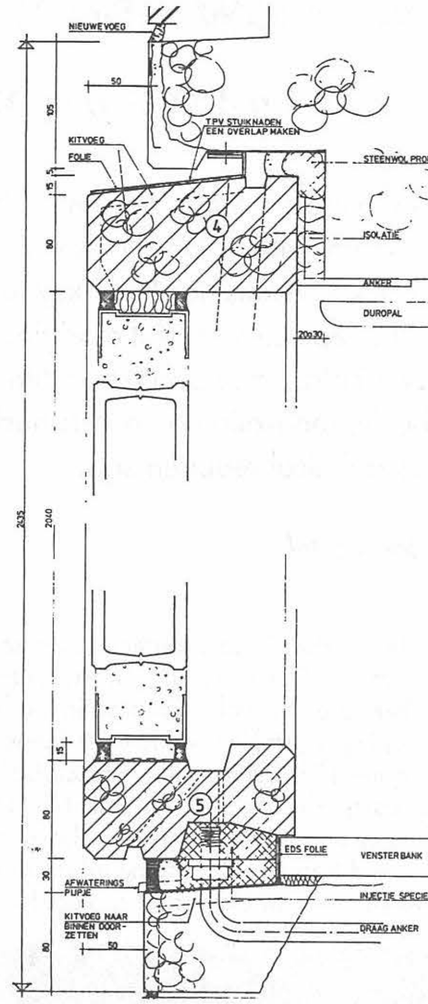
The Post Office after restoration in 1990. All photos and drawings: Kraaijvanger-Urbis architects.



Facade fragment of the proposed division of the glass brick sections into 1-4-1.



Horizontal detail for the restoration of the glass brick sections.



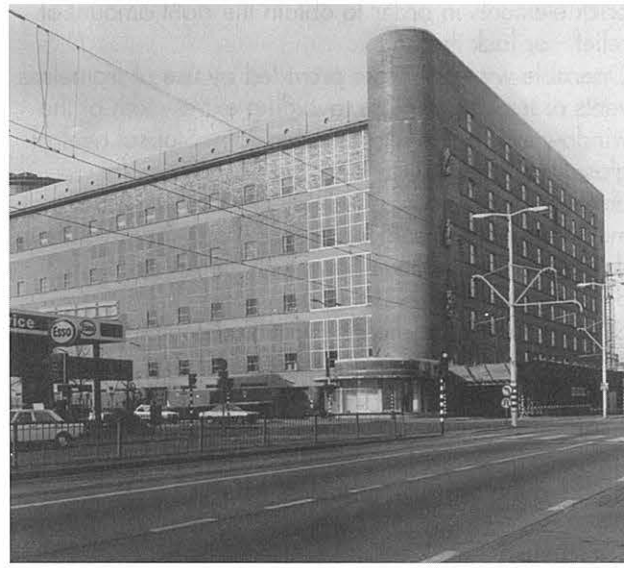
Vertical detail for the glass brick elements.

Yet, the windows are conceived as an exception to the rule, a rhythm of relatively small holes in the large surfaces of the facade. In restoring this remarkable building, our office has contrived to reduce visual changes to a minimum, while meeting structural demands to avoid future damage.

Original

The architect G. C. Bremer, who was at the time the state architect, designed the Central Post Office of The Hague between 1935 and 1939. Because of the Second World War, actual construction took place only between 1948 and 1950. The design, certainly the most radical example in the oeuvre of Bremer, was praised by J.J.P. Oud as a milestone in the development of Dutch architecture.
The building consists of a wing with broad double-high spaces for mail distribution, and a shallow wing with office spaces. Together, the two wings form a T-shape, with rounded edges that contribute to the sense of continuity. Most conspicuous is the facade: large surfaces of translucent glass brick perforated by a series of small windows. Strips of glazed masonry create a horizontal articulation.
The structural concept of a monolithical outer skin had provoked a range of problems that had resulted in the deterioration of the facade, virtually from the start. The glass brick and the surrounding concrete frame differ in thermal capacity, resulting in temperature differences. Moreover, the frames and lintels were connected to the main structure without dilatation joints. Hence, thermal and structural forces were imposed on the facade, resulting in cracked concrete and glass brick breakage.
Also, the masonry ran up directly against the inner concrete wall, since it had been used as the outer formwork for casting. Paradoxically, because no insulation had been applied and the joints were badly filled, the masonry was still in relatively good shape: temperatures below zero had been avoided and the brick had dried easily.
The largest problem here had occurred by casting the concrete against the masonry. The concrete was left with one 'blind' side, so that concentrations of aggregate could not be spotted. The infiltration of water had done the rest. A combination of the iron particles from the nearby railway and the high concentration of chlorides in the coastal climate of The Hague aggravated the whole situation. Large parts of the exposed concrete were spalling, with

Full-size mock-up to test the aluminium replacement windows.


The Central Post Office of The Hague before restoration.




Left: instalment of the replacement windows. Middle: repair of the concrete lintels. Right: instalment of the concrete frames. Glass brick sections are placed in secondary aluminium frames.

reinforcement appearing at the surface. The degree of damage had forced the client to build a temporary tunnel to protect passers-by. Finally, the single glazed steel framed windows needed to be replaced, primarily to improve thermal comfort levels.

Restoration

The restoration started with an extensive research of the causes of damage. In order to make this possible, the facade was extensively cleaned. Also, a plan was established for repair and replacement that included all operational aspects like scaffolding, assembly, and planning.
The latter was crucial, since the building's central function allowed for no interruption. The maximum timespan for the execution of all works on one floor following another was set at 5 days! In terms of planning the removal of the existing concrete frames around the glass brick elements by a wet-sawing system was most critical.
The original glass brick had been manufactured in America and measured 5"x9", approximately 125 x 230 mm. Each section of 7 x 15 glass bricks was enclosed by a concrete frame. A double vertical joint articulated the number of seven into 1-5-1.

To solve the thermal expansion problems of the translucent facade elements, the glass brick was installed in an aluminium subframe and then enclosed in a concrete frame. This meant that the dimensions of the infill were to be reduced, thereby disturbing the careful proportioning of the glass brick sections. Moreover, the original imperial-size glass brick appeared no longer readily available and for the restoration we had to re-sort to current European products, typically measuring 120 x 240 mm. In order not to compromise the origi-nal design idea more than necessary and to solve both problems at once, the frames were redesigned to accommodate 6 x 14 elements each, the number of six now divided into 1-4-1. The joints were made of so-called Leica-concrete, that has a similar thermal performance as glass brick.
The single glazed original steel window casings were replaced by insulated aluminium frames.
A maximum width of 50 mm was considered to be acceptable for the aluminium profiles.
A purpose-made extrusion was designed, based on the minimal version of a standard curtain wall profile.
A full-size mock-up demonstrated that the windows had to be slightly recessed in the pane of the glass

brick elements in order to obtain the right amount of relief - or lack thereof.
Operable windows were provided by use of frameless vents of temperate glass, avoiding extra width of the window frames. To master solar gain, Stopsol neutral glass was used. (Since then, the possibilities for particular extrusions as well as glass coatings are much more advanced and today, it may be possible to design replacement windows without any visible differences with the original.)
On demand of the client a functional compromise was made on the facade of the office wing. The ratio between windows and glass brick of 1:2 was inverted. It can be considered a virtue of the original composition to see how little this inversion has changed the overall expression.

Execution
The removal of the existing concrete frames around the glass brick facade elements required special attention. The applied wet-sawing system called for special care to avoid water damage on lower floors, where mail continued to be handled night and day.
To prevent early damage to the fragile facade elements, transport was provided with air-suspended trucks. Assembly on site took place from the scaffold of the window-cleaning installation, which further limited the maximum weight per element.
The dimensioning of the prefabricated concrete frames was critical due to the calculated tensions as a result of the variation in thermal expansion of the different materials. Even if the glass brick was placed in an aluminium subframe that was separated from the concrete frame by elastic joints, the section of the concrete frame, and in particular the dimensions of the lower lintel, was critical. A superior concrete quality B 60 had to be applied though primarily to obtain the proper density, rather than strength.
During the period of restoration, Rob Ligtvoet of Kraaijvanger-Urbis made a new extension with the same function. The new building reacts by its concave floorplan to the rounded forms of Bremer's scheme, while having a similarly continuous facade, made of a contemporary honeycomb aluminium sandwich panel.

Epilogue
At the time the building was constructed, architect and engineers did not have the same awareness of building physics as they do today. The detailing of the Central Post Office building showed serious deficiencies, particularly: the lack of any cavity or detachment between the masonry and the concrete; the composition and the dimensions of the concrete frames around the glass brick; and the decision to cast the steel window frames directly into the concrete. In order to keep the original architectural expression, a compromise had to be accepted concerning the aspects of building physics. However, some improvements are achieved: the interior became more comfortable because of the new windows with double glazing, and the joints are carefully composed to match the heat resistance of the glass brick. An important decision has been made not to add any insulation. The benefits of insulation would have been limited anyway, since the insulation value of glass bricks is limited and many inside surfaces that would have remained without insulation, would continue to act as heat conductors. But most important is that only by not insulating the skin, the construction, and in particular the masonry, could be kept in good shape. Although some new materials are applied and the detailing has changed, the appearance of the building continues to be as Bremer had envisaged it.

Dirk Jan Postel is an architect with Kraaijvanger-Urbis architects in Rotterdam, The Netherlands, and a member of DOCOMOMO-NL. Rob Ligtvoet of the same firm has been the job architect for the refurbishment of the Central Post Office in The Hague between 1982-89.

Detail of the restored facade showing the additional windows.

Retention and replacement: a careful balance

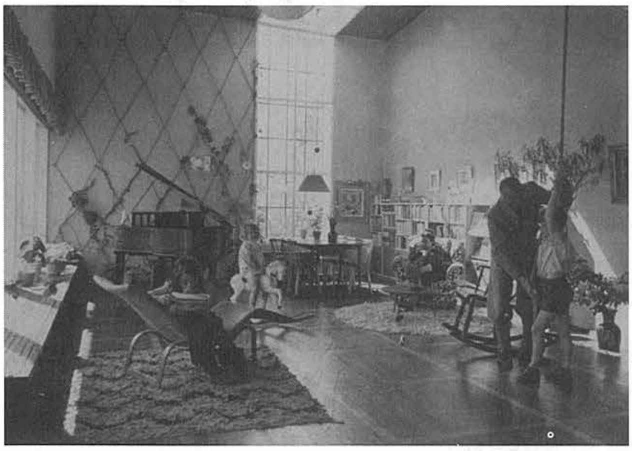
The Westman House in Lund, Sweden (1939)

After designation as a listed building, the new owners of the Westman House were unexpectedly confronted with the regulations of conservation authorities. As is mostly the case with modern heritage, the issue of window replacement posed particular problems. The final solutions were the result of a careful design process, balancing the criteria for preservation with users requirements. Though costly, the restoration of the Westman House is now regarded an example for future restorations of modern buildings in Sweden.

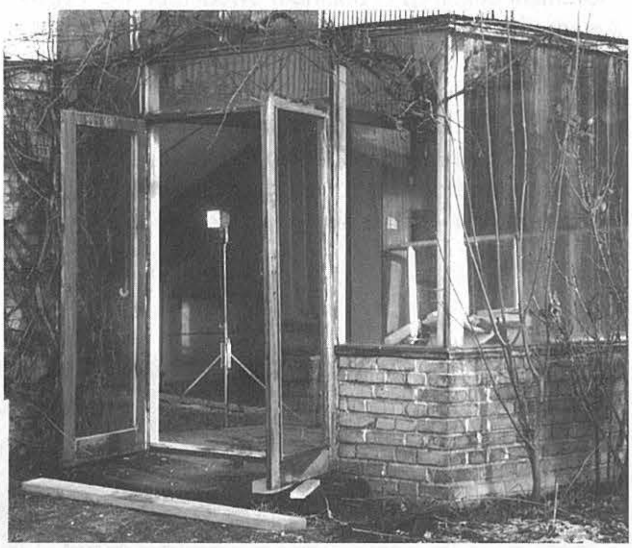
by Thomas Tägil

Hans Westman (1905-1991) was one of the best known architects in Southern Sweden and a pioneer of the Modern Movement within the region.
He worked mostly in Lund, an old university town, where he designed over 100 buildings from the middle of the 1930s until the 1980s. As he was one of the first to be educated as a modern architect, he was commissioned to design many of the early Modern Movement buildings in Southern Sweden in the 1930s. Among them were the elegant public baths of Lund (1938), which unfortunately were demolished just forty years later. The success of the public baths made it possible for Hans Westman to design his own house in one of the older residential neighbourhoods of Lund. The Westman House attracted much attention for its modern design when it was completed in 1939.[1]

Southern view of Villa Westman in the mid-1940s. Period photo courtesy Lund School of Architecture archives.



Living room with tall window facing west. Period photo courtesy Lund School of Architecture archives.



Detail of the conservatory before restoration.
Photo: Thomas Tägil, 1998.

Detail of the replaced window casements with restored teak wood pivot windows. Photo: Thomas Tägil, 1999.

Open plan

The house differed from its neighbours because it was placed far back from the street to leave space for a garden on the sunny southern side. The idea of opening up the house to the sun was important. The family quarters face to the south with large windows, whereas yellow and red brick walls close off the interior to the north and east. The overlap between exterior and interior is demonstrated by the use of similar materials and details outside and inside.
The interior is dominated by the large living room, the western part of which is designed as a double-height studio. The height of the space is emphasized by a tall window facing west. To the east, the upper floor ends in an indoor balcony, the parapet of which continues visually onto the outdoor terrace. The terrace floor is covered by the same blue ceramic mosaic tile that is used in the conservatory below.

Window defects

In 1994, three years after Hans Westman's death, the house was designated as a listed building and gained legal protection against any exterior or interior changes. By that time, the condition of the house had seriously deteriorated due to the lack of maintenance.
In 1997, the new owners were faced with a costly and complicated restoration project.
The main problems were caused by a number of technical deficiencies, and the severe damage due to damp, the extent of which was only discovered when the works started.
Another problem was the indoor climate. The house was built without insulation and the many windows were single glazed. As the conservationist in charge, I was repeatedly faced with the dilemma of how to balance the aspects of preservation with the need of the owners to have a comfortable and modern life in this listed building.
Obviously, the windows became one of the main issues. As with many architectural works of the Modern Movement, the window details are important for the character of the building. Here, the windows were mainly of two types: fixed windows in a white painted casing made of ordinary timber and elegant pivot windows made of teak wood.

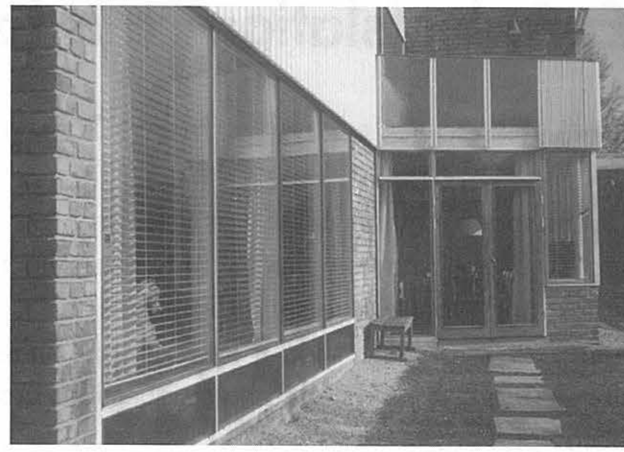
Sheet glass

In order to cut back on heating costs, the owners wanted to install insulated glazing in all windows. Their demand was refused by our office regarding the teak windows, which were of good quality and not damaged.
A specialist for window restoration needed only to lubricate the mechanical parts and treat the surface of the wood. Today the teak windows have regained their warm colour that lends the house its particular character. A compromise was found for the renovation of the fixed living room windows facing south. Given the large size of these windows, the use of double glazing was regarded inevitable. It was required however that the wooden part between the windowpanes would be

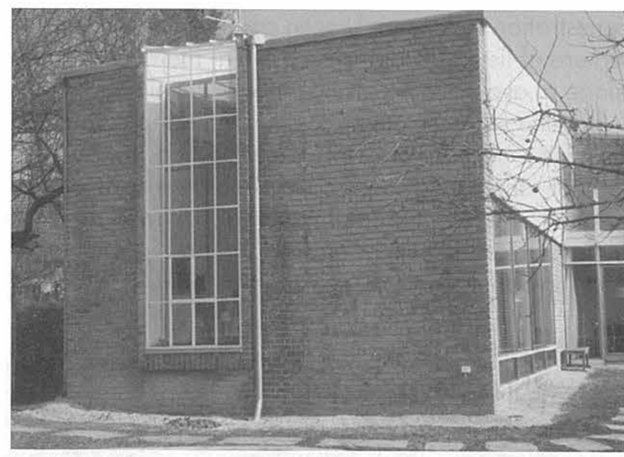
painted white so that it could easily be distinguished from the timber frames.
Moreover, it was demanded and accepted that the outer windowpanes would be replaced by sheet glass instead of float glass, as this would have caused a sterile and unsuitable appearance of the house. Although there was no difficulty in finding sheet glass as such, it appeared almost impossible to find this type of glass in such large dimensions in Sweden. In the end, a manufacturer in Germany appeared able to render this solution possible.
The architectural advantage of providing double glazing for the fixed windows was that the secondary outer windows of blue painted steel, that were added during the 1940s, could now be removed. In this way, the position of the windows was no longer too far in front as compared to the rest of the facade surface and the elegantly profiled timber jambs became visible again.
Another difficult task was the tall window with its thin steel profiles that continues into the roof and provides daylight to the living room from above. Because of design failure in the construction, leakage had frequently occurred and the roof light had consequently been covered.
The old steel profiles were destroyed by corrosion and it was just a question of time before the construction would have fallen apart. The whole window had to be reconstructed of stainless steel profiles as commonly used for greenhouses. The new construction was almost entirely true to the original design, but at a very high cost.

Costly experience
One always learns something new from the restoration of a modern building, as experiences are different from those with older buildings. It can be difficult to motivate both owner and contractor to bear the expenses of special solutions for a building that is only sixty years old. In this case, the lack of experience of the contractor made it even more difficult. Had the house not been listed, the result would have been quite different.
In the case of the Westman House, apart from the restoration problems, we also faced severe technical deficiencies. A great part of the economical responsibility was handed over to a new owner who, in this case, was not responsible for the lack of maintenance. The restoration work became very costly to the owner, despite the fact that the County Council contributed to the overall cost with a large part of its own annual budget. The authorities considered their generosity for 'the Westman project' worthwhile as it could serve as an example for future restorations of Modern Movement buildings. Accordingly, the exchange of experience gained from similar projects is of great importance for all architects.

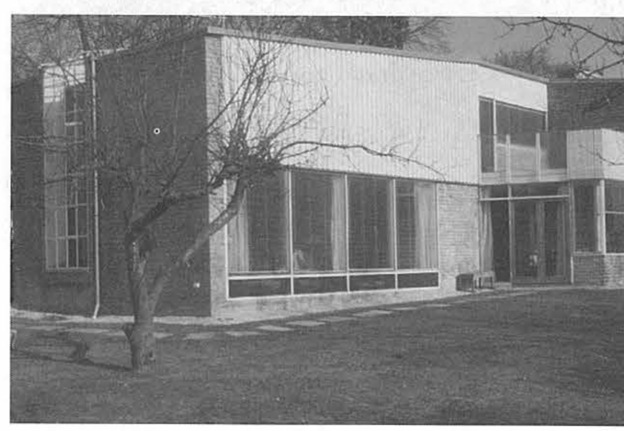
Tomas Tägil is a practicing architect SAR, PhD (Eng) and an assistant professor at the Lund School of Architecture, Lund University, Sweden.



South facade with new conservatory windows.
Photo: Thomas Tägil, 1999.



West elevation with replaced stainless steel window.
Photo: Thomas Tägil, 1999.



Main view of Westman House after restoration.
Photo: Thomas Tägil, 1999.

Note:
1. The Westman house was presented in DOCOMOMO Journal no 15, 1996.

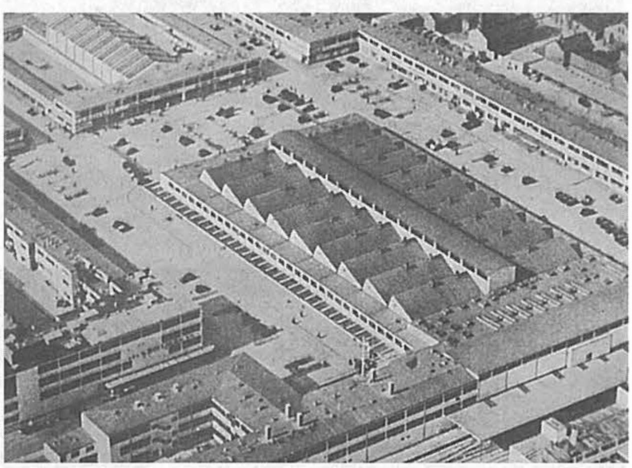
Euro-legislation calls for changes

Copenhagen's White Meat Town (1932-34)

Copenhagen's meatmarket was listed in 1995 as a fine example of a Modern Movement industrial building complex. Shortly after, the Historic Buildings Department of the National Forest and Nature Agency in Denmark had to accept the replacement of original steel framed windows, doors and shop fronts with aluminium, due to new Euro-legislation. By challenging the standard answers to complex questions a satisfying solution could eventually be accomplished.

by Jens Borsholt

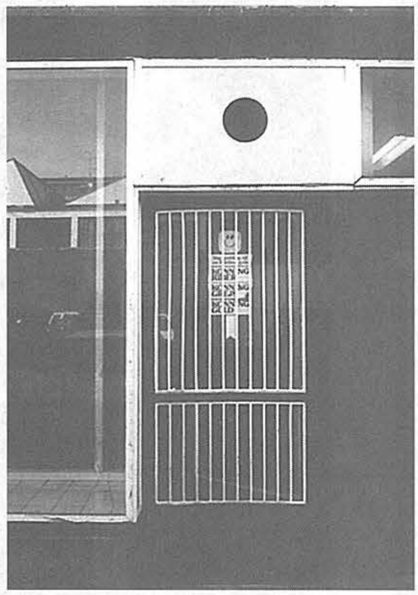
Fenestration is commonly seen as a very important feature of listed buildings and, often, many efforts are made to avoid the replacement of original windows. When the replacement of original windows cannot be avoided - because of severe deterioration, rot or dry-rot - the substitute product is mostly a copy of the original, made of the same material, with the same dimensioning, detailing, and colour, and in some cases even involving the reuse of the fittings of the original window. This is nowadays widely accepted by owners and users of listed buildings, and normally does not cause any problem.
When, at a time when the buildings had just been listed, the municipality of Copenhagen asked for permission to replace almost all the original steel framed windows, doors and shop fronts in the White Meat Town with new ones made of modern aluminium profiles, the Historic Buildings Department got quite shocked.

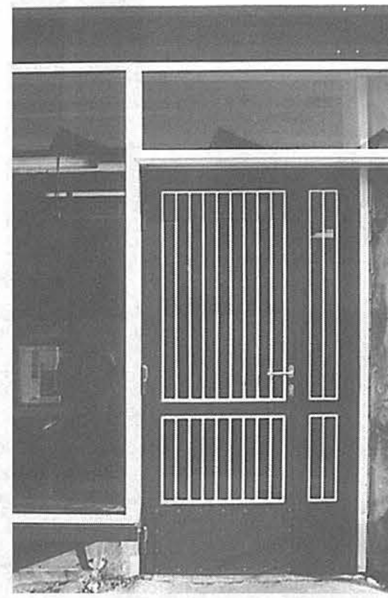


The White Meat Town in Copenhagen on a period photo of 1935. All photographs by courtesy of the Danish Department of Historic Buildings, National Nature and Forest Agency.

Shop fronts of the meatmarket before (top right) and after (bottom right) renewal.

Entrance door showing lower and upper vents to dry shops at night.





Entrance doors with trellis-work before (left) and after (right) renewal.

White Meat Town

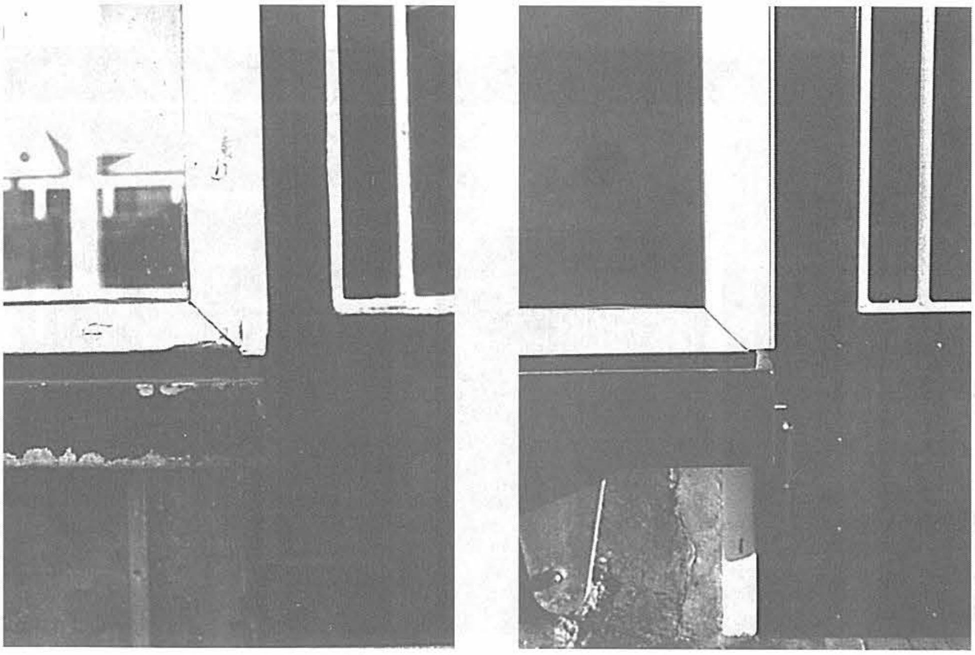
Den Hvide Kødby, as the White Meat Town is locally known, was built in 1932-34 by the architectural office of the municipality of Copenhagen. It was originally designed to accommodate the whole range of services involved in the processing of meat and meat products for Copenhagen, receiving live animals at one end and delivering steaks and sausages at the other end.
The meatmarket consisted of a slaughterhouse, various cold stores, a veterinarian controls department, and a central wholesale market hall surrounded by shops for individual butchers and small meat-processing factories. The White Meat Town actually was a small town in itself, with its own bank, post office and restaurant, and with a central cooling plant for the refrigeration of the shops and stores in all areas of the complex.
At the time of listing, the Meat Town had been in function for more than 60 years. And although a lot of alterations had been made in connection with the closing down of the slaughterhouse and the main hall being turned into a wholesales supermarket, the Meat Town still featured a great deal of its original parts, including the original windows, doors and shop fronts.

New regulations

At the same time, the deadline for implementation of new Euro-legislation was approaching fast. The new regulations made greater demands to the flow of production and to the performance of spaces for handling fresh meat, regarding climate control, hygiene and resistance against vermin, and the materials used in the interior as well as the exterior design.
In a review of the shops and factories, the butchers had amongst other things been asked to replace all the windows, doors and shop fronts, because they were in a very bad state of repair, and corroded. The shop fronts were partly made of wood and the new regulations did not allow any use of organic material in such shops.

Original windows

The original fenestration in the White Meat Town involved horizontal bands of windows, made of rolled steel profiles. The mullions are wide U-shaped profiles that are set 1 m apart and allow to put up partition walls against the facade at regular intervals, producing a great flexibility.
The shop fronts are made of simple L- and T- shaped profiles. They are designed as a kind of elevated bay windows, about 40 cm above street level, that sit on a wide concrete sill that projects about 30 cm. The glass is fixed by wooden beads screwed directly into the L- and T-profiles. A steel casing in which a sunscreen is hidden closes the top of the shop window. Around the entrance doors the fronts are arranged as a small niche to allow the doors to be set back in line with the main facade.
The doors are made of steel profiles with a rectangular section and feature two panels consisting of a window opening to the inside and a trellis-work



Corner detail showing the characteristic white frames produced by painted wooden beads at the original (top) and with the new aluminium frames after renewal (bottom).

on the outside. After having cleaned the shop the butcher would leave the door windows open at night to allow the washed floors to dry before the next morning.
The trellis-work prevented burglary. Seen from the outside, all parts of the shop front are framed by the same, white-painted wooden glass beads. The windows, doors and shop fronts are designed in a very straightforward way, but are at the same time very refined in the way that architectural problems are solved.

Preserve or replace

At first, our department proposed to repair the original windows and put an internal secondary glazing behind it. This was rejected by the veterinarian officers, because they didn't trust the butchers to clean the space between the inner and outer glazing as often as necessary.
Consequently, a survey of the windows, doors and shop fronts revealed that it was not possible to make the original windows meet the new standards just by repair and technical improvements. We tried to persuade the municipality to get new steel framed windows, which we knew - through DOCOMOMO - are still being produced in Britain. But no company was found willing to import these windows in Denmark and give a guaranty as required by the municipality.
The wooden beads in the shop fronts were a problem too. The veterinarian officers would not accept them even though the beads were on the outside of the shop fronts.

After matching the various demands it became clear, that if the buildings were to fulfil their original purpose, new windows, doors and shop fronts would have to be accepted. The veterinarian officers preferred new window frames of PVC with double glazing. The owner, the municipality of Copenhagen wanted a 10-year guaranty. Finally, the Historic Buildings Department - after ample considerations - decided to find a substitute as close to the original as possible, to preserve the overall appearance of the meatmarket.

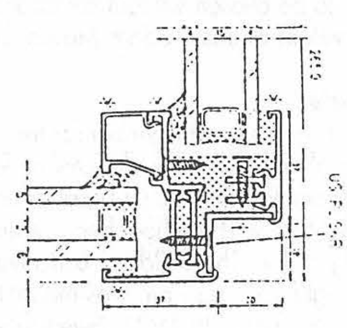
A modern replacement

The shop fronts with their very delicate wooden framing turned out to be the most difficult to replace. The first proposal to use a standard aluminium system was promptly rejected by everybody involved.
Consequently, H.S. Hansen, a major Danish window manufacturing company that had developed aluminium windows with outstanding aesthetic qualities before, was invited to come up with a proposal for replacing the shop fronts.
Their first proposal was to use their own standard series, but combined in new ways to meet the demands. In contrast to the original shop fronts the glazing in this system had to be mounted from the inside, which was regarded to be inadequate for maintenance. Also in aesthetic terms it failed because of the very flat outside appearance without any of the original relief, and because of the rounded corners which diverged principally from the original concave corner details.
In the second proposal, the shop front was given more

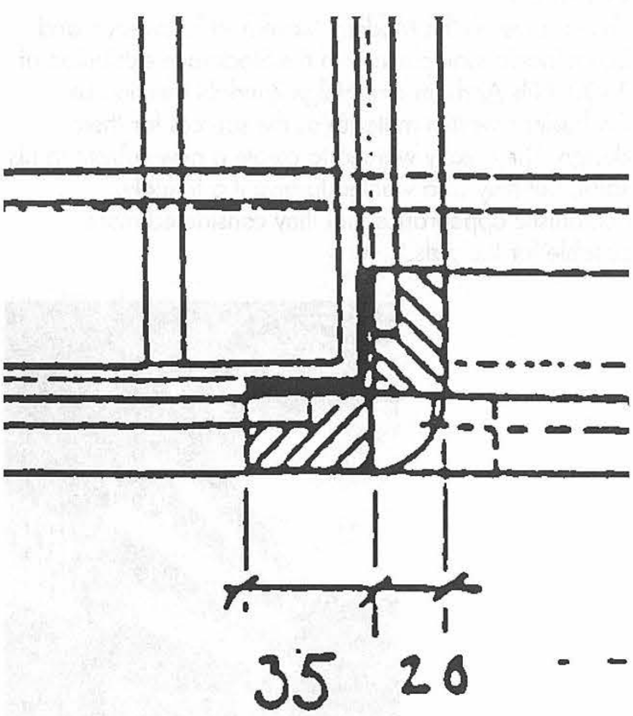
relief on the outside. The joint between two adjoining frames, that had been detailed as a fine line in the first proposal, was widened to define the individual frames more strongly. The details were changed to feature convex corners, but the construction inside the corner profiles was a jumble.
The third proposal involved the instalment of glazing from the outside, but divided the glass beads into two parts. The sunscreen in the casing on top of the shop windows could not be kept due to pigeon problems, but was made new as a closed casing with the same look.
With the ultimate proposal, that was actually built, the glass is mounted from the outside, the glass beads are not divided but are given more body to make the relief in the fronts stronger, and even the construction inside the profiles makes sense. In the end we succeeded in getting new shop fronts of insulated aluminium profiles that have an appearance close to the original, but are true to their own nature.
At the start of the project it had seemed hopeless to the Historic Buildings Department to get an acceptable solution by working with aluminium profiles.
By continuously questioning what is possible and what is not, the debate on the demands - which seemed provocative at first - slowly evolved into a fruitful dialogue.

Jens Borsholt is an architect with the Department of Historic Buildings of the National Nature and Forest Agency of Denmark.

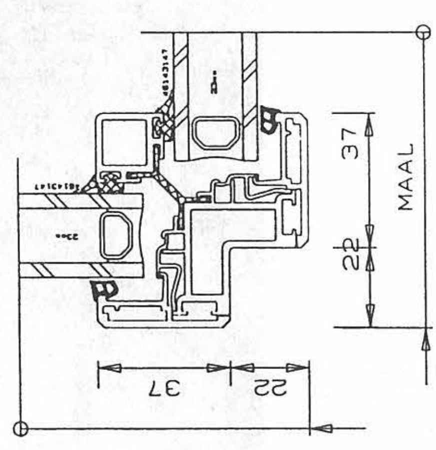
Typical window detail original (bottom), the third proposal and the ultimate solution (right).



Third proposal.



Original detail.



Ultimate solution.

Light and air in a poisonous and noisy world

Sveaplan School in Stockholm (Ahrbom and Zimdahl, 1936)

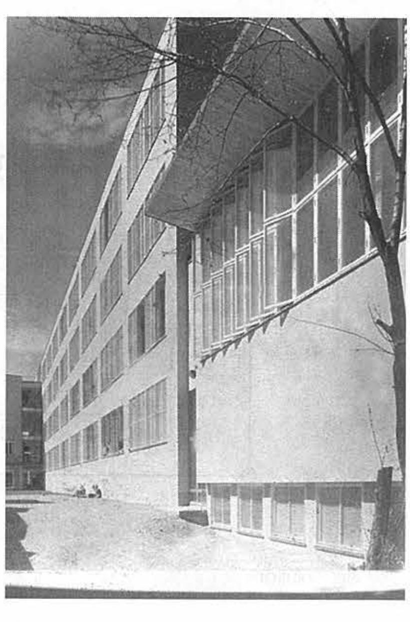
New solutions for windows and glazing were key issues for the restoration and conversion of Sveaplan upper secondary school for girls in Stockholm, designed by Nils Ahrbom and Helge Zimdahl in 1936. The building has been put to a new use for Stockholm University and was restored by Arksam architects between 1994 and 1996.

by Torbjörn Almqvist

The building was originally organized so as to allow maximum exposure to the sun as a functional requirement. It was an ideal vision of light and air as the source for health, where climate was to be controlled by opening the windows and letting in cool and clean, refreshing air.
The building was no longer needed as a high school, and it had to be converted to accommodate new functions. The new use as regular offices, in combination with the present occurrence of heavily polluted air and noise due to traffic intensity, demanded new solutions for window framing, glazing and sun shading. These solutions had to be chosen without compromising the architectural values of this Modern Movement building.

Backgrounds

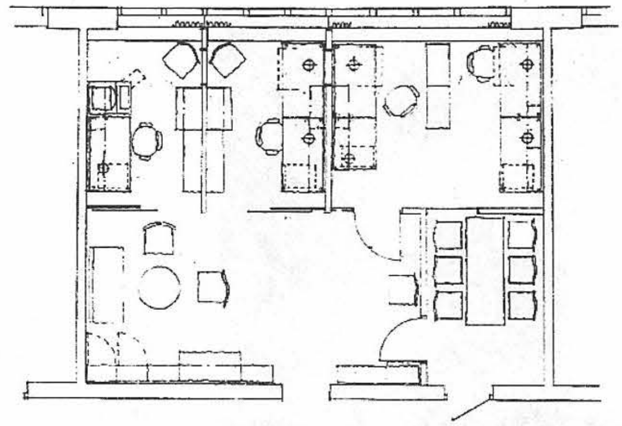
The building is an important symbol for the emancipation of women in Sweden. Many female politicians, especially from the Olof Palme era, were raised here politically. The school became emblematic for a new way of life. The building, conceived to provide the girls with light and fresh air, was meant to guide their way into the future. In 1921, Swedish women got voting rights and shortly afterwards, a new law allowed women to hold qualified positions in the governmental administration. But no women applied for these positions during the 1920s in Sweden, as they were too poorly educated.
Therefore by the end of the 1920s special incentives were designated to pre-university education for women only. Sveaplan was one of five new schools, and the first one to be built with the aim of accelerating this process. In order to find the best solution for the school building, a competition for architects was announced.
Nils Ahrbom and Helge Zimdahl won the competition at the age of 25 and 27. Later in life both of them became professors at different schools of architecture in Sweden. Nils Ahrbom died 1997 and Helge Zimdahl is now 95 years old. Their design involved a very artistic but simply shaped building with its different parts articulated by their function and with generous daylight everywhere.
The turnover to the Modern Movement in Sweden and Scandinavia took place with the Stockholm exhibition of 1930. Nils Ahrbom and Helge Zimdahl mention Le Corbusier's written material as the sources for their design. They really wanted to create a new cubism in his spirit, but they also wanted to give it a friendly, humanistic appearance that they considered more suitable for the girls.



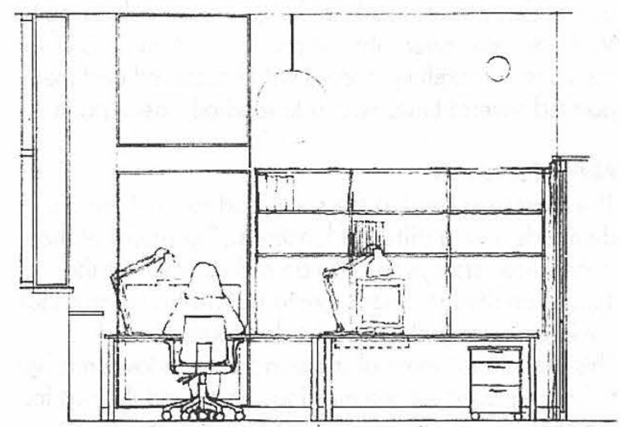
Sveaplan School seen from the east, 1936.
Photo: G. Rosenberg, by courtesy of the Swedish Museum of Architecture.

The restored Sveaplan school seen from the east.
Photo: Mats Håkansson.

Original timber window detail. Photo: T. Almqvist.



Former classroom, now to accommodate five persons. Drawing: T. Almqvist.



Elevation of partition wall which is partly glazed to create more spacious rooms. Drawing: T. Almqvist.

Building history

Their design was an educational tool. As 'light and air' in the building had become symbiotic with 'reason and clearness' as outspoken goals for the education, windows and glazing became central features of the design. Generous window measures and well designed details of the glazing were important means for creating a new spirit in the building. The lighting of the classrooms was very carefully analysed to provide the light to flood the ceiling and the back wall. The whitewashed ceiling and the opposite inner wall assisted the light in getting as deep inside as possible. To soften the eye's perception of the white chalk writings on the blackboard, a dark colour was chosen for the side walls. Throughout the project the use of standardized measures was a goal of its own. Helge Zimdahl always says that all glazing was designed to involve one standard glass unit only, which is almost true.

In the mid-1970s the building's use as a high school came to an end. Since then discussions involved several proposals to save it, by making contemporary additions with 11.000 m^2 of new office space, to tear it down, and finally to save it and prevent it from the hostile process of being damaged by remodelling.

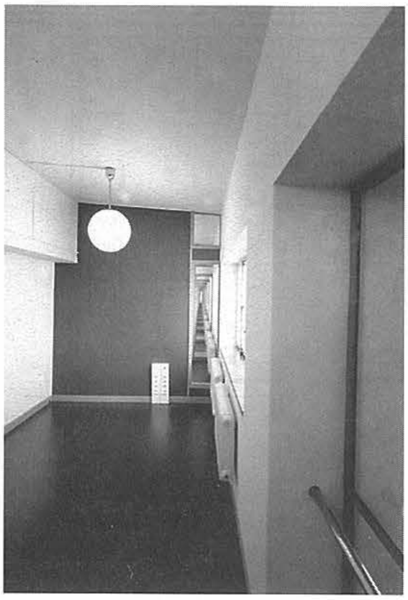
In co-operation with the conservation officers it was decided therefore to reuse the former high school for university purposes. This meant that 75% of the old classrooms had to be turned into working areas for scientists and teachers. The ground floor was to be kept intact and the upper storeys were to be handled so that the interventions could easily be reversed in the future.

Window repair

After convincing the investors of the importance of keeping the original timber windows, the windows were restored and damaged wooden frames and sills were changed. Although the best material from the original windows could be preserved, we were forced to change around 50% of the sills and bottom ends of the jambs.

The frames were put extremely close to the front of the facade surface and thus required the use of excellent material (core wood with high content of resin) for the repair work. The details were carefully designed to allow a maximum of light into the rooms. The original window design was based on the same knowledge of how to treat light on its way into a room, as in the building

Glazed corridor wall. Photo: Mats Håkansson.



Were the partition meets the facade, a strip of glass allows to appreciate the original structure, to spread light between rooms and to keep sight lines. Photo: Mats Håkansson.

Steel frame detailing of meeting room windows. Photo: T. Almqvist.

tradition back in the 18th Century. Unfortunately, during the modernist era, this knowledge was largely forgotten. With the restoration, the sill and the bottom ends of the jambs were carefully treated with linseed oil and then painted several times with a linseed-oil-based paint.

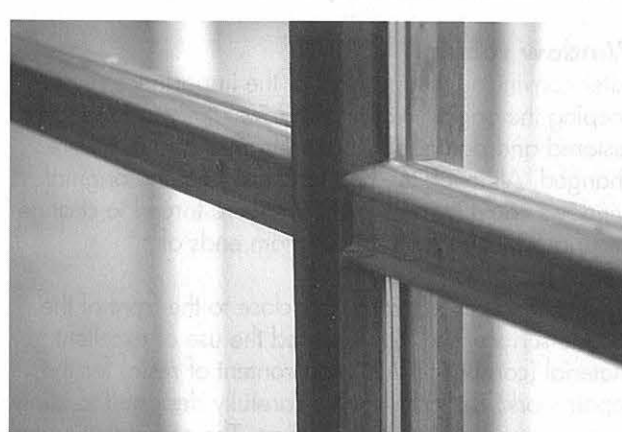
New function

The rooms exposed to the south had to meet various demands due to different functions. The rooms at the upper three storeys were to be offices whereas the spaces on the first floor were to be meeting rooms that could be arranged in the old classrooms.
This meant that some of the standard window units had to be upgraded for the meeting rooms and the rest for the office areas, both with specific requirements. Our work on the standard windows addressed three main issues:

1. How to design a proper solution for the facade windows to receive the newly added inner partition walls. The only way to do this properly was by glazing the end part of the partition wall. Still, it meant that the window had to be modified by cutting away a part of the rabbet and by installing new hinges;
2. In order to reduce noise sufficiently for office work conditions, the present glass in the outer frame was kept. A laminated glazing unit made of two panes of 3 and 4 mm thickness was put in the inner rabbet. Acoustic measuring on site showed that the right conditions were obtained;
3. To reduce heat gain nothing was done with the glazing that could render colour to the daylight inside. Solar gain was reduced through sunshades and a mechanical cooling system was added to master interior temperatures.

Daylight

Once the light had come safely inside, it was taken care of everywhere.
Like in the original layout where shade and darkness were avoided everywhere in the house, big efforts were made to bring light into every corner.
The former classrooms on the higher floors now had to accommodate five scientists. It still occupies the same area as was enclosed by the original classroom walls. Common facilities and services are placed against the existing wall that separates the classroom from the corridor. The small workspaces had to be visually enlarged. The partitions between the offices were therefore glazed as much as possible, without ignoring functional requirements for bookshelves, computers and so on.
Much work was put into the glazed walls parallel to the facade, involving concealed inlets for air overflow through the wall ends. Many efforts were made to create a simple appearance. Details were designed to prevent individual users from obstructing the light to spread along the ceiling. A small piece of glass near the former corridor windows was preserved to remind of the original structure, to spread light between rooms and to keep sightlines.



Teakwood double glazing detail. Photo: T. Almqvist.

Many efforts were put in avoiding fireproof walls in the open staircase hall. Photo: Mats Håkansson.

Soundproofing
The basic problems were the same for the meeting rooms on the first floor but, in addition, the meeting rooms had to be far more soundproof.
We therefore had to deal with protection against heat, cooling problems as well as noise reduction. All these problems were finally solved by using sunscreens, a new air cooling system and secondary steel framed glazing on the inside.
For soundproofing, steel framed glazing with three laminated glass sheets of different thickness totalling 12 mm had to be added. The frames were put in at some distance to the original ones. This construction eliminated nearly all problems. Only the vibrations from heavy traffic through the ground, consisting mostly of pure clay, were impossible to stop.
The climatizing system producing both hot and cool air through the same unit were put in the same place as the old radiator beneath the new glazing. We also had to deal with an intricate opening geometry, to reduce the amount of curtain fixings. We therefore had to put them far off the windows into the plastered ceiling, to allow room to open the steel and timber window frames for cleaning.

Teakwood glazing
Another task was to find out how to double glaze the originally single glazed teakwood framing without compromising the shape of the ground floor windows. In Sweden, single glazing gives too much trouble as to comfort to make a successful argument for preserving it. In connection with an unfortunate maintenance operation in the 1960s, these frames were painted with the same white paint as the ordinary windows, disrupting the subtle interrelation between the cubist volumes.
There was no doubt that originally they were meant to stand out separately from the ordinary windows, and after much arguing we succeeded in returning to this design intention by allowing 400 hours of work to be put in cleaning, to give them the right teakwood character again. The teakwood frames were remodelled to accommodate double glazing without spoiling the shape.

Features
Concerning the sunscreens the task was to find a reliable construction that did not intervene with the facade, and to find an appropriate colouring of the fabric. The colour chosen matched the coppertone of the roof covering.
Also strengthening bolts had to be used in order to prevent the wind from tearing out the whole system in case the automatic wind control would be out of order.
A lot of work was done to reshape the inner partition glazing. New limits for fire compartments were defined in order to avoid additional fireproofing of the steel framed glazing. This made it possible to remove the additional fire security partitions that were put in later, without the necessity to install new expensive ones, that might have ruined the project economically. Now, normal clear and cheap glass could again be used.
Much work was put into a struggle to keep the thin steel doors. The only changes that finally were made were minor alterations to allow the instalment of magnetic card opening systems, automatic doors and so on.
A dedicated blacksmith did his very best with the remodelling, and the doors could be saved.

Original spirit
In order to give this remarkably modern building at Sveaplan in Stockholm a chance to continue ageing, some changes were made in the design of windows and glazing units. Consequently, the first thing to do was to save the original timber frames, with their superb details and easy functional handling, for the inside spaces. Replacement units would have meant a disaster, as their instalment would have caused the loss of many original qualities.
Secondly, a policy was adopted to keep and restore natural light as the primary source of lighting, according to the original design conception for the building. This has just as well been a guiding principle in the design of various additions, as a consequence of the building's new use.
Glazing solutions to protect against sound, pollution and heat were chosen so as not to affect the incoming light in terms of distortion and colour. The existing outer glass pane was kept in all original windows, though additions were made with float glass. New details were developed so as to cause as little 'visual noise'' as possible, in a contemporary design that remained close to the spirit of the original building. Therefore, window restoration played an important role in the process of how to save, enhance and remodel the Modern Movement values of the Sveaplan upper secondary school for girls.

Torbjörn Almqvist is an architect SAR with Arksam Architects in Sweden.

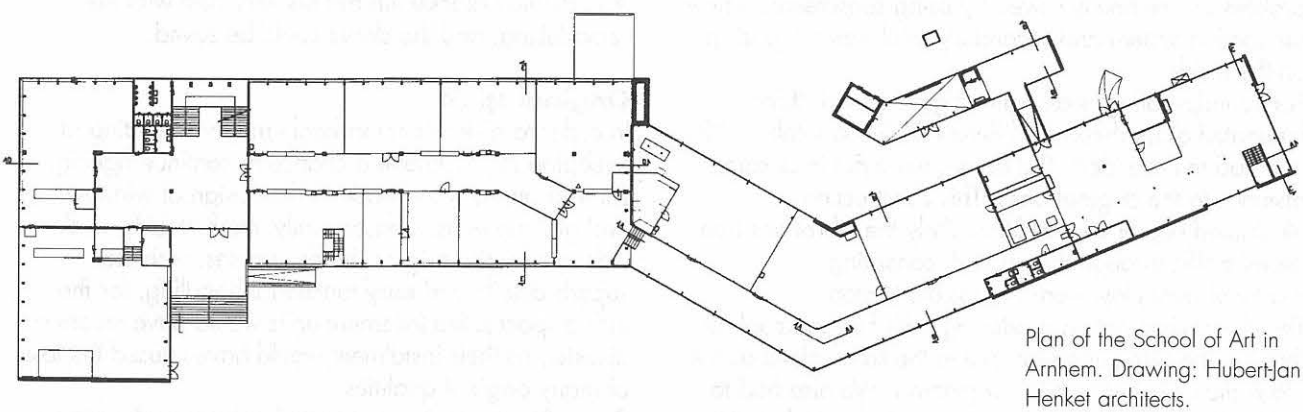
Re-use of a building where less is more

Rietveld's School of Art, Arnhem (1958-63)

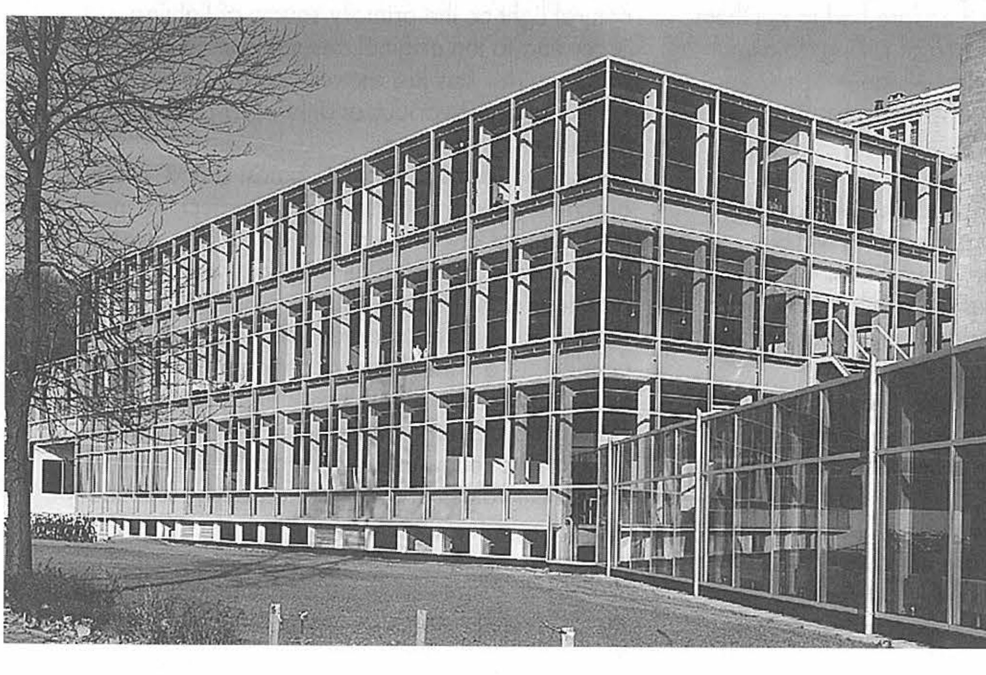
Rietveld's School of Art in Arnhem, The Netherlands, is a transparent pavilion with austere materials and details, and a simple and powerful architecture. The extreme transparency of the single glazed envelope, the lack of thermal insulation and comfort, and solar gain in summer made the building alternatively a hot house or a fridge.
The key to restoring this minimalist' building has been to conserve the original idea rather then the authenticity of its machine produced components. The original features of Rietveld's building dictated the starting points for a sensitive refurbishment.

by Hubert-Jan Henket

The city of Arnhem - in the east part of The Netherlands - is situated between two remarkable landscapes. Sandhills, silent remainders of the last ice age, undulate towards the north. Forests of large beech trees surround the outskirts. On the south side of the city is a large flat polder landscape of clay, deposited by the river Rhine, with meadows and orchards. The river meanders in between these two geological areas as a distinct demarcation line. The densely built city stops abruptly on the northern side of



Plan of the School of Art in Arnhem. Drawing: Hubert-Jan Henket architects.



Overview of the main volume after refurbishment, showing the retained transparency of the facade.
Photo: Hans Vroege.

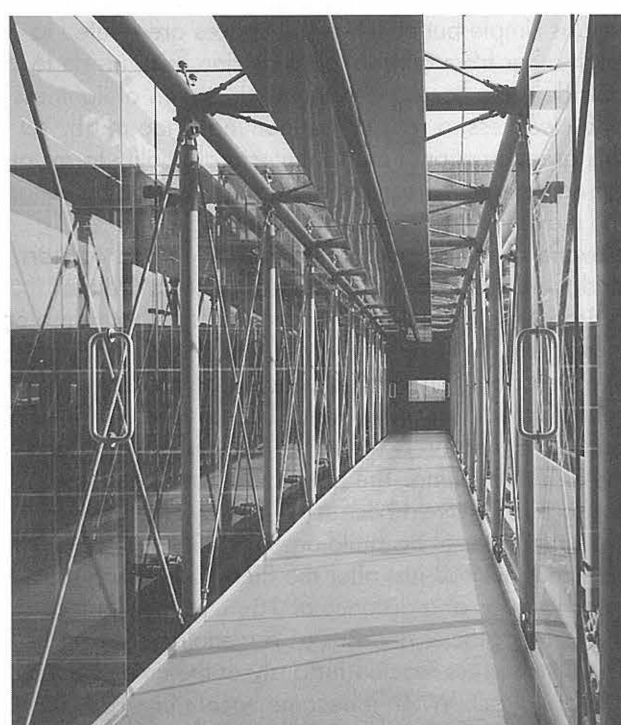
The main entrance. The details of the renewed facade are subtle. Photo: Hans Vroege.

the river on the edge of the glacier deposits left there 20,000 years ago, dropping 30 m down. A narrow strip of flat land between the north side of the Rhine and the former glacier deposits, varying between 24 m and 100 m wide, is a city park. For that beautiful spot, where the river, the glacier deposits, the city buildings and the narrow park meet, Gerrit Rietveld has designed the School of Art between 1958 and 1963.

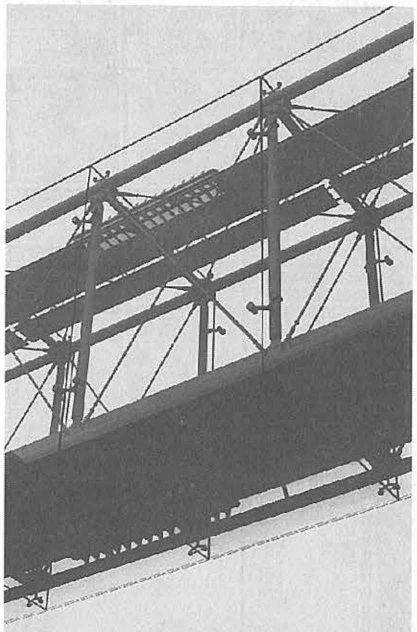
Simple and effective

The School of Art is a transparent and clear pavilion contrasting beautifully with the force of the landscapes and the water. The organization is simple and effective. The ground floor is 1 m above street level on a semi-basement. The spacious outside steps to the entrance are a popular sitting area when the sun shines. The entrance hall is an important meeting area surrounded by the school restaurant and the main staircase. Various departments such as photography, graphics, fashion and painting, each with their own identity requirements, are arranged around wide central corridors. This opens the possibility for the students to develop their own identity as well as the interaction between various identities.

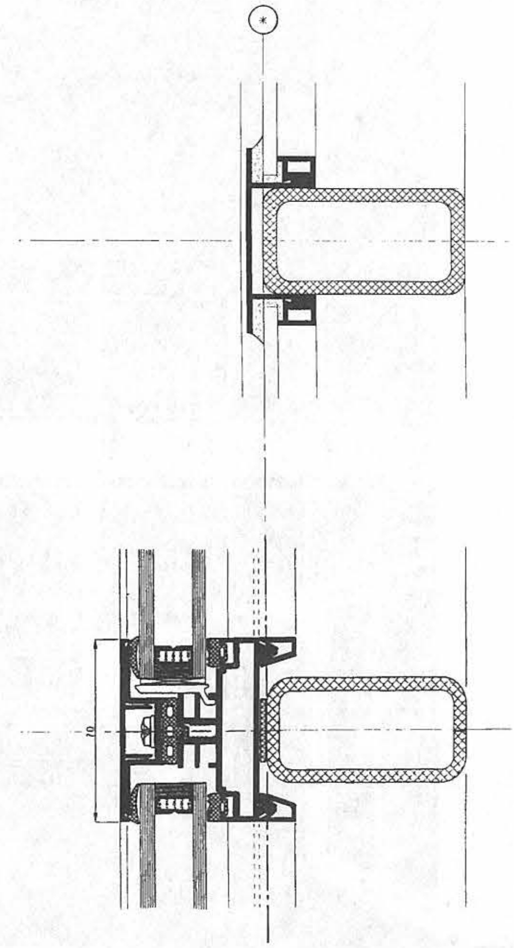
The materials and details are sober, the architectural



The new bridge connecting the school building with the PGEM building behind it. Photo: Van der Vlugt & Claus.



Details of the new bridge. Photo: Van der Vlugt & Claus.



The refurbishment detail (bottom) compared to the original facade detail (top). Drawing: Hubert-Jan Henket architects.

means simple but effective. All spaces are related to each other from outside to inside and from inside to outside. One has a permanent perception of lightness and clearness, a feeling that nothing is too much. Yet this great emotional and architectural quality forms at the same time the core of the problem of the building: the maximum transparency of the single glazed elevations, the lack of thermal insulation and comfort and the limited amount of service systems are the reason why the building is alternatively a hot house or a fridge.

We were familiar with the building before the refurbishment process started, because we designed a bridge connection between the Rietveld building and the PGEM building. The latter must have been and eyesore for Rietveld because it destroys the pavilion-type character of his building. The PGEM was realized in 1963 just after the Rietveld building was handed over, at a distance of 18 m, in the slope of the former glacier deposits as a monolithic structure. The Dutch press reacted furiously at the time about this brutal act. When it became vacant in 1994, the School of Art bought the PGEM building for its music department. The new bridge unites the two parts of the school.

Flat surface

Rietveld's building is characterized by the glass envelope that sits as a three-dimensional single glazed curtain wall over the concrete superstructure. The columns sit approx. 0.4 m away from the curtain wall and are 2.1 m centre to centre. All horizontal and vertical corners of the elevations are transparent, which means that particularly the views through the corners are important. Besides, Rietveld designed the curtain wall as an extremely flat surface on the outside. The glazing beads only project 5 mm in front of the glass.

The details are sober and do not conceal anything, nothing is superfluous. If Philip Johnson defines architecture as 'the art of wasted space', the architecture of Gerrit Rietveld is, 'the art of efficient space'. As a consequence, that was the core of our refurbishment task in order to meet the requirements of the users, which were: less heat in the summer, less downdraught in winter and saving of energy. The complaints of the students and staff had been continuous for the last twenty years. Many efforts had been undertaken to reduce the solar gain by painting the glass, adding louvres, foils, plastic sheeting, and so on.

Less nor more

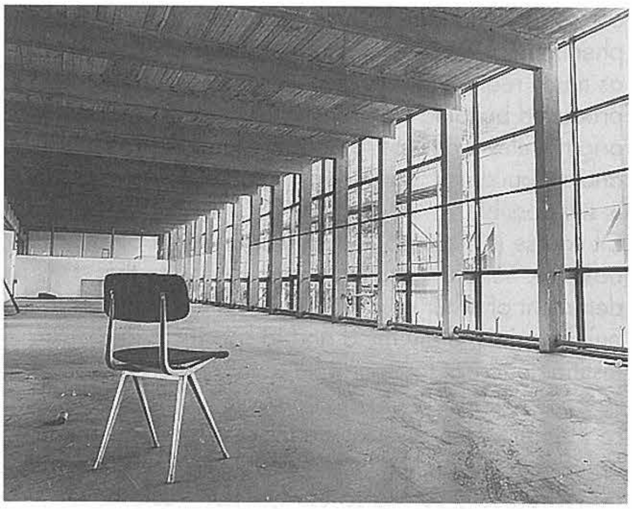
The starting point of the design team to keep the original architectural qualities as much as possible, was equally noble as it was complicated and expensive. This was mainly due to the eternal triangle between the physical performance of the building, the available alternatives to improve it, and restoration ambitions.
In restoration terms the principal question is: why does one do what? Are you going back to the original situation wherever possible, does one go for a more pragmatic approach with respect for Rietveld's heritage, or is his building the source of inspiration for a completely new sensation today? The latter approach was rejected straight away because the key to restoring 20th Century architecture is to conserve the value and the uniqueness of the original idea. However, this position creates quite a few problems to overcome.
When Rietveld designed the building the energy crises of the early 1970s was still far away. Therefore a single glazed curtain wall was an attractive solution both financially and visually. Due to experience gained in similar projects, like the 1926-31 Van Nelle factories by Brinkman & Van der Vlugt in Rotterdam and the 1935 Glass Palace for Schunck in Heerlen by Peutz, it was well known at the time that an envelope like this created problems of comfort. But one should not forget that before the 1970s energy crisis, everybody was used to large temperature differences inside buildings. Putting on a sweater or taking it off was a normal remedy, instead of switching heaters or coolers on and off. Only after that the comfort requirements started to change substantially.
Today one does not accept the extremes in temperature and downdraught in a building any longer. And since user satisfaction is the key to economic preservation of a building (and therefore also to cultural preservation) one has to search for technical solutions. But these, whether one likes it or not, will always clash with the visual characteristics of buildings where simple and minimal detailing is used, as is the case in many buildings belonging to the Modern Movement.
This means that the original building doesn't provide any margin neither for less nor for more. Only with more material, more layers, more complex connections and systems, it is possible to find solutions that comply with current comfort and energy requirements. Any interference in the original fabric has to fit the original key factors of the original idea in such a way that the new meaning and perception matches the original.

Dictate by building

For extreme heat concentration in summer and down-draught in winter there are two main groups of solutions. The first consists of solving the problem simply with services, such as heating and cooling systems.
In that case, the single glazed curtain wall can be kept. The main problems of this solution are that the size of the ducts will dominate the spatial experience completely and that the energy consumption will be phenomenal. Besides, it is disputable if one has to have as much respect for the authenticity of machine produced building components (such as Rietveld's original elevations) as for the hand made products in ancient buildings, particularly if complete reproduction is still possible.
Of course it is best to keep the authentic if at all possible. Yet, if this would financially be to the detriment of other essential preservation activities in the building, it is to my mind and in specific cases justifiable to opt for (partial) reconstruction.
The other direction of possibilities is to find solutions in combinations of physical means and services. The first option we researched was a double skin solution with a mechanically ventilated cavity. That would have meant keeping the authentic single glazed curtain wall as the outer skin, a mechanically ventilated cavity of 300 mm and a pre-stressed glass inner skin. This solution however demands air ducts through the superstructure and the rooms, with radical visual implications. Besides, this solution required a sophisticated level of detailing alien to the no-nonsense and simple solutions of Gerrit Rietveld. This is why this option was rejected as well.
The rejection of both these alternatives demonstrates that one is simply forced to use double glazing, particularly to combat downdraught. Double glazing however has its drawbacks as well. The advantage in the winter situation is its disadvantage in the summer, due to heat gain caused by double glass layers. To respond to this problem one can add a sun reflective coating or again increase the amount of services.
In the end we decided to use a bit of both. The section of the central corridor dictated the maximum allowable duct dimensions. Our starting point was that ducts were not acceptable under the main beams on either side of the corridor because this allowed less mechanical ventilation than required. This meant that we had to optimize the heat storing capacity of the existing concrete structure. That is why the original ceilings have been removed and replaced by smaller ceiling units at a lower level to guarantee maximum air circulation along the concrete surfaces. Visually the new ceilings are as similar as possible to Rietveld's solution.

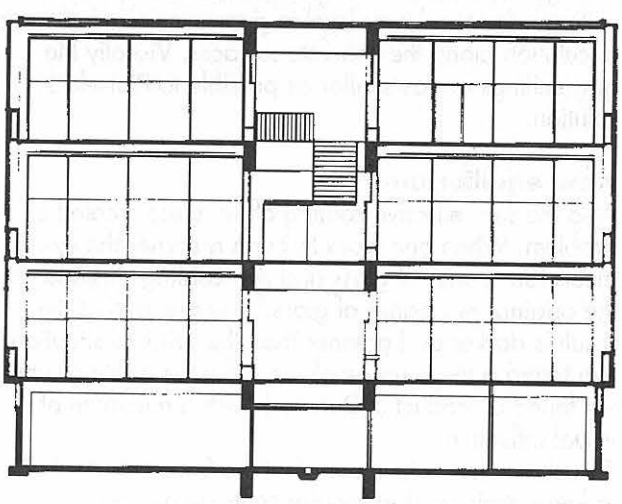
New equilibrium

Also the sun reflective coating of the glass created a problem. When one looks through a corner the eye meets four panes of glass and two coatings instead of the original two panes of glass. That means that the result is darker and greener than the original situation. We tested a large range of sun reflective coatings until we found a product in Denmark with a minimum of visual influence.
This choice however meant that the School of Art had to lower their comfort requirements slightly by accepting more temperature exceeding hours. Also, the energy bill is slightly higher than is to be expected in a



Empty school room with exposed concrete superstructure after removal of the false ceilings to increase thermal storing capacity. Photo: Hans Vroege.

The amount of services packed between the lateral girders, before the vertical louvre ceiling was installed. Photo: Hans Vroege.



Section of the main volume showing lateral girders along corridors. Drawing: Hubert-Jan Henket architects.

technically more advantageous solution.
Another delicate subject is that, in case of double glazing, the dimensions of the glazing beads have to be increased. Besides, in order to minimize maintenance costs we changed the original mastic painting to a dry glazing system with gaskets.
The result visually comes very close to the authentic solution. In the central corridors the existing ceiling was removed and changed to a vertical louvre system, to get a maximum spatial effect and to show the enormous amount of services needed to get at acceptable levels of comfort, in a building where less is more.
Summarizing, we approached this building pragmatically but always in such a way that the result of this pragmatism will match the authentic idea of Rietveld and the experiences that go with it. New additions such as ducts, ceilings and the connection bridge always show technical possibilities of today, yet always in an equilibrium with Rietveld's idea, never in competition or contrast. The starting point of restoration is the conservation of a cultural object of the past, in this case a Rietveld building and it is not primarily the promotion of the form language of the restoration architect.

Hubert-Jan Henket is a practising architect and professor of architecture at the Delft University of Technology in The Netherlands. He is also the Chairman of DOCOMOMO International.

Hubert-Jan Henket Architecten bna (architect), ABT Advies-bureau voor Bouwtechniek (building management and technical supervision), Delta Bouw (main contractor), Bestisol Group The Netherlands (elevation consultant and contractor).

Conclusion

The debate concluding the 'Reframing the Moderns' seminar addressed both principal and particular matters, touching upon many of the topics that had been put forward in the various presentations. The discussion eventually focussed on glass and its pivotal role in architecture and architectural preservation as the medium in which light is carried into all corners of architectural space.

by Ola Wedebrunn

The English Heritage campaign on window conservation policies met great interest as it emphasized the importance of window restoration across a wide front. The Rotterdam campaign addressed the effort to move the issue of window replacement into a more general question regarding its effects on townscapes of the recent past. It was considered a good example of how the problem of window restoration could be raised to the scale of neighbourhood planning.
This project also raised the question of the possibility and appropriateness to substitute original windows not only by new ones of the same material, but also to change traditional timber frames for aluminium or plastic ones. The refurbishment of the Copenhagen meatmarket involved similar questions. Here the original single glazed steel framed windows were replaced by aluminium frames of similar geometry and dimension with insulated glazing. This large-scale scheme can be considered a development project as it suggested various solutions of both technical and aesthetical value.
Remarkably, all of these presentations stressed the issue of glass quality in window restoration, identifying the substitution of original plate glass by float glass as a key problem.

Traditionally, the character of glass is often regarded as a matter of transparency, colour and the way daylight is filtered. The effect that the properties of glass have on the architectural expression of buildings stresses the fact that its character is just as well defined by its surface, structure and material substance. In many renovated buildings the disregard of these essential qualities has resulted in a significant loss of sensibility in the architectural expression of windows and glass.

The neglect of the material aspects of glass is further fueled by the difficulty to obtain products with the same properties as the glass that was produced through outdated industrial processes, like plate glass. This is due to the fact that big companies often buy old production plants only to close them. Today, most European plate glass is produced by older East-European industries. Cylinder glass can rarely be obtained and it seems to be produced only in France in small amounts and at high costs. In contrast to industries that relied on hand craftsmanship, the continued operation of outdated industrial plants requires not only the maintenance of knowledge and tradition but just as well of expensive plants and machinery.
Such circumstances make the restoration of some features of Modern Movement architecture, that depends on a specialized technology, a difficult task. Another example is glass block, the production of which requires a certain scale and specialized tools like moulds.

The issue of reflection is also complicated, as it is not only the perfect mirror image produced by present products that deviates from the blurred reflections known from the old glass types, but also the double or triple images created by multiple glazing.
Such considerations were essential to the solution that was eventually adopted for the large vision windows of Villa Westman in Lund, Sweden, that had to be insulated. To replace the former secondary window frames, the preservation authorities demanded insulated glazing units to be produced with an outside pane of plate glass, with good results.

Contemporary glass technology was debated in aesthetic and technical terms, addressing surface properties, colour, reflective coatings and the filtering of daylight. It was agreed that a lot of research and experiments are still to be done in this field to arrive at the quality levels required by architects today, but also by the conservation community.
Conservation should not be regarded as an absolute matter of reconstruction, but rather as being related to solutions through contemporary techniques. Therefore, the issue of interior climatic circumstances, in terms of temperature, acoustics and so on, has to be seen in relation to a restoration philosophy that involves technical as well as aesthetical and cultural values.
This means that there is little doubt that contemporary technology has to be employed, for instance to provide better thermal insulation. This does not mean that generally applied solutions have to be taken for granted, but that alternative technologies must be considered and perhaps even individually developed for each single case.
The case studies of the Arnhem School of Art by Rietveld and the Sveaplan Gymnasium in Stockholm showed how contemporary technology can be creatively and successfully adopted in architectural

restoration, providing comfort, thermal and acoustical insulation.
The perfected surface of float glass seems to respond to a wish for a facade and windows that constitute one flat plane - an aspect of Modern Movement architecture that defines the geometry of the volume rather than the mass of the material.
But float glass also has a very distinctive and predominant character through the perfect reflection of mirror images. The reflection capacity of float glass creates an emphasis on the environs of the building, that are mirrored as sharp-edged whimsy images that are beyond our control, rather than on the building itself. This is quite different with facades that involve the products of older glass technologies. Sheet and plate glass are characterized by unfocused and distorted reflections that are less easily perceived and recognized, and therefore do not distract our mind.
The urge to maintain traditional glass manufacturing is therefore not only romantic and sentimental. It poses just as well the technological challenge to develop a variety of glass products with different material characteristics, which could be assembled to insulated glass units that can be used for conservation purposes as well as in contemporary architecture.

To summon up, the following issues must be considered as key to the appropriate restoration of windows and glass:

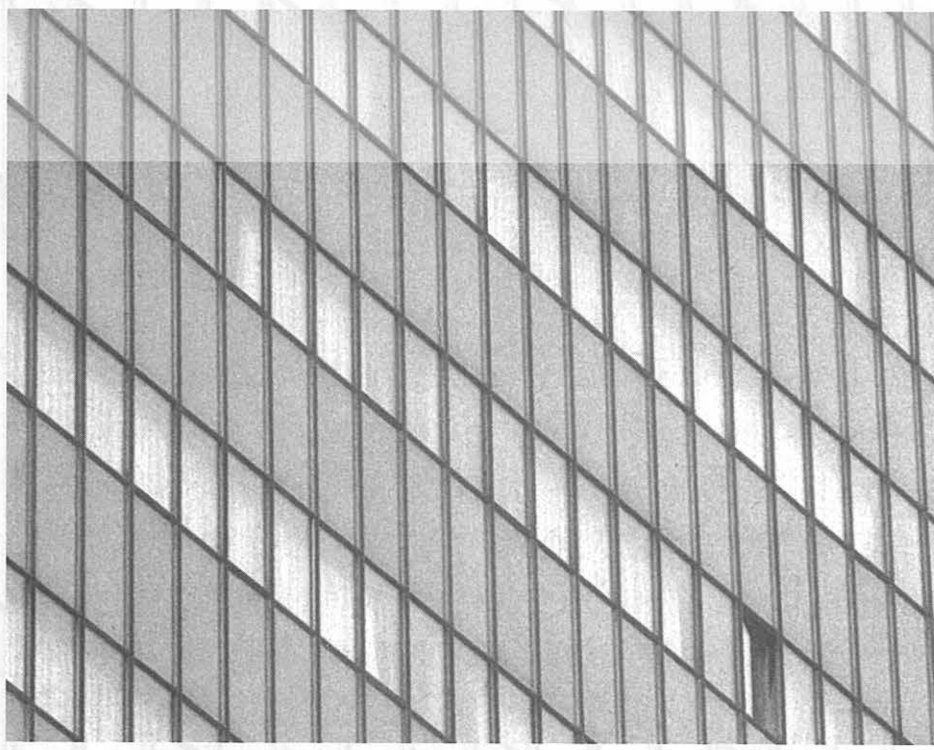
- The ingress of daylight and its migration through space;
- The qualities of glass in terms of reflection, surface and structure;
- The geometry and proportions of the window frames;
- The interrelation and integration of the window frames in the geometry of the architectural volume;
- The technical solution in relation to acoustics, thermal insulation and sun shading.

Even if the light of the sunset, mirrored in a shallow lake, touches our hearts once in a while, we would certainly not choose to live without the roaring waves of the ocean that we perceive when the reflection of the sky is distorted - frightful and grey - through the uneven surface of window glass. This means that it is of great importance not to rule out the possibilities of the varied experiences through diverse material properties. Though, in the end, it is neither glass nor frame but the window itself, as a gate connecting the interior to the outdoors as a continuous space and as the vehicle that makes us experience light as actual matter.

The light projected on the geometry and surface of the profiles of the window frames is sometimes caught in the subtlest play of light and shadow, articulating the transition from outdoor sunlight to the controlled light of our indoor spaces. Thus the proportions of the frames as well as their form and surface are of major importance when it comes to the minimalist design of Modern Movement windows.
Changing the qualities of the window glass, or altering the frames does not only affect the material appearance of the window but also its main purpose, which is the way in which the light is controlled.
The final conclusion is that the major question regarding modern window restoration consists of a range of details that give us the means to handle the light, to lead it into the spaces to evoke the beauty of trans-parency, reflection and shadows. As Le Corbusier expressed it in *Vers une Architecture* it is all about 'the masterly, correct and magnificent play of masses brought together in light.'

Ola Wedebrunn, seminar organizer
Chairman of the DOCOMOMO International Specialist Committee on Technology

Appendices



Program

08.45 Reception

09.15 Opening
Hubert-Jan Henket

09.30 Window replacement in Rotterdam's 1930-1960 districts
Wessel de Jonge

10.00 Framing Opinions - English Heritage's campaign to conserve windows & doors in buildings of special architectural & historic interest
Chris Wood, English Heritage

10.30 Coffee

11.00 Restoring windows in early American skyscrapers
(The Reliance Building, Chicago)
Gunny Harboe

11.30 Recording and measurement - the detail of the window
(Vestersøhus, Copenhagen and more)
Søren Lundquist

12.00 Using new aluminium profiles as replacement for original steelframe windows
(The Meatmarket, Copenhagen)
Jens Borsholt / Jack De Stobbeleir

12.30 Lunch

13.30 Light and air in a poisonous and noisy world
(Sveaplan gymnasium, Stockholm)
Torbjörn Almqvist

14.00 The window and the plane
(Central Post Office, The Hague)
Dirk Jan Postel

14.30 Academy of Fine Arts (Rietveld, 1958-63), Arnhem, The Netherlands
Hubert-Jan Henket

15.00 Coffee

15.30 The restoration of the steel-/glass facade of the Fagus-factory (Fagus, Alfeld an der Leine)
Dieter Rentschler - Weißmann - presented by
Berthold Burkhardt

16.00 Windows in modern buildings
A conflict between building physics and conservation (Bauhaus, Dessau)
Berthold Burkhardt

16.30 Debate and questions
Chair: Hubert-Jan Henket

17.00 Cocktailparty


Hubert-Jan Henket

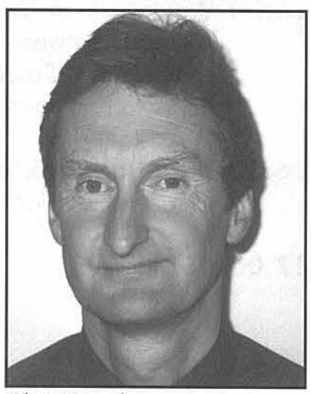

Ola Wedebrunn


Boje Lundgaard


Marianna Heikinheimo

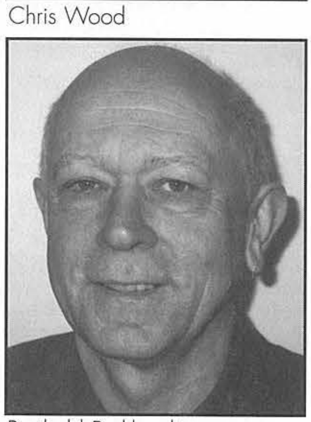

Anne Beim


Gunny Harboe


Chris Wood


Wessel de Jonge

Andri Ksenofontov


Berthold Burkhardt

Dieter Rentschler - Weißmann

Alberto Artioli

Resume of authors

Hubert-Jan Henket is an architect in Esch, The Netherlands. Among his most noted works are the extensions for the Museum Boymans-van Beuningen in Rotterdam and Teylers Museum in Haarlem, and the restoration of Gerrit Rietveld's Academy of Fine Arts in Arnhem. He is a professor at the Delft University of Technology, and the chairman and co-founder of DOCOMOMO International.

Ola Wedebrunn is an architect, a researcher and a teacher at the Royal Danish Academy of Fine Arts in Copenhagen. As the chairman of DOCOMOMO Denmark since 1997 he has been the editor of 'Modern Movement - Scandinavia', published in 1998 by the national DOCOMOMO Working parties of the five Nordic countries.
The subject of his present PhD research entitled 'Characters and Language of Materials' has so far resulted in several articles and publications. Since 1998 he holds the chair of the DOCOMOMO International Specialist Committee on Technology (ISC/T).

Boje Lundgaard is a professor of the Institute of Building Science at The Royal Danish Academy of Fine Arts. He is also a practising architect, and has realized a large number of buildings ranging from housing projects, institutions, museums, to power plants etc. As a professor of the Institute of Building Science he is also the leader of several major research projects on architecture and new technology.

Marianna Heikinheimo is an architect (SAFA) and has an MA in Fine Arts. As a researcher at the Helsinki University of Technology, she is currently working on a thesis called 'The relation between Architecture and Technology in Paimo Sanatorium and Viipuri Library.'

Anne Beim is a teaching assistant and researching architect at the Institute of Building Science, The Royal Danish Academy of Fine Arts. Her work is closely tied to architectural practice and technology as well as to the industrialization of the Modern Movement. Her PhD project 'Tectonic Visions in Architecture' is scheduled to conclude in 2000.

Gunny Harboe (AIA) is an architect with McClier, Chicago, Illinois. He is the director of the Preservation Group, responsible for all projects involving preservation, restoration, or rehabilitation of older structures that are of historic or architectural significance.
He has served as project manager, project architect and restoration architect.

Chris Wood is a senior architectural conservator working in the Architectural Conservation Team at English Heritage. He is responsible for carrying out research projects and providing specialist advice on problems related to building materials used on historic buildings. He ran the English Heritage training school and is now coordinating the Framing Opinions campaign.

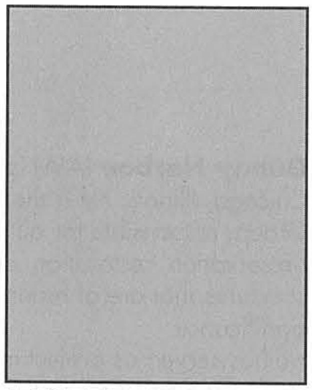
Wessel de Jonge is an architect in Rotterdam, The Netherlands, and has been in charge of the restoration of several prominent modern buildings. He is a researcher at the Delft University of Technology, specialized in restoration technology for modern structures. He is the secretary and co-founder of DOCOMOMO International and the former chairman of their Specialist Committee on Technology.

Andri Ksenofontov is an architect inspector with the Central Board of Antiquities of Estonia.

Berthold Burkhardt is an architect and structural engineer, as well as a professor at the Technical University of Braunschweig, Germany. His area of expertise includes structures (concrete, steel, wood, lightweight), particularly of the Modern Movement. Berthold Burkhardt is also advisor regarding the Bauhaus buildings in Germany.

Dieter Rentschler - Weißmann, was employed, after studying architecture at the Technical Universities of Hannover and Berlin, in several architectural offices and planning authorities. In 1983 he became a regional conservator in the Monument Department of Lower-Saxony and was until 1997, responsible for the restoration of the Fagus-Factory in Alfeld an der Leine.

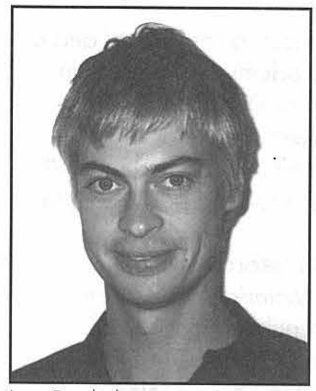
Alberto Artioli is an architect with the Lombardian Department for Conservation in Milan. He has been in charge of the restoration of the Casa del Fascio in Como, Italy.

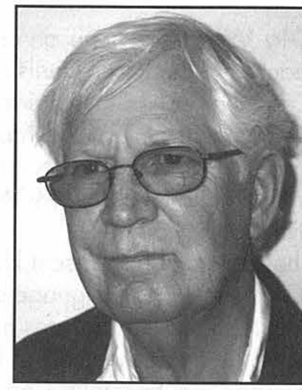

Winfried Brenne

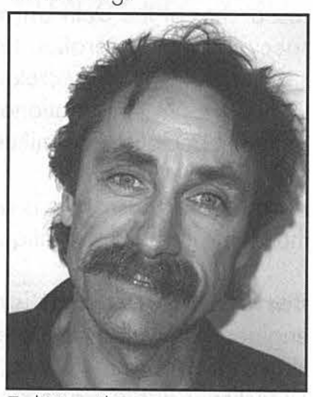

Søren Lundqvist


Dirk Jan Postel


Thomas Tägil


Jens Borsholt


Jack De Stobbeleir


Torbjörn Almquist

Winfried Brenne is a practising architect in Berlin and a member of DOCOMOMO Germany. He has been in charge of the rehabilitation of several housing estates of the 1920s in Berlin, amongst others the Onkel Toms Hütte by Taut and the Weiße Stadt Siedlung.

Søren Lundqvist is a practising architect in Hillerød, Denmark. His office works exclusively with restoration projects, with special focus on combining tradition, knowledge of arts and craft, and new technology. The office takes great care with recording and measuring existing conditions as the starting point for new projects, among which the restoration of the castle of Fredriksberg is among their most recent works.

Dirk Jan Postel is an associate architect of Kraaijvanger-Urbis, specialized in industrial and office building. At present, he is working on a variety of projects: Inner-city renovation, experimental research, rehabilitation of a large event's and exhibition building, industrial design and glass. His glass bridge (Rotterdam 1994) has been nominated for the Rotterdam Design Prize, as well as receiving an honorary mention for the Benedictus Award (Washington DC 1995).

Thomas Tägil is an architect and researcher at the Architect School of Lund in Sweden. His dissertation on regional aspects of functionalism and the works of the architect Hans Westman focuses on regional tendencies and a remarkable path of another tradition within the Modern Movement.

Jens Borsholt is an architect, employed at The National Forest and Nature Agency, in charge of listed buildings. Over a long period, the National Forest and Nature Agency has concentrated on developing knowledge, and collecting data on historic and listed buildings. With the project for the restoration of the Meatmarket in Copenhagen they have co-operated with the City Architects Directorate of Copenhagen.

Jack De Stobbeleir is a senior member of the City Architects Directorate of Copenhagen and has been in charge of the building site at the Meatmarket.

Torbjörn Almquist is an architect with a practice in Stockholm. The office, ARKSAM, works with restoration, as well as new constructions, often in environments of historical significance. One of the major restoration projects is the restoration of the Gripsholm castle. Restoration of the buildings of Modern Movement architecture has lately been included as a special task, with Sveaplan Gymnasium and Markelius Collective house as two examples.

Selected bibliography

The following references give a selective guide to further reading in the main areas covered by this publication. Very few books yet exist on specific subjects involved in modern conservation - an indication of how recently this field has emerged. The general material available is more often in the form of articles in the professional press, exhibition catalogues, reports or collections of conference papers.
The list opens with some relevant background literature. There are a number of valuable technical publications dealing with window repair and replacement on a purely scientific basis (that is, without regard to conservationist considerations). Trade literature from particular manufactures and specialist contractors is not comprehensively included, though there is often useful technical information available in such publications.

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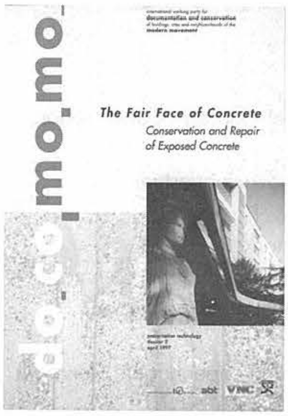

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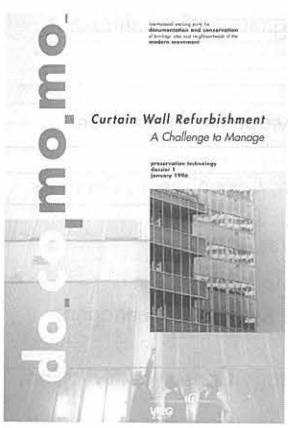

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The preservation of windows and glass is not a new strand to architectural conservation. But it may very well become a vexing problem when the original components concern the large and often mass produced units that are characteristic to the architecture of the Modern Movement.
The vanguard vision of a crystalline architecture was the culmination of a long search for a new architecture, contemporary with a new appreciation of daylight and fresh air as preconditions for physical health. Along with the development of loadbearing structural frames the small subdivided traditional windows evolved into ever larger units, the construction of which often involved innovative and industrial technology. Ironically, the re-production of products of – by now – obsolete industrial processes is mostly prohibitive today, while traditional techniques may be technically or conceptually inappropriate for their repair or replacement. Finally, we have to face the economical consequences of large-scale window replacement programs that are relevant to the social housing estates of the Modern Movement today.

The 'Reframing the Moderns' seminar in Copenhagen, of which this publication is the result, has been aimed at the exchange of knowledge and experience between professionals from various countries regarding strategies for succesfull conservation and replacement of modern windows and glass. The arrangement of fenestration in the facade, the effect of windows to the interior, the shape and type of operable parts, its materials, details, window furniture, colour and type of glass, its physical performance in terms of ventilation, heating, and humidity control, day and nighttime transparency, sun shading, and security: These are all aspects that define the complexity of a window's role in a building.
Although the starting point for any succesfull preservation program must be to retain the original architectural qualities of a building's fenestration as much as possible, the key lies within the eternal triangle between the physical performance of a building, the available alternatives to improve it, and restoration ambitons. Since user satisfaction is essential to economic preservation of a building – and therefore also to cultural preservation – one has to search for technical solutions, and this publication provides a wealth of information in this respect. The ten seminar lectures have been complemented with eight additional papers, providing further guidelines to find a proper balance between these factors when considering the preservation of window units, glazing and glass block in modern buildings.

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