

o.
m.
o.
m.
o.
c.
o.
p.

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

Curtain Wall Refurbishment *A Challenge to Manage*

preservation technology
dossier 1
january 1996



Technische Universiteit **tu** Eindhoven

VMRG
Vereniging Moderne Ruimte
en Monumenten

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

Curtain Wall Refurbishment *A Challenge to Manage*



Marble panels being removed from the Amoco facade high above the streets of Chicago's Loop. Photo: Wiss, Janney, Elstner Associates, Inc.

Curtain Wall Refurbishment A Challenge to Manage

Proceedings International DOCOMOMO Seminar, January 25, 1996, at the Eindhoven University of Technology, the Netherlands

Editors

Wessel de Jonge
Arjan Doolaar

Production

Joke Stolk

Design

Ton Davits, Art Studio, Faculty of Architecture

Printing

Eindhoven University of Technology printshop

ISBN

90-6814-069-8

© 1997, DOCOMOMO International
Eindhoven University of Technology
BPU Postvak 8
P.O. Box 513
5600 MB Eindhoven
The Netherlands
tel. +31-40-2472433
fax +31-40-2459741
e-mail docomomo@bwk.tue.nl

Cover photographs

When in 1929 the famous Van Nelle factories were completed, the curtain wall was still a breathtaking expression of progress, that was looked up at in wonder (period photo Van Nelle archives). Today, original architecture of the Reconstruction period, contrasts with the smooth and shiny facades of refurbished buildings in downtown Rotterdam, such as the Rijnhotel (photo: Wessel de Jonge).

Committee of Recommendation

- Fons Asselbergs, Director, Rijksdienst voor de Monumentenzorg
- Antoon van Osch, President, Vereniging Metalen Ramen en Gevelbranche VMRG
- Hubert-Jan Henket, Professor, Eindhoven University of Technology

Sponsors

This seminar enjoyed financial support from:

- Eindhoven University of Technology, Faculty of Architecture
- Vereniging Metalen Ramen en Gevelbranche VMRG
- Ingenieursbedrijf Starke Diekstra bv

In cooperation with:

- Nederlands Vlaamse Bouwfysica Vereniging
- English Heritage, Conservation Department, London
- DOCOMOMO International Specialist Committee on Technology
- Section Renovation Technology, Eindhoven University of Technology

The editors have tried to verify all photo credits. If a photo credit is incorrect or incomplete, please contact the DOCOMOMO International Secretariat.

do.co.mo.mo



CONTENTS

- 5 **Preface**
Carl van Amstel, VMRG

- 7 **Introduction**
Curtain wall refurbishment:
A challenge to the industry
Wessel de Jonge

LECTURES

- 13 **Opening**
Hubert-Jan Henket
- 16 **An image of modernity**
An American history of the curtain
wall
Stephen J. Kelley
- 22 **Curtain walls in the Netherlands**
Refurbishing an architectural
phenomenon
Wessel de Jonge
- 31 **A future for curtain walls**
Typology, development, lifespan and
refurbishment
Just Renckens
- 35 **Curtain walls as a system of building
physics**
A perspective for refurbishment
Jacques Mertens
- 41 **Natural stone**
Ageing curtain walls in the United
Kingdom
John Redding
- 49 **Redevelopment of postwar real estate**
Hans de Jonge

CASE STUDIES

- 57 **Curtain walls in the USA**
Failures, investigation and repair
Stephen J. Kelley and Bruce S. Kaskel
- 62 **Blaak 333 (Kraaijvanger, 1961)**
A critical review of a second life
Dirk Jan Postel
- 67 **The Rijnhotel (Merkelbach & Elling,
1957)**
An approximate image
George Köhlen and Leon Wolters

- 71 **City Savings Bank (Tvarozek, 1930)***
Slovakia's first curtain wall refurbished
*Matús Dulla, Henrieta H. Moravciková
and Elena Stolicná*

- 74 **St. Cuthbert's (Marwick & Sons,
1936)***
An early curtain wall
Suzanne Ewing

- 76 **The Thyssen Haus (HPP Architects,
1957)***
A curtain wall replaced from head to
toe
Eberhard Zerres

- 80 **The Amoco Building (Stone, 1970)***
Recladding of a marble landmark
Ian R. Chin and Jack P. Stecich

- 83 **Boots Factory (Williams, 1932)***
Careful medication for a curtain wall
James Strike

APPENDICES

- 89 **Programme**
90 **Resumé of speakers**
92 **List of participants**

* Additional article, not presented at the Curtain Wall
Seminar on January 25, 1996

Preface

With great pleasure I have responded to the invitation to introduce the proceedings of the DOCOMOMO International seminar on repair and replacement of historic curtain walls. On the following pages the challenges, options and experiences with curtain wall refurbishment are addressed with great professionalism.

As a matter of fact, in the recent past too many such renovations took place in a very radical or poor way, simple and inexpensive rather than respectful as regards the architectural character and details. The *Vereniging Metalen Ramen en Gevelbranche* VMRG, as the representative of the Dutch curtain wall industry, strongly supports DOCOMOMO's initiative to point out the opportunities and options -which are certainly there!- for responsible repair and replacement of significant historic curtain walls.

Our Association is therefore pleased to have been the main sponsor of the seminar, and will continue to foster the exchange of ideas and professional experiences in the future. Only then, successful refurbishments of curtain walls, with their original architectural expression and features, can be expected!

On behalf of our members, I wish all the readers of these proceedings a lot of reading pleasure!

Carl van Amstel, managing director
Vereniging Metalen Ramen en Gevelbranche VMRG

Introduction

Curtain wall refurbishment: A challenge to the industry

To the pioneers of the Modern Movement of the prewar period, the employment of steel in light facade constructions became almost emblematic. The typical combination of load bearing frames with sheer curtain walls or ribbon windows of light steel profiles are today almost synonymous with the image of modernity in architecture.

The curtain wall concept matched seamlessly with the ideals of the avantgarde as regards openness, daylighting, ventilation and hygiene. The generation of the Reconstruction again embraced the transparency of these constructions as an image of an open and new postwar society. Not surprisingly, many notable buildings from the recent past are characterized by metal window frames and curtain walls.

Increasing requirements

Over the years the requirements to which facade constructions had to comply, have dramatically changed. In particular after the 1970s energy crises it became evident, that the energy consumption for buildings would have to be reduced. After a slow start, double glazing became common and the steady increase of requirements in the Dutch Building Regulations (Bouwverordering) made it into a standard feature.

Recently, a new norm was again set with the Energy Performance Standard (Energie Prestatienorm). In a similar way various other performance requirements have increased as well, and have consequently been consolidated in the new Building Act (Bouwbesluit). These concern thermal performance, but just as well fire security, acoustics, hygrical aspects and safety-in-use. At the same time we witness a great change in the assessment of the image of commercial buildings, as well as its valuation in terms of corporate identity and its position on the real estate market.

Aluminium

After the war, the use of aluminium became popular. Originally developed to serve the aircraft industry during World War II, the aluminium industry found a new, civil market in building.

An initial problem was, that aluminium was more expensive than the more common product of steel. Moreover, due to the relatively low stiffness of the material, it was necessary to design heavier sections than were common practice in steel. The development of ever higher buildings, primarily in the US, made weight reduction of facade constructions profitable. Through savings on foundations, the high investments for aluminium facades were compensated. Through the design of more sophisticated sections, the aluminium profiles gained strength and stiffness, using

less material at the same time. The superficial and relatively harmless corrosion of the material suggested the redundancy of finishings, coatings and maintenance.

Insulation

With the introduction of double glazing, the high energy transmission of aluminium became an increasing problem.

At first, the energy loss was not the point. The slender profiles form only a minor part of the full facade surface, and only the most strict bookkeeper would have a problem with that.

But condensation on the interior surface of the metal was a more serious setback, particularly in winter, when the ventilation lights would freeze to the frames. The same occurred with steel windows, though not as easily.

After some years of trial and error, the industry provided a solution: aluminium profiles with a thermal break. The isolation of an outer and an inner aluminium profile through a synthetic or resin strip appeared operational. The extrusion of aluminium allowed for a design of profiles with sophisticated sections, that could easily accommodate such isolators. With steel, it was more complicated to receive isolators by means of folded notches for instance. Profile sections had to increase to accommodate such complicated features, and the characteristic thinness of steel windows was largely lost with such products.

Dimensions

Yet, with the increase of thermal performance also the aluminium profiles grew in size. An unintended result of the introduction of the thermal breaks had been, that the static performance of the profiles decreased dramatically. To resist wind loads and other lateral forces without disproportionate bending, the aluminium sections had to increase in circumference yet even more. The early aluminium systems with a thermal break are therefore even less elegant than the steel ones.

The technical improvements as compared to the earlier facade constructions in steel were, however, evident. In the course of the 1960s, steel framed facade constructions more and more lost their position on the market. The poor air-tightness as well as the high maintenance costs for regular paint jobs were felt to be major setbacks as compared to aluminium systems. Also, the repeated paintwork often resulted in an uneven surface of flanges, preventing vents to close tight and causing even more draught.

With the introduction of the insulated aluminium systems in the 1970s, steel again lost part of the market as a result of its relatively modest thermal performance.

Innovation in restoration

Over the last two decades, we have gotten spoiled by the climitization of our buildings. Regardless of the seasons, office personnel wants to work in sleeves in winter, or wearing a fancy jacket in summer. A strong control of interior conditions therefore has become a predominant factor. The insulated aluminium systems fitted in to this concept very well, and could therefore consolidate their position on the market.

Architects on the other hand more and more opposed the heavy dimensions of such products. Although for new buildings architects desired more slender and smarter systems as well, it was in fact the restoration profession that ran into trouble fifteen years ago with the then present metal framed window systems.

The Department for Conservation, that deals with buildings only over fifty years old in the Netherlands, was more and more being confronted with early examples of modern architecture that typically featured extremely slender steel windows and light curtain walls. The often disastrous condition of such windows dating from the 1850–1920 period mostly necessitated replacement.

The change in performance requirements and standards prevented similar facade elements to be installed. Although there was a natural preference for metal products, the systems then available were all so bulky that they were in fact as unsuitable to replace steel framed windows as timber or, later, U-PVC windows.

A new brief for metal replacement windows was formulated in the 1980s through a research at the Eindhoven University of Technology, Faculty of Architecture, commissioned by the Netherlands Department for Conservation.¹ A number of producers that were involved in the project have been engaged to develop smarter profiles since then. Most manufacturers of steel window profiles have concentrated on minimizing the dimensions of existing series, and soon met their limitations.

In the aluminium sector, some firms have taken the question to a more conceptual level. In addition to an obvious 'weight watching' routine some participants reassessed the principles of construction on which the sections had been based. Some profiles have since been developed that feature a thermal break, not as a centrally located synthetic strip but in the form of a U-PVC flange that covers over the inside. The result is an original product that, despite some limitations when applied in larger surface areas, is doing remarkably well in architectural terms.

Still, also the weight-watchers have been quite successful in providing an alternative for early steel windows. With a width of 43 mm the ultimate stage in this development seems to be at hand. Other factors, such as sufficient room for window furnitures pose their limitations. It should be noted, however, that these present products always differ from the old steel ones, since the total depth of the profile today should be sufficient to receive double glazing. Also when

applied to larger surface areas, additional flanges might be needed to increase stiffness of the construction, that could easily spoil the interior view. All in all, this means that such products remain unsuitable for listed buildings.

Renovation market

It would be a mistake to assume, that renovation and reuse will remain a small segment of the construction industry. It must be recognized, that the renovation market will develop from quite a marginal niche into a much more significant volume in turnover, since the number of renovation jobs will grow exponentially over the coming years.

It should be noted, that of all the building stock in the Netherlands, 80% has been constructed only since World War II. In downtown Rotterdam, that has been completely rebuilt after the 1940 fire storm bombardments, all 322 buildings of the Reconstruction have been registered². Half of these appeared to have been fitted with steel framed windows, while another 60 featured aluminium windows or facade systems when completed. Of these 220 buildings that had metal windows originally, today 30 have been renovated with new metal framed windows –mostly aluminium–, 50 with another type of product –mostly U-PVC–, and 140 remain more or less unchanged as far as the windows are concerned.

It can easily be assessed that, for the whole of Rotterdam, some 200–250 buildings remain with original metal windows or curtain walls. On a national scale, we are therefore dealing with a market potential of probably a thousand buildings with metal facades that need our care in the near future.

It is obvious that the renovation market will increase dramatically, since most facade constructions are due for refurbishment after about 40 years. Of course not all of these are qualified to faithful preservation of their appearance, but still. Another factor that will affect the renovation industry is the increasing role of reuse and refurbishment within the concept of sustainable building. Reuse of structures, or parts thereof, implicitly results in a decrease of the demand for raw building materials, while a reduction of rubble and waste is achieved at the same time. It is clear, that such arguments are becoming increasingly valid. Therefore, reuse of buildings will become a much more common architectural issue.

A third factor that should be mentioned, is that many postwar buildings are no longer excluded from listing by the fifty-year rule of the Netherlands Monuments Act of 1988. Although this category requires the highest aesthetic level of intervention, it will however remain a relatively small part of the market by its very nature.

New developments in facade constructions

As set out by Just Renckens in his lecture, there is an exciting future in light and intelligent facade constructions ahead of us. The new concept of

interactive facades will provide buildings with interior conditions being directly related to exterior conditions, and tailored according to individual needs instead of absolute standards.

Remarkably, Renckens focusses on what he calls alu-glass facades and it must be questioned if this challenging new concept should be limited to one material already now. We could be missing out on interesting innovations for instance in high performance synthetics, compressed timber, steel or metal alloys.

It is important for the metal window industry to identify those properties of steel that match the requirements for such light facade constructions, as well as those aspects that need an innovative reassessment. Although it is not so easy to produce a comprehensive proposal instantly, a few remarks might stimulate such a debate.

1. In view of recent standards for sustainable construction a tremendous change is occurring as regards the techniques to control interior climate conditions. The properties of steel seem to offer an excellent starting point to play a significant role in the development of such constructions. The interactive facade systems that are currently under development provide a promising opportunity for steel, that can be seized if the particular properties of the material could be taken advantage of.
2. The exploitation of the environment through the production and recycling of building materials is a factor that is increasingly decisive. As regards durability, production energy and recyclability, steel is offered a new chance.
3. The high strength and stiffness of steel make this material ultimately appropriate to respond to the need for a minimal use of materials, both in terms of current architectural ideas as well as environmental concern.
4. The new developments in glazing technology, reducing double glazing spacers, will allow for a decrease of pocket dimensions. Thereby, a restriction for further reduction of profile dimensions is dropped. It must be assumed, that steel profiles can benefit from such developments to a greater extent than aluminium, as a result of the material's greater strength.
5. It would be interesting to survey possibilities for a thermal break in steel profiles, without disturbing the static performance and thus without an increase of the section. This might be achieved through new technology in adhesives, that still must allow for easy separation of materials for recycling afterwards. Relocation of the isolator at either of the perimeters could be considered.
6. Alternatives in corrosion protection could counter the still standing suspicion against steel elements as applied in facades. A disadvantage of applied protective coatings can be that problems might arise with recycling afterwards. Could cathodic

protection, as is now more frequently applied to prevent corrosion of rebar in concrete constructions, provide an alternative? Or could the surface of steel be modified in such a way, that corrosion is without chance?

At first it might seem that the above poses questions rather than provides answers. Yet the only way to anticipate the future is to recognize one's own shortcomings and qualities, as well as new opportunities. A debate within the facade industry, and steel window manufacturing in particular, is vital to get on terms with the new standards that are to be set sooner than we might think.

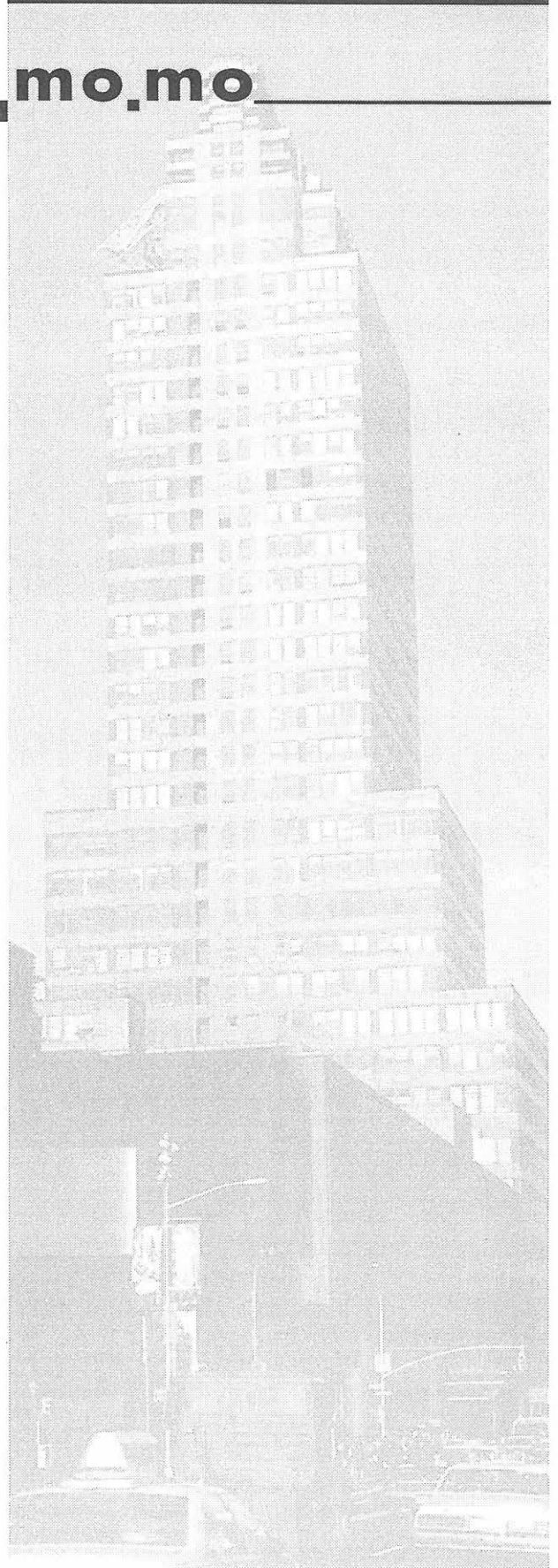
Wessel de Jonge, seminar organizer
DOCOMOMO International Specialist Committee on Technology.

Notes:

1. Hubert-Jan Henket and Wessel de Jonge, *Het Nieuwe Bouwen en Restaureren*, with extensive English summary, Den Haag-Zeist 1990.
2. A comprehensive register of Rotterdam Reconstruction architecture has been produced by the *Comité Wederopbouw* (Committee for Reconstruction Architecture), and is available on CD-ROM. The data mentioned here are taken from this source.

LECTURES

do.co.mo.mo



Opening

by Hubert-Jan Henket

At the Eindhoven University of Technology we have been active in the field of refurbishing buildings for about ten years now. This has resulted in several publications, such as *Herbestemming Industrieel Erfgoed in Nederland* (Refurbishment of Industrial Heritage in the Netherlands), written by Ed Schulte. Another one, from a series of Ph.D. studies, is 'Deterioration Characteristics of Building Components', by Marleen Hermans.

Then there is DOCOMOMO, an international organization which is involved with the documentation and conservation of buildings and neighbourhoods of the Modern Movement, and sticking out its neck for buildings of the 20th Century. Wessel de Jonge and I started the organisation about seven years ago and at the moment we have working parties in 33 countries. One of the working parties which has been set up recently is in the United States, and therefore we are very pleased that Stephen Kelley is here, who is one of our DOCOMOMO members in Chicago. DOCOMOMO is a network of about 800 people, thinking about what to do with 20th Century buildings, how to protect them, how to document them, et cetera. It does not mean that we only are interested in restoring them, obviously for many buildings there is a much more pragmatic approach.

We are going to talk about curtain walls today. The curtain wall, in fact, is pretty old. I always like the picture of the proposal by Sir John Soane for the Bank of England, a thousand years after its existence. Soane was a real *Beaux Arts*-architect and he designed, as most people at that time and before him, for eternity. Therefore, he asked his Indian draughtsman to make this beautiful picture of the building in ruins to show that the Bank of England was not only an aesthetically and functionally suitable building for the end of the 18th Century, but also after a thousand years, because it would look like the Acropolis: beautiful.

At the same time the guilds were abolished and, because of the Industrial Revolution, the performance requirements on buildings changed very rapidly. The famous Crystal Palace was designed by Joseph Paxton about 50 years after Sir John Soane. Architects and engineers in Britain, like Paxton, designed buildings for a completely different reason. The performance requirements changed dramatically, became much more specific and therefore this building was not designed for a thousand years. It was designed and built in nine months and intended as a building which could change; it was not designed to last long, but just for a short time.

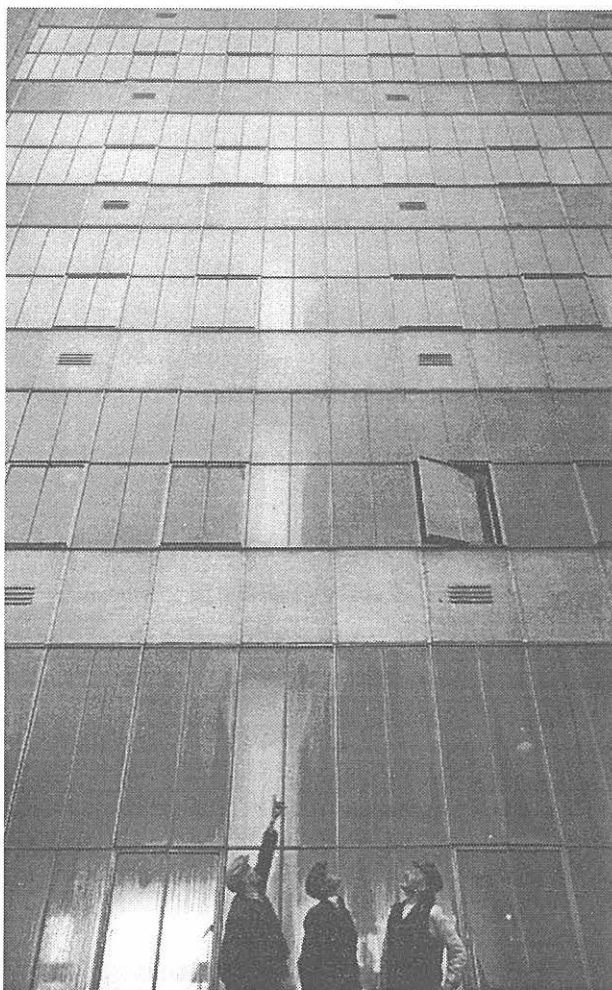
A completely different approach is to make a

loadbearing structure and a skin put over it. In Dutch, we talk about *vliesgevel*, in English it is curtain wall. The word 'curtain' explains very clearly what a curtain wall is. It is a skin which hangs from the building and it does not do anything as far as loadbearing functions are concerned.

A very important building as far as Holland is concerned, the Van Nelle factory, was designed in the 1920s. Here you can see what a curtain wall really is intended to do. It has to keep the temperature out, to keep part of the climate in, let the light in, it has to protect the owner from unwanted people going in, and has to be beautiful. In the early 1920s people tried to make the skin as transparent as possible and that is what this building displays very clearly. The office of the Van Nelle factory has been refurbished about five years ago. You can see there are some problems if we talk about the restoration or refurbishment of these elevations. I will talk about what sort of problems we have a little later.

The refurbishment of curtain walls is very much in debate at the moment. Why is that? First you have to remember that since the last eighty years more buildings have been built than ever before in history

When in 1929 the famous Van Nelle factories in Rotterdam were completed, the curtain wall was still a breathtaking expression of progress, that was looked up at in wonder.



put together. So the quantity of recent buildings is enormous. After the First World War, but particularly after the Second World War, the curtain wall became very fashionable. After 30, 40 years it is obvious that we start to look at them to see what we can do and so today we are faced with a huge quantity of curtain walls to be refurbished. Another factor is that a lot of performance requirements have changed since the 1950s. Energy conservation, insulation requirements, safety requirements, all sorts of requirements are changing so rapidly, particularly nowadays, that most of the elevations are now taken down after 10, 15 years. Another reason for that is just fashion. Particularly in office buildings in this country you can see that the elevations of the 1960s and 70s, and curtain walls in particular, are being removed, not so much because they are not functioning any longer but because they have not got the 'look' to let them to new tenants.

The technical failures of curtain walls on the whole are not all that dramatic, particularly not for the glass curtain walls. It is more the functional requirements which have changed that cause problems. It is interesting to note that when we started to look for cases in this country to be presented at this seminar, it

was very difficult to find proper cases of refurbishments of curtain walls. Good examples were scarce, which shows that this sort of seminar is very much in need, since there are very few people who really know what to do with them. That is also why we thought it would be interesting to invite people from abroad, since they often have more experience.

In many cases you see that people just take the curtain wall down and put completely different elevations back, which changes the building dramatically. An example is the Schunck department store in Heerlen, designed by Frits Peutz in 1936. When one compares the original situation with the new elevation, it becomes clear that the whole visual appearance has dramatically changed. In the city of Heerlen, this is not a building which is recognised any longer as an important building, whereas in the past it used to be. It now fits all the performance requirements as far as energy conservation, insulation, et cetera are concerned. But the visual appearance has disappeared, which I think is one of the most important things. If you go, for example, to Rotterdam you will see housing schemes designed by the architect Van den Broek. They were once very beautiful buildings with very thin window frames

A screen with an image of a Prussian palace is reflected in the curtain wall of the former DDR Houses of Parliament in Berlin.



which have been altered in the last 5 to 10 years. Today you see huge thick aluminium frames which visually totally change the look of the buildings, which is really a pity.

One of the things we try to establish in this seminar is not only how to deal with old curtain walls technically, but we also try to stress the visual importance of these buildings, to try to refurbish with the original visual concept in mind. This is one of the main problems. Now an added problem is that the industry does not provide us architects sufficiently with the systems to make the elevations as we would like them to be. In many of the original constructions you see that very thin window frames have been used. It is very difficult, particularly with the performance requirements we have today, to bring them back to that sort of shape. I am sure there is still a lot to be improved by the industry in this respect.

Another challenge is the visual quality of glass, in relation to the energy and sun protection performance of glass. If you look at the original buildings, it is very often possible to look through the building over an angle, in other words they are very transparent. This is extremely difficult to relate to the performance requirements of today, because to avoid sun penetration and get as much light inside we have to use glass which is either too dark or too reflective as compared to the original visual appearance. In other words, the original transparency is lost. So a lot of improvement in the quality of glass, particularly the visual quality, has to be introduced. As far as insulation is concerned, if you have transparent buildings, then architects are also looking for translucent insulation. Also on that side very little has been developed up to now by the industry.

If we have a proper system, as far as curtain walls for example are concerned, then there is very often the problem of the connection with another product. The connection between two products, or two components, in the building industry, at least in our part of the world, is still extremely difficult. Not so much technically, but particularly as far as the process is concerned, as far as contracts, responsibilities, et cetera are concerned. I would very strongly ask the building industry to help the engineers and architects on that field.

To finish this short introduction, I thought it would be nice to show the most literal translation of a curtain wall which is a screen in Berlin. On this spot there used to be a Prussian palace, which was bombed during the war. Opposite are the Houses of Parliament of the DDR. There is a long debate going on in Berlin to restore the original palace. It is a very important building for many reasons. The Prussian kings, Hitler and all sorts of other important people have lived there.

There have been two competitions to find out whether it would be nice to have a new building up there. A gentleman from Hamburg did not agree with the way these competitions were going and he said 'I want to make a case of putting this building back. I will prove that as far as the urban landscape is concerned, this is the best solution'. So he had this screen made, just a skin of exactly one millimetre thick, and painted by some theatre artists in Paris. This huge screen was fixed to scaffolding. A mirror was put against the DDR Houses of Parliament so that you got the complete appearance of what it used to be with a completely fake curtain wall.

I hope today we are not talking about fake, but about reality. I wish you all a very interesting seminar.

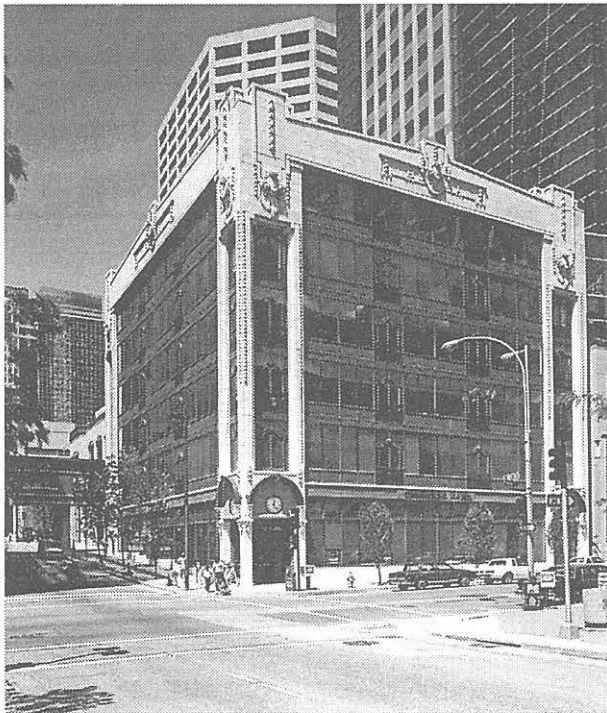
Hubert-Jan Henket is an architect, professor of building technology at the Eindhoven University of Technology and the chairman of DOCOMOMO International.

An image of modernity

An American history of the curtain wall

As defined in the first half of this century, a curtain wall is an enclosing wall built and supported between columns and piers, and on girders or other support, and sustaining no weight other than its own. The curtain wall serves only transfer lateral loads to the frame, protect the building from fire and the elements, and as an expression of architecture. The curtain wall dichotomy can be traced back to numerous 19th and early 20th Century antecedents, including glass exhibition pavilions, cast-iron fronts, and masonry infilled metal frame structures.

by Stephen J. Kelley



The Boley Building (Louis Curtis, 1909) in Kansas City.
All photos: Wiss, Janney, Elstner Associates, Inc.

The development of the curtain wall was primarily governed by three factors. Its technology was dependent upon the introduction of the metal skeleton frame and the development of adequate fireproofing systems. Economy dictated that the amount and weights of materials used be minimized, that fabrication occur in the factory rather than the site, and that construction become standardized. Aesthetics called for ever greater expanses of glass, and reflected the technological and economic developments.

In the United States curtain wall development became intertwined with that of the skyscraper. Skyscrapers would not have been technically feasible without the lightweight curtain wall. And it was through the skyscraper that the curtain wall achieved its greatest realization.

Antecedents of the curtain wall

London's Great Exhibition building of 1851, the Crystal Palace, is identified by Pevsner as the 'touchstone' of those technical achievements that point forward to our own era. The Crystal Palace had precedents in smaller, earlier structures, and set a precedent for later 19th Century exhibition buildings. It was an example on a very large scale of the aesthetic of a transparent skin encasing a wholly-visible iron frame. It was an early illustration of the use of mass-production, and was designed in standard parts - sections of cast iron and glass based on a modular unit.¹ Only by means of prefabrication and the use of construction techniques using dry materials (glass and metal) rather than wet materials (masonry) could a building of such a size be erected in the short time of four months.² The Crystal Palace also exhibited the future trends in construction in which operations performed on site would be transferred to the factory.³

The Crystal Palace and later glass-walled exhibition buildings of the nineteenth century were never built to last, and the glass curtain wall aesthetic that was employed did not make its way into mainstream architecture until the middle of the 20th Century. By the mid-19th Century, cast-iron architecture was in widespread use in the urban centers of the United States.

Since slender iron columns could support an entire facade, larger windows were made possible than in traditional masonry. Columns and lintels became a narrow grid for the support of windows that dominated the facade. The parts of an iron facade were fabricated and tested for fit at the foundry, and then the prefabricated parts were assembled at the site.⁴ Though these facades were not technically curtain walls, the aesthetic of a glass facade had been realized.

Perhaps the most significant development by a cast-iron front manufacturer was not the iron front but the McCullough Shot Tower (1855) erected in New York City. Constructed by James Bogardus, the tower was 175 feet high and was supported by an octagonal

cast iron frame. The frame was visible from the exterior and was infilled with brick.⁵

The American skyscraper

The late 19th Century was an inventive era in American construction. The metallurgical industries, accelerated by the demands of the American Civil War, were able to supply structural metals in quantity for construction. Clay tile which could be used to fireproof the new metal skeletons was developed. Production of glass became industrialized, and larger sizes of glass were made possible.⁶ Chicago architect William LeBaron Jenney was an innovator of the application of the iron frame and masonry curtain wall to the high office building. The Home Insurance Building (1884-1885), exhibited the essentials of the



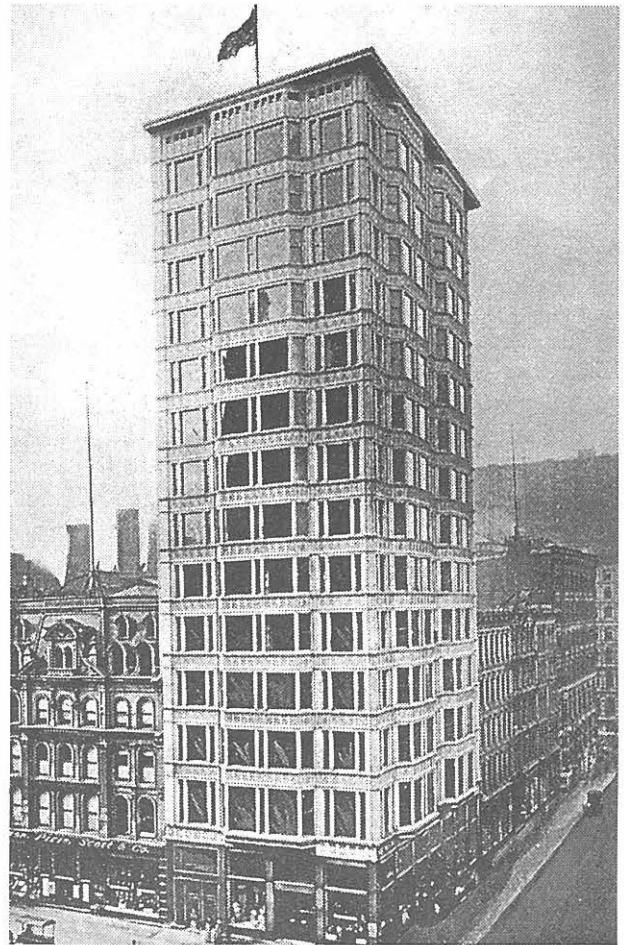
An example of cast-iron architecture in New York, mid-19th Century.

fully-developed skyscraper on its main facades with a masonry curtain wall.⁷

Spandrel beams supported the exterior walls at the fourth, sixth, ninth, and above the tenth levels. These loads were transferred to stone pier footings via the metal frame without load-bearing masonry walls.⁸ Frederick Baumann, a noted Chicago structural engineer of the period, clearly described the potential of the masonry curtain wall for tall buildings.⁹ Jenney trained many of the architects who designed

Chicago's early skyscrapers including Louis Sullivan, William Holabird, Martin Roche, and Daniel Burnham. The masonry curtain wall technique was fully developed within a few years by these architects, and was utilized in a functional aesthetic that came to be known as the Chicago School of Architecture. These architects were well aware of the contributions of Bogardus and Johnson.¹⁰

An archetype of the Chicago School can be found in the rigid frame Reliance Building (D.H. Burnham, 1895), the first skyscraper to use terra cotta exclusively as a cladding. The Reliance Building curtain wall is a clear aesthetic expression of the underlying structure and provides a maximum of natural lighting. The terra cotta units of the curtain wall are connected to a gridwork of cast-iron mullions,



The Reliance Building (Daniel Burnham, 1895) in Chicago.

lintels, and sills which span between levels. Unlike the Home Insurance Building and other similar buildings, the Reliance Building did not rely upon the masonry curtain for lateral support. In New York City the rigid steel frame and masonry curtain wall established themselves with the American Surety Building in New York City (Bruce Price, 1894), and, once adopted, skyscraper heights increased dramatically. The once impressive twenty-story buildings of Chicago were overshadowed by buildings 300, 600, and finally 792 feet with the Woolworth Building (Cass Gilbert, 1913).

The Woolworth building utilized the latest developments in steel frame construction, but its masonry curtain wall, which incorporated gothic references, had not abandoned the hand-crafted ethic of masonry construction and ornament.

Early experiments

In Europe by the end of the century, architects were exploring the aesthetic possibilities of glass and metal on building facades. Similar themes were explored in the United States. The Boley Building (Kansas City, 1909) by Louis Curtis, incorporated a transparent glass wall enclosing an entire structure. An early glass curtain wall appeared at the Hallidie Building (Willis Polk, 1918) in San Francisco. These experiments in the aesthetic possibilities of the glass curtain wall were largely ignored by American architects of the period.¹¹

Europe

Prior to the First World War, German architects addressed the development of a modern aesthetic for the glass curtain wall. Upon leaving Behrens' office, Gropius and Meyer were commissioned to build the Faguswerke Factory (Alfeld-an-der-Leine, 1911), regarded as one of the founding monuments of European modernism. At this factory, each level is indicated by solid spandrel panels that are installed like the glass above and below them, a treatment echoed by post-World War II highrise curtain walls.¹² The First World War administered the final blow to the arts and crafts movement in Europe, and the machine became the basis of the new architecture. Modern European architecture required that the labor of producing the parts be performed in the factory rather than by skilled craftsmen on site.¹³ German intellectuals were in awe of the example of the American skyscraper, a strong symbol of the new world for which they endeavored.¹⁴ Mies van der Rohe prepared a series of unrealized projects in which the most famous came to be known as the 'Glass Skyscraper,' a highrise enveloped totally in glass.¹⁵ The theme of the curtain wall of the Faguswerke Factory, and Mies van der Rohe's glass skyscraper projects were furthered by the construction of the Bauhaus (Dessau, 1925) designed by Gropius.¹⁶

The 'International Style' in the United States

Contemporary with the European modernists, America had entered a second skyscraper era. The post World War I period brought a demand for increased speed in design and erection. Curtain wall construction, however, continued to utilize the masonry panel and metal frame techniques that had been developed by the turn-of-the-century.¹⁷

In 1922, Americans were not ready to accept the aesthetic of the very plain reticulated tower that was proposed by Gropius and Meyer for one of the most influential design contests of the 20th Century, the International Chicago Tribune Competition.¹⁸ The

Competition demonstrated the variety of the eclectic styles of the period and illustrated the split between American designers who borrowed from past styles, and some Europeans who were ready to embrace the machine aesthetic of the glass box. One of the architects of the Empire State Building (New York City, 1931) wrote of the masonry curtain wall:

'Tradition has clung to the heritage of thick masonry walls. We inherited masonry walls and seem unable to outgrow our inheritance. The idea that masonry is the only form of permanent construction was so deeply rooted that practically all building codes made masonry walls mandatory ... The covering of the observation tower ... accomplished by a combination of aluminum, chrome-steel and glass, [was] designed and fabricated into forms entirely free from masonry influences. The extension of similar treatment to embrace all of the inclosing walls of a tall building is quite conceivable and, if backed with insulating materials to reduce heat loss and properly finished on the interior, will result in a light wall, readily made weathertight, easy to fabricate and erect and requiring practically no maintenance.'¹⁹

The European Modern Movement, which was known in the United States as the 'International Style,' was formally introduced to American architects in 1932.²⁰ The style dovetailed with demands of economy, efficiency, and the elimination of decorative features on the facade.²¹

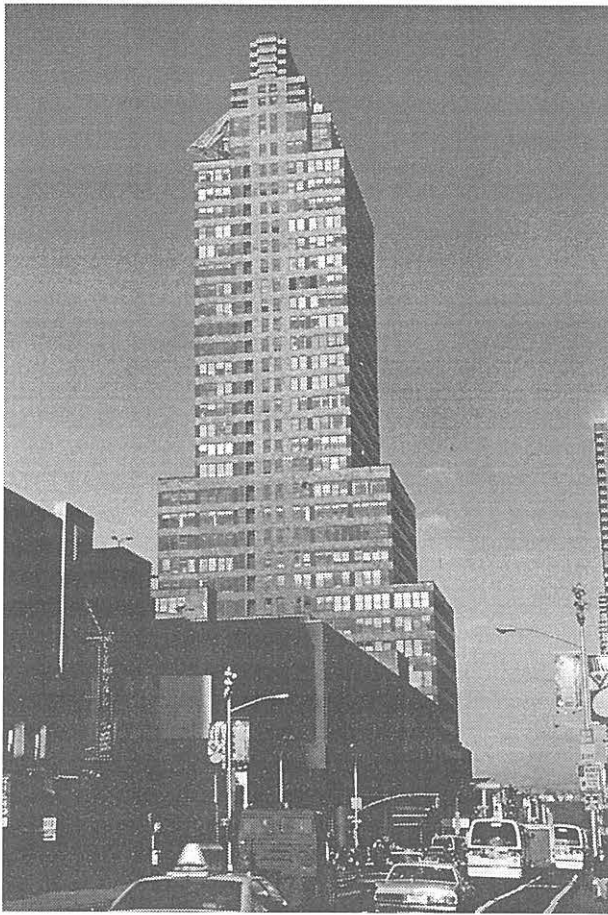
This trend was illustrated at the new headquarters for the New York Daily News (Hood and Howells, 1930), the McGraw-Hill building (Hood and Foulhoux, 1932), and the Philadelphia Savings Fund Society building (Howe and Lescase, 1931). The effects of the Great Depression and the Second World War brought a halt to building in America in the late 1930s and early 1940s.

The glass and metal curtain wall

New technologies resulting from World War II had a great influence on the acceptance of the metal and glass curtain wall. These technologies were achieved through improvements in materials (of which aluminum was the principal metal), innovations in glazing, glazing treatments, sealants, and insulating materials. Extruded metal components were suitable for standardization and could be prefabricated for delivery to the site. This was important because labor costs had become a significant part of construction costs. The glass and metal curtain wall further decreased building weight²² and construction cost, and increased usable floor area. Given the abundant postwar supply, aluminum was also reasonably priced. Glass curtain wall installation was less limited by cold temperatures which prohibited erection of 'wet' walls of brick and mortar. Out of this economic environment, the curtain wall had finally become almost entirely machine-made.²³ One of the first postwar buildings to be constructed with a glass curtain wall was the Equitable building

(Pietro Belluschi, 1948) in Portland, Oregon. Belluschi was able to take advantage of leftover aluminum stockpiled for World War II by smelters and to utilize assembly techniques derived from West Coast airplane plants.²⁴ The Equitable Building was constructed with cladding panels made from rolled sheets of aluminum, and glazing frames of extruded shapes.²⁵

The 860-880 Lake Shore Drive buildings in Chicago (Mies van der Rohe, 1949-51) were among the first residential buildings in the United States to be sheathed entirely in glass, and were the realization of Mies' 1920 proposal for a glass skyscraper. The steel, aluminum, and glass skin was assembled on the buildings' roofs in two story high units, and then lowered into place on the facade.²⁶ During the 1950s,



The McGraw-Hill Building (Hood & Foulhoux, 1932).

glass-walled buildings following this distinctive aesthetic began to appear in many American downtowns.

At the Lever House (Skidmore, Owings & Merrill, 1952), the curtain wall has an interior frame of mild steel clad with stainless steel. Its simple appearance 'belies its complex internal construction which was cobbled together from off the shelf parts.'²⁷ Similar curtain wall effects were soon made easier by catalogue components, and the curtain wall industry of the early 1950s became dominated by manufacturers and contractors who had experience

with aluminum windows. At the United Nations Secretariat building (Harrison and Abramovitz, 1950), curtain walls were conceived as an assembly of aluminum windows held in place with a grid of reinforced mullions.²⁸

As at the Lever House, the lower portion of the curtain wall at each level was backed up by a concrete masonry wall to provide the fire rating that code officials felt was not provided by the curtain wall.²⁹ Technical guidance in the use of metal and glass curtain walls for 1950s designers was limited.³⁰ The ideal curtain wall was defined as being between two and five inches thick, self-insulating, able to withstand high winds, weatherproof on the outer surface, vapor-proof on the inner surface, ventilated and drained for control of internal moisture, designed for expansion and contraction of the building, easily removable for repair, sound deadening, adaptable to all types of building frames, installed from the inside without scaffolding, easy to fabricate, ship, and handle, attractive, maintenance free, and moderate in cost. Furthermore, this system was intended to last 40 to 100 years.³¹

The approach to curtain wall design that quickly evolved was to make the joints as weathertight as possible, then provide positive means for conducting any water leakage out of the wall.³² The economic impact of large lites of clear glass were also becoming apparent. The orientation of buildings in consideration of path of the sun, and the reduction in the size of windows to reduce solar heat gain were being practised.³³

An alternative response to the all glass curtain wall, the Alcoa Building (Harrison, 1952) in Pittsburgh, used story-high panels of aluminum penetrated by relatively small windows. The windows were set in aluminum frames with rubber gaskets. Aluminum panels were formed with a pressed pattern to add rigidity, create relief, and produce scale.³⁴ This type of sheathing became quite popular during the mid-1960s. In the Alcoa Building perlite insulation was sprayed on aluminum lath to provide fireproofing instead of using masonry behind the wall panels.

Continued development

While the machine-made potential of the glass curtain wall was being exploited, alternate cladding systems could not initially compete with the economy of glass-and-metal systems. In the face of competition, the adaptation of precast concrete, masonry, and thin stone veneers to the new curtain wall technology was comparatively slow to develop. Acceptance of these cladding systems did not come until the 1960s.

The first extensive use precast concrete for cladding was at LeHavre after the War, where panels were cast on site with standardized molds to be used on an extensive network of buildings.³⁵ The Hilton Hotel at Denver, Colorado, (I.M. Pei, 1958-1959), can be regarded as marking the beginnings of the use of precast concrete as a curtain wall cladding material in

America.³⁶ Further examples of the development of precast concrete cladding include the Pan-American Building (1961, Walter Gropius and the Architects Collaborative) in New York, and the International Building in San Francisco (Anshen and Allen, 1959). The development of masonry as a prefabricated cladding for curtain walls is traceable to Switzerland, France, and Denmark in the 1950s, and the United States in the early 1960s. The Brick Institute of America developed and patented a prefabricated brick masonry system which was used in construction of several building panels in the Chicago area.³⁷ Factory panelization techniques using latex mortar additives, however, fell into disfavor as evidenced by the reduction of companies that prefabricate masonry panels from 15 to only a few.³⁸



The 860-880 Lake Shore Drive Buildings (Ludwig Mies van der Rohe, 1945-51) in Chicago.

Exceedingly thin veneers of stone such as marble and granite appeared on high rise buildings in the 1960s. Rational rather than empirical design principles for stone were established to reduce the weight and cost of stone.³⁹ Stone panels became thin enough to be erected within the metal grid employed by the metal curtain wall industry.⁴⁰ Examples include the Amoco building (Edward Durrell Stone, 1973) in Chicago,

and Lincoln Center (Wallace K. Harrison, Philip Johnson and Max Abramovitz, 1966) in New York City.

Future directions

New technologies have created the economy of using less material to cover more area, and of using new materials and installation techniques to achieve cost-effective construction. Structural silicone glazing is responsible for the large expanses of mullionless glass. Thin stone veneer applied to precast concrete panels and ceramics cast into glass fiber-reinforced concrete are just two examples of composite panels which take advantage of the permanence and appearance of the exterior material and the strength of the backup material. The rain screen curtain wall principle developed in Canada may help realize the abolition of sealants on building skins. Latex-modified stucco panels can now be fabricated for curtain walls and are being used for highrise buildings. The polyvinylchloride (PVC) window industry is also being utilized in curtain wall technology.

A distinction of our era is the relaxation of the guidelines established by the Modernists. The use of historical styles on highrise buildings are no longer looked upon by designers with disdain, and are used more for 'nostalgia, novelty, and innuendo.'⁴¹ Though the International style is no longer the strict dogma of designers, the appearance and details of the curtain wall will remain forever influenced by the machine made aesthetic with which the early Modernists were captivated.

Stephen J. Kelley is an architect and structural engineer with Wiss, Janney, Elstner Associates, Inc. in Chicago.

Notes:

1. J.M. Richards, *An Introduction to Modern Architecture*, Baltimore 1962, pp. 66-67.
2. Nikolaus Pevsner, *Pioneers of Modern Design*, Hammondsworth-Middlesex-Baltimore 1974, p. 133.
3. Trevor I. Williams, *A History of Technology*, Oxford 1878, pp. 937-938.
4. Margot Gayle, *Cast-Iron Architecture in New York*, New York 1974.
5. Peter B. Wight, 'Recent Fireproof Building in Chicago - Part II,' *Inland Architect and News Record*, Volume 19, March 1892, p. 22.
6. Marcus Whiffen and Frederick Koeper, *American Architecture 1607-1976*, Cambridge 1981, p.168.
7. New York, Chicago, and Minneapolis have all claimed to be the birthplace of the skyscraper. The question of whether the skyscraper originated in New York or Chicago remains a matter of controversy to this day. Comparative characteristics include the development of the curtain wall as well as the first use of the iron frame, appearance of the beam-column moment connection, height limits, and the theory of frame stiffness.

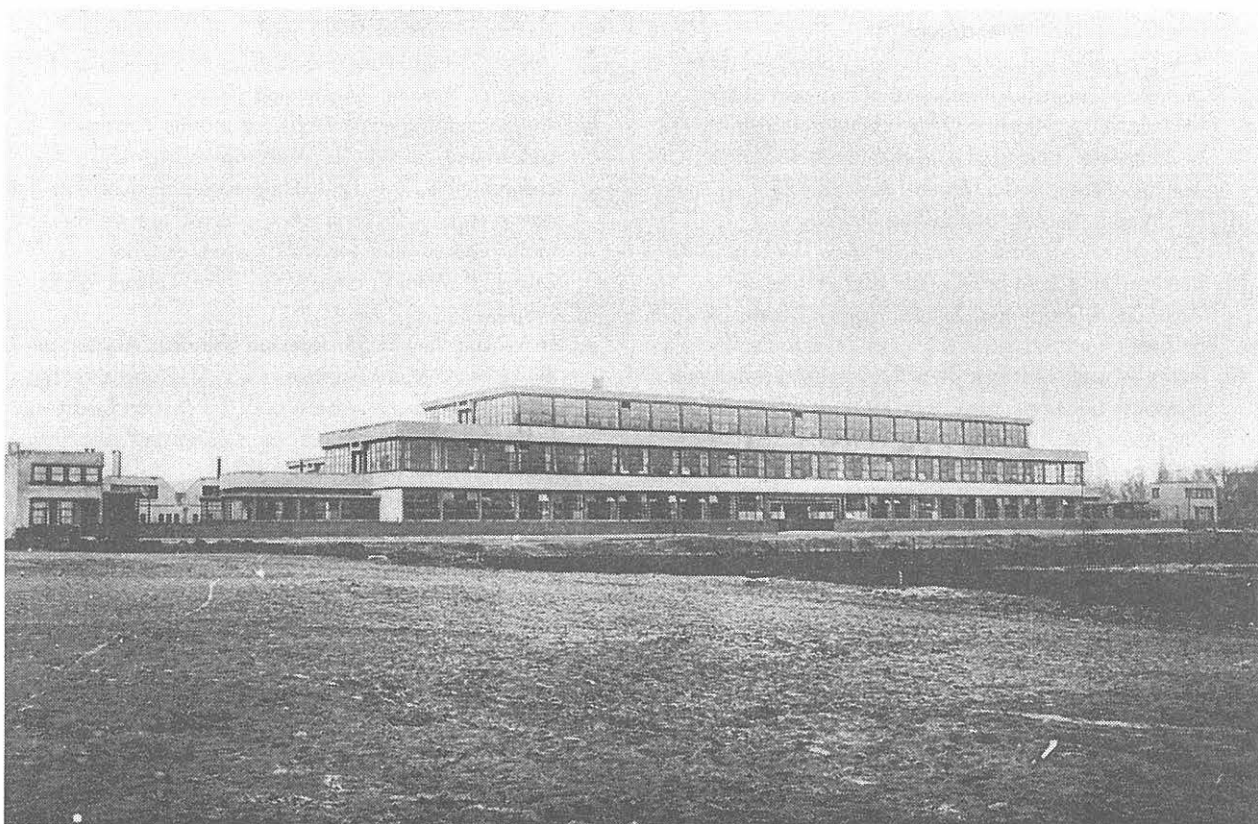
8. E.M. Upjohn, 'Buffington and the Skyscraper,' *The Art Bulletin*, Volume XVII, N° 1, March 1935, p.53.
9. The design is to erect on foundations a firm and rigid skeleton, or hull, of iron... The enclosure, whether of stone, terra cotta, or brick, or any combination of these materials, may be erected at the same time the iron structure is being put in place. But the latter might proceed much faster than the former; while the hull might be roofed within two months, the enclosure might not have proceeded further than the fourth story. Thus there need be no delay to a steady progress. Light, the great desideratum in all city buildings, is secured, even on the lowest -the most valuable- floors, whereas, otherwise, the necessarily broad piers would be a hindrance. The iron uprights are to be provided with a series of projecting brackets for the purpose of anchoring and supporting the parts forming the exterior enclosure. These supporting brackets will be so arranged as to permit an independent removal of any part of the exterior lining, which may have been damaged by fire or otherwise. 'Improved Construction in Buildings,' *Sanitary News*, 3, 15 March 1884, p. 123.
10. P.B. Wight, 'Recent Fireproofing Building in Chicago,' *The British Architect*, 6 May 1892, p. 347.
11. Burchard and Bush Brown, *The Architecture of America: a Social and Cultural History*, Boston 1966, p. 346.
12. Henry Russell Hitchcock, *Architecture: Nineteenth and Twentieth Centuries*, New York 1977, p. 491.
13. J.M. Richards, *An Introduction to Modern Architecture*, Baltimore 1962, p. 31.
14. Franz Schulze, *Mies van der Rohe, A Critical Biography*, Chicago 1985, p. 96.
15. Schulze, pp. 96-97, 100-101.
16. Hitchcock, p. 449.
17. Richards, p. 71-72.
18. Hitchcock, p. 483-484.
19. H.R. Dowsell, 'Walls, Floors, and Partitions in the Tall Building,' *Engineering News Record*, 19 February 1931, pp. 319, 321.
20. The exhibition on the International Style opened at the Museum of Modern Art on 10 February 1932, in the middle of the Great Depression. The style, with architecture stripped of ornament, was presented to a profession that was 85 % unemployed and created an immediate sensation. James Marston Fitch, *American Building and the Historical Forces that Shaped It*, Boston 1966, pp. 247-248.
21. Fitch, pp. 259-260.
22. Prewar masonry curtain walls could weigh up to 175 pounds per square foot. The new glass and metal curtain walls were designed to weigh about 5 to 15 pounds per square foot. Building structures and their foundations could be more economical since they would be designed to support a lesser load. 'The Trend to Building with Metal Curtain Walls,' *Engineering News Record*, 20 October 1955.
23. Paul Goldberger, *The Skyscraper*, New York 1989, pp. 103-105.
24. In 1943, during the planning stages for the Equitable Building, Belluschi stated 'Our assumptions were affected by the peculiar circumstances found in our Northwest region - cheap power and a tremendous expanded production of light metal for war use, which beg utilization after the emergency.' *Architectural Forum*, May 1943.
25. 'Icons of Modernism or Machine-age Dinosaurs?', *Architectural Record*, June 1989, p. 145.
26. Peter Carter, *Mies van der Rohe at Work*, New York 1974, p. 46.
27. 'Icons of Modernism or Machine-age Dinosaurs?' p.142.
28. American Architectural Manufacturers Association, *Aluminum Curtain Walls*, Volume 5, p.8.
29. 'The Trend to Building with Metal Curtain Walls,' *Engineering News Record*, 20 October 1955.
30. *Aluminum Curtain Walls*, p. 8.
31. 'Metal Curtain Walls,' *Proceedings of the Building Research Institute*, Washington 1955.
32. At first caulking compounds, ubiquitous in today's curtain wall construction, were not recommended for sealing joints. They held little promise because they 'fail due to expansion/contraction and will require constant maintenance.' John Hancock Callender, 'The Design of Metal Curtain Walls,' *Metal Curtain Walls: Proceedings*, pp. 79-97.
33. H. Wright, July 1955. A lesson had been learned at the United Nations Secretariat building where the two all glass facades had been oriented east and west and were subjected to the harsh rising and setting sun.
34. Burchard and Bush Brown, p. 473.
35. A.E.J. Morris, pp. 45, 66-71. Perret was the innovator of precast panels being used as cladding. At the apartment block at 51-55 rue Raynouard in Paris, he had hung precast concrete wall panels on a poured concrete frame in 1930. *Macmillan Encyclopedia of Architects*, Volume 3, New York 1982, p. 394.
36. Morris, p. 161.
37. Brick Institute of America, *Technote 40*, October-November 1973.
38. Mark A. Wallace, 'Brick Panels, Ohio Style,' *The Magazine of Masonry Construction*, June 1990, p. 267.
39. Ian R. Chin, John P. Stecich and Bernard Erlin, 'Design of Thin Stone Veneers on Buildings,' *Proceedings of the Third North American Masonry Conference*, June 1985.
40. Clar Monk, 'The Rational Use of Masonry,' *Proceedings of the Third North American Masonry Conference*, June 1985.
41. Ada Louise Huxtable, *The Tall Building Artistically Reconsidered: The Search for a Skyscraper Style*, New York 1982, p. 18.

Curtain walls in the Netherlands

Refurbishing an architectural phenomenon

When, in 1929, the famous Van Nelle Factories in Rotterdam were completed, the curtain wall was still a breathtaking expression of progress, that was looked up at in wonder. This type of facade constructions originates from the US and was introduced to the Old World in the early 20th Century. Early European appliances are mainly industrial buildings, such as the AEG Turbine Hall, designed by Peter Behrens in 1908. Of course, the properties of curtain walls were very appropriate for factory buildings, where production efficiency would benefit from the almost unhampered entry of daylight and easy ventilation.

by Wessel de Jonge



The Groningen Polytechnic, designed by Wiebenga and van der Vlugt in 1923, is a remarkably early modern building with light facade constructions. Photo: Gemeentearchief Groningen, courtesy of Stichting Analyse van Gebouwen.

Yet, various groups of progressive designers proposed a similar, rational approach where other types of buildings were concerned.

The *Deutscher Werkbund*, an association of designers in Germany, propagated rational and efficient planning of both workplace and dwelling, as regards interior as well as exterior. Their 1913 yearbook includes illustrations of American factories like the Ford Old Shop in Highland Park in Detroit, Michigan. The Werkbund Pavilion in Cologne of 1914, designed by Walter Gropius and Adolf Meyer, featured several modern elements and constructions. The building's fully glazed facades could be regarded as European prototypes of curtain wall technology for

non-industrial buildings. The same architect's design for the Fagus Werke in Alfeld-an-der-Leine is contemporary with the pavilion and includes similar elements. Today, it is widely recognized as one of the main starting points of the Modern Movement in architecture. This implied, that some of the pragmatic guidelines for industrial buildings as developed by American engineers, now became *conceptual principles* for a small group of progressive European architects.

Skeleton and light envelope: Bauhaus

'The new freedoms sought in planning, daylighting and architectural expression relied on new frame

techniques, larger window openings and sheer planar effects. The evolution of two-way spanning panel and slab structure liberated architects from the inhibiting constraints of traditional masonry load-bearing construction.¹¹

By doing away with the loadbearing function of the facades, daylight and fresh air could enter the buildings where and whenever desired. Le Corbusier included this principle in one of his 'five points' for good architecture in *Vers une architecture* in 1923. Between 1925–26, Gropius designed the new Bauhaus in Dessau.

The fully glazed workshop wing of this famous building formed a next milestone in the development of curtain walls in architecture. Gropius promoted this functional and flexible approach for buildings in the



Bauhaus in Dessau after reconstruction of the curtain wall in 1976. Photo: Bauhaus eV.

curriculum for his Bauhaus students – before they returned to their respective countries, disseminating these ideas all over the world.

After the school had to close down in 1933 as a result of nazi terror, the prototypical curtain walls were walled up with plastered brick. The new use as a training center for the SA required the abolishment of the 'cosmopolitic' appearance of Gropius' building. In 1976, the original steel and glass facades were carefully reconstructed by the municipal Conservation Architect Wolfgang Paul and his staff. Despite the troublesome economy and the pernicious lack of materials in the former DDR his team managed to produce a highly convincing remake in slender aluminium frames with thin double glazed lights. Today the famous and provocative glazed corner can again be enjoyed in its full glory.

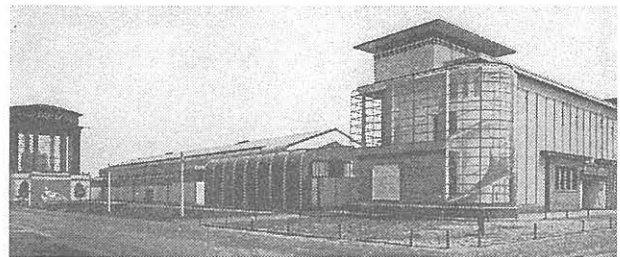
Wiebenga, the 'apostle'

Also in the Netherlands some modern architects were eager to master the great potential of curtain wall constructions. The designers of *Het Nieuwe Bouwen* set great value on the connection between form, function, applied materials, economy and time. User requirements and economy were seen as the causes,

while appearance and form emerged as a result. They regarded buildings as utilities with a limited lifespan by definition, and sometimes even as throwaway articles.

One of their ideas was, that highrise buildings would provide a solution to many of those problems society was suffering from in the years of crisis. Building high meant saving materials, reducing the footprint of buildings to allow for green recreation areas, and providing the inhabitants with common services such as elevators, central heating and laundry rooms, that were normally unaffordable. For building high, light constructions were indispensable and the curtain wall represented all the required properties, including its progressive image.

Structural engineer Jan Gerko Wiebenga



Werkbund Pavilion, Cologne (Walter Gropius, 1914). Photo: Archives Mme Lucia Moholy-Nagy; photographer unknown.

(1886–1974) was a key figure in introducing the building technology that allowed the architects of the Modern Movement to materialize their abstractions.² With architect Van der Vlugt he designed the remarkably modern new Polytechnic in Groningen as early as in 1923.

This building demonstrates the use of a load-bearing concrete frame by the horizontal ribbon of windows, placed on a brick spandrel. The school is a remarkable and very early example of some of Le Corbusier's five points, conceived at a moment his theories still had to be published.³

Wiebenga returned from a three year working experience in New York in 1926, and published series of articles in the professional press on functional planning, rational working methods, and efficient construction systems as applied in for instance steelframed skyscrapers such as the Empire State Building.

Zonnestraal Sanatorium (Hilversum; Duiker & Bijvoet, 1926–28)

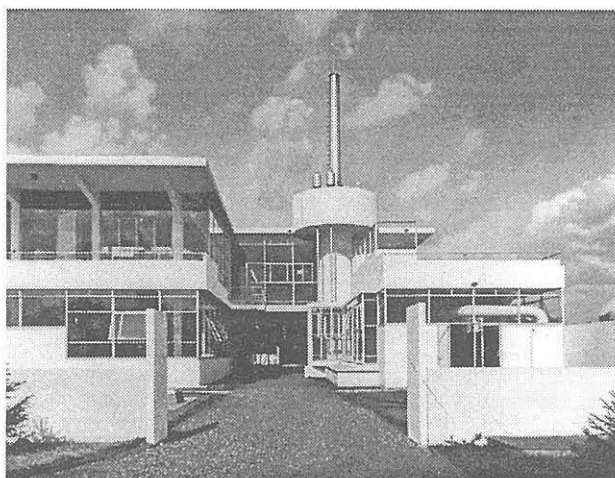
Immediately after his return, Wiebenga became involved in the planning of Sanatorium Zonnestraal (1926–28) as a structural engineer. Architects Duiker and Bijvoet however owe him as well for many of the building's clever solutions in facade technology, systems and even finishings of the interior. An American system for light partitions and facades, published by Wiebenga in 1926, was copied for the Zonnestraal pavilions.⁴ Only the timber posts were

replaced by steel ones, as already suggested by Wiebenga in his article.

Although the facades of Zonnestraal might not fully comply with the definitions of the curtain wall, they are nothing more than a membrane of steel and glass, a curtain wall *avant la lettre*. Related to the idea of varied lifespans, the use of prefabricated parts was another means to arrive at the goals of the Modern Movement. It allowed the easy replacement of deteriorated parts.

The prefabricated concrete spandrel panels of the sanatorium are likely to be the first ones ever to be applied in Holland.

All in all, Zonnestraal represents an important step in the development of these facade systems in Dutch modern architecture.



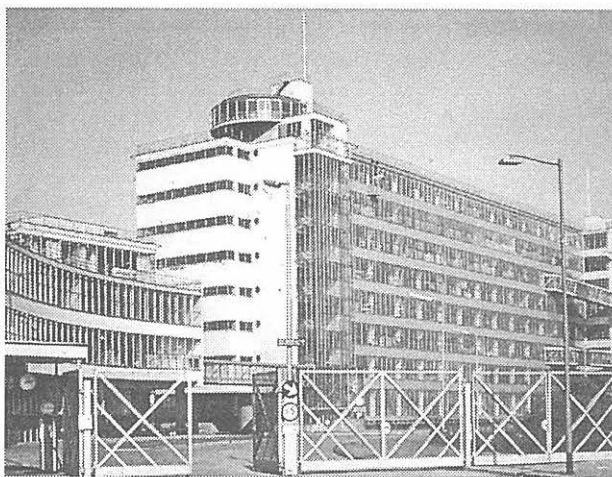
Zonnestraal sanatorium in Hilversum, main building.

Van Nelle factories (Rotterdam; Brinkman & Van der Vlugt, 1926–29)

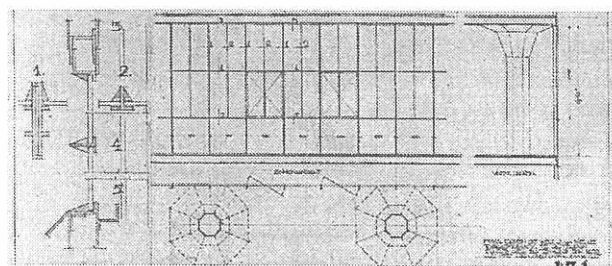
Another main project Wiebenga became involved with immediately after his return, was the famous Van Nelle factory, designed between 1926–29 by architects Brinkman & Van der Vlugt. Again, they owe their structural engineer for many of the technical solutions that lend the building its strong and modern image as well as its highly functional planning. Tobacco, coffee and tea were manufactured in individual sections of various heights, connected by staircases and sanitary units to form one volume. With each step of the processing, the products descended another floor, to end in the warehouses across the yard. Company director L.C. van der Leeuw and Wiebenga shared their interest in American ideas on rational planning. Also Van der Leeuw had travelled the US extensively to study modern daylight factories. The Van Nelle factories are constructed with a concrete frame of mushroom columns and beamless floorslabs. By placing the columns off the perimeter of the floorslabs, the buildings could be fitted with a completely smooth, continuous curtain wall. Self-supportive facade elements in zinc-sprayed steel span from floor to floor. Between standard steel sections, produced in Holland under license of the British firm

Crittall Windows that still produces them today, steel sheets have been welded to create a spandrel. The parapet was internally insulated with 'torfoleum', an impregnated peat product. Originally, the interior was additionally ventilated through inlets in the spandrels. It seems that this was not functioning very well, and the facade has been changed rather soon to overcome these problems.

Over the last years parts of the buildings have been refurbished. A starting point was, that the entire factory should in the end be double glazed. First, the facades of the office block have been replaced using a rather heavy aluminium section – probably the best available option at the time. The image of the replacement facade is however quite dramatically different as compared to the original membrane of



Van Nelle factories in Rotterdam feature emblematic prewar curtain walls. Photo: Wessel de Jonge.



The construction of the curtain wall of the tobacco factory. Drawing: Archive Van den Broek & Bakema architects.

steel and glass. Also, it was evident that care should be given to additional elements like window furniture. Calculations by renovation architects Van den Broek & Bakema could prove, that double glazing for the factory wings would not be an investment with sufficient return. Due to a quite exceptional level of maintenance performed until then, the condition of the original facade elements still allowed for repair, grit blasting and repainting.

Building physics

Modern architects tried to take advantage of the specific qualities of materials. It was made an architectural principle to select the most appropriate

material for each element and to construct as light as possible, with a minimum of material used. Duiker named this 'spiritual economy' that, as he wrote in 1932, 'leads to the ultimate construction, depending on the applied material, and develops towards the immaterial, the spiritual'.⁵

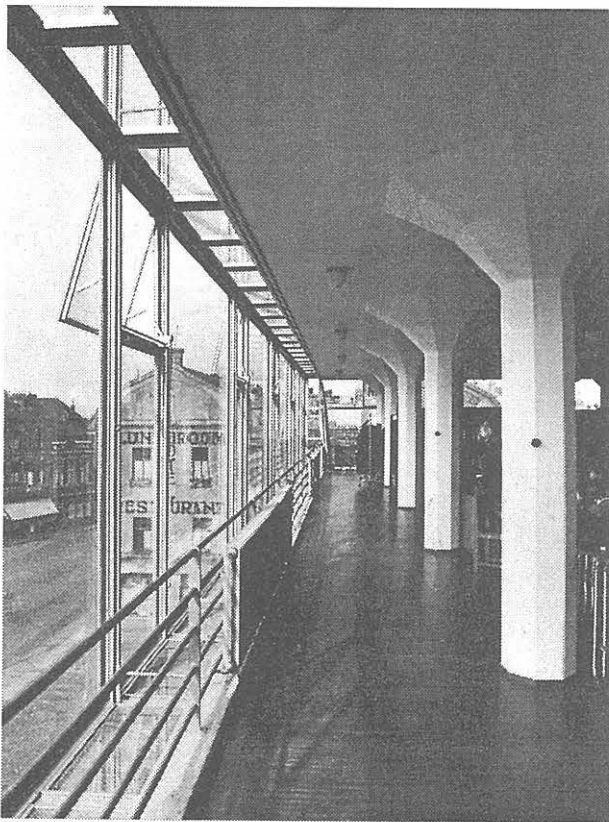
In doing so, buildings were designed with an extreme sensitiveness concerning building physics. Some designers were quite well aware of this, and building physics were seriously studied by Duiker, Wiebenga, Van Loghem and some others. Although identified as 'a great triumph in building construction', Van Loghem warned his colleagues in 1936 'that the elimination of the loadbearing function true eliminated one problem, but that the requirements of *Het Nieuwe Bouwen* on the other hand created at least ten new problems'.⁶ It

that had been introduced by *Het Nieuwe Bouwen* in the first place. Apparently, the few mentioned above are exceptions. But also Wiebenga's articles indicate that it is too easy to justify radical alterations of historic modern buildings by saying that they just didn't know any better.

It is rather the combination of their dedication to the experiment with a degree of professional naivety, not to mention the wish for a minimalist aesthetic to be realized by use of young technologies, that lies the origin of many of early modern architecture's technical shortcomings.⁷

Schunck department store (Heerlen; Peutz 1934–42)

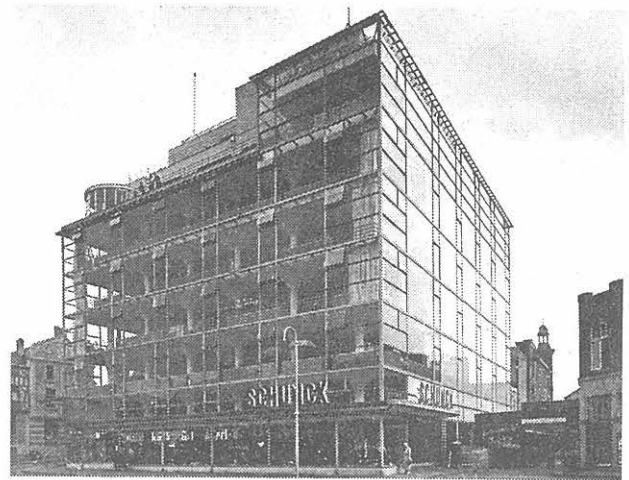
Before deciding on interventions for any building, but



The Schunck departement store of 1936 is a prototype of a climate facade. The curtain wall is set at a 50 cm. distance off the floor edge, to allow warm air to leave the building through large window vents on the roof. Photo: W. Mantz.

would be a mistake to assume, that the significant problems we face today as regards the building physics of their buildings should be attributed purely to ignorance and a lack of knowledge of the original designers. In 1936 Van Loghem published a first reference work on building physics in the Netherlands, that is surprisingly in line with contemporary standards.

However, in the introduction to the book he admits that the main reason for publishing it was the lack of knowledge among modern designers, that were therefore not able to cope with the technical problem



Schunck building in its original splendour at the Heerlen Marketplace (F. Peutz, 1936). Photo: W. Mantz.

particularly in the case of early modern structures, it is essential to have a comprehensive understanding of the way the building is put together and works, and about what the designer wanted to accomplish. This is not only necessary as regards the lay-out and constructions as applied in the building, but also, and not in the least, with respect to building physics.

The Schunck department store was designed in 1936–42 by F.J. Peutz for Heerlen.⁸ His brief was to design a contemporary store, where customers could make their choice of a garment in daylight. Peutz designed the building as a set of market places, stacked on top of each other. The concrete mushroom frame was enclosed by a curtain wall to allow for a maximum of daylight. To avoid overheating, he set the glass membrane at a 50 cm distance off the floors' perimeter. By leaving the intermediate space open, except for some steel mesh for safety, hot air could leave the building through large window vents on the roof terrace level.

This construction was an experiment, because the optimal spacing between facade and floors could not yet be specified. Recent research indicated that indeed only a 5 m wide zone along the facades actually benefitted from the natural ventilation.⁹ Considerable

differences in air temperature resulted in inconvenient draught. Also, in winter, the system operated in a reversed way by supplying cold air to the lower levels. Finally, the cavity did not comply with current fire regulations.

No wonder that the building had to undergo alterations when refurbishment was necessary to accommodate the offices of the National Pensions Fund ABP in 1972.

However, the way this job was done is extremely unsensible.

Refurbishment for ABP

To use the building as an office is of course totally contrary to the nature of the structure. Noise could spread freely through the cavity. Also for security reasons, the cavity had to be closed. Although this could have been done in glass or a similar transparent material, it was closed with fire resistant plasterboard. The steel facade was replaced by an aluminium curtain wall. The proportioning of the original facades was not fully followed, but was destroyed anyway by the highly inelegant, wide aluminium profiles. The originally clear glazing was replaced by dark sun reflective lights. As can be expected, all these interventions necessitated the use of an extensive air conditioning system. Along the floor perimeter 1.2 m high units were placed, leaving a useless 50 cm space behind it. Not relevant for today's subject but indicative for the approach of the refurbishment, is that most floors were divided into office rooms with a standard partition system. Such systems are unsuitable to match the form of the mushroom columns, and therefore totally inadequate to provide the required sound proofing between rooms. All in all, the essential qualities of this relatively unknown highlight of prewar modern architecture have gone completely down the drain.

Although not really a curtain wall, the restoration of Gooiland Hotel (Duiker, 1934) could serve as an opposite as far as the design approach of the restoration architect is concerned. The larger part of the floor-to-floor steel framed windows has been repaired in a similar way as for the Van Nelle factories.

One facade at the back, that could never been seen together with any of the front facades, served to supply spare parts for these repairs. In the end this facade was fitted with new windows, that were composed of the steel sections that are still being produced in England.

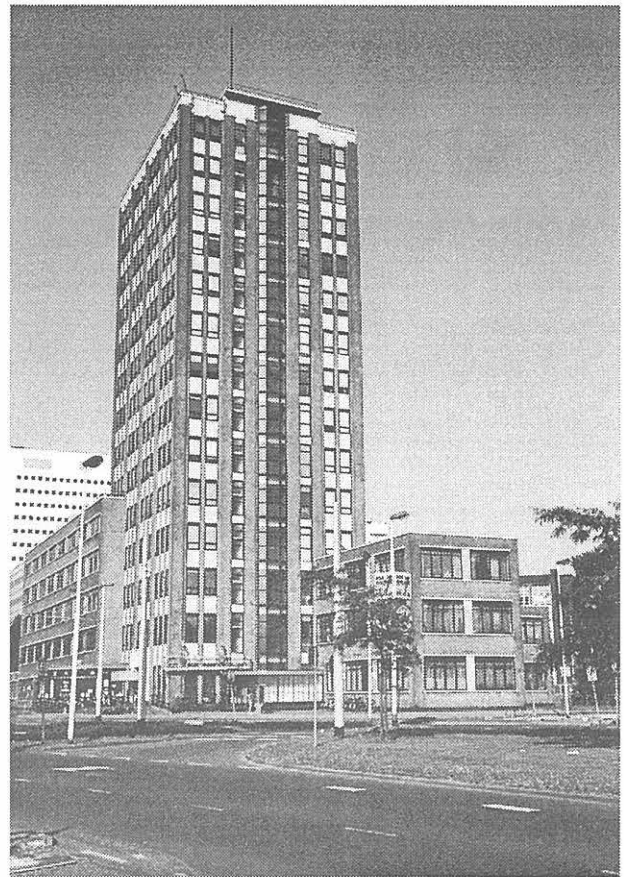
Like for the Van Nelle factories, single glazing has again been fitted after calculation proved that the return on investment for double glazing would be negative over a thirty year period.

Characteristics of prewar curtain walls

'Much of (the) visual impact (of modernism) depended upon the impression of lightness, thinness, whiteness and geometric purity [...].

The rejection of traditional embellishment in the drive for formal clarity tended to lead to the omission of conventional details such as copings, sills, drips and overhangs, weathering falls and surface relief generally.¹¹⁰ A practical problem is to maintain this purity, given the poor material quality of many of such buildings. Modern buildings weather very inelegantly and, in contrast to most older structures, a 'patina' on their concrete or steel envelope rarely suits them. It is important to identify the main architectural characteristics of prewar curtain walls, in order to develop an appropriate strategy for their conservation, repair, maintenance or even replacement. They could be summarized as follows:

- lightness, thinness;
- geometry, regular rhythmic patterns;



G.E.B. building (Rotterdam; Poot, Witteveen & Van der Steur 1927–31) renovated by Van Rassel Architects around 1994.

Photo: Wessel de Jonge.

- window-type, floor to floor elements > no hierarchy between transoms and mullions > similar dimensions of horizontals and verticals;
- window-type structure mostly provide some relief; light and shadow break the smooth surface and give a sense of human scale;
- sometimes still with alternating clad and glazed parts (GEB Building);
- high transparency, 2/3 glass, clear glass;
- concealed spandrels (colour, texture) to stress curtain character;

- restrained use of colour;
- sashes, vents or similar to provide natural ventilation (no AC);
- mostly steel; single glazed; slightly insulated spandrels.

These characteristics can be illustrated with :

- GEB Building (Rotterdam; Poot, Witteveen & Van der Steur, 1927–31), renovated by Van Rassel Architects, ca. 1994;
- Bank Mees (Rotterdam; Brinkman & Van der Vlugt, 1929–31), renovation around 1990 by an unknown architect;
- Parklaanflat (Rotterdam; Van Tijen, 1933), renovated by architect Van der Zwan, 1994–95
- Rijksverzekeringsbank (Amsterdam; Roosenburg,



G.E.B. building, close up of renovated facade. Photo: Wessel de Jonge.

1937–49), renovated by LIAG architects, The Hague, around 1993.

Postwar MoMo boom

After the Second World War, the need for housing and commercial space was enormous. No surprise, Dutch designers took the architecture of their liberators again as a model.

But in North America things had changed too. The American industrial 'nonarchitecture' had returned to the New World like a boomerang. The 'raw material' had meanwhile been fostered and developed to

another conceptual level by prewar vanguard architects in Europe. They again inspired a whole new generation of American designers, many of them educated by Mies van der Rohe or Gropius, or by other Bauhaus trained refugees. In the New World the architectural vocabulary of the European avantgarde became part of a general architectural practice and hundreds of curtain walled buildings were erected on the North American continent. Inspired by an ongoing strive after optimal use and efficiency, the curtain wall developed into an ultra light membrane of glass and metal, mainly aluminium.

Lever House in New York, designed in 1952 by Skidmore, Owings and Merrill, became one of the main examples for young architects that had to build up Europe after the War. This building ultimately



The Lever House in New York (S.O.M. 1953–54) has been a source of inspiration for the postwar generation of architects in the Netherlands. Photo: reconstruction architect Leo de Jonge, 1956.

demonstrates how modern design rejected heavy, stone and brick facades with holes for windows. Traditional detailing was almost completely put aside, though it was recognized, that some of the traditional elements, like drips, had been done away with too easily by the prewar modernists. With the introduction of air conditioning systems, even vents became redundant. By adopting a limited diversity in elements, and accepting a limited technical lifespan of components, the concept of a flexible, adaptable envelope with a limited period of use became reality. It seemed that both economical and architectural assets coincided in these developments, that, however, today poses an enormous challenge as regards maintenance and management of the large amount of postwar curtain walled buildings.

Characteristics of postwar curtain walls

As compared to the earlier curtain walls, the early postwar examples differ in some respects:

- in addition to the window-type elements, new systems were developed that make use of an expandable structural frame, that extends over the facade surface and that is then fitted with glass and spandrels (stick system);
- due to this, these curtain walls refer less to the human scale and stress the architectural entirety of the facade surface,
- often by use of a greater depth for the verticals, creating a pattern of light and shadow over the full height of the building;
- alternating clad and glazed parts are rare, but curtain walled facades are sometimes enclosed by

- often aluminium; single glazed; slightly insulated spandrels.

These characteristics are illustrated with :

- Tetterode (Amsterdam; Merkelbach & Karsten/Elling, 1949–50)
- Geillustreerde Pers (Amsterdam; Merkelbach & Elling, 1957)
- TU buildings (Eindhoven; Van Embden & Choisy/OD 205, 1954–64)

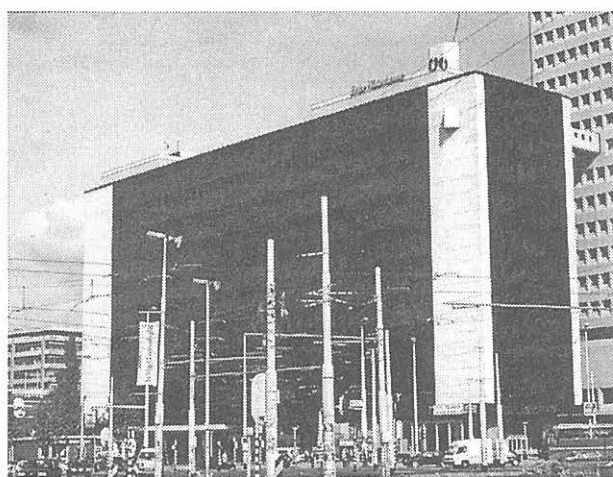
Common problems

Single glazed curtain walls have a poor thermal performance as compared to current standards for energy efficiency and thermal comfort. Condensation on the glass is mostly controlled by use of a condensation gutter and weepage holes. Introduction



The main building of the Eindhoven University of Technology features a typical early postwar curtain wall. The staircase has been recently refurbished and displays a much more smooth facade. Photo: Patrick van Buijtenen.

- clad parts like 'bookshelves';
- often combined with 'heavy' materials like blasted, tiled or mosaic clad concrete, particularly for the lower floors;
- increasing use of colour, contrasting spandrels are introduced;
- sashes, vents disappear with the introduction of AC;



Shell building (Abspoel, 1956–60) after renovation. Photo: Wessel de Jonge.

of double glazing in such a system might mean the introduction of cold bridges in locations where condensation is uncontrollable. By improving the facade's overall sealing, the relative humidity will rise, increasing the risk for a condensation as well. Such hygro-thermal issues are a common argument for a complete refurbishment or replacement of postwar curtain walls.

Architectural Review Committees (Commissies voor Welstand), architects and preservationists are however getting more and more concerned about the growing loss of typical postwar architecture as a result of such renovations. Double glazing and sun reflective coatings make deep inroads on the appearance of such buildings. The requirements as set in the new Building Act as regards the Thermal Coefficient (*It-waarde*) and, recently, the Energy Performance Standard (*Energie Prestatienorm*) result in a dramatic decrease of the glazed surface, thereby loosing the typical transparency of this architecture. For example, the original Shell building in Rotterdam has been expertly refurbished in technical and, I may presume, in financial terms. One could argue that the building even has a quite distinguished architectural image. Still, the dark coating on the glass absolutely

destroyed the concepts architect Abspoel must have had when designing the building between 1956–60. Similar things happened with other Reconstruction buildings, such as The Utrecht Insurance Company, designed by Oud between 1955–62, and the Ennia building (Bodon, 1954–1960), that looks like an architectural zombie today. One could only fear what will become of the original elegance of such buildings as the Huf shoe store, designed by Van den Broek & Bakema in 1952–54, and also located in Rotterdam.

Life cycle

Remarkably, recent developments in facade technology seem to offer new opportunities for the upgrading of existing postwar buildings, with less violence being done to the nature of the original



Cebeco Handelsraad in Rotterdam, exterior. Photo: Wessel de Jonge.

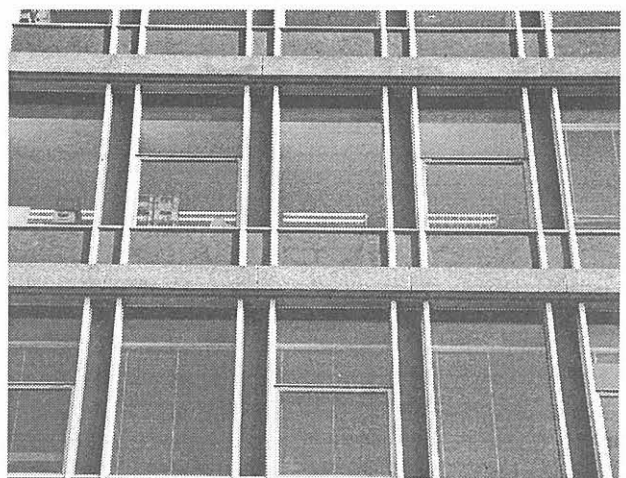
architecture. The cases presented at this seminar, and particular those for the Rijnhotel (Rotterdam; Merkelbach & Karsten/Elling, 1949–59) and the Thyssen Haus (Düsseldorf, HPP Architects, 1957) are encouraging in that respect. These examples might feature solutions that are not unique, yet they illustrate that also for a commercial client a architecturally satisfying result can be achieved. And one should bear in mind that 'good architecture is good business'. The life cycle of many postwar buildings seems to be cut short due to financial considerations. The life expectancy for envelopes today is being chosen even shorter than ever was the case in the great days of modernism. Investors are aware of the short life of fashionable architectural concepts, that are hardly skin deep. The American practice to produce buildings with a life expectancy of 80 years for the superstructure, 10 years for the facade and a mere 5 years for the partitions, implies an investment policy that is starting to determine our built environment to a far too great extent. Buildings that, technically speaking, could be sustained for a number of future years, undergo a radical 'face lift' to create an appealing image. But the whim of the day dictates what will be old fashioned tomorrow.

In the long run, high initial investments could mean a better financial result. In such a case, a high technical standard will contribute to reduce maintenance and running costs, and to extend the life of the building. A restrained, less fashionable design must then be considered to be an advantage.

At present, investors are much more interested in the short term returns on their stock. A long term vision on the quality of our built and unbuilt environment is however necessary. Not only to create a durable world to live in, but just as well to advance that returns on investment will sustain.

Conclusion

Postwar architecture is going through a revaluation today. Apart from DOCOMOMO, an international



Cebeco Handelsraad, close up of the facade. Photo: Wessel de Jonge.

network of professionals in modern conservation and documentation and today's host, we have seen the establishment of a Postwar Foundation (Stichting van na de Oorlog) and, in Rotterdam, a Committee for Reconstruction Architecture (Comité Wederopbouw). Such initiatives will lead to a more general appreciation of the sometimes unexpected architectural qualities of postwar modern architecture. The architecture of the Reconstruction period can then shake off its negative image and will be given a second chance, allowing the original architecture to be respected to a much greater extent. Such an approach first of all requires an open mind and creativity from all those who are professionally involved in the maintenance, management and refurbishment of postwar architecture. What is now felt as a problem will actually appear a fantastic challenge to revitalize our recent architectural past.

Wessel de Jonge is an architect with Leodejongearchitecten, a researcher at the Eindhoven University of Technology and chairman of the DOCOMOMO International Specialist Committee on Technology.

Literature:

- R. Michael Rostrom, *Light Cladding of Buildings*, London 1964.
- Hubert-Jan Henket and Wessel de Jonge, *Het Nieuwe Bouwen en Restaureren*, with extensive English summary, Den Haag-Zeist 1990.
- John Allan, 'The Conservation of Modern Buildings', in *Building Maintenance & Preservation; a guide to design and management*, 2nd revised edition, Oxford 1994.
- Edward R. Ford, *The Details of Modern Architecture*, Cambridge Mass.-London 1990.
- Jan Molema and Wessel de Jonge, 'Johannes Duiker', in *The Architectural Review*, n° 1055, January 1985, pp. 48-55.
- *DOCOMOMO Conference Proceedings*, Eindhoven 1991; Dessau 1993; Barcelona 1996.
- *De 8 en Opbouw*, 1932-1943, reprint, Amsterdam 1985.
- Jan Molema and Peter Bak (ed.), Jan Gerko Wiebenga; apostel van het Nieuwe Bouwen, Rotterdam 1987.
- Le Corbusier, *Towards a New Architecture*, 1923; English edition, London 1931.
- Rayner Banham, *A Concrete Atlantis*, Cambridge Mass. 1989.
- Jan Duiker, *Hoogbouw*, Amsterdam 1930.
- J. van Loghem, *Acoustisch en Thermisch Bouwen*, Amsterdam 1932.
- William PARS Graatsma, *Schunck's Glass Palace*, bilingual English/Dutch, Nuth 1996.

Notes:

1. John Allan, 'The Conservation of Modern Buildings', in *Building Maintenance & Preservation; a guide to design and management*, Edward Mills (ed.), 2nd revised edition, Oxford 1994, p.151.
2. More on Wiebenga in: Jan Molema and Peter Bak (ed.), *Jan Gerko Wiebenga; apostel van het Nieuwe Bouwen*, Rotterdam 1987.
3. See note 2, pp. 46, 55.
4. Jan Gerko Wiebenga, 'Amerikaanse bouwmethoden, een economisch succes', in *Gewapend Beton*, 1926, pp. 32, 35.
5. Jan Duiker, 'Dr. Berlage en de Nieuwe Zakelijkheid', in *De 8 en Opbouw*, 1932, pp. 43, 51.
6. J. van Loghem, *Acoustisch en Thermisch Bouwen*, Amsterdam 1932, pp. 136-137.
7. See note 1, p. 152.
8. More on Peutz in: William PARS Graatsma, *Schunck's Glass Palace*, bilingual English/Dutch, Nuth 1996.
9. Arno Kolen, 'A Neglected Monument: the 'Glasspalace' at Heerlen (F.P.J. Peutz, 1934)', in *Conference Proceedings, First International DOCOMOMO Conference*, Eindhoven 1991, pp. 194, 196.
10. See note 1, p. 151.

A future for curtain walls

Typology, development, lifespan and refurbishment

The lifespan of a building is much longer than the lifespan of most organizations. Given the increasing speed of changed use of building space due to alterations in processes, social aspects and technological developments, the period after which a commercial building is likely to be renovated is shortening. We have to take into account minor refurbishment every 10 years, and extensive renovation work, either inside or outside, and often including an extension of the building every 25 years. The curtain wall, as an added non-loadbearing envelope of a building, is implicitly most suitable for alterations and renovations.

by Just Renckens

Considering refurbishment of curtain walls, we can also take into account that it is possible to renovate with curtain walls. This is often executed to reclad and improve stone or concrete clad facades. In such a case the original architecture is lost. It is also used for extensions of older stone or concrete clad buildings in order to create additional space, establishing an architectural contrast with the preserved architecture of the original. Changing the facade not always means that the architecture of a building is changed without good reason. A number of projects of that period, and certainly some of the 1980s, with trendy curtain walls, hardly have any architectural value. In that case a new aesthetic appearance, complying with the present and near future trend, is justified. Or even better: is taking the opportunity to invest in high quality architecture to give the building an added value for the users and the built environment, thus ensuring an extended use of the building and consequently also of the curtain wall. The lifespan of the curtain wall and its components is an important factor of return on investment, but also an aspect of environmental efficiency. It is obvious that the lifespan of the design is better secured if interim adjustments of facades are efficiently feasible. If the curtain wall can be adjusted to new demands and space requirements the facade is secured for a longer period of time. The type of curtain wall, the applied materials and the nature and method of construction are of influence to the suitability for future renovations and of the reuse and recycling value of the facade components, elements and materials at the end of their lifespan.

Lifespan

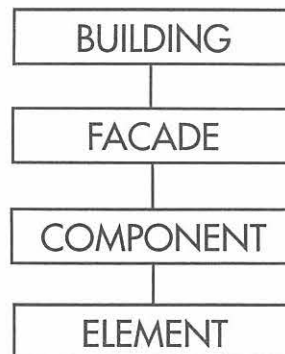
The most important lifespan of a commercial building, and consequently of its facade, is the economic one: the economic lifespan is decisive for the overall lifespan. If the market offers better quality office space for less rent the economic lifespan of a building concept has ended. In other words: the economic lifespan is the period in which the overall earning capacity of the investment is fulfilling the demands of the return on investments. Thus the economic lifespan

can be influenced by economic factors, but also by:

- the aesthetic lifespan. This is the period in which a facade is still considered to fulfil the image requirements of the users.
- the functional and technical performances: respectively the comfort realized and influenced by a curtain wall and the technical condition of a curtain wall construction in relation to legitimate users requirements.
- the suitability of a facade for adjustments to future requirements. Through renovation of the building, sometimes for another functional purpose, changing an office building into housing for instance, a new life cycle can start, until finally ending at the demolition of the building.

The economic lifespan of a facade, starting with the delivery of the building, is the period in which the acceptance of a facade's image, the functional and technical performances, the energy efficiency and the maintenance costs are still in accordance with the requirements. A curtain wall's lifespan is subordinate to the lifespan of the building as a whole, as the lifespans of facade components and elements are subsequently subordinate to the lifespan of the facade. Refurbishment of a curtain wall might be executed:

- to give the building a facelift in order to improve the image, the quality of the architecture;



The lifetime of a curtain wall is subordinate to the economic lifetime of a building, as the lifetimes of facade-components and elements are subsequently subordinate to the facade-lifetime.

- to adjust the facade to changed inside conditions: layout (rearrangement of space) or other use of space (change of function);

- to adjust the facade to new technical developments and regulations.
It is important to frequently adjust the facade performance to a state-of-the-art level, as a measure to support the relation between client and building. A flexible and easily adjustable curtain wall is implicitly offering a better opportunity to comply with the design lifespan of the facade. The relatively easy dismantling of curtain wall components and elements is a positive factor for refurbishment of a curtain wall, and serving its management over the full lifespan of this vital part of a building.

Curtain wall types

The curtain wall is a non loadbearing envelope of building space with vision glazing and spandrels, anchored to a skeleton type of building structure. A cold cavity rainscreen clad semi curtain wall consists of an outside screen, fixed at cavity distance to a tight building structure insulated on the outside. The cavity serves as a barrier to secure watertightness of the facade construction by pressure equalization. The airtightness is fulfilled by the closed building structure and by the thermally insulated vision components, that close the openings in the facade. A warm cavity facade is a second type of semi curtain wall enclosures: an insulated facade construction with vision and spandrel components is fixed at cavity distance on an airtight building structure with openings at the vision areas of the facade. The pure curtain wall is most suitable for technical and functional refurbishment, as well as for aesthetic alterations. The rainscreen cladding facade is most suitable for aesthetic renovations, and suitable for functional and technical refurbishment within the limits of the closed building structure. The facade construction with a warm cavity is suitable for aesthetic, functional and technical refurbishment within the limits of the closed building structure.

Construction methods and life cycle

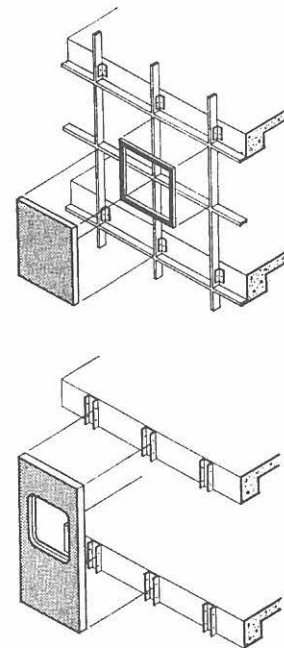
The construction method of a curtain wall can be of importance in relation to the easiness of refurbishment. We can divide the construction on site

components or units with the spandrel and vision parts already placed in the workshop.

A curtain wall construction can be:

- a frame-system with infills of vision and spandrel components;
- a panel system with built-in vision sections, or with glazed sections between the panels.

In order to control the life cycle of a curtain wall we have to consider the difference in lifespans of its components and elements, including the lifespans of additions such as the surface treatment of aluminium profiles and sheets, mainly organic coating or anodizing. The part with the shorter lifespan has to be dismantled and replaced in a higher frequency. A further consideration is the reuse and recycling of elements, components and finally the curtain wall as a whole. The technical lifespan increases from the outside to the inside. As a result, the aesthetic aspects are predominant. Due to the operation of the weather



Analysis of light cladding by construction: a) stick construction, b) panel construction. From: R. Michael Rostron, *Light cladding of buildings*, London 1964.

REFURBISHMENT	CURTAIN WALL	RAINSCREEN WALL COLD CAVITY	THERMAL INSULATED WALL: WARM CAVITY
AESTHETICAL	++	+++	++
FUNCTIONAL	+++	++	+
TECHNICAL	+++	++	+

into two principles:

- Stick system. In this case the facade elements are assembled on site by individual fixing during erection and by consequently fitting in spandrel infills and glazing for the vision components.
- Component system. By increasing the industrialization of curtain wall prefabrication, construction on site is executed by fixing larger

conditions upon the facade, it can be necessary to replace parts or even the complete outside of the facade in order to keep the image of the building at a required aesthetic level.

Early aluminium curtain walls

Starting in the 1950s the use of aluminium for curtain walls was increasing. Up to the middle of the 1970s

the main concern was to realize weathertight and fire-safe enclosures. In the period 1975 up to 1990 the main attention was to improve the thermal performance of curtain walls and to take advantage of new sunreflective glazing for both vision and spandrel areas. As of 1990 a third generation curtain wall, the alu-glass-facade, is in development. The early curtain walls often have cultural value. At that time architects having the courage to combine new materials and innovative facade technology into advanced architecture have made a statement worth to preserve when refurbishments are necessary. Renovating these older facades poses the following problems:

- new fully insulated facade constructions are heavier than the original curtain walls and subsequently for highrise buildings the total weight can be more than acceptable for the building's foundations;
- on the level of facade components the heavier

cases the original architecture has to be adjusted. Also because of the present building codes concerning energy efficiency, sound insulation, daylight and outlook, fire safety, health etc. it might be necessary to alter the existing architecture.

Real estate

The Netherlands minister of Housing, Planning and Environment (VROM) is not supporting an increased depreciation of real estate, as argued by the Dutch Institute of Real Estate Brokers. According to the brokers an average office building is 'ripe' for demolition after 20 years of service, while the fiscal dictated depreciation period is 40 to 50 years, resulting in a low or negative return on investments. But according to the minister we have to guard against short lifespans of commercial facilities, which can cause a decrease of architectural quality of commercial buildings and is against the principle of

BUILDING FUNCTION	ARCHITECTURE		
	VALUABLE	AVERAGE	POOR
NOT CHANGED	PRESERVE	IMPROVE OR RENOVATE	ALTER
SIMILAR	PRESERVE POSSIBLY WITH MINOR ADJUSTMENT	IMPROVE OR RENOVATE	ALTER
CHANGED	PRESERVE IF POSSIBLE, OR CHANGE RESPECTFULLY	ALTER	ALTER

construction can be too much for the existing anchoring to the building structure;

- the renovated facade has to comply with the existing applicable standards, which are more strict than the regulations at the time of construction.

Facility requirements

It appears increasingly possible to renovate curtain walls while respecting the original architecture. Yet, renovating and taking advantage of today's technological possibilities within a limited budget is easier if also the architecture of the building is adjusted to the new technology. The latter is not a setback if the original architecture is not worth to preserve, either by its concept, or due to required adjustment to the image of the buildings in the environment, or because of a change in function for the building.

We have to take into account as well that a change in facility requirements often means another proportioning of the facade is necessary. For instance: less vision glass; lower ceiling heights due to new airducts, or higher spandrel heights because of computer floors; more space per user; a change in lighting requirements because of working with computers etc. and consequently other or more advanced materials for elements and infills. In such

durable use of materials. She is of the opinion that developers, building owners, architects and contractors have to consider long lasting building concepts, soundly constructed for lifespans much longer than 20 years. In this connection, and given the increasing speed of changes in use due to alterations in processes, social aspects and technological developments, the curtain wall is suitable for durable building concepts. It can serve to preserve high quality architecture or to replace low quality architecture as part of a process of frequent refurbishment of facades to comply with new requirements, and in order to extend and secure the facade's lifespan.

Future developments

The demands concerning the performance of facade constructions are increasing. Up to now the curtain wall is typically an upgraded passive construction to separate the inside from the outside weather conditions. The inside climate is usually controlled by a mechanical or air conditioning installation. The alu-glass-facade, the modern curtain wall, is reactively anticipating, and, if intelligently controlled, even pro-active: a membrane taking advantage of outside weather conditions, offering natural ventilation, transferring sustainable energy (mainly sun

energy), thus maintaining the inside climate (temperature, humidity, fresh-air etc.) on a comfortable level with the help of a mechanical installation. Increasing the technology and developing a facade from a passive into an active building envelope means that the lifespan of the construction is shortening (compare it with computer technology: the more advanced and powerful computers are offered, the faster new concepts are presented, with new soft and hardware, consequently decreasing the lifespan of the hardware). In this connection the ability and easiness of adjusting curtain walls to new technical developments is an advantage. This ability is also important in case this new performances have to be realized within the existing architecture of the facade.

Conclusions

A curtain wall is typically fit for alterations to comply with changed functional or technical demands imposed on the envelope of a building. The architecture of the facade can be preserved or a similar appearance can be realized, but if the architecture is of a poor quality, also an architectural facelift can easily be realized.

Where real estate developers are arguing for short lifespans to be reflected in the fiscal legislation in order to secure a proper return on investment, the government wants long lasting new buildings, adjusted to the demand for high quality architecture and a durable use of building materials. As the curtain wall is subordinate to the lifespan of the building and the functional and technical developments of glass facade technology are accelerated, the adaptability of curtain walls is a valuable feature. The pure curtain wall in combination with a skeleton type structure is the most flexible and adjustable type of a facade, even when compared with rainscreen claddings and thermal wall cavity facades. As a group, the latter two are again far better suitable for alterations and refurbishment than conventional facades in stone, brick or concrete.

Just Renckens is the founder of Renckens Consultancy for Facade Technology, and a staff member of the Delft University of Technology, the Netherlands.

Curtain walls as a system of building physics

A perspective for refurbishment

Renovation of curtain walls is a somewhat delicate question, for what is renovation of a curtain wall? Usually a construction is improved by adding parts or by replacing small parts. Renovation of a curtain wall however easily leads to replacement of large parts: glazing, insulating panels or even the entire facade. Therefore the title of this symposium seems to be inadequate: renovation can be more than refurbishment.

by Jacques Mertens

What reasons does one have for renovation. Is it the architecture of the building? Is it the lettability? Is the life expectancy of components exceeded? Are there complaints concerning the climate inside of the building? Is the energy consumption at such a level that renovation financially becomes interesting? Often, the reason for renovation is a combination of several of the aspects mentioned. For example, the lettability of the building may reduce because of the energy costs as well as the architectural image. The aim of the renovation is (or should be) to obtain a building that complies to the current demands, and will most likely comply to demands in the future. One of the requirements to be met in order to arrive at such aims is to respond to the demands as regards building physics, both statutory and those prevailing in the discipline.

This article briefly summarizes the demands as regards building physics, as stated in the Dutch Building Code, *Bouwbesluit*. In addition to this, additional requirements in relation to building physics will be mentioned. When the demands to which the facade should comply are clear, it is time to put it into practice. The major construction parts of a more or less common curtain wall will be examined and most demands will be briefly checked for each of them. It will become clear that there may be conflicting demands, so in several cases it may be necessary to go into it in more detail.

Finally, a rather specific case will be discussed, in which some of the demands mentioned have their part. It will be demonstrated that, by using various calculations, it is possible to predict the effects of the renovation with respect to building physics.

Requirements

The most relevant requirements for new buildings, both statutory and those concerning building physics are listed here. Usually in case of renovation, no specific statutory requirements are applicable, and the replacement actually should equal the old parts or be better. When the level of renovation is comparable to newly constructed buildings, the statutory requirements mentioned below are to be applied. In practice, building physics requirements will always have to be met in such cases.

Thermal insulation – The thermal insulation of the building envelope must be $R_C = 2.5 \text{ m}^2\text{K/W}$ or better, which equals a U-value of $0.37 \text{ W/m}^2\text{K}$ or less. The minimum thickness of insulating panels in a facade may equal the depth of the aluminum profiles. In this case the U-value can be more than the above $0.37 \text{ W/m}^2\text{K}$. Glazing must have a U-value of $4.2 \text{ W/m}^2\text{K}$ or less. This implies the use of double glazing or better, as regards energy efficiency.

Energy performance – Apart from these requirements in the Netherlands a new building must comply with requirements concerning the energy performance. The energy performance is a function of a wide variety of factors, such as the nature of the building envelope, orientation, ventilation, cooling (if applicable), heating, lighting and so on.

Condensation – In the Building Code is stated a minimum f-value of 0.50 (offices); this requirement however does not apply to the framing. Given this requirement condensation against framing and glazing (especially along the perimeter) can not always be prevented, and depends on the outside temperature and the relative humidity inside the building. Formulation of additional demands may therefore be necessary.

Tightness – The facade must be air- and watertight. These requirements are to be tested at a given test pressure, depending on the geographical position and the height of the building.

Acoustics – The airborne sound insulation performance of the facade should apply to the requirement that the noise level due to traffic etc. does not exceed 40 dB(A) in offices and 35 dB(A) in meeting rooms and small offices (single user). This may require special glazing and insulating panels (mineral wool, steel).

Safety – It is quite obvious that it should be prevented that people can fall through a facade. Depending on the layout of the facade special glazing or additional provisions may be required.

Fire security – At least the bottom 2.5 m of the exterior of a building should be non flammable. To prevent floor-to-floor flashover, the resistance to fire movement usually must be 60 minutes or more. This can be obtained by choosing an adequate height of the spandrels, optionally in combination with fire resistant glazing. The use of sprinklers can lead to an equivalent level of fire-safety, avoiding such measures at the facade.

Daylight and solar gain – It is important that people inside a building are able to look out. Also the use of daylight can lead to a significant reduction in energy cost for lighting. An area of 5 % of the office area and a width of 10 % of the perimeter of the room are therefore the minimum demands related to window dimensions. Of course blinding must be prevented, which implies the use of a light-shading device. With reference to solar energy transmission no direct requirements are present although various requirements with respect to blinding and acceptable temperature levels are given. In order to reduce solar gain, and to keep down expenses on cooling, an effective sun-shading device is required.

Thermal comfort – Thermal comfort is a requirement related to the performance of the facade. Thermal

comfort is defined by the parameters air temperature, radiant temperature, air velocity, turbulence intensity, and relative humidity, as well as the activity and clothing level of the persons involved. The main conditions for a good thermal comfort are appropriate air and radiant temperatures, air velocity and turbulence intensity, which determine the restlessness of the air. These conditions are also interdependent: at higher air temperatures, higher air velocities are acceptable, as is illustrated in figure 1. A high level of turbulence implies a limitation of the acceptable air velocity. Air velocity and turbulence intensity depend on the method of ventilation as well as on the thermal performance of the facade. A poorly insulated facade can lead to draught and therefore relatively high air velocities, as will be seen in the case of Schiphol Airterminal.

Summary – Usually, most requirements can be complied with without serious problems. The requirements with respect to condensation, fire safety and sunshading however may imply additional features.

Glazing

Renovation often means replacement, and this is especially true for glazing. At the moment the use of low-energy glazing with U-values of less than 1.8 W/m²K is most appropriate when replacing the glazing. This glazing amply complies with the requirements on thermal insulation.

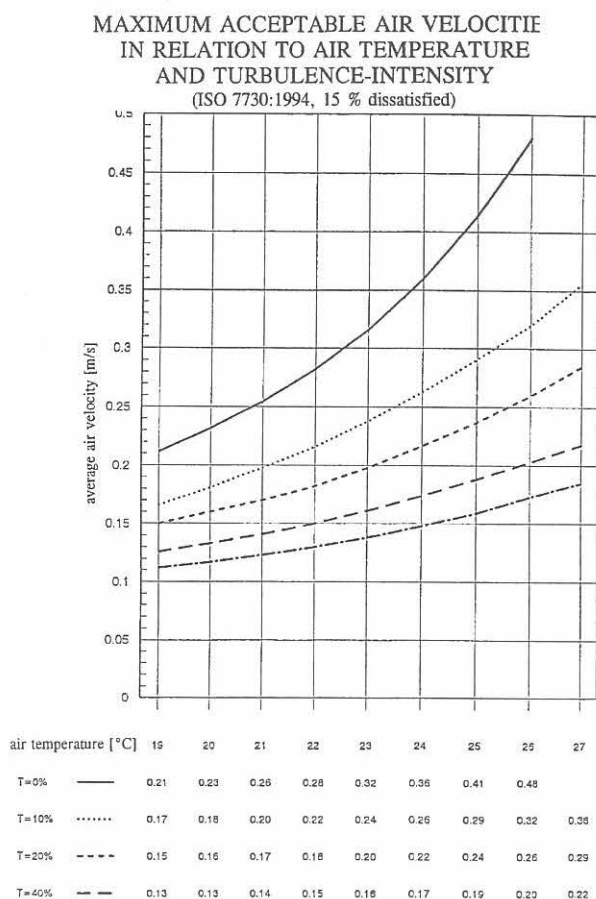
Condensation however may still be a problem since the spacer between inner and outer blade usually consists of an aluminum tube and thus forms a cold bridge. The condensation will therefore typically start at the perimeter of the glazing, as is illustrated in figure 2. Should condensation be a problem there are mainly three ways of limiting the risk of condensation:

- apply glazing with a synthetic spacer;
- reduce the relative humidity during periods with low outside temperatures;
- add a form of heating into the cladding profiles.

In order to increase the thermal performance and/or the acoustic performance, the cavity in the glazing may be filled with gas instead of dry air. Care must be taken in this case: thermally advantageous gasses (e.g. argon) are lighter than air and therefore acoustically disadvantageous.

Transmission of solar energy and daylight also can be conflicting. Limitation of solar gain often leads to limitation of vision and daylighting and therefore often to the use of artificial lighting. Limitation of solar gain can best be obtained by the use of a controllable sun shading device, which will only be operated when necessary. In winter, on the other hand, one can again benefit from solar gain. As illustrated in figure 3, the best results are obtained by use of an external device or a special construction, such as a climate facade, in which the sunshading device is integrated in a

Fig.1 Maximum acceptable air velocities in relation to air temperature and turbulence intensity (ISO 7730:1994, 15% dissatisfied). Graph: Peutz & Associés b.v.



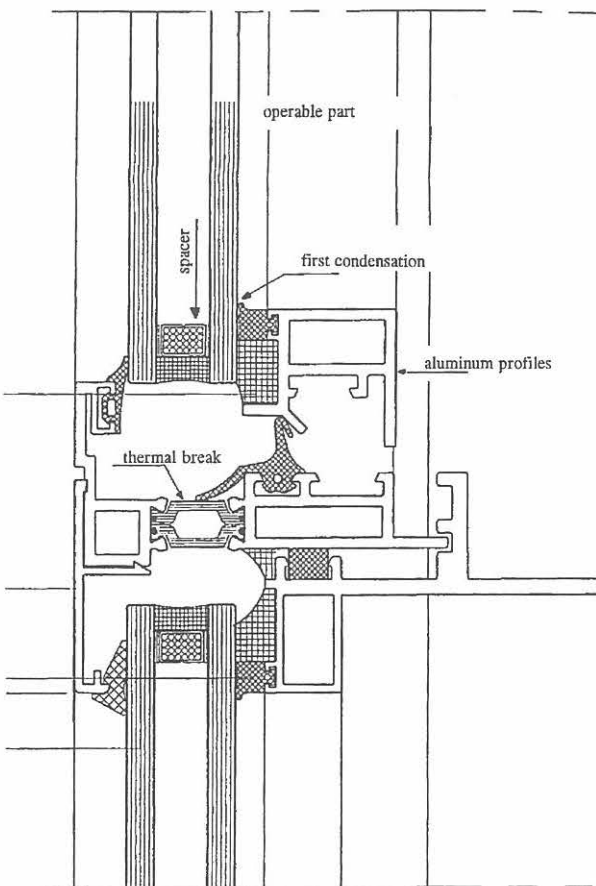
ventilated air cavity. The use of exterior devices requires special attention in relation to windeffects. Sun reflecting glass and sun absorbing glass also lead to a reduction of solar energy transmission but these have some disadvantages. These glazings continuously reduce the light transmission which leads to an increase of artificial lighting. The transmitted daylight will usually be coloured which can lead to a less positive appreciation by the users. Especially absorbing glazing can lead to relatively high surface temperatures which consequently can cause comfort problems.

Finally it is important to realize that in relation to the transmission of solar energy the product of ZTA (Total Solar Energy Transmission, in absolute value) times Percentage Glass is of interest. Therefore, if architectonically acceptable or even desirable, reduction of solar transmission can also be obtained by decreasing the glazed area.

Spandrels

The existing panels usually are limited in thickness and therefore in insulating effectiveness. When replacing these panels it is to be advised to improve the thermal properties of the panels, although in most cases this will not be a statutory demand. The most recent Dutch Building Code allows for the thickness of panels to comply with the thickness of the cladding profiles,

Fig.2 Typical occurrence of condensation along the glazing perimeter. Drawing: Peutz & Associés b.v.



even if this leads to a lower level of insulation than required. The panels may be important in realising the floor-to-floor flashover resistance required as regards fire-proofing. The acoustical performance mainly depends on the weight of the panels and on the insulation material used. Best results can be obtained using mineral wool as insulating material. Care should be taken that the inner and outer sheet have different resonance frequencies.

Finally the acoustic performance required should be determined in conjunction with the performance of the glazing: with a small percentage of panels usually an acoustic performance that about equals the glazing (usually 25 – 30 dB) is sufficient, while a large percentage of panels consequently requires higher values.

Cladding profiles

Renovation of the profiles themselves is sometimes possible by adding a new profile over the existing ones. This depends, however, strongly on the profiles used, and for most systems there is no standard solution. From a building-physics point of view the essential part often is the thermal break in the profiles. Still, the thermal properties of the profiles are usually not the main reason for replacement of the profiles, unless the existing facade consists of profiles without thermal break whatsoever. Other important motives for replacement can be draughts due to a poor airtightness, defects as regards watertightness, or the

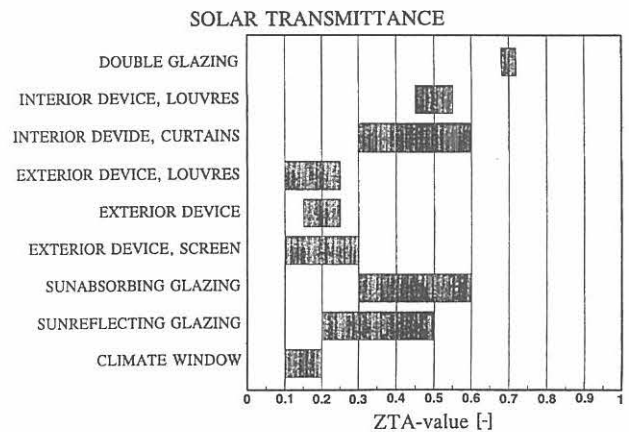


Fig.3 Solar transmission and sunshading. Graph: Peutz & Associés b.v.

thickness of new glazing or panels. Finally the desired new image of a building may be an important motive.

Departures Hall Schiphol Airport

As a case study the facade of the Departures Hall of Schiphol Airport in Amsterdam illustrates many of the present problems with curtain wall refurbishment. The facade of the original Departures Hall features single glazing over the full height of approx. 7 m. Given this height, the cladding profiles have rather robust dimensions, with an overall depth of about 400 mm. The dimensions of the transoms are less. At a distance

width of 1 m, including desks, canopy etc. Starting from this general model, other models were developed for the new situation: low-E glazing, radiators (central part of the Hall, fig. 5) or ventilation with warm air at the foot of the facade (south part of the Hall, fig. 6). The first calculations were performed without the desks; aim was to validate the downdraught routines. The downdraught reaches velocities of over 50 cm/s, in the desk area the velocities over the floor are about 30 cm/s, at a temperature of 21 °C – 22 °C. The order of the velocities corresponds with the velocities measured, given the different boundary conditions. This is one of the steps to the conclusion that the model is valid. After more extensive validation of the model, calculations were carried out for both future situations. Figure 5 shows the results with convective heating at the foot of the facade. The downdraught disappeared almost completely. Velocities of 20 cm/s are found in the corridor behind the desks but in the desks the velocities are limited to 10 – 13 cm/s. For the situation with ventilation at the foot of the facade the downdraught has vanished completely. The velocities in the desks are low again to about 10 cm/s, as can be learned from figure 6. The conclusion of the study consequently is, that the downdraught that causes the complaints at the desks can successfully be countered by improving the thermal quality of the facade. As a result of the study

it has been decided to actually renovate the facade. The glazing will be replaced with low-E glazing, the mullions will most probably hardly be adapted.

Summary

There may be many motives for renovation, or refurbishment if you like, of a facade. The main aim however is a facade that complies with architectural demands and that does not give cause to complaints by the occupiers. Therefore, it is important that the 'new' facade complies with generally accepted requirements concerning building physics in addition to the statutory requirements.

As a case study, the Departures Hall at Schiphol Airport shows an example of a renovation that was inspired by building physics: thermal discomfort lead to complaints. Yet, also other aspects are significant, such as the energy consumption, that will be considerably limited, which helps to reduce the use of fossil fuels. So, even if renovation may be mainly prompted by a single aspect, it can be a perspective for several others!

Jacques Mertens is an engineer and a senior consultant with Peutz & Associés Consultancy b.v. in Mook, the Netherlands. He is in charge of consultancy on building physics for a.o. Schiphol Departures Hall in Amsterdam.

The Schiphol Departures Hall. Photo: Facility Management Amsterdam Airport Schiphol.



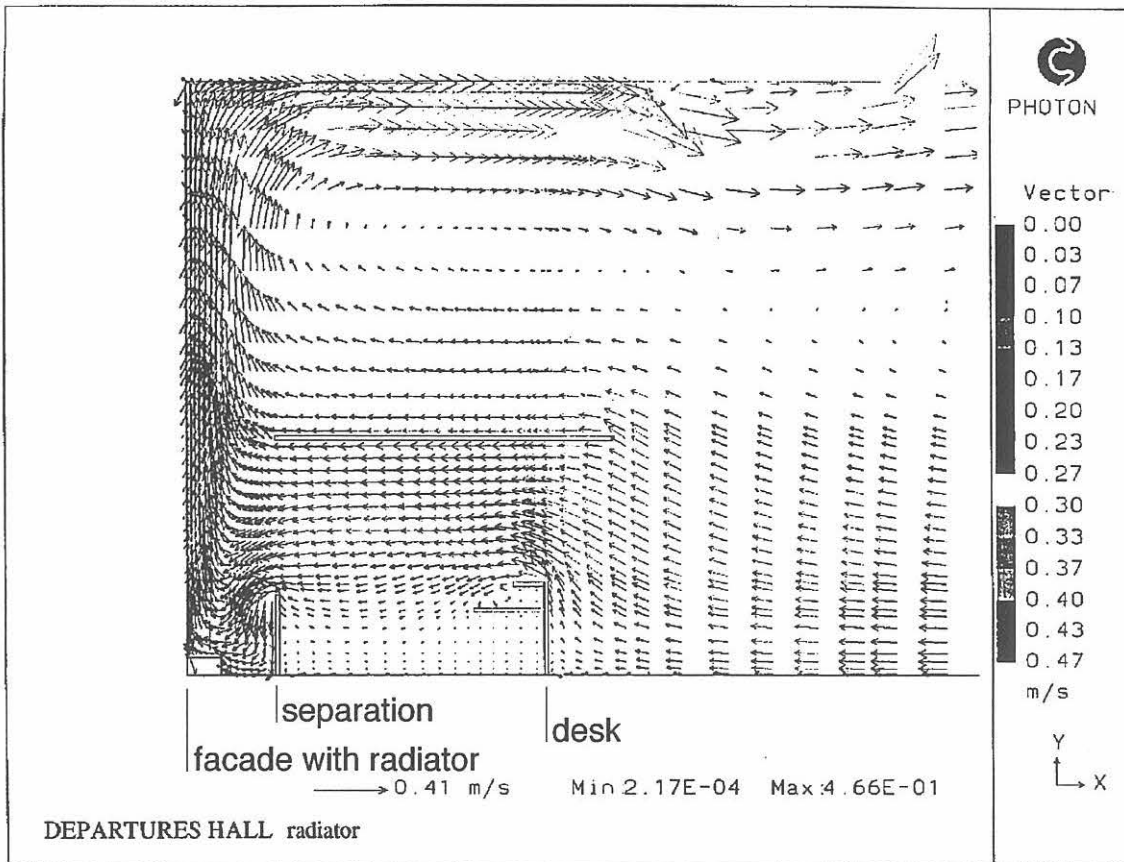
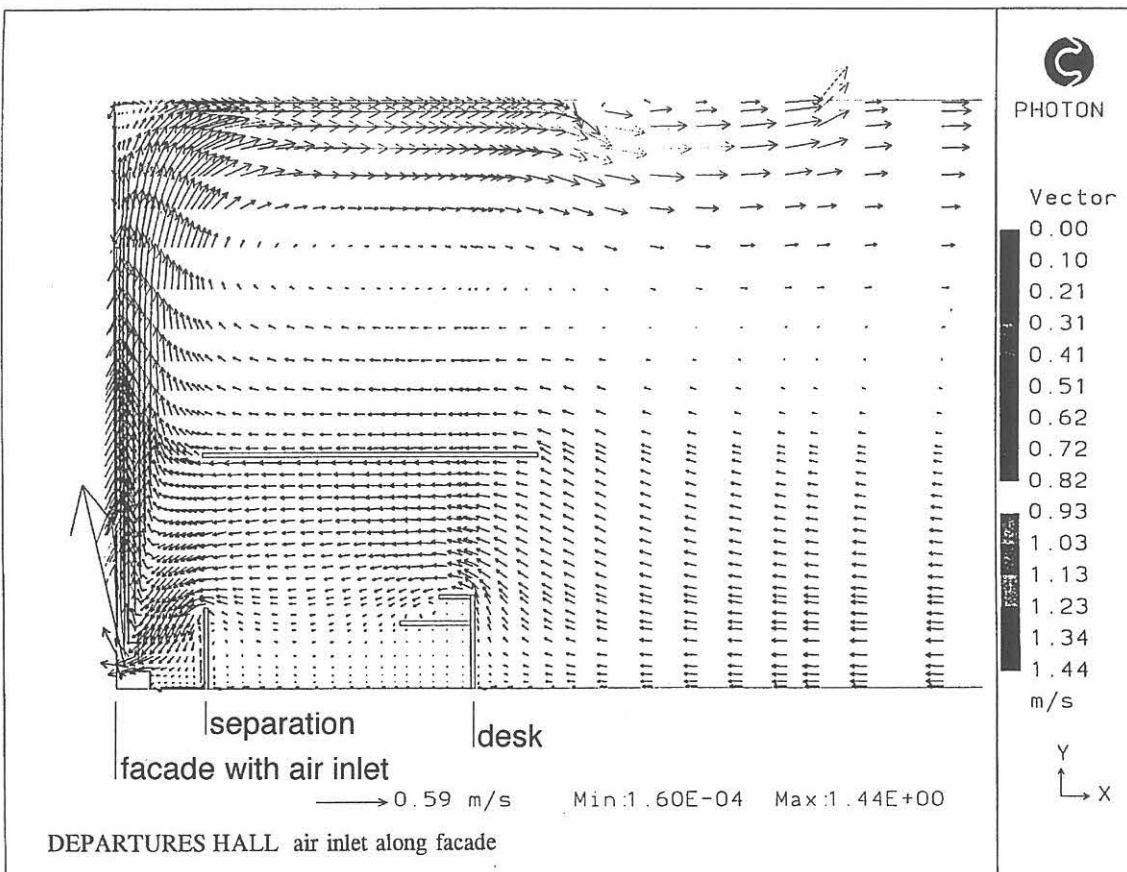


Fig.5 Airflow pattern in the Departures Hall at radiator heating. Graph: Peutz & Associés b.v.

Fig.6 Airflow pattern in the Departures Hall at air inlets. Graph: Peutz & Associés b.v.

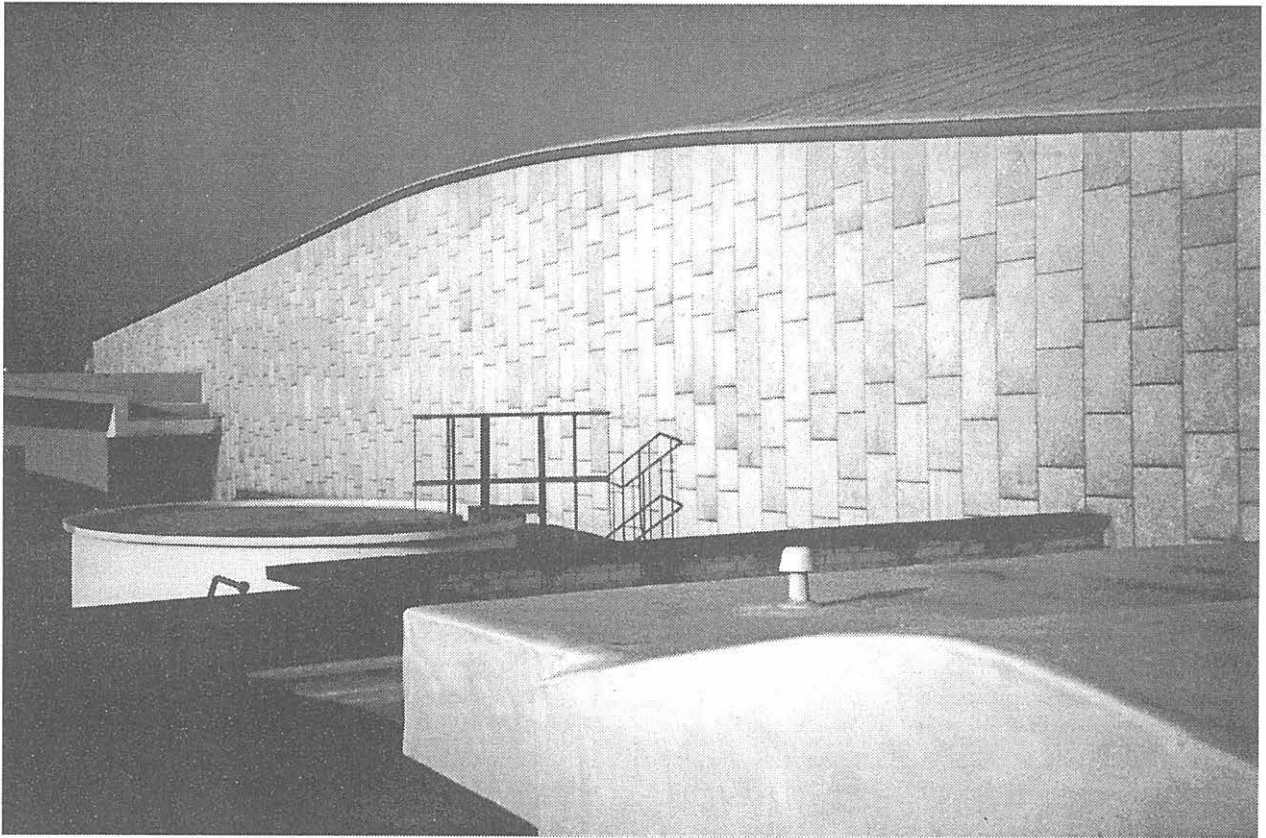


Natural stone

Ageing curtain walls in the United Kingdom

Stone clad curtain walls first started to appear in the United Kingdom in the 1930s, largely imported from the USA, where its use in high-rise buildings was far more advanced. Not until after World War II, however, did it start to become popular in Britain and the European Continent, where its subsequent widespread use can be seen to have significantly influenced the direction and pace of postwar urban reconstruction. Forty years on, ageing as regards appearance, performance and functionality is increasingly being seen as a reason for recladding. If this postwar heritage is to survive, renovation of these claddings need to be looked at in a wider context, including restoration and preservation.

by John Redding



The Royal Festival in London (1955–60) is a landmark of the postwar period. The main walls were clad in Portland Stone, the roof level walls in Derbyshire Limestone. All photos: Ove Arup and Partners.

Stone clad curtain walling proved particularly appropriate for new multi-storey town centre buildings, such as: offices, banks, corporate headquarters and larger public buildings. Stone's perceived image of solidity, permanence and historical linkage, was apposite for the time and combined well with the more progressive and imaginative uses of concrete and glass.

Forty years on, however, physical age and 'dated' appearance, poor performance, escalating cost of maintenance and limited functionality compared to

modern curtain wall facades, are being seen, increasingly, as reasons for cladding replacement. Removal and replacement of existing stone cladding is relatively straightforward and can often be accomplished with minimum disruption to the internal space adjacent to the facade. Building owners and developers, therefore, see it as an opportunity to upgrade the performance of the wall and at the same time, revamp the image of the building. The result is often a radical change to the original facade appearance and an irreversible change to the

architectural balance of the area. With the approaching millennium, pressure for building renewal will undoubtedly grow. If the postwar building heritage of our cities is to survive, we need, therefore, to look more seriously at renovation in its wider context, not just of replacement, but also of restoration and preservation of stone claddings.

Wall construction

Stone has had a very long history of usage in wall construction for all types of dwelling, workplace, religious and public buildings, and even from pre-historic times stone has provided, and been synonymous with, protection and enclosure from the elements.

During historic times, solid masonry walls successfully combined a structural and weathershield function, with a wide ranging freedom of architectural expression.



Spalling damage due to weathering to facebedded Derbyshire.

During the latter part of the 19th Century, however, and largely as a result of the development of structural steel, the structural and architectural roles started to become separated; initially with the development of traditional ashlar wall construction. This is where the stone facade functions as a non-load bearing outer skin supported from ground level, and intermittently tied-back to the inner structural wall or building frame. With this type of self-supporting wall, the stone has to be a certain minimum thickness, typically 100–150 mm.

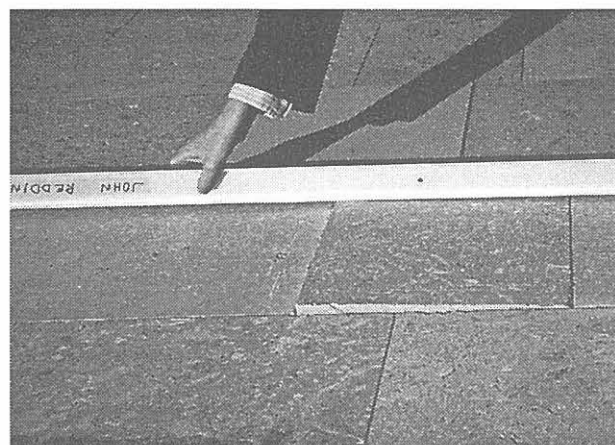
The desire to more fully utilise the load-bearing capabilities of structural steel, led subsequently to cladding, where the weight of the stone is fully supported by the building frame and the stone acts solely as a decorative facing and rainscreen.

At each stage in the evolutionary development of wall construction, the thickness of the stone has decreased, both in absolute terms and as proportion of the total wall thickness.

In the case of modern high-rise steel and reinforced concrete frame buildings, cladding weight has become a major factor governing the thickness of the stone. Cladding on tall buildings typically uses stone in the thickness range 30–50 mm. Future curtain wall

construction (and possibly overcladding of existing walls) may well see even thinner stone veneers of 5 mm or less being more frequently used, adhesively bonded to light-weight rigid backing materials. While the physical thickness may have progressively diminished, stone's projected image has remained more or less constant. Belief, rightly or wrongly, in the permanence of stone, has often been a deciding factor for architects and developers in the choice of stone over other materials.

Changes in source and availability of stone have also run in parallel with changes in wall construction: from locally sourced stone for masonry walls; through regionally or nationally popular stone used in traditional ashlar and early thick cladding walls; to globally sourced stone for modern thin stone cladding. Source and availability have also influenced architectural style. For instance, during the 1950s and



Forward displacement of stone on a Derbyshire Limestone facade. Note mortar has been routed out preparatory to stone being removed.

1960s London saw a plethora of buildings clad in Portland Stone, largely because at the time few other materials were available. During the 1970s dark Scandinavian granites started to become available and more widely used. While the 1980s witnessed a proliferation in the use of exotic multi-coloured granites, as both architectural horizons and the stone supply industry as a whole, expanded on a global scale.

Stone has now become what might be called a 'fashionable or trendy' material. But just as fashions change so particular stones can become samey and out of date. This is particularly the case with granites used in the boom years of the late 1980s. At the time, granites projected an image of strength, confidence and prosperity – every bank headquarters building had to be clad in granite. In the more austere, reflective 1990s the architectural mood is much more in sympathy with sandstones and limestones, which are perceived to be more interesting and thought provoking materials.

A little publicised, but nevertheless important factor that has influenced the changing role of stone, is its

cost. In the ground, stone has no real value; only when it is quarried, processed and brought to site does its value develop and increase. Stone was originally used because it was a cheap construction material. Not so now, when the cost of cladding with exotic foreign stone can amount to 1/4 or even 1/3 of the total building cost.

Stone cladding

Although the stone facing is the single most visible element in any curtain wall cladding, the hidden part is of equal importance in terms of overall performance and life expectancy. Here, too, significant development changes have taken place.

Early UK curtain wall construction using natural stone, essentially followed, what was by then, established American practice. The first specific UK national design guidance document was published in 1962 by



Reuters Building in Fleet Street, London. The typical streaking effect seen in Portland Stone, is due to general dirt discolouration and localised washing, where water runs down face of stone.

the British Stone Federation. This was followed in 1965 by a rather more detailed guidance document issued by the Copper Development Association, that dealt, specifically, with stone fixings. This was followed, in 1972, by the first edition of the British Standard Code of Practice: CP298 (Natural Stone Cladding), which was superseded in 1989 by the current British Standard: BS8298.

Throughout the early development years a more-or-less standard approach to stone fixing was adopted. Stone thicknesses of 50 mm (2 inch) or 100 mm (4 inch) were generally used, for harder and weaker stones, respectively. Gravity supports were provided at vertical intervals of 3 to 4 m up the building, and comprised either corbal plates or brackets, particularly for the thinner stone, or concrete boot lintels (nibs) in the case of thicker stone. Wire ties or metal cramps and dowels were used to provide fixity and lateral restraint.

Stone courses were built upwards, with wooden wedges or lead shims being used to support and space each course of stones and to enable hard setting mortar to be trowelled into the joints. Either an

opening cavity was left behind the stone, with mortar dabs to provide additional temporary and permanent restraint, or the cavity was filled with a mixture of mortar and stone dust to provide additional bonding of the stone to the backing wall.

Fixing was done by hand from scaffolding and was labour intensive, and often involved additional on-site cutting, shaping and drilling of the stone to make it fit. Workmanship was, therefore, an important feature of stone cladding curtain wall construction at this time.

Initially copper, then various types of copper/zinc alloy (brass and bronze) fixings were extensively used. Only after about 1965 did stainless steel start to become more widely used as a fixing material. This was partly as a result of certain copper/zinc alloys being shown to be susceptible to stress corrosion cracking.

During the postwar years in the UK, copper and its

Defect	Manifestation	Possible Cause
Surface spalling	Flakes of stone become detached from the surface	Salt/frost damage. Weathering along bedding or joints parallel to the surface. Thermal fatigue.
Stone has become friable	Small fragments of stone frequently become detached and the surface is crumbly	Salt/frost damage, or acidic corrosion (particularly in calcareous sandstones). Moisture variation.
Increased permeability/porosity	Moisture penetrates through the stone, and the backing wall may show persistent dampness	Penetrative weathering of bedding/joint discontinuities, or penetrative leaching of matrix minerals. Failure of mortar joint material.

Table 1. Common durability defects.

alloys were expensive and in short supply, and commanded a high scrap value. It was not uncommon, therefore, for fewer fixings to be installed than specified.

Guidance, specifically, on the use of stone, was initially very rudimentary. However, this was partly compensated for by the fact that stone cladding contractors, at the time, were generally experienced in stone masonry and familiar with the use and performance of local stones. The early stone cladding industry was also very much craft based, and as such empirical rules and rules-of-thumb were widely applied.

In modern stone cladding wall construction, the stone is generally held away from the building using a variety of purpose design support systems, and thermal insulation and a moisture barrier are typically interposed between the stone and the backing wall. Because thinner stone is typically used, it has much less thermal mass and experiences larger thermal movement. Soft joints, between the individual stones, are more important. These may be filled with mastic, as is typically the case in the UK, or left open, which is more commonly the case in continental Europe.

Conceptions and misconceptions

Stone's antiquity, measured in 100s or even 1000s of million years, and its natural origins, sets it apart from other man-made construction materials, and helps to

support an image of stone as a strong and long lasting material. This is largely a myth. It is important to appreciate that stone is not a single material, but comes in many different varieties, each of which can be composed of different rock forming minerals. This varied mineralogy, coupled with an often complex history of formation, results in an often wide range of physical and chemical behaviour. Limestones, for instance, which are composed of calcium carbonate are essentially soluble, particularly when exposed to acid. The Taj Mahal, is currently estimated to be dissolving at a very high rate as a result of exposure to acid rain generated by nearby industry. Many limestone-faced buildings in urban areas attest to the effects of etching by acid rain and acidic gases in the atmosphere caused by past open burning of coal fires, and present day vehicle emissions. Salts also, both in the stone and formed by

Defect	Manifestation	Possible Cause
Cracking	Linear, parallel, evenly distributed cracks seen in many or all stones	Intrinsic feature of stone
	Short irregular cracks more prevalent towards the edges of individual stones	Induced during processing of stone or subsequently due to mechanical damage
	Cracking at fixings	Mechanical damage, cleaning cradle impact, corrosion expansion of fixings, wind/bomb damage, building movement
	Cracking of porous stone	Frost damage
	Cracking at columns, windows, etc.	Building movement
Bowing	Faces of stones curve, edges lapped	Induced thermal/moisture flexing of stone Building settlement, or column shrinkage
Displacement	Individual stones out of plane and/or showing forward or backward displacement	Relaxation or structural failure of fixings. Corrosion expansion of backing wall

Table 2. Common structural defects.

reaction with atmospheric pollutants, can cause surface decay of porous sedimentary stones like limestones and sandstones. Marbles, especially, can be dimensionally unstable in temperate climates and can undergo considerable warping and bowing when used in thin cladding form. It is perhaps an indication of the way in which we often forget, or choose to ignore, the undesirable qualities of stone that bowing of marble, well documented in the USA in the 1920s, still continues to cause a problem. Many stones, to varying extents, will lose strength with time and exposure to the elements. Even granite, which is generally considered to be an ideal cladding stone, may experience loss of strength due to repeated changes of temperature, moisture and frost exposure. Partly this has to do with the presence of micro-cracks, which are a persistent feature of most granites. These allow moisture into the stone, and expansion of this moisture over many cycles can lead to strength fatigue. In an effort to increase the visual interest of granites,

which are otherwise often very uniform in their appearance, a variety of textural finishes have been used. Flame texturing is a commonly applied finish, whose application, previously done by hand, has now been fully automated. Flaming, even under the most controlled conditions, however, not only reduces the physical thickness of the stone, but can induce or open up existing micro-cracks and thus weaken the stone both immediately in the longer term. Many sedimentary stones have depositional bedding features which with time and exposure to the elements can become weathered out. Weathering was of less concern in blockwork or thick stone walling where stones rested one on top of another, but as a precaution against surface spalling, it became standard practise to cut sedimentary stones normal to the bedding and install them with the bedding horizontal. For many years this has also been

Defect	Manifestation	Possible Cause
Dirty appearance	General or localised darkening/blackening of the surface	Accumulated dirt from vehicle exhausts, smoke fires, etc
Streaking	Vertical dirt or colour streaks	Differential run-off washing of the surface. Localised leaching and redeposition of colour (typically iron oxides) from the stone
Bleaching	Loss of colour and lightening of stone	Bleaching of colour due to sunlight exposure. Leaching or oxidation of colouring agent (typically iron oxides). Formation of surface bloom due to acid reaction (eg hard limestones). Etching of surface due to acidic corrosion or general exposure.
Change of surface texture	Typically surface becomes roughened	Etching of surface due to acidic corrosion or general exposure

Table 3. Common appearance and surface weathering defects.

'conventional wisdom' in the stone cladding industry. However, with certain stones it can result in penetrative cracks developing through the stone, which can seriously affect the structural integrity of the cladding. In short, there are a myriad of ways in which cladding stone can misbehave and it is precisely in early curtain walls that such stone-related defects are most apparent. Stone clad walls are, therefore, of interest in their own right, as a means for studying performance of stone on buildings.

Structural defects

Common structural defects that tend to occur in older (and sometimes newer) stone clad curtain walls, are listed in Table 1 and 2. The table summarises the typical manifestations of these defects, together with their possible cause(s) and implications for the performance of the wall. Excluded from this table are the purely visual defects that can occur in stone, which are discussed later. Some defects tend to be more prevalent at or close to ground level, others at higher levels on the building. Defect detection generally forms an important part of any detailed condition survey of the cladding. On

older buildings, which do not have functional window cleaning cradles, cladding surveys may have to be carried out from a cherry picker or by abseiling. Occasionally, it may be appropriate to erect scaffolding, if additional remedial work or removal of stone is being contemplated. Ironically, it was the bombs in the City of London in the 1980s that led to the development of a more systematic approach to condition surveying and defect detection. This is because bomb damage forced building owners, for loss adjustment reasons, to consider how much significant damage had been caused and how much stone needed to be replaced. The identification of many defects that could not be readily attributable to bomb damage in stone cladding that had only been in place for a few years, also led to further development of crack detection and crack dating techniques.

Option	Purpose	Constraint
Thorough cleaning	Removal of surface dirt to improve the overall appearance of stone	Wall needs to be essentially sound, with stone in good condition.
Replacement of individual stones	Making good	Wall needs to be essentially sound with the majority of stones in good condition. Matching replacement stone needs to be available.
Face fixing/re-fixing individual stones	Making good	Stone and backing wall needs to be in good conditions and suitable for drilling and mechanical fixing.
Sealing surface/re-sealing joints	Improved rainscreen performance	Wall needs to be mechanically sound. Existing joint materials must be removable, totally or partially, without impairing support. Mastic must be compatible with stone.
Complete replacement using existing or identical stone	Renewal of fixings/making good. Resealing backing wall	Stone essentially suitable.
Replacement using identical/similar stone but upgrading wall spec.	Improving and upgrading overall wall performance (insulation/moisture barrier)	Stone suitable. Existing backing wall suitable. Wall thickness may need to be increased.
Replacement using different stone and upgrading of wall spec.	Improving and overall upgrading of wall. Change of image	Existing backing wall suitable. Wall thickness may need to be increased. Planning approval.
Over-cladding	Improved weatherscreen. Change of image	Building frame has to be capable of taking extra weight. Backing wall and existing cladding suitable for anchors. Extra wall thickness.

Table 4. Options for cladding wall renovation.

Apart from close visual inspection, a range of in situ tests can be carried out on stone cladding, including:

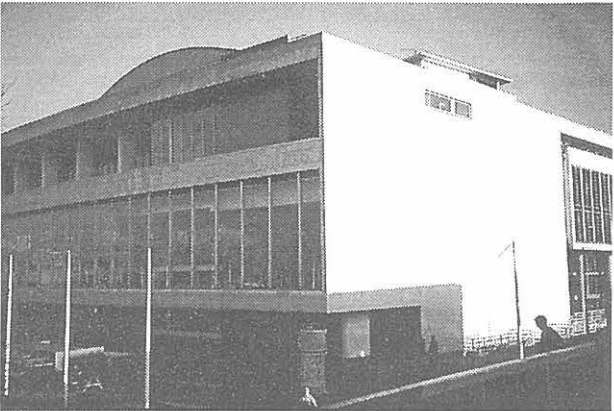
- dye penetration testing, for crack detection; which is effective for most hard stones and can also be successfully carried out on flame textured granites,
- soft body impact tests, which can be used to assess the integrity of both the stone and fixings,
- covermeter, magnetometer and penetrating radar techniques, which can be used to determine the position and composition of fixings,
- ultrasonic testing, which can also help with crack detection,
- simply tapping with a rubber mallet and listening to the ‘ring’ of the stone, can also give an indication of local weaknesses in the stone and fixings,
- a straight edge can be useful for detecting bowing or out of planeness of the face of polished stone that

may be an indication of warping in the stone or failure at, or of, individual fixings.

It is generally necessary, particularly with older stone cladding, to remove one or more stones in order to establish the type and condition of the fixings and the condition of the backing wall.

These stones will usually be ones which show obvious signs of distress or which are considered most likely to give a representative picture of the construction and condition of the wall. It is particularly important when removing individual stones from older buildings to ensure that support is provided to stones at a higher level.

It can be very instructive to examine the rear face of stones removed from a building. Any cracking of the stone or failure of the mortar joints allowing moisture through to the rear of the stone, will generally be evident.



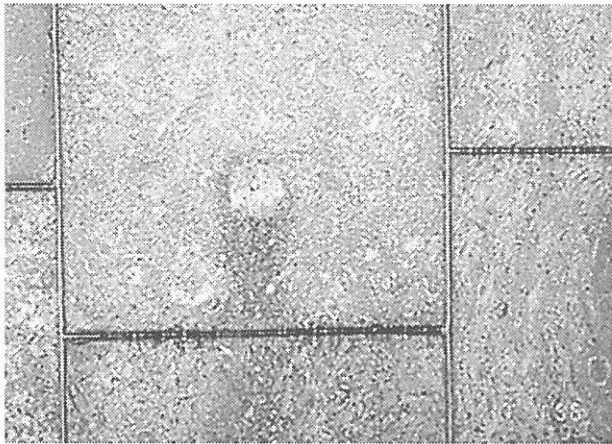
Royal Festival Hall, London. A landmark postwar building (first opened in 1955), clad in Portland Stone (main walls) and Derbyshire Limestone (roof level walls). The building was completed in 1960.

Crack development due to deep weathering of edge bedded Derbyshire Limestone. Note replacement mastic jointfiller which has partially penetrated into stone.

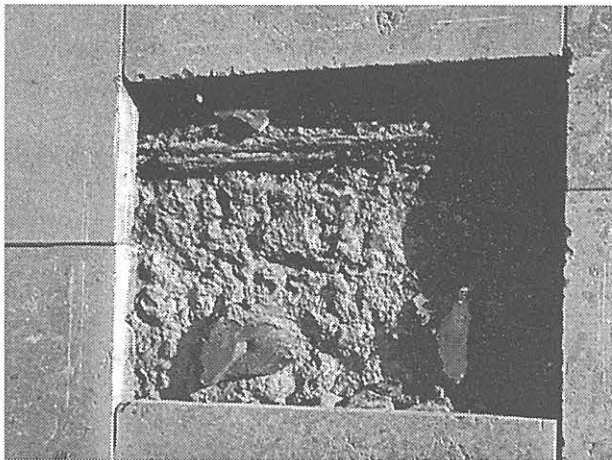


Removed stones can be tested for a range of parameters, just as with new stone. What is generally of interest with older stone is loss of strength and durability compared to when the stone was first installed and the implications for longer term future performance of the stone. Comparison obviously depends on suitable control samples being available, for instance from unused replacement stone kept in the building, samples from the source quarry or samples from less exposed parts of the building.

Such testing, on material which does not otherwise exhibit obvious signs of deterioration, may not be particularly instructive, because the results will generally fall within the range of values that would be expected from the material as a whole and the number of results may be statistically too small. However, testing can be useful as a means of confirming and quantifying visible deterioration.



Face fixing has helped to stabilise stones, but visual quality of fixings is not good.

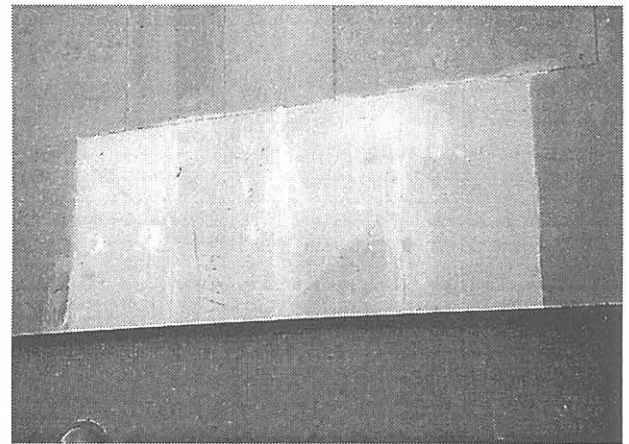


Removed stone highlights problem of corrosion of reinforcing steel in backing wall. Oxidation and expansion of steel has pushed stone forward.

Many of the stones used in older curtain walling in the United Kingdom were previously used in earlier forms of wall construction, some of considerable antiquity. By assessing the performance of the stone in these older walls it is often possible to obtain a greater

insight into the longer term performance of the stone in existing and future wall construction. Care needs to be exercised, however, in the application of such retrospective performance assessment, because of changing climatic and atmospheric conditions in city centre locations and because of differing run-off and moisture retention characteristics of heavily sculptured blockwork walls compared to plain curtain walls; also because of the differing ways in which stone has been used. Building maintenance records, usually kept by the building manager, can also provide a very useful complement to any condition survey. For instance, they may indicate recurring leaks or dampness where cladding has become porous. They may record stones having to be replaced because of cracking, or periodically facefixed because of progressive failure of the original facings.

It is important to remember that a variety of structural



Replacement Portland stone on main wall. Note clean replacement stone contrasts with older dirty original stone.

defects can be induced in older stone cladding by external factors. Because of the very rigid arrangement of stones and limited use of movement joints in early curtain walls, stones are susceptible to cracking due to, for instance, differential settlement or internal movement of the building. Settlement cracking may stem from foundation problems or be induced by tunnelling under or deep excavation next to the building, or even excessive lowering of the groundwater table. Shrinkage of load-bearing columns, for instance due to creep in concrete columns and elastic shortening in steel columns, can also sometimes lead to cracking or bowing of stone. Unusual wind loads, such as were experienced during the hurricane of October 1987 and also bomb blasts can induce cracking and forward displacement of stones. The latter may occur due to differential pressure in front of and behind the stone. Wind effects will generally be more noticeable at higher levels on the building. Bomb blast effects, however can be highly unpredictable in terms of their location, and can occur at surprising distances from the centre of the blast and unusual positions on a building, due to channelling effects and reflection off other buildings.

Appearance defects

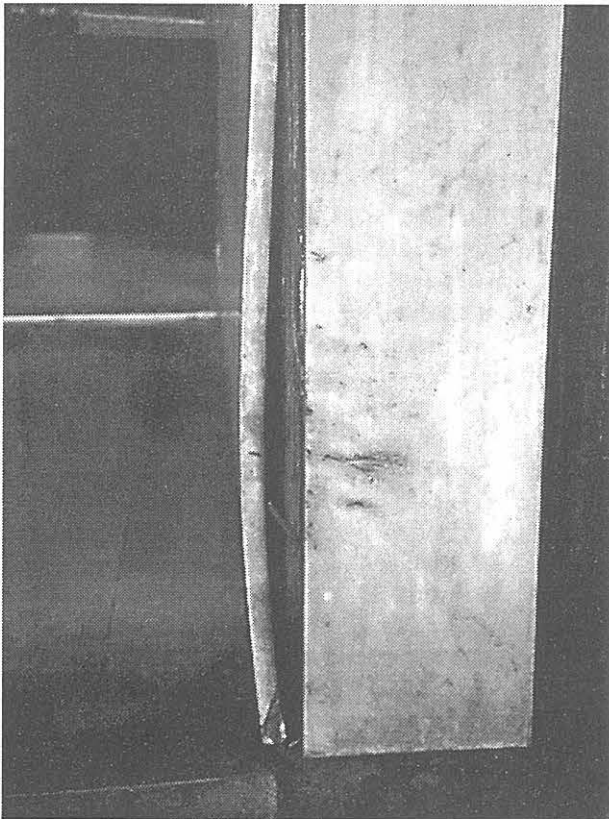
Typical appearance defects which can affect stone cladding are listed in Table 3, together with their common causes. Many of these develop through a combination of environmental exposure, location on the building and intrinsic features in the stone.

Dirt discolouration and streaking, for example, is a common feature of older walls which are clad in porous sedimentary stones, particularly lighter coloured limestones. Portland Stone, widely used in London, is particularly susceptible. Airborne dirt, especially the fine carbon particles from vehicle exhausts, tends to lodge on surface irregularities and be adsorbed onto the surface as water droplets soak into the stone. Streaking in Portland stone facades, generally occurs where runoff is channelled down the face of the stone from window sills and parapets. In these areas, the frequent washing actions helps to

secondary iron deposition in the matrix of the stone can become streaked and/or bleached due to mobility of the iron. Acid washing, during cleaning, can accelerate this. Equally, stones may become stained as a result of contact or proximity to rusting ferrous metal or copper.

Staining due to migration of oil from mastic joint fillers is a common defect that can affect all types of stone, including granites. Although this is more commonly seen in recent cladding, it also occurs where the original mortar joint filling has been replaced by mastic sealants. The problem, in terms of distance of oil migration, is often exacerbated by the increased porosity of the stone, which frequently occurs with length of exposure on the building.

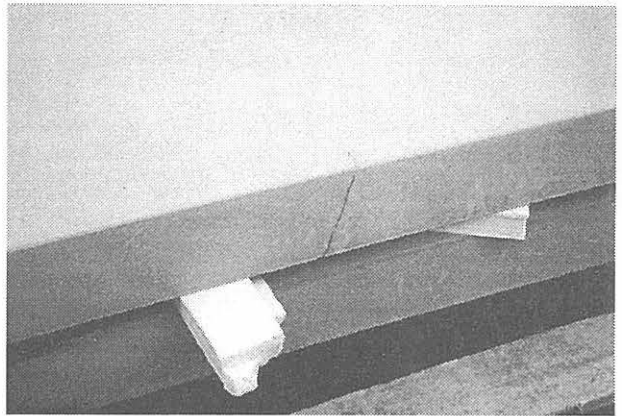
Efflorescence, where salts migrate towards and collect on the surface of the stone due to evaporation of moisture, can occur, due to their original presence in



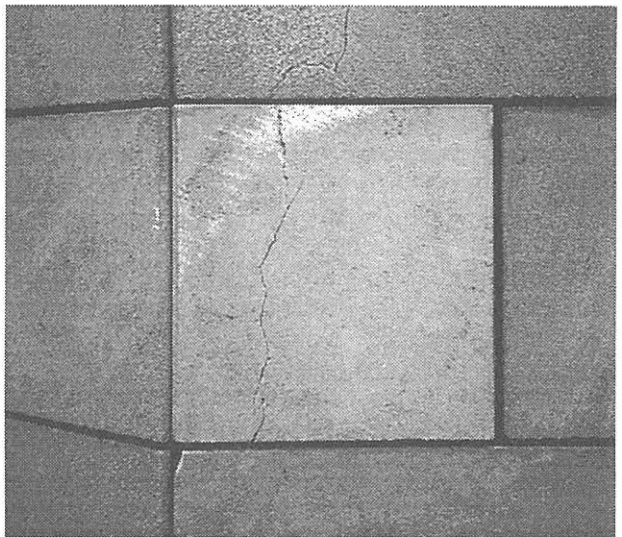
Bowing in thin marble cladding, due to excessive loading from overlying stone.

keep the stone clean. Self cleaning is also often seen on west facing walls which are more frequently exposed to driving rain. These elevations are generally more noticeably etched than elsewhere.

Granites and other hard, low absorbency stones with a polished or honed finish, are far less susceptible to dirt accumulation on the surface. However, with time, many limestones will tend to develop a rougher etched and more porous surface due to exposure, and this may contribute to their becoming progressively more susceptible to dirt accumulation. Some limestones and sandstones, in which the colour of the stone is due to



Natural crack in sandstone, due to absence of calcite within joint.



Cracking in sandstone, due to mechanical damage.

the stone or their secondary introduction i.e. in the water used for cutting the stone or through chemical reaction. Bleed-out of salts can also occur if the stone is in direct contact with a concrete or brick backing wall and the wall frequently gets wet.

Walls which are persistently cold and damp, i.e. north

facing walls, may sometimes experience algal and lichen growth. However lichen growth is unusual in urban environments because it is generally inhibited by pollutants in the atmosphere.

Renovation options

Various options that might be considered in terms of renovation of a stone cladding curtain wall are listed in Table 4. They are presented in order of increasing alteration to the original wall appearance and construction. For each option, its purpose and the conditions under which it would be most appropriate are also given. A decision to employ one or more of those options will be technically complex, added to which will be considerations of cost and commercial issues, especially if the building is tenant occupied.



Cracking in granite, due to blast damage during quarrying. Note dye penetration treatment has been used to highlight cracks.

Planning constraints may also be important. A detailed condition survey will generally form the starting point and basis for decision making. Provided that the stone, the fixings and the backing wall are all in reasonably good condition and are not progressively deteriorating, one or more of the preservation options may well be appropriate. A critical question will be the future lifespan of the wall and at what frequency further cleaning and maintenance will be required. If the wall is already in a moribund condition, preservation will probably not be the answer. Indeed, if the future structural integrity of the wall cannot be assured, there may be an increasing risk of the building becoming classified as a dangerous structure.

Replacement, using identical stone is frequently a viable option in the UK, because the majority of stones used in early curtain walls are still available today. However, if it is essentially the stone that has failed, then it will be more appropriate to use a similar looking but more durable stone; likewise, if the original stone is no longer available or cannot be traced.

Matching of replacement stone needs to be done with care, particularly if part of the original stonework is being retained. This is because many stones subtly change their appearance with time on a building, and cease to look like the original stone. Equally, the source material may have changed as the quarry has developed and expanded.

While it is quite feasible to use an identical or similar method of fixing for the replacement stone, consideration will generally be given to the possibility of upgrading the wall by introducing insulation and a vapour barrier, this will inevitably require a different fixing system to be used. Some increase in wall thickness will also be required, which will involve remodelling of window sills, etc.

However, depending on the type of stone and method of fixing used, it may be possible to use thinner stone than was originally used, thereby, retaining the original wall thickness. Upgrading will generally be one of the key considerations in terms of a more drastic restoration of any curtain wall. However, while it has generally been necessary and desirable to use granite as a thin stone replacement to thicker stone cladding, with inevitable changes to the character of the building, the 1994 revision to the British Standard now permits other types of stone, such as sandstones and limestones to be used in thinner section, if this can be justified by testing.

This recent revision may, therefore, help to encourage the more widespread use of similar stone for replacement cladding, and therefore a more conscious effort to retain the character of the original facade. Hitherto, the requirement of the Standard to use granites or hard limestones (the latter not being indigenous to the UK) has generally meant cladding replacement and wall upgrading could only be done with different stone.

Overcladding has not been widely carried out in the UK and when it has been done, it has generally been with lighter weight cladding materials than stone, because of the added weight problem and the difficulty of supporting stone using long anchors through the existing cladding into the backing wall. The difficulty of positioning such anchors, because of the need to avoid reinforcement in the backing wall, has meant that a adjustable clip-on or cassette systems of fixing have often been employed. These lend themselves to the use of thin stone such as granite, which has been an additional factor in the move away from traditional stone.

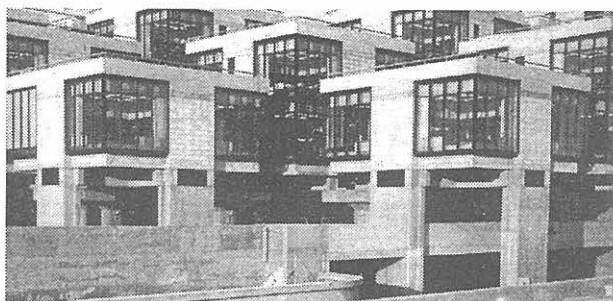
The future for lightweight overcladding using traditional stone may well lie in veneer stone bonded to synthetic honeycomb or metal-glass backing panels. However, the tendency will surely be to use these space-age type materials in architecturally forward looking ways rather than in architectural preservation.

John Redding is an engineering geologist working for Ove Arup and Partners, London.

Redevelopment of postwar real estate

After having gotten acquainted with various aspects of the curtain wall itself, now it is time for some psychological breath. If you all stand up, please, and wave your arms, and take some deep breaths, you will experience physically what an open air system for facades essentially is. At the same time, it will stimulate our oxygen and blood circulation, which will allow our minds to look at some of these issues from a totally different point of view. For a while, let's not talk about curtains at all. As far as I'm concerned, coats are about protecting something, and I would rather talk about the contents behind it, because somewhere somehow there is somebody inside that coat.

by Hans de Jonge



Centraal Beheer office building in Apeldoorn, designed by Herman Hertzberger in 1972.

Of course we could have lengthy discussions about what has to be preserved. I suppose that the Romans did not, and we have not kept a lot of what they built. We might think we have, but all the domestic architecture has passed unnoticed. What I mean to say is that we have to realize that all real estate is just an imprint of human activity and is going to disappear over time. There is nothing bad about that, that is just the way it is. We want to keep just a few things, so we have to look into what is interesting to preserve, what we would like to do with it and what the position of the curtain wall in that could be. Therefore, I'd like to kick off with four topics. One is real estate in figures, to twist a few numbers in your minds. Then, I will speak about challenges. Not the challenges that we are facing, but the challenges the clients, the users of our buildings, are facing. Then, there are the redevelopment opportunities resulting from that and, finally, I'd like to draw some conclusions. Some of these might feel like a twist of the arm, since I'm going to say a few things that probably not all of you will like.

Real estate figures

When we look at the figures for the Netherlands, we have to take four things into account. One is that all our efforts, and all the knowledge that architects are trained with, are adding something to a large stock. The numbers of buildings we are dealing with are vast, and we really don't know what kind of knowledge we need for managing all that. Secondly,

we should speak about maintenance of course, but I'd like to talk about that in a wider context. I'm talking about the challenges posed by making proper use of the existing stock. A third issue is, of course, caring for our cultural heritage. Now, heritage has the connotation of, let's say, preserving the things that are worth while keeping, which puts the issue of durability in a different perspective. Finally, we will have to touch upon physical planning as well.

Before most of us were born, the Dutch were rather busy producing a lot. So, it was only natural that after the Second World War we all started building like crazy, in a similar way as the present developments in Southern China. That job has not very carefully been performed. It has merely been a matter of providing space at a high rate, disregarding many of the qualities addressed today. At the time, it was anticipated that Holland would need as much as 3.5 million dwellings to accommodate the unimaginable account of 15 million people around the year 2000. But in the Netherlands today, 1 million kilometers of infrastructure –cables and ducts–, 125,000 kilometers of roads and railroads, and 6 million dwellings have been produced, while another million dwellings are to be projected.

Apart from dwellings, Holland has 1.3 million other buildings in which roughly 1,800 billion Dutch guilders has been invested. About one fifth is spent on maintenance to keep these up. If you compare these figures with those on newly constructed buildings today, it becomes obvious that the present additions to that vast stock of real estate are absolutely unimportant.

Challenges

If we look at the challenges the clients and users are facing, there are five topics I would like to address: economy, dynamics, cost consequences, information technology and environment.

The Netherlands has surpassed the U.S. as regards the number of people working in services industry. The percentage of working people in Holland is low, but the percentage in services industry grew from 30 % in 1971, already one of the highest in Europe, to 35% in

1987. As the figure continued since then, today half of Holland's work force is in services industry. This development is significant to us, since it has caused an enormous demand for office buildings over the past thirty years.

Yet, the organizations that we are dealing with over that same period have changed even faster. Berlage's insurance office of 1895–96 had its name 'De Nederlanden van 1845' chiseled in marble. Today, we hesitate to even fix a company's name plate to a facade with bolts, or rather use removable glue. In a similar way, the organizations themselves are no longer the reliable, hierarchical, military style organizations that they were. They are continuously being transformed in all types of ways, such as in flexible project teams.

Although common practice to us, this is not so the case in the production industries. The regrouping of project teams causes a different demand for space almost every other year.

In the 1970s, the answer was sought by tailoring the buildings. The briefs were refined to great detail, carefully studied and materialized by "carving out" the raw material to closely suit the clients needs. Some architects realized that a flexible demand of volume would require expendable and adjustable buildings. Others wanted to provide a choice of buildings to work in, but just a few companies actually operated in inflatable cable-net constructions and other semi-permanent structures.

Lifespan

The above is an illustration of the relationship between the three lifespans of a building, that Just Renckens addressed in his contribution. One of the things that we should realize is that the technical lifespan of a building can be extended as much as we want. Some architectural monuments are over a thousand years old, which is no problem as long as there is money for it.

The real problem is that the functional lifespan is shortening all the time. In offices it dropped to about ten to eleven years, in hospitals it's seven and in laboratories it's only two. So it means that you have an overhaul of interiors, of functional design of buildings. As a result of the dynamics I mentioned before, the functional lifespan will soon be so short, that a tension between functional change and technical possibilities will occur. The question is therefore if we are willing to again extend this lifespan, in view of the sustainability issue, or stick to ever further reaching adaptability.

In view of this, I have advised the Minister for the Environment to reject the broker's proposal to change depreciation percentages, that was mentioned by Just Renckens earlier on. If you allow to depreciate not at 2 but at 5 %, buildings will be depreciated far too soon and done away with, which is ridiculous. Along lines of a fiscal approach, real estate parties must be forced to think about durability.

Dynamics

The problems and the economy are changing, and organizations have to respond to these dynamics. For a business, the costs of operating a building are vital. From the figures it can be learned, that the costs per annum for a workplace totals about US \$ 14,000. In Holland it is between f 15,000 and f 30,000. These costs can be divided into:

- capital costs;
- running costs that are building-related, like for energy, maintenance, cleaning and security;
- running costs that are process-related, like communication, data-services, and catering.

It is essential to understand a user's cost profile when assessing the costs of operating a building. Most users do not realize the whole figure of operating costs and tend to concentrate on the 33% capital costs when they have to deal with cut backs. But even if we do so, we have to realize that only half of these actually have to do with the building itself, which is only 16–20% of the costs we started with.

As an illustration, I borrowed the costs of an average lease car in services industry to approach the costs of mobility. This part of a contract might be discussed for half an hour at the interview, and that's it. Still, costs for mobility exceed by far a company's expenditures for operating their building.

Just to give another example, it will surprise you to know that, at present, expenses for catering more than double the average costs for maintenance of a building. Still it is common practice to cut down on maintenance, whereas this example illustrates that the financial effects of such decisions can not be but marginal. It is therefore important to make clients conscious about cost profiles

Information technology

An important aspect of the present dynamics is information technology, that will change the face of our world. Real estate is the footprint of our economic activities and our economy is increasingly dependent on the handling of data. It means that work activities are getting detached from work place. Just think about the Internet, electronic banking and the Amsterdam stock exchange, that works largely electronic by now. Analogous laboratories will be digitalized, employing simulations rather than real life experiments. Education is already available through CD-ROM, and you can get a lecture whenever and from whoever you want. So for the client, the essential question is what kind of work environment he wants.

Environment

In terms of environmental effects of the building industry it is important to develop durable concepts, and to employ the proper materials and sustainable constructions. The Netherlands is not doing such a bad job when research in this field is concerned, since we can partly rely on the engineering that we have developed in other industries. Yet, these concepts are

still insufficiently put to practice. We have always designed buildings as how to put them together, but now, we also have to design how to take them apart. If we would build cars like we do buildings we would need a welder to repair them, and that is not very sensible.

Although it's a bit late, now that we have already produced most of our building stock, our building processes need to be re-invented.

Hopefully, the economies of the rapidly developing countries in Asia for instance can still benefit from this as well, to prevent them to make the same mistakes again.

A problem that is increasingly alarming in Holland and in the large North American cities, is mobility. The hours lost in traffic strongly affect productivity. Yet, most meetings you are in are actually unnecessary. By telephone they would cost you 20 minutes but if you go there physically it takes you half a day. Still, your presence is essential, since a lot of the informal information takes place off the record before and after the meeting. So meeting each other remains necessary, but not necessarily in the way we do now.

Office in transition

What becomes apparent from the above is, that there are a lot of ideas and actions in there that are not valid anymore. The coming 20 years will prove if I am right.

It is illustrative to have a look at the past, in order to be able to look forward and understand some of the changes in the future.

In the intricate medieval town of Maastricht, functions were intermingled: close-by, small scale. Good architecture that obviously accommodates totally different functions today because the city is still there, happily enough, and it is still functioning for our sort of activities. Offices did not exist, and business was performed in the house. The Italians probably invented the service building with the Uffizi. In the U.S. this typology was further developed, but when it grew bigger it got out of hand so we ended up with these big schemes.

During the Industrial Revolution growth was exponential, as was the need for housing for the new work force that migrated to the cities, that soon suffocated. CIAM and Team Ten responded to the needs of the industrial society by a rational organization of urban activities, designating separate areas for living, working and recreation. But through organizing space, also mobility was organized. This is where the trouble started, since they did not only organize space to live in, but also space to work in. Work therefore got detached from living, introducing a totally new concept at the time: the modern office. A corridor with cells at both sides might resemble a prison, but it's an office and it is still in use. The lower ranking people were operating in large rooms, sitting in standard rows, standard machines with standard features, and no computers, nothing. This looks like

yester-year, but in fact this is only the 1960s.

Then the Germans came up with the idea to put everybody in one room. The idea was that it would be more economic, because you make one big envelope that protects the entire organization from the outside. By merely moving plants and partitions around, it would be extremely effective. People will still have their privacy, in a certain sense, but they will communicate a lot as well. It could not be foreseen that people would become ill because of so much communication. When your neighbours answered the phone, you were out of order, and people got totally disordered by noise in what was then a normal working environment.

In the 1970s, telephones lasted for 20 years and offices featured no single PC. The management seemed like a special kind of people that we could not understand due to their secret language and a salary that was average three times ours, in a room that you could only enter by doors with special locks. What they had in that room was classified, but we have it all on our laptops now.

Revolutionaries like Herman Hertzberger wanted to reassess the concept of the work place. He came up with the principle of structuring space through architectural means, and just waiting what people would do with it. The fact is that his 1972 Centraal Beheer building, that has small scale curtain walls as well, has recently been renovated. The entire internal traffic system has been changed, the functionality of the building has changed, but the envelope and the architectural system remained and is still going strong. So another statement from my end is, that real architectonic quality will survive in the end.

Image

A picture of down town Toronto could easily be exchanged for an image of almost any other large North American city, or even a European or Asian metropolis. The issue is, that we unrooted architecture from local materials, and transport alien materials over large distances. I will get back to this later on. The head office of Unilever in Rotterdam is an illustration how rapidly organizations start to change. It's an enormous organization with a head office that is relatively small. As a joke I always ask the people from Unilever if this was the original size they had in mind and then shrunk the building, but that's not the fact. They wanted a small building to communicate from, it's their brain centre and all the work is done in the periphery. They do not invest in all kinds of static things, but need small features there.

Other companies have different opinions about what a head office is. They want to communicate to the public through their building. The NMB main offices in Amsterdam is intended to communicate something to their clients, although I don't know exactly what it is they want to get across. The company decided even to have it on their bank-card, although the bank has a logo of its own. NMB states they have a 150 million

PR-value, just of that building. Another head office, of IBM France, illustrates a kind of company that went for corporate architecture. Olivetti and Braun are other examples. Mostly, such decisions depend on individuals, like with the Van Nelle factories in the 1920s. Individual quality people on the client side and individual quality people at the design side, that combination is the secret to make such special buildings that are worth keeping.

In recent years, the client is growing to be more and more anonymous and often not even in the picture. Far too often, decisions are made by real estate investors and real estate developers, without a client even being known. Examples of the results of such building processes are, I am sorry to say, found more and more. Without any substantial feedback, there is not much more to do for an architect but to create some nice and hopefully interesting forms, without any relation with the functions performed in the building. Due to the speed of change, the form will never follow the function.

So we try to make meaningful buildings by architectural means, to express something, to make people interested in built forms. We also try to communicate something, like the China Bank in Hong Kong, which is supposed to reflect power, or whatever. By the way, this is a facade that, despite its height, can be opened for individual ventilation.

Carried to an extreme, you might even look upon offices, and head offices in particular, as a cathedral. As we forgot about other kinds of metaphysical issues and work seems to be our religion, we go to the head office once a week to hear the message and then we do our own thing, to hear next week that we did the wrong thing. It seems there is an analogy there.

Flexibility

The organizations with the highest rate of change started to think about an extreme level of flexibility first. The Lloyd's of London is actually one large container where the office staff was simply moved into its totally flexible interior. This put some people up to create a working environment by themselves, without the help of engineers. The Digital company in Finland is an appealing example, but there are now more and more examples of this. If people can read a rapport at home, lying on their couch, why do they need a standard chair from a specialized factory for four times the price that they pay around the corner at their local furniture shop. So give them the budget, and they will do it themselves. At Digital's they swapped screens all the time, and made their own lay out arrangements.

The same company also came up with the idea to do away with fixed work places for people who are never there, or only 20 minutes a day to look up some data. So here you come into a fluid space, and there's a large tree with wooden apples. You pull one apple and there is a PC attached. You look into the data, you push it up again and off you are. It means that

we will have to look to how we use space from a totally different angle. Our spacial demand patterns are getting much more fluid.

If we take this idea to an extreme you end up with a concept which is not so much like a building, but rather like a hotel where technical services are provided.

In a hotel the service is of a totally different nature, an attitude that is unfamiliar in real estate. In the United States, our firm entered into talks with some hotels to see whether it would be viable to put a few hotel floors to use as office space. They agreed on the experiment, which was successful and it put various companies up to exploit space like that. This means that in the future, you might rent space in Hamburg or Berlin, while your contract allows you the incidental use of other such spaces in the total portfolio of that company, even if it is in Singapore.

Mobility

The difference will be dramatic. First we owned cars, then we leased them and now we are going into another product, which is mobility itself. During the week you will drive a company car, in the weekends you drive a space wagon with your family and when you move, you can have a furniture van if you want. They already make contracts that flexible, so you can tell what you want. It is not as much a seller's market, nor a buyer's market, it is about individual attention to individual clients.

When buildings are concerned this leads to the IBM example. New building typologies that are not allocating space to a specified function, but provide facilities over a certain period of time with the client getting billed accordingly. The client walks in, orders a room for a day and gets it there and then. He can employ a PC, the Internet, e-mail, telefax, interconnected with his own laptop and portable phone. After use, he gets a bill, pays by creditcard, and runs off.

Some things, however, requires working together with other people. This could happen in something like a clubroom, where you find yourself with other colleagues to realize that you are actually part of an organization. A video conference room, a phenomenon of the early 1990s that was intended to serve such purposes, is already outdated by the newest generation of Macintosh computers that actually can provide an eye on people across the ocean. It is obvious that the communications industry is rapidly changing and the need to meet will soon be dealt with for, I guess, by 70 to 80 % in an electronic way.

This means that you have to think about what made cities work. Why are cities formed like they are? Of course, there is an economic bloodstream below. Twenty, thirty years ago, Jacobs said that cities were formed through economic powers, such as land prices and building codes, but I think there is more to it. As soon as distance is no longer relevant, a different

approach in urban design will develop. Some companies are actually reconsidering their position as regards their properties. As you may gather, these developments are bad news for real estate owners. Similarly to the fixed values, that run at a steady rate, investments in real estate are attractive as opposed to the volatile stock market. But as the real estate market is becoming volatile too now, investors tend to withdraw. Investors look for quick and certain deals. In Holland, where we face an overproduction of office buildings, there is a tendency not to invest in offices, and certainly not to refurbish them. This is a serious disadvantage for the preservation of postwar commercial architecture.

Reuse by law?

One thing we have to bear in mind when redesigning cities is that if the urban planning strategies are not able to stop the cities to spread out, the city centers themselves will be vacated. The emergence of all the 'brain parks' –or rather "brainless parks"– at the periphery of our large cities, that everybody is so crazy about, means that the cities themselves are being emptied and will be caught in a downward spiral not only in rents but just as well in their social structure.

When the decay of a city will eventually be a fact, the costs of responding to the inevitable social problems that will come along with that will have to be paid by society as a whole. That is why society now, as a preventive measure, should prevent companies and developers to create even more overproductive spaces at the outskirts of cities.

In a broader sense, this has also to do with the issue of sustainability. It means that we have to reassess the building stock that is available in the inner cities. Along these lines you come back to the whole issue of revitalization and refurbishment, that again touches upon today's theme of preserving architectural curtain walls.

In the near future a new building code can be expected that will restrict building permits for new buildings. Only when all alternatives in the existing stock have been looked into and no viable solution has been found, a permit will be submitted.

Quality

A main issue when looking at real estate value is architectural quality. I am convinced –but this conviction has nothing to do with science– that meaningful architecture, created with a lot of emotion and quality, will last. That is why Herman Hertzberger's building lasts, and that is why Maastricht lasts.

There must be a reality and a truth beneath the Amsterdam grid, to give just another example. Why do people operate from the centre of Amsterdam which is totally dysfunctional and twisted, where they can't park their cars and they might get mugged and mobbed? It has to do with the quality of that

environment, that can not simply be repeated anywhere. From such considerations a few conclusions can be drawn but first, another example will illustrate the relation between architectural quality and investments.

Transitorium, The Hague

This office building in central The Hague is an example of how we responded to the issue of redevelopment at the Gouvernmental Building Agency, where I was in charge of real estate development at the time. This was a building of the 1960s that featured what some of you will consider a beautiful curtain wall construction. I would disagree with such a position since in my view a lot of trash has been produced over the last thirty years in our hurry to catch up with our postwar economy. Looking at the decrease in their turnover, some architects even suggested to include dynamite as a building material, to take away all the errors of the past and to create portfolios for the future.

The building is state-owned and located in an absolutely devastated area in central The Hague. But even if the building itself was not the kind of property that I would normally go for, we still decided not to demolish the building but to strip it. The way this was done, however, had nothing to do with curtain wall refurbishment. Michael Graves was the architect in charge and he proposed to knock off a few stories, to cut it in half, put up a few new roofs and to try again. Frankly, it all seems ridiculous to me. What's the rationality in going back to the bare structure? It looks a little bit like the urban renewal projects of the 1970s, when entire streets were pulled down except for six townhouses –like pulling teeth– and then try to make something very intricate. My view is to do away with it and start again, and try to find real quality to keep.

The entire building will be reclad, but not by a curtain wall. Curtain walls are no longer fashionable and a new chapter in styling has begun, using materials like marble and stone. Of course also the environment of the building at street level will be redesigned as well and it will all look very smooth and beautiful, but the whole thing will have nothing to do with sensible reuse.

Electro building, Delft

Another example is my own university in Delft. It totals 600,000 m², or six million sq. ft. of floorarea. The activities of the TU Delft require only about 400,000 m². One of the eye catchers of the campus is the Faculty of Electrotechnology, designed by G. Drexhage in 1959–67, that features a beautiful curtain wall. It was an ultimately modern building at the time and it was attracting the attention of every technician in the room.

But this building is an awful headache for the organization. The building's transparency is regarded a great architectural quality by outsiders. But inside,

people can't work in it because of solar gain and overheating. Indeed, the building is beautiful, but it should be workable in the first place. I agree with the consumers that the priority in qualities should read: workable, useable and then beautiful. No surprise that the users of this building threatened to go to court to have the building closed, if nothing would be changed as regards the internal performance of it. What we are doing now is to put some extra service systems in at one floor to have a pilot study. The actual problem is, that making the climatization systems really work will cost something like 25 million guilders and we don't have the money to do it. But it is still beautiful.

Ministry of Economic Affairs

To my mind, all that cutting, slashing and starting all over is ridiculous, unless you have a very good reason to do so. I could give you scores of successful cases, like the new Ministry of Economic Affairs, that in fact is an old building that was very carefully renovated by Hans Ruysenaars. Still, I think we will learn more from some cases where things went wrong.

My last example shows a building in which the envelope is used as a means. In this building another, new phase into curtain wall technology is explored in which the various functions of the facade construction are separated. The facade is actually just a rain coat. It is a single-pane facade and the internal partitions are also singlepaned with vents opening to large atria with a so called 'half climate', the roofs of which can be opened on hot and sunny days. These atria were not in the programme but it is a beautiful space that you can use in the summer. In winter, it is still beautiful but too cold to use. The whole thing was an experiment that turned out very well and I feel this could serve as a concept for other old buildings too, to just repack them. It would be a nice thing to invite Christo for the job.

Conclusions

Of course it has been a great idea to put together a seminar on curtain wall refurbishment, and some of the older examples are worth to preserve indeed. My first statement is, however, that a lot of post war real estate is functionally and technologically obsolete and should be done away with as soon as possible. Curtain walls are just part of a problem, that actually originates at another level.

The first priority is to define which buildings are worth refurbishment, in financial, functional, technical or architectural terms. If I take the analogy with the 1970s urban renewal policies again, I fear that we are going to make the same mistakes when starting to refurbish and renew buildings that don't deserve it. In this respect, I think that the former Shell building in Rotterdam is a good example of a building that deserved refurbishment. Not because it was beautiful but because of the location and the market opportunities being excellent. The starting points for this refurbishment were therefore sound and it is only

too bad that there has not been taken more advantage of this situation in architectural terms. The second conclusion is, that the changes in society demand for other buildings and other cities. The building industry shouldn't serve itself, or architects, or history books, but its clients. Instead of responding to the needs of the customer, still buildings are being designed as everlasting products in a certain combination. The building profession has to be re-engineered, and aimed at designing for varied lifespans. Longtime, durable superstructures at locations that will keep their value, combined with interchangeable, reusable, recyclable parts that can be taken out and put in again as fashion requires. The cycle of fashion is going faster everyday, and customers will start to ask for the newest style. Architects might resist at first, but if the client asks for it, the investors and developers will soon follow and it will happen anyway.

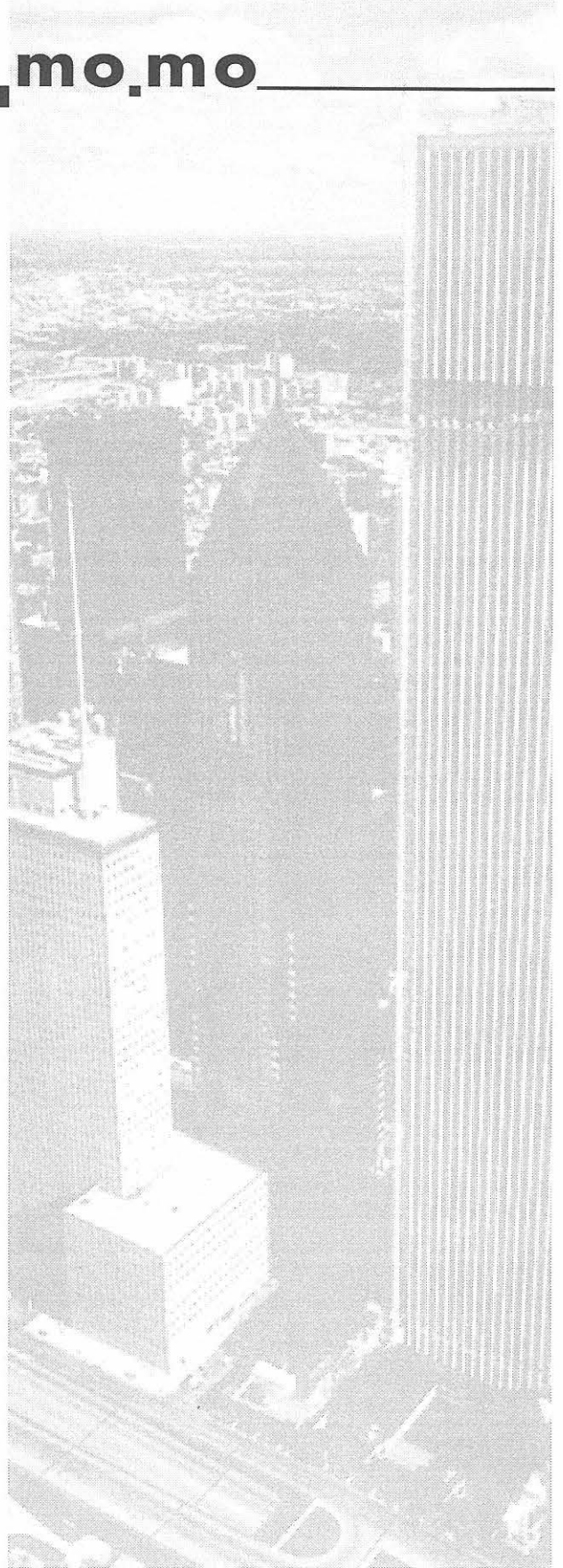
My third statement is, that the exodus from the inner cities has to be stopped. The technological and economical changes indeed allow for the redesign of cities, which means that orchestrated action on the level of urban planning is urgently required in order to keep our inner cities together. If we fail to do so, the periphery might flourish but the city centres will erode and the examples in Great Britain show us the magnitude of the problems that will come over us then. At the same time, the existing building stock will have to be assessed and redeveloped. That is where the knowledge presented at this seminar comes in, technological and financial knowledge of redevelopment strategies.

Yet, in the last resort, the demand for refurbishment is determined by a building's redevelopment options. If a building is to be preserved and it is economically not viable, there are only two ways. One is to get it designated as a historic monument. The other one is to kill the client. These are the only two ways to do it.

Hans de Jonge is director of Starke Diekstra Holding nv and a professor in Real Estate Management at the Delft University of Technology, the Netherlands. The editor apologizes for not including illustrations, due to these not being available for publication.

CASE STUDIES

do.co.mo.mo



Curtain walls in the USA

Failures, investigation and repair

The curtain wall can be defined as, 'an exterior building wall made of non-load bearing panels that is supported on a structural frame. The curtain wall spans between floors and transfers lateral loads, such as those produced by winds, to the structural frame, while the structural frame alone carries these horizontal as well as all gravity loads.'

Beyond the curtain wall's ability to withstand wind loads, it is also designed to provide light and sometimes ventilation, prevent water penetration, and provide thermal insulation. Of these traits, water penetration is probably the most important.

by Stephen J. Kelley and Bruce S. Kaskel

The advantages of a curtain wall are its light weight, prefabrication, ease of erection, and relative small cost when compared to a traditional masonry wall. To prevent water leakage, glass and metal curtain walls are typically designed with more than one line of defense. The first defense is a 'watertight' /design to keep water from penetrating the exterior face. The second is a series of internal gutters and weepholes designed to collect water which breaches the exterior face and directs it back to the outside. A curtain wall with two lines of defense is referred to as a drainage system.

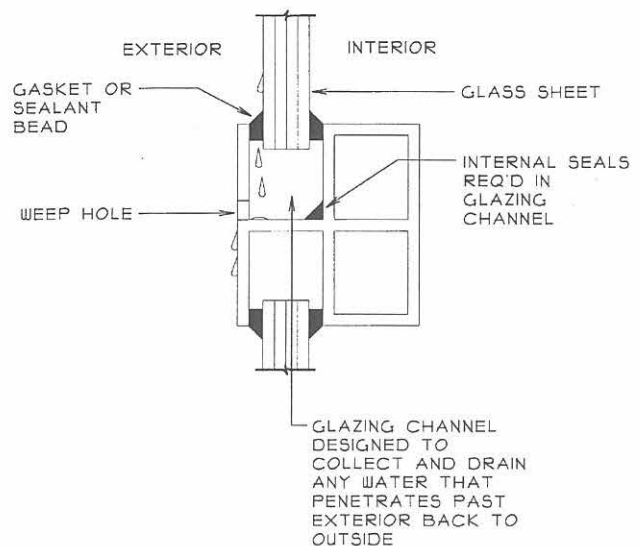
Another concept to achieve watertightness in curtain walls that has become popular since the late 1960s employs pressure equalization. A pressure equalized curtain wall relies upon the inclusion of an interior air space formed between an inner and outer wall of the curtain wall. The outer wall is designed to shed most of the water but is not airtight. The inner wall is designed to prevent air and water tight and withstand pressure induced by wind. The pressure within the interior air space between these walls equalizes to the outside pressure and prevents the build-up of pressure across the outer wall. A curtain wall which does not have a second line of defense (no gutters or weeps) is referred to as a barrier system. A barrier system is therefore, entirely dependent upon the watertight seal.

Water Penetration

The most common problem experienced by curtain walls is water penetration. The following are descriptions of some of the more common causes:

Improper design – Interior gutters may not be designed with enough depth to counteract the force of water driven into the system by high outside wind pressures. The profiles of the curtain wall should be examined to determine if they were properly designed to control wind-driven rain.

Improper installation – A curtain wall employing a drainage system can not perform adequately unless it is properly sealed on the interior. End dams that are



DRAINAGE WALL SYSTEM

The interior drainage or 'weeped' system shown employs internal gutters and weep holes direct leaked water back to the outside of the wall. This system also utilizes the exterior seal of the curtain wall to control water penetration.

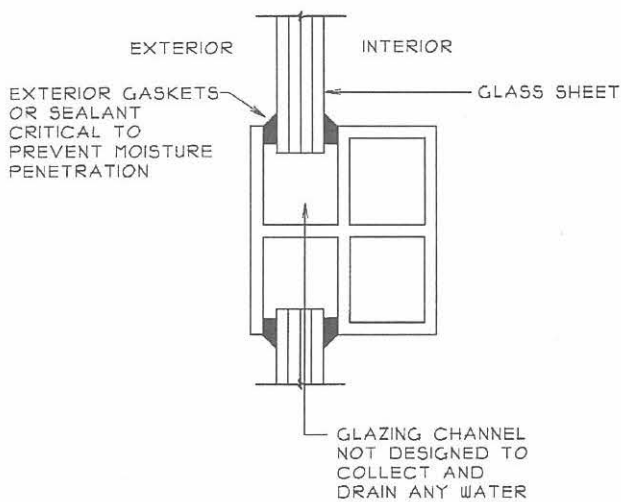
formed in gutters where horizontal and vertical members meet when not watertight are a common source of leakage. Structural connections created through gutter systems are another source of leakage.

Glazing leaks – The joints between the metal frame and glass or other inserted panel is a common point of leakage. In dry glazing systems, glazing gaskets, if installed improperly, will pull away from the corners of the panel allowing an avenue for leakage.

Sealant failures – When contemporary elastomeric sealants are properly installed, they typically are long lasting. Improperly installed sealants – such as those that have 'three-way adhesion' (rather than two-way adhesion) or that are applied too thin or thick – will not be as durable. Sealant that fails cohesively (failure forms within the sealant joint) has either lost its

flexibility due to aging or has been used in a joint which requires greater flexibility than the sealant can provide. Sealant fails adhesively (failure occurs between the sealant and the surface to which it is bonded) if the surface was not properly prepared prior to sealant application, the choice of sealant was inappropriate, or the sealant has reached the end of its service life.

Weatherstripping – Weatherstripping is used in operable window vents within curtain walls as a means of sealing the window frame to the curtain wall frame when in a closed position. Weatherstripping is commonly the first part of a window to wear away and should be designed to be replaceable. Weatherstripping should fit loosely within a receptor



BARRIER WALL SYSTEM

The barrier system shown relies entirely upon the exterior seal of the curtain wall to control water penetration.

in the metal frame so that it can move independently of the frame (Adhesive-backed weatherstripping, held in place with an adhesive, may be effective but will not last as long). Weatherstripping can wear out, shrink away from the corners, or become unattached. Weatherstripping may have been improperly designed, that is not made continuous around the operable vent or improperly sized so that it is not effective when the vent is closed. All of these conditions can lead to leakage.

Thermal break shrinkage – There is a condition that occasionally occurs in aluminum frame systems that incorporate a thermoset plastic break to separate the interior metal from the exterior metal. Shrinkage of this plastic 'thermal break' material can form gaps in the interior gutter systems resulting in leakage.

Improper repairs – It is not uncommon to discover previous repairs which seal weep holes and other joints which were originally provided to allow leaked

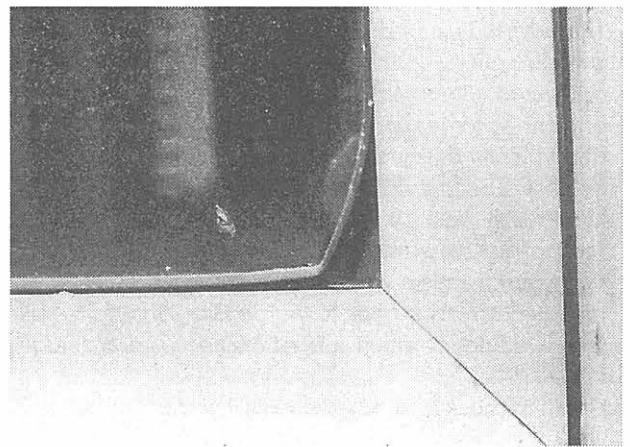
water to drain from the interior of the curtain wall system. When this occurs, leaked water will find another pathway, perhaps into the building.

Air leakage and thermal discomfort

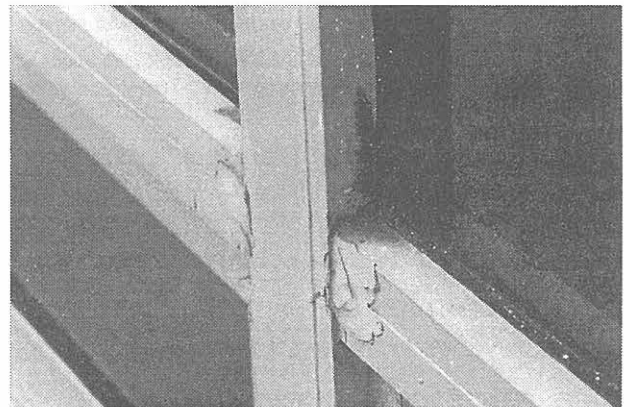
One of the main causes of thermal discomfort with curtain wall systems is air infiltration. Air infiltration is closely linked with water penetration discussed above due to the fact that where air leaks into the building, water can also follow.

The main sources of air leakage are normally around operable window vents.

Condensation occurs on curtain wall systems when climatic conditions are such that water vapor turns to liquid or ice on the interior surface. It is not uncommon for condensation to occur during unusually



The photograph shows a dry glazing gasket which has pulled away from the corner of the window lite. This condition is a typical source of glazing leakage. All photos: Wiss, Janney, Elstner Associates, Inc.



This remedial repair has sealed the weep holes and has rendered the interior drainage system ineffective. This type of repair can cause water leaks that were not previously experienced.

cold winter days in northern climates.

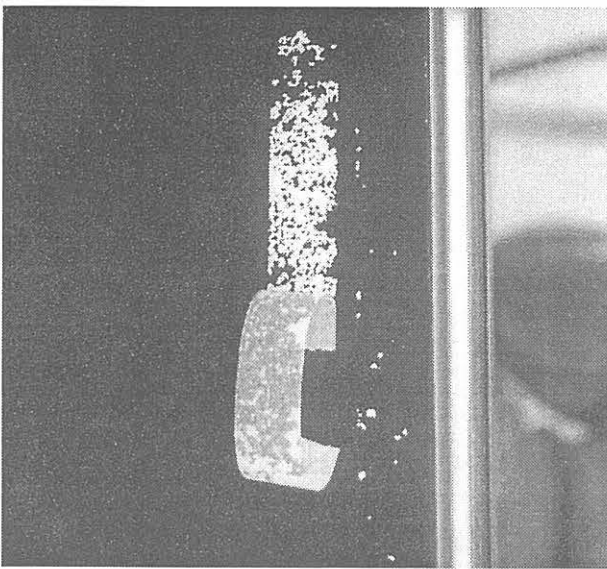
Older curtain wall systems that do not use thermal breaks or insulated glass are more prone to condensation.

They were normally designed with an inside gutter at the base of the curtain wall at each level to collect the

condensate run-off which was then expected to evaporate. Excessive condensation may indicate a poor thermal design, a bridge across a thermally-broken system, or areas of excessive air infiltration. Condensation is also a concern because water run-off can cause damage to interior finishes.

Structural failure

Permanent distortion of the curtain wall system due to wind is rare, although distortion has occurred as a result of earthquakes motions. The more common type of structural failure occurs at connections of the curtain wall to the structural frame. Areas of the building where curtain walls are subjected to high pressures such as at corners or at the tops of tall buildings are more prone to connection failure.

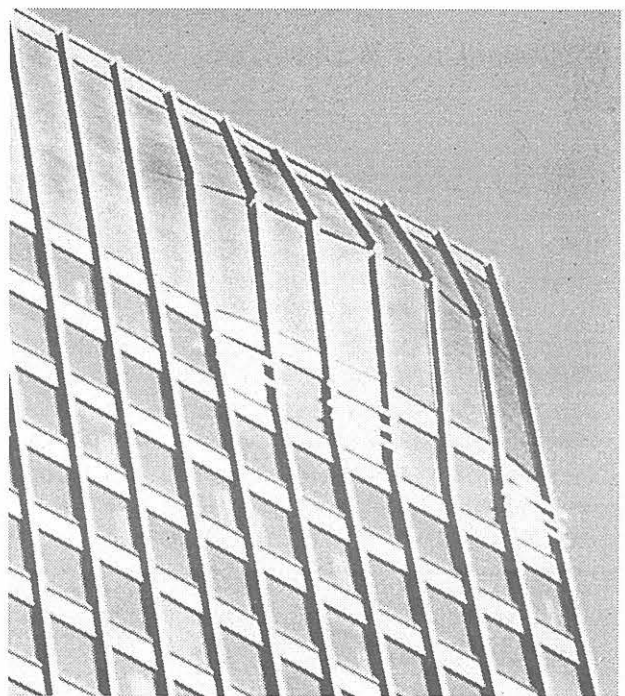


The testing procedure shown (adaptation of American Society for Testing and Materials or ASTM Standard D3359) illustrates failure of a factory applied paint coating due to improper

Material failures

Failure of sealant and thermal breaks were discussed previously in conjunction with water leakage. Aluminum has become almost ubiquitous with curtain walls because aluminum is a relatively inexpensive metal that forms a tough, protective coating of aluminum oxide as it weathers. This coating arrests further oxidation of the aluminum surface. Aluminum anodizing, a popular aluminum colorant, is a factory-controlled aluminum oxide coating formed integrally with or without a dye. Older aluminum curtain walls dating from the 1950s or earlier may not have any protective treatment at all. In these cases, pitting of the frame form as the aluminum oxidizes in an uneven fashion. There is no method to treat this unsightly oxidation, however, pitting of the frame normally does not cause more than aesthetic concerns. Though durable, aluminum is a highly cathodic metal. It can deteriorate through electrolytic action when in contact with anodic metals such as lead, copper, or mild steel in the presence of water. Staining, excessive

oxidation, or frame failure can result if this phenomenon is not accommodated in the frame or connection design. A difficulty with curtain walls composed of mild steel is the tendency of ferrous metals to corrode. Corrosion of the steel frame over time can cause glass breakage, loss of easy operation of moveable parts, and structural failure of the frame. Steel curtain wall systems can last a long time but only if they are frequently and properly maintained. Other metals such as copper, stainless steel, and bronze have also been used for curtain walls. Like aluminum, these metals are extremely durable and may only cause problems with staining as they weather. Peeling or chalking paint coatings on aluminum can cause chronic maintenance problems. Causes for paint failure include improperly selected paint coatings or



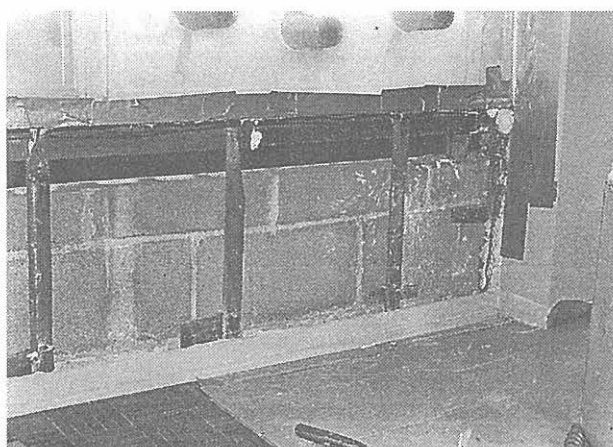
The curtain wall failure illustrated is located on the facade of a skyscraper where wind pressures are the greatest. This failure occurred at the connections that attached the curtain wall to the structural frame.

poorly prepared surfaces that are to be painted. Aluminum surfaces are best painted in the factory where all the variables for a successful paint coating can be controlled. Repair of painted aluminum surfaces in the field must be carefully monitored to approximate these factory controls.

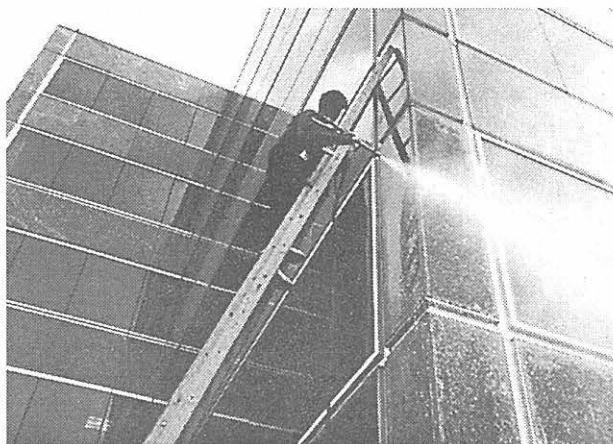
Glass

Impurities in the manufacture of glass have resulted in glass failures. Glass that is heat-tempered can spontaneously break due to nickel sulfide inclusions that expand within the glass some time after fabrication. The expanding inclusions break the glass. Glass can also break when struck by projectiles such as roof gravel or larger building materials during high winds. Glass surfaces can become damaged when

they come into contact with chemicals which are used to treat other parts of the building facade. Glass treatments such as low emissivity and reflective coatings can become splotchy, discolored, or begin to peel. Insulating glass units can fail if excessive moisture collects between the two sheets of glass. Insulating glass units are designed with a hermetic edge seal to prevent moisture access into the unit. However, the edge seal can break down, especially if the unit is subjected to standing water. Panel systems made of composite materials are also a source of material failure. A good example would be a panel encompassing an insulating material sandwiched between aluminum or porcelain-coated steel sheets. Some insulating materials are volumetrically unstable in the presence of moisture and



The interior finishes were removed at this curtain wall assembly to reveal the interior construction. In this case, the inspection opening was implemented in tandem with field testing to monitor leakage into the wall construction.



The testing procedure shown (AAMA 501.2 'Field Check of Metal Curtain Walls for Water Leakage') is one tool used in the field to locate the areas of water leakage or to test repairs.

bowing of the panels can result due to water leakage.

Investigative techniques

Investigating curtain wall problems requires techniques from basic to sophisticated. Basic techniques often help to determine the necessary sophisticated

techniques to complete the diagnosis. Following is a description of investigative techniques ranging from basic to sophisticated:

Document review – The architectural, structural, and shop drawings, and the specifications, if available, should all be reviewed to understand the original intent of the curtain wall. Drawings and specifications can shed light on the relationship of the curtain wall to the structural system, the presence and location of flashings, conditions hidden within the wall, and the type of connections utilized. Curtain wall systems, however, are not always realized in strict accordance with the architectural plans.

Review of previous reports and repair procedures may also shed light on the curtain wall make-up, and



Full scale curtain wall removal and recladding has become a popular repair choice. In this case, curtain wall removal and replacement is occurring simultaneously.

shortcomings in the curtain wall performance.

Occupant survey – After the document review, a general survey of the curtain wall should be performed. In large buildings, the survey may take the form of a questionnaire to which building occupants

are to respond. Data received from such a survey will be qualitative rather than quantitative but can provide insight into problems with the curtain wall. Insight can be gained on the types of problems, their locations, their frequency, and conditions which cause the problems.

Visual inspection – After the document review and survey is completed, the curtain wall should be inspected in detail. The inspection should determine if the curtain wall construction matches the original design documents. Conditions can be determined of all the parts that make up the curtain wall including glazing, frame material, material finishes, hardware, and sealant joints. The operability of window vents can be checked. Locations of water leakage or damage can be viewed. The type and amount of maintenance or repairs, such as paint coats, should be documented.

Curtain wall disassembly – Partial disassembly of the representative components and adjacent construction can reveal concealed conditions. Trim, glazing stops, glass, and hardware can sometimes be disassembled in order to expose connections and flashings. Inspection openings in adjacent walls are typically performed in areas where interior finishes have already been damaged by water leakage, necessitating their repair.

Field testing – If water and air leakage was determined during the inspection or survey, testing is a useful tool to locate the causes of leakage. It is also a useful tool for measuring the effectiveness of repairs. Testing more than one area is recommended in order to obtain representative window behavior. Structural testing can also be performed in the field. In the U.S., standard testing procedures have been defined by the American Society for Testing and Materials (ASTM) and the American Architectural Manufacturers Association (AAMA). Based upon the findings of the investigation, different options may be available to repair excessive air infiltration or water penetration, as described below. Curtain walls can also be tested after repairs are implemented to verify their effectiveness.

Laboratory testing – Laboratory testing of materials and finishes may prove beneficial. Physical properties of the frame material may be required prior to implementing repairs. New and existing paint and sealant samples may need to be evaluated in the laboratory to determine their compatibility with repair treatments. Samples of existing paint and putty can be tested to determine the presence of lead.

Repair techniques

Repair options can range from temporary stabilization to complete replacement. The options are discussed below:

Band-aid repairs – A 'band-aid' can be defined as a short-term solution to water leakage or air infiltration and entail the introduction of sealant to the exterior of the curtain wall. Sealant can be introduced to all metal-to-metal joints, at glazing joints, or where curtain walls abut stone or masonry. Properly designed, band-aids verified by testing can be effective but should be considered temporary.

Selective reconstruction – In a selective reconstruction only those members of the curtain wall which are defective would be removed and replaced with members that are identical or similar. Examples would be the selective replacement of corroded portions of steel frames, reglazing of existing frames, or selective replacement of spandrel glass.

Overcladding – With overcladding, the original curtain wall system is left in place and is clad over with a new curtain wall. The old curtain system can become part of the waterproofing for the new curtain wall or it can be abandoned behind the new wall all together. Overcladding will normally have an impact on the appearance of the building. The increased load of the new curtain wall on the existing structure must be taken into account. It is also important that the connections for the new curtain wall adequately transfer all loads to the building frame.

Recladding – The recladding option has become quite popular with 1950s era skyscrapers and entails complete replacement of the original curtain wall. It is a popular because it allows the building owner to completely update image of the building, as well as install a state-of-the-art curtain wall that will perform better than the original curtain wall. This option, however, is bound to become more controversial as the buildings being clad come to be considered as landmarks.

Conclusion

Curtain wall technology continues to evolve. The result will be curtain walls that are lighter, more economical, and constructed of new materials. This ever-increasing sophistication will present new challenges in preservation and restoration as our new buildings become old and cherished reminders of our building heritage.

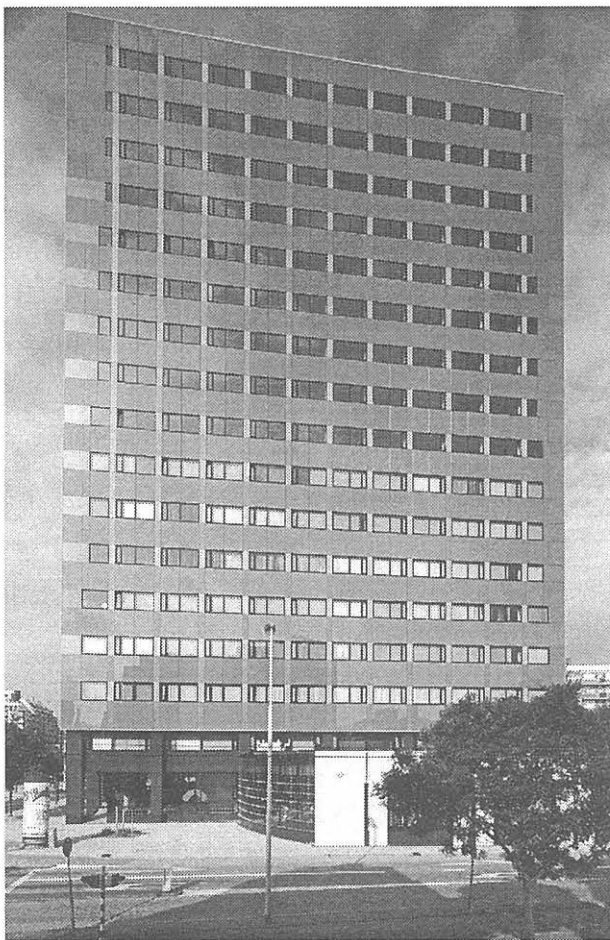
Stephen J. Kelley is an architect and engineer specializing in preservation technology and skyscrapers. Bruce S. Kaskel is an architect and engineer specializing in curtain wall systems. Both work at the Chicago, USA based firm of Wiss, Janney, Elstner Associates, Inc.

Blaak 333 (Kraaijvanger, 1961)

A critical review of a second life

From 1987 until 1992, Kraaijvanger•Urbis architects has been involved in the complete renewal and extension of Blaak 333, a postwar landmark in downtown Rotterdam, Holland. I became a member of the design-team only in late 1988 when the definite design stage was said to be nearly completed. Thirty-one years old and working freelance three days a week for Kraaijvanger, I soon turned out to be the project architect, changing whatever was conceived before. The result can therefore be seen as the product of my imagination, for better or for worse.

by Dirk Jan Postel



Present appearance of the building that now serves as a Rabobank office. Photo: Jannes Linders.



Period photo of Blaak 333 in Rotterdam. Photo: Archives Kraaijvanger•Urbis.

Since its completion in 1992, however, the assessment of the metamorphosis of Blaak 333 has turned for the worse, primarily for two reasons:

- The new facade, made out of point-fixed, heat strengthened glass, proved to be deficient. Although only 6 out of 600 panels actually came down (which in a normal industrial process is an acceptable fall-out) the whole building was wrapped in nets, just two month after the official reopening. I need to say that our office was not to blame, but it is only after

making the awarded Glass Bridge that I can express a certain pride in being the architect not only of one of the most advanced contemporary glass constructions, but also of the greatest glass-disaster in Dutch history. The new fixing bolts –not 'countersunked' but 'built-on'– have reduced the facade to push-pin architecture and are a daily pain in the eye.

- Secondly, and maybe inspired by examples like Blaak 333, we have seen the rising of a fresh appreciation for the heritage of the 'Reconstruction

Period' (de Wederopbouw) that is so typical to war-struck Rotterdam –and to our office. The great benefit of this is the growing awareness for the merits of the existing.

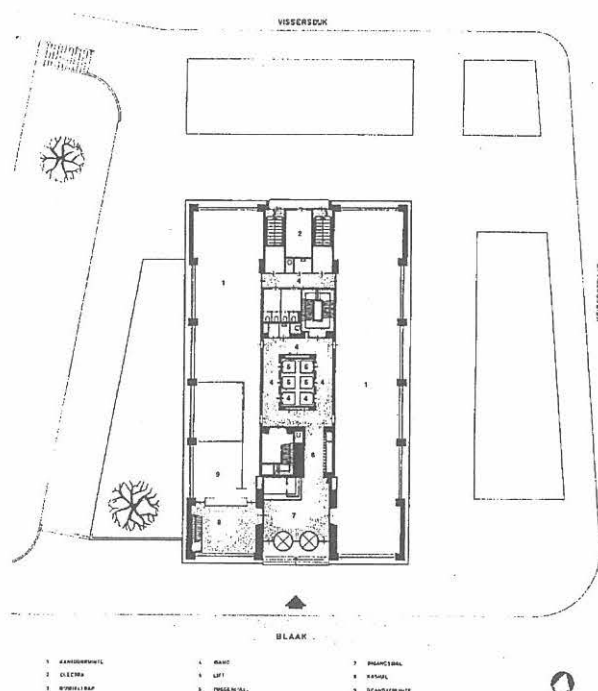
In spite of our increased wealth, buildings of the past are not easily replaced by something better. But the appreciation sometimes verges on nostalgia, neglecting the fact that the relished objects of the fifties often are technical failures that need to be thoroughly changed and revised.

All this is not an apology of the building as it stands today. But knowing what I know now, and being in the position I am in, I would above all challenge the starting points of the project. Namely, that the existing building was not seen as a source of inspiration, but as a structure that was cheaper to renew than to

the building dominated its environment for long. Of course, the building was much too hot in summer on one side and much too cold in winter on the other. An outside sunscreen was added later; the first automatic system in the Netherlands. In all its simplicity, the design of the facade showed a very attractive combination of transparency, depth, and a rich variety of scale. The ground floor design might have been a bit weaker, showing little contrast with the tower above while potentially being the socle. At the street level corners the facade had been closed by two slabs, like blinkers. The interior had become obsolete, with an ubiquitous, musty smell of the fifties.

Operation

The metamorphosis of Blaak 333 consists of four main



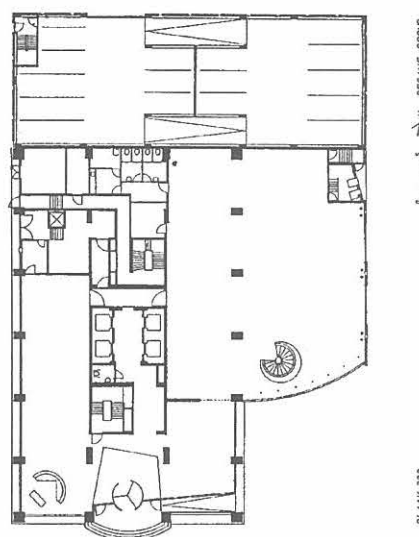
BECAME GROUND

Original ground floor of Blaak 333 (Kraaijvanger, 1961) in Rotterdam. All drawings: Kraaijvanger•Urbis.

replace. And that might be the reason why I am here today at this DOCOMOMO symposium.

Original

The original building –formerly known as 'De Hoofdpoort'– was designed by our office between 1958 and 1961. The concept was derived from the Lever–Sunlight building in New York by S.O.M. of 1952. It consisted of a concrete skeleton structure with free floors around a central core that contained all necessary services. Around this structure a thin, single layer of glass in steel window frames was wrapped, with a system of alternating high and low ventilation lights. Being the first postwar skyscraper in the area,



The present extended ground floor differs quite a lot from the original.

interventions, all of them determined before I became involved:

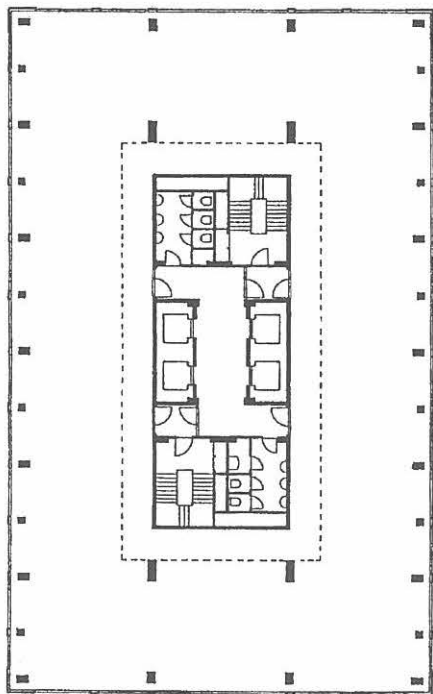
- The replacement of the original facade
- The reconfiguration of the central core, i.p. the elevators
- The addition of three more floors
- The extension of the ground floor on two strips of no man's land adjacent to the building.

This extra floor area contains a parking (for 57 cars), and an extension to the main hall.

With regard to the present theme, the replacement of the facade is the most interesting. But before pursuing this subject, I will briefly address the other parts of the operation. The exchange of two landings and the back-to-back elevators for a central hall with 4 modern elevators is by any standard an improvement. But it was a radical intervention – big toys for big boys. We learned how concrete can be sawn like plywood.

The original structure had naturally strengthened over the years and by means of a light weight prefab construction, the maximum we could add were three

more floors. The critical factor was a large perimeter beam on the second floor that separated the tower from the somewhat recessed socle. This beam allowed for a double distance of the ground- and first floors (from 3.25 m. to 6.50 m.). These columns had to be reinforced by adding prefabricated strips. The extension of the 13-floor building by new floors meant that the penthouse on the 14th floor had to be demolished, much too my regret. It was one of the most peculiar and specific places in Rotterdam, containing a large boardroom and a tiny apartment for the building's concierge. The idea of living on the building you are managing and the shameless smallness of the apartment showed an old fashioned commitment that would deserve preservation. And the penthouse beautifully topped the building. The new plantroom failed to acquire the same beauty –let alone it ever could have functioned the same way. I should



Typical floorplan after refurbishment.

have realised that the modern way of going about is to integrate the plantroom in the main volume. The extension of the groundfloor offered an interesting architectural problem: how to connect to a tower, that is by definition a stand-alone. The problem is solved by cladding the new volume with a well-detailed glazed brick wall. This wall is detached from the tower by a curved glass wall on one side, and the more graphic sloping masonry line on the other. The building has become 'anchored' in the urban setting, following the parcelling lines of the site. This results in an interesting sequence of spaces, widening from the Keizerstraat too the large open axis of the Blaak. The new ramp behind the old structure plays a crucial role in this, as well as the enhanced transparency of the ground floor in general. The fact that the available money has been directed towards the low rise parts

–'where you can touch the building'– does show off. The contrast between high-rise and socle has become greater, also by the reinforcement of the main columns, fulfilling the potentials of the original design.

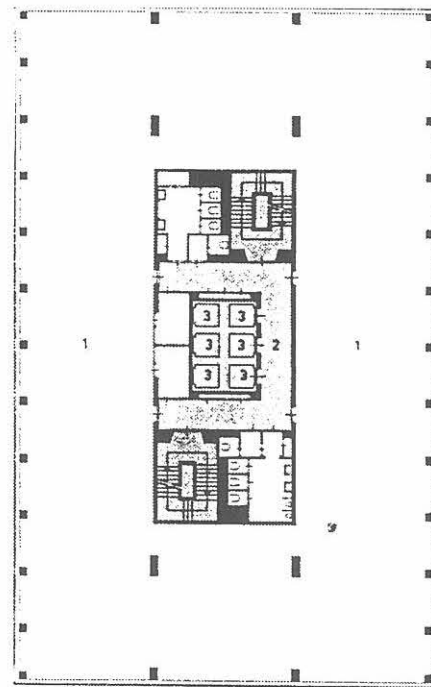
Facade

Back to the facade of the high rise. The three demands were:

- light weight, which prevented any concrete panel to be applied
- cheap, which excluded a curtain wall or a double skinned 'climate facade'
- 30% windows, with a ZTA (Total Solar Energy Transmission, in absolute value) of 0,39.

This indicated the use of reflective glass and made the original transparency virtually impossible.

The contractor –who was also the client– had gone one step further. He proposed the total concept of the



Floorplan of 7th floor showing a different elevator block and office layout.

facade: a light weight Eternit panel, insulated and waterproof, with a cladding of enamelled glass panels, point-fixed to aluminium strips. I personally liked the glass and began the design.

At first we started along the wrong track, since a well known building management group had produced a well paid advice to the client to design according to the 1.80 m. standard, which led to great difficulties in relation to the existing structure of 3.25 m. We found out the rooms were not 5.40 m. deep but 6.10 m., resulting in the 20 m² and 30 m² units that building management groups put in their standard programs; so in the end everybody was happy in keeping the original 3.25 m. structure.

The light weight panel suggested a system of holes in a plane facade, like a series of television screens. The

final composition consists of 4 elements: the window, the parapet, the strip between the windows and the strip in the parapet. The latter two just cover the column behind.

The parapet is made of grey enamelled float glass, the strip in between is of the same colour but of a different texture (crepy, looking like an orange's skin). The strip between the windows represent the only colour: glass-like turquoise. For the window we tried to come close to a normal transparent glass –that is: as far removed from reflective glass as possible. It has been a long fight, since the technical advantages of reflective glass are evident. We won, but before the building was finished the municipal Review Commission for Architecture had banned reflective glazing altogether, so it looked as if there had been no fight at all. The solution came from lightly tinted green glass that combined a sufficient ZTA with a high

The horizontals are evident in almost any office building with 30% windows, but the vertical had to be created by the alternating strips of crepy and turquoise glass. Because of the neutral grey and moreover the crepy surface, the facade changes with weather conditions and the hour of the day. This dynamic, or rather chameleon-like feature must be known to regular passers-by. The corner windows become smaller the higher you go. This gives a twist to your perception of the tower, that seems to lean towards you. Basically the idea was to replace the literal transparency of the original –that means in reality looking into a shallow space of max. 50 cm deep– by a virtual transparency, where columns were 'showing through' the outer enamelled skin. So, after all, the main architectural theme of the building remained the same, i.e. the wrapping of the structure in a thin layer of glass.



Present appearance of the building. Photo: Wessel de Jonge.

transparency, while avoiding the greyish veil from inside. Today's glass technology with invisible coatings has advanced incredibly in only five years time, and could possibly have provided the same characteristics without tinted glass by now.

The effect we pursued was to express both a horizontal and a vertical articulation of the facade.



Close up of the new curtain wall. Photo: Wessel de Jonge.

Conclusion

Blaak 333 has turned into a completely new building that works much better than the former one. Its climate and inner logistics have improved dramatically. I believe the lower level –the socle and the extension– is much better now than before, both architecturally and from an urban point of view. For the tower I regret the loss of depth and the balance in the various dimensions of the old facade. In spite of the attempt to maximize the set back of the windows from the enamelled skin, the facade remains 2-dimensional. Had the original facade been exploited as a source of inspiration, we might have considered applying a framework that would have mediated between the scale of a window and the total block.

Perhaps most important –as in any project– are the very first starting points:

- Can the old inspire the new or does it deserve preservation?
- Does the composition of the building team allow sufficient influence for the designer; and room for an open process and necessary research?
- Are there any technical demands that determine the

result and that might have to be challenged? (In case of Blaak 333 the standard 30% window ratio).

I'll conclude with an example of a renewed facade in one of our projects, where the architectural quality of the building made, referring to –or even keeping to– the original, an obvious demand: the Waldorpstraat Postoffice in The Hague (1986–89). Technically, the facade had to be replaced completely. In changing the function to offices the need for more windows arose. Here, the larger glass brick areas were changed into windows and vice versa. When assessing the design, the Architectural Review Commission of The Hague asked why we had submitted similar drawings for existing and new, which was a proof of the success of this intervention.

This is not to say that keeping to the original is better than replacing it *tabula rasa*. But the choice should be a conscious one. Once that choice is made it doesn't matter what you do, but how you do it.

Dirk Jan Postel is an architect with Kraaijvanger•Urbis in Rotterdam.



Waldorpstraat Postoffice in The Hague (1986–89). Photo: Sybolt Voeten.

The Rijnhotel (Merkelbach & Elling, 1957)

An approximate image

The former Rijnhotel is one of the most outstanding examples of post war reconstruction architecture in Rotterdam, Holland's second large city that was heavily damaged in the first days of war in 1940. The building has been designed by Ben Merkelbach and Piet Elling in 1957 and is an outstanding example of *Het Nieuwe Bouwen*, the Dutch interpretation of the Modern Movement. Apart from the hotel, the original complex accommodated as well a youth association in a separate wing, that has recently been respectfully refurbished.

by George Köhlen and Leon Wolters



The west end facade of the office wing of the Rijnhotel after refurbishment. The filigree character could be recreated, including the loggias. Photo: George Köhlen.

The Rijnhotel is located on a remarkable site at the perimeter of the reconstructed city centre. Before the recent refurbishment started, the complex looked like a set of individual buildings designed by different architects, due to earlier renovation works. The original scheme consists of four components in a perpendicular lay out:

- to the north, a hotel in a 10 storey high rise, on top of a large substructure containing restaurants and conference facilities;
 - to the east, a 3 storey volume with two service apartments;
 - to the west, a 6 storey office block for the youth association AMVJ on a very narrow footprint;
 - a long volume along the Mauritsweg to the south, for sports facilities and a theatre, today in use as a music library and a cinema.
- The recent renovation works concerned the east and west wings of the building.

Historic perspective

The entire complex has a loadbearing frame of reinforced concrete. The original facades were constructed with a steel and glass curtain wall, that seems inspired by the Lever House of 1952. The proportions of the curtain wall were very characteristic for early post war architecture, with single glazed vision panels for the upper two thirds of each floor height, and a coloured glass spandrel panel for the lower third. The use of glass for the spandrels, before an insulated parapet of brick, created a sense of continuous transparency over the full surface of the facade. By using outside glazing, the slender lines of the standard steel frames of the windows were very prominent, which gave the facade an open character and an outward orientation. The mullion profiles were a bit wider and projected outward. In daylight these vertical ribs created a very sensible articulation and accentuated the filigree character of the curtain wall. The first floors of the various wings were connected. In the substructure along the main street, some space was left for a terrace and a side entrance for the offices. Therefore, access to the office building was provided without necessitating another entrance in the narrow end facade of the office block, that is set at a right angle with the street. This allowed the architects to continue the facade construction over the full height of the building, including the ground floor. The end facade of the office wing is enclosing a series of loggias and therefore completely open. The loggias are trapezoid in plan and illustrate the

conflict between the rational lay out of the building and the limitations of the extremely narrow site, and are therefore valuable in a historic perspective.

Contrasting views

The hotel wing had been renovated already in 1987, when the curtain wall had totally been changed. The proportions of the vision panels and the spandrels were reversed to reduce energy consumption. A new curtain wall has been constructed with flat profiles without any relief on the outside. Double glazing with a sun protective silvery coating almost matches the silvery finish on the metal spandrel panels, depriving the building of its transparency.

The result is a closed and totally flat facade, that

contrasted sharply with the original office wing. As refurbishing architects we had to take the present state of the hotel wing into account, because it is so prominently placed. The question was if it would make any sense to propose a conservative restoration for the office wing, when there had already been such radical changes elsewhere. Eventually, our conclusion was that this remarkable example of post war reconstruction architecture in Rotterdam had to be respected.

It was therefore decided to restore the image of the original curtain wall. The idea was that two different views on refurbishment within one structure might create an interesting contrast just as well. The client could be convinced mainly with the argument, that this

The Rijnhotel in 1957. The hotel wing is remarkably transparent, a quality that has been lost during a 1987 renovation. In the middle, the side entrance to the AMVJ offices. To the right, the theatre and sports hall. Photo from *Het Nieuwe Bouwen in Rotterdam 1920-1960*.



approach would give the best chance for short permit procedures.

An approximate image

The brief was to design a new facade proper for the building's commercial use, that would require a modest investment in order not to undermine the excellent market position as a building on a top location yet with a modest rent level. This meant that the thermal and acoustic performance of the building had to improve, and that double glazing was therefore required. Given the systems for curtain wall constructions available today, some ranges of aluminium profiles that are especially produced for renovations seemed the best choice. Although these profiles have a thermal break, they are still rather slender. Due to their typical geometry with a slanted front, their appearance reminds the old putty glazed fenestrations. In this phase, a facade construction

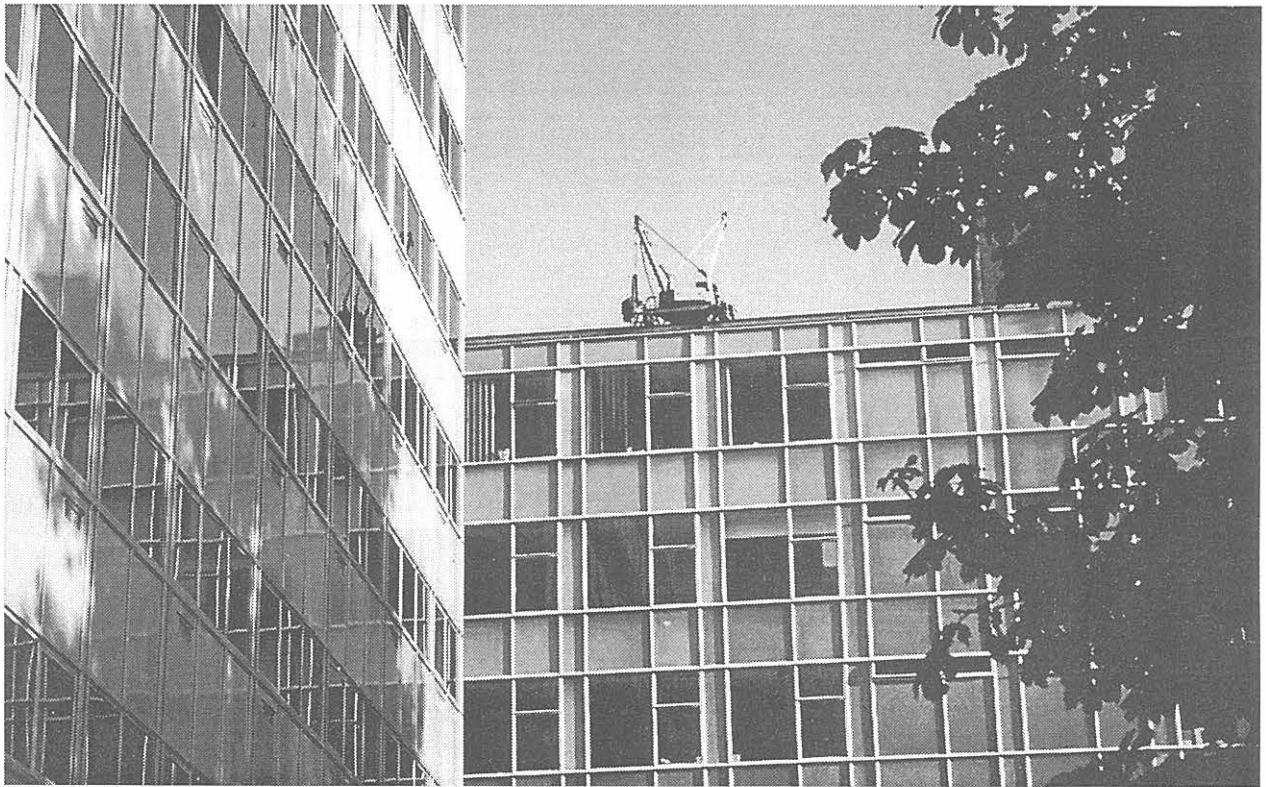
applied techniques for assembling and surface treatment of aluminium ensure reliability and a high performance over the years. The prerequisites for a successful refurbishment can be summarized as follows:

- the value of the property is recognized;
- an interactive process is initiated and sustained between supervising authorities, client, architect and facade designer;
- dedication, creativity, knowledge, perseverance and respect are beyond questioning;
- the property itself is large and has a sufficient degree of regularity to allow for custom solutions at reasonable costs.

Yet, it is obvious that exact imitation of an original steel curtain wall in aluminium is an illusion.

A suitable profile series was selected according to the following criteria:

- visual similarity with the original steel windows;



The original facade was very open, with two third transparent glass, and one third coloured glass for spandrels. The 1987 curtain wall, to the left, is extremely flush and has only one third vision panels. Photo: Wessel de Jonge.

company was involved in the planning process. We assessed our main task to arrive at a result, that could probably best be described as an approximate image.

Profile

For these purposes, aluminium has some decisive advantages over steel.

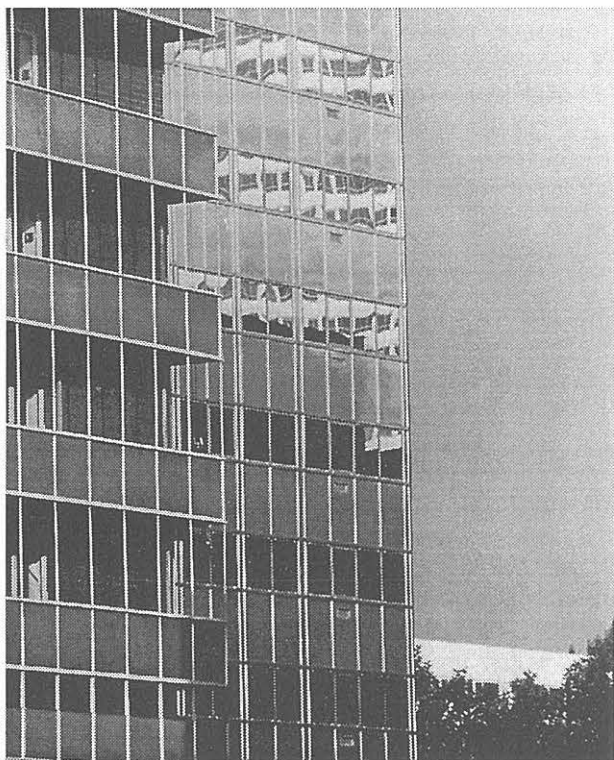
The production of aluminium through extrusion ensures precise and stable dimensions, and allows for freedom and a high sophistication in geometry at relatively low costs. Air and water penetration can therefore be controlled easily in the rebates. Also the

- technical similarity with current systems to ensure easy production;
- suitability for large casements;
- proven quality and availability;
- support by provider in view of guarantees etc.;
- flexibility to respond to custom requirements.

In view of the last item, some specific circumstances had to be taken into account for the project, for instance at the loggias and for the sunscreens. Outside glazing is today unusual for high rise buildings, but decisive for the appearance of the Rijnhotel. This required a specific geometry of the section.

A darker shade of grey

For the architecture of the new curtain wall two aspects were of prime importance. The first was to maintain the continuous band of parapets, defined by horizontal lines at floor level and at the window sills. The other main concern was to keep the vertical ribs that create the filigree like appearance of the facade. A conflict with the client arose as he required to have the loggias closed to avoid pollution by the pigeons. Fortunately, we arrived at an agreement with him and the municipal Review Committee for Architecture and Conservation, by closing off the loggias at the east



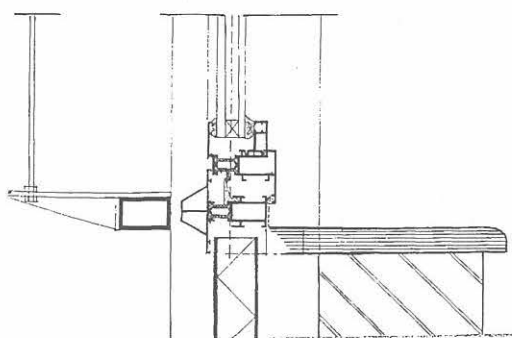
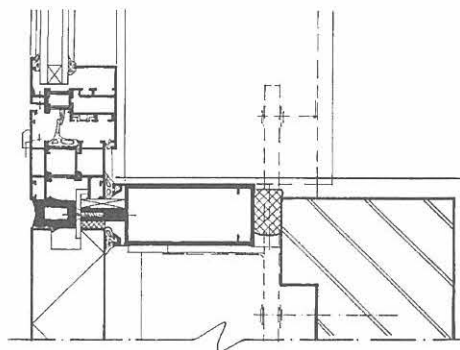
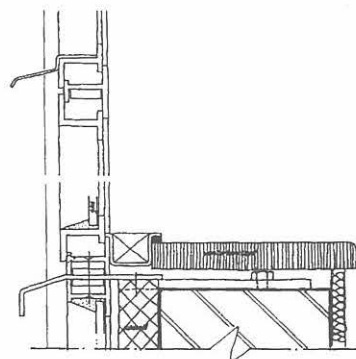
The original loggias in the foreground, compared to the 1987 facade in the background. Photo: Wessel de Jonge.

end of the block, but leaving them open in the much more prominent west facade. The open loggias posed some very specific technical problems as some facade elements had to be left unglazed.

By choosing for clear glass and keeping two thirds of the facade for vision panels, we could recreate the original transparency, but we had to avoid overheating by the sun at the south facade. Therefore, the Venetian blinds that were installed there had to be redesigned to improve their effectiveness. The suspended construction for the sunscreens made custom made solutions necessary. To avoid early effects of pollution, the original white colour of the steel profiles was changed to light grey. In order to maintain the original graphic effect, the spandrels had to change from light to a darker shade of grey.

It looks the same to me...

As a whole the job was an exercise in sustaining a subservient attitude, which is in our opinion a



Top to bottom: Vertical section through the sill of the original facade of 1957, the 1987 renovation, and the recent refurbishment. Drawings: Wessel de Jonge.

necessary condition when dealing with such architecture. When our client visited the works one day, he asked: 'what exactly did you do, it looks still the same to me.' Of course we took it as a compliment.

We hope that the results of our work will serve as an inspiration to again refurbish the hotel wing in a similar way as we did with the office block. Then, the centre of Rotterdam will again be enriched with the full qualities of Merkelbach and Elling's architecture of the 1950s.

George Köhlen is an independent architect in Maastricht, the Netherlands. With Leon Wolters, director of ASW Facade Constructions in Weert, the Netherlands, he has been in charge of the refurbishment of the Rijnhotel.

Text rewritten by the editor.

City Savings Bank (Tvarozek, 1930)

Slovakia's first curtain wall refurbished

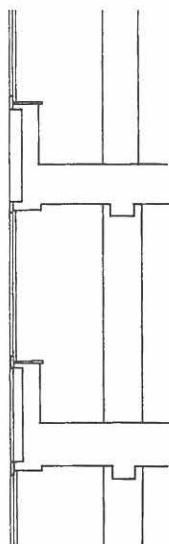
In 1930 a branch of the City Savings Bank was built in Bratislava, after a project by the Slovak architect Juraj Tvarozek (1887–1966). Although never graduated from any architectural university, Tvarozek significantly contributed to the introduction of modernism in Slovak architecture. This bank was the country's first structure featuring a steel and glass curtain wall: an unprecedented construction in prewar Slovakia. Assessing the qualities of the building, period literature concluded that 'the future belongs to functionalism'. At the time, it was considered to be the most progressive construction in Bratislava and it has therefore been crucial for the Modern Movement in Slovakia. Even today, the building still gives a fresh and modern impression on its urban context.

by Matúš Dulla, Henrieta H. Moravčíková and Elena Stolicná

The City Savings Bank in 1995.



In the mid-1920s, Tvarozek tried to introduce a Slovak national style, based on traditional architectural elements and decorations. In Bratislava, we can still find several of Tvarozek's buildings with painted vaulted portals. Also the first project for the City Savings Bank was based on classic forms. Disposition and mass structures within the building were quite strictly limited by the client's requests and urban architectural requirements. The lot was quite narrow and the new volume was supposed to include a deep passage also. The architect segmented the facade by small windows, framed by mouldings. The ground floor was the only part of the building to have some large openings, yet still designed in a traditional monumental style. The front side was decorated with an impressive cornice. This concept was very similar to solutions presented by the architects F. Wimmer and A. Szonyi, who also entered for the bank's competition in 1928. Tvarozek, the winner of the competition, however implemented a more modern concept in 1930 and radically changed the idea of the facade. His solution of a curtain wall had never been used in Slovakia before.



Section of the main facade. Drawing by the authors.

Engineers aesthetics

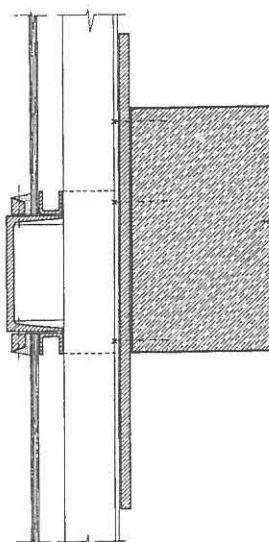
The front facade of the City Savings Bank is a typical example of an engineer's aesthetics, when a professional from the constructional discipline creates a composition with a harmonious effect. The building's exceptional merit is anchored not only in pure technical solutions of high quality, but just as well in being the country's earliest example of the curtain wall system. The sophisticated simplicity of the construction perfectly met the special requirements posed by the bank's board in terms of hygiene and efficiency. The demonstration of progress in the facade expresses the young financial company's commitment to invest in experiments.

The loadbearing construction of the building consists of a plain reinforced concrete frame with rib-shaped floor slabs. The building's spatial firmness is secured

by reinforcements and perimetral beams. Infills and partitions are constructed from Aristos hollow brick. At the front side, a series of 1,15 m consoles project from the frame construction. The consoles, together with concrete columns between the windows and the brick infill for the parapets constitute the inner construction of the envelop. A steel framework on the outside has an infill of Miropax panels, a non-translucent, opaque type of glass. For the City Savings Bank, both white and cream coloured Miropax are used. In addition, the red-brown steel frame of the facade contains steel framed window sashes according to the Kraus system, a patent of Kraus and the architect Weinwurm, deposited in Bratislava in 1928.

Glazing changed

The steel frame of the curtain wall is suspended from the main construction. A primary structure of mullions consists of a series of double L-profiles 48x48x5 mm. In between the two profiles is a joint plate of 180x100x7 mm, that is welded perpendicularly to another steel plate of 410x110x8 mm. The latter are



A vertical detail of the anchoring of the suspended facade frame. Drawing by the authors.

anchored to the concrete construction where the verticals meet the horizontal perimeter beams of the parapet. To the outer end of the joint plates, large U 100 profiles are welded horizontally. These transoms create a strong expression of horizontal segments in the facade. The transoms receive the 6,2 mm Miropax glass panes in a rebate that is created by welding smaller U profiles on the outside of the U 100. The glass is then fixed by small 11x14 mm beads. Despite its proper dilatation and the sophistication of the static solution, the facade of the City Savings Bank was damaged by chemical and mechanic forces in the course of time. The steel framework corroded and pollution caused the glass panes to break and fall down. In 1992, the glazing had therefore to be changed for new Chodopak panes, that have a similar

appearance. The steel windows of the Kraus system had a non-traditional opening mechanism. They opened to their central axis and were fitted with a ventilation supply opening in the upper part. With the recent refurbishment the windows were substituted by PVC ones, that are optically similar. Although some construction details were changed, the framework that is so typical for the facade, remained the same.

Unique furnitures

In addition to the bank hall and office space, there were as well some rented shops and apartments in the building. The structure has six floors and a basement. The ground and first floors cover the entire lot and include a partly day lit passage over the full length of the building at street level. The passage led to the centre of the building and made the ground floor accessible to the public. Two higher volumes with office floors rise out of the lower section, one at the street side and another one in the courtyard. The day lit bank hall is situated in between them, on the first floor in the centre of the building. The hall is covered by an arched glass-concrete roof, that has been a typical feature of Central European bank architecture since the times of Wagner's Post Savings Bank in Vienna.

The interior of the building was decorated by unique furnitures of a simple modern form. The architect used thin panels of so called golden onyx as a component for banisters and as a cladding on one of the walls of the entrance staircase. When seen against the light, the panels create an impressive effect of yellow hues.

Passage reconstructed

The building still serves its original purpose although the City Savings Bank was transformed into the Slovak Savings Bank. The interior of the central hall has been refurnished with a new equipment in 1975. However, the original character has been relatively maintained by the architect S. Brezina.

The passage had to undergo the most radical reconstruction. The passage had never been extended to adjacent lots, as was originally intended, and therefore it was not used by the bank. After it had been closed for a long time, the passage was finally renovated by the architect J. Danak and returned to its original purpose in 1995. Some of the bank offices can now be entered through the passage. Still, this new architectural concept seems to respect the simple, but brilliant character of the original building and its interiors. Preparations for a reconstruction of the interiors and a construction of new rooms at the rear of the lot, designed by the architect J. Bahna, are currently taking place. This reconstruction is as well supposed to recover the original appearance of the main hall, as it was in 1930.

A noble experiment

At the time, the new building of the City Savings Bank was glorified by a professional press. The magazine

Slovensky Staviteľ ('Slovak Builder') presented a detailed review, emphasizing the fact that Slovak architecture succeeded to create the country's first modern building with functionalist features. According to the magazine, nobody had believed in such a project even two decades ago. In keeping, all pioneers of functionalism were mistrusted. In his publication on the new building of the City Savings Bank author A. Horejs stated, that Slovakia successfully overtook advanced Czech architecture by this work and 'achieved the contemporary architectural image of the rest of Europe'. The City Savings Bank is compared to similar constructions built in the Czech lands, such as the Bata department store in Prague and the Avion Hotel in Brno, both by B. Fuchs, and the Morava Bank in Brno, that Fuchs designed with E. Wiesner. The building of the City Savings Bank is said to be a courageous and noble experiment, that 'helped architecture of one nation get very close to the newest creations by the rest of the world'.

Matús Dulla, Henrieta H. Moravčíková and Elena Stolicná are all working at the Department of Architecture of the Slovak Academy of Sciences, and are members of DOCOMOMO Slovakia.

Literature:

- 'Mestská sporiteľňa v Bratislave' ('City Savings Bank in Bratislava'), *Slovenský Staviteľ*, 2, 1932, 3, p. 69–79.
- A. Horejs, Z. Rossmann and J. Tvarozek, *Städtliche Sparkassa* (City Savings Bank in Bratislava), Bratislava 1932.
- L. Foltyn, *Slowakische Architektur und die Tschechische Avantgarde 1918–1939* (Slovak Architecture and Czech Avantgarde 1918–1939), Dresden 1991.
- J. Bahna, 'Mestská sporiteľňa v Bratislave' ('City Savings Bank in Bratislava'), *Projekt*, 32, 1990, 4, 18–20.
- *Moderne Architektur in der Slowakei. 20-er und 30-er Jahre* (Modern architecture in Slovakia. The twenties and the thirties), edited by S. Slachta, Bratislava 1991.
- DOCOMOMO Slovakia, *Top Register – Slovakia, 1st proposal*, edited by K. Kubicková, Bratislava 1994.
- S. Bartková, 'Mestská sporiteľňa' ('City Savings Bank in Bratislava'), *Architektúra & Urbanizmus*, 29, 1995, 1–2, 54–59.

St. Cuthbert's (Marwick & Sons, 1936)

An early curtain wall

The 1937 extension of the St. Cuthbert's Co-operative Association Department Store at 28–32 Bread Street, Edinburgh by Thomas P. Marwick and Sons introduced one of the first curtain walls of glass into Scotland. It is of some significance now due to the survival of the original glazing and mullions.

by Suzanne Ewing



St. Cuthbert's Co-operative Association Department Store in Edinburgh, designed by Thomas P. Marwick and Sons in 1936. Photograph taken shortly after completion of the building. Photo: British Architectural Library, RIBA, London.

Client innovation

Neighbouring by four storey stone *palazzo* buildings (of 1892 and 1914) and with a plain rendered brick rear extension, the four storey infill block has its principal facade to the south side of a built up street south of Edinburgh's historic centre. The new building was constructed of a steel frame with pre-cast concrete floors to allow maximum useable showroom space. The expanding department store, already occupying the adjacent buildings, wanted an area of flexible space to be used as new furniture showrooms. Lift and stairs were located to the south west corner with ground floor access to other areas of the

department store. The ground and basement floors later housed a footwear salon.

The client chose a suitably innovative architectural solution to express the 'modern' aspirations of both a developing building type, the city Department Store, and also the democracy of the Co-operative Movement. Drawings of the Bread Street elevation with conventional windows in a masonry wall facade were superseded in 1936 by the present design. The expression of the facade as essentially an oversized window stood apart from contemporary department stores developed elsewhere in Edinburgh, for instance, Jay's store, Princes Street, by the same architects. Similarities with the St. Cuthbert's facade can be seen at the Peter Jones Department Store, London (Slater and Moberly, 1936) and in particular at the Bila Labut department store, Prague (Josef Kittrich and Josef Hruby, 1937–39). The latter elevation is also composed of a massive central 'window' with a glazed grid of obscured and clear glass panels. A subsequent department store also developed by St. Cuthbert's Co-operative Department Store in Clerk Street, Edinburgh, utilized a curtain wall facade in a similar situation to the Bread Street showrooms.

Technical innovation – glass skin/bronze sashes

Technically the Bread Street showrooms displayed an innovative use of a complete glass skin in an urban situation, overcoming the limitations of a long, narrow north facing site where neighbouring premises prevent any sunlight reaching the facade, while also meeting the principal criteria of the brief: to maximize visibility of showroom goods from the street.

To the Bread Street facade, the narrow flanking piers and parapet around the central curtain wall 'window' are of brick construction, faced with grey granite in banded courses. Bronze sashes are cantilevered from the structural steel framework with attachments to stanchions and floors at regular intervals. The soffit of the continuous bronze canopy to the top of the curtain wall provided a facility for floodlighting the facade. The original shopfront below comprised plate glass, stainless steel and bronze components. Unfortunately the distinctive external cellulosed finish sign lettering above the entrance has now been replaced.

The architectural language of the exterior was

unashamedly 'modern' with the slightly projecting large glass wall appearing to float on the stone trim of the surround. The detailing and grid of the curtain wall, subdivided into 12 panels horizontally and 9 panels vertically, with its physical fixings to the proportionally related internal structure combine with the lit panels in the canopy soffit to link the exterior and interior. A transformation of the two dimensional exterior grid of the facade skin was achieved as it visually extended into the primary structural frame to become a coherent expression of the flexible, accessible spaces inside, particularly successful when the showrooms were lit at night.

Current condition

Unfortunately alterations to the facade (1961, 1964 to the shopfront, entrance doors, replacement of external signage lettering; 1988 general alterations and painting of portions of the glass curtain wall) coupled with change of use to a Paintball Warfare Centre leave current perceptions of the building dulled and negative. The 1937 facade is at present Category 'A' listed and any future development which recaptures the original's daring and unashamedly 'modern' vision for transparency between building and street, fusing exposed frame structure, interior open space and exterior skin through the materials, detailing and integrated use of lighting would be very welcome.

Suzanne Ewing is a member of the DOCOMOMO Scottish National Group.

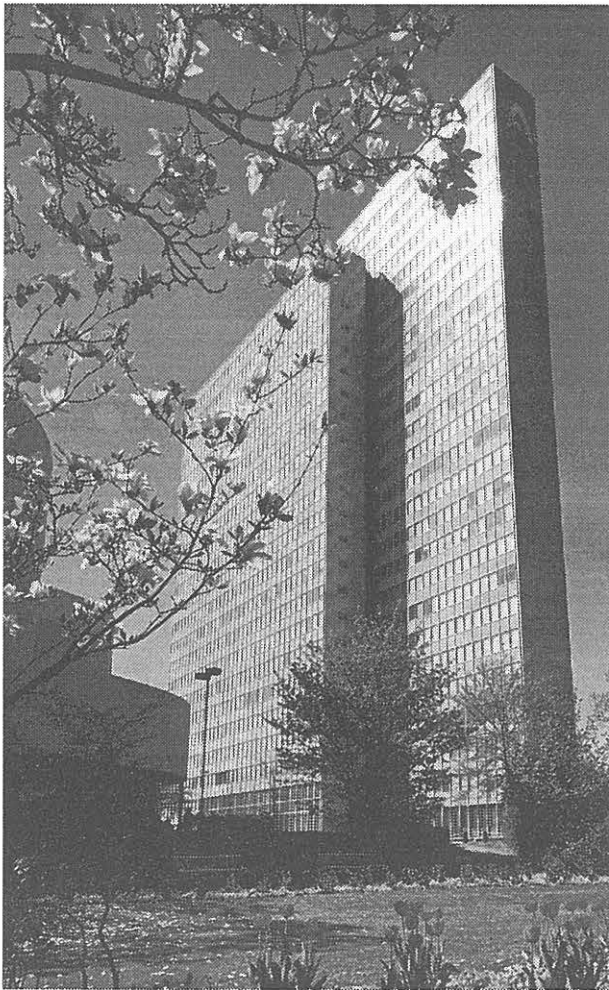
The Thyssen Haus (HPP Architects, 1957)

A curtain wall replaced from head to toe

For the city of Düsseldorf it is a landmark, and for architects probably the best known high rise office in Germany: the 96 m. high Thyssen Haus. Recently, the complete refurbishment of the 24 floor building has been completed.

Also the Thyssen high rise became well of years and repairs became frequent. At a certain moment, repairs were no longer sufficient and the building had to be renovated from the bottom up in order to secure its durable preservation. Apart from the more common financial and technical issues, questions of architectural history played an important role in the decision making for the renovation of this icon of postwar modern architecture in Germany.

by Eberhard Zerres



Despite a complete renovation of the building two years ago, this icon of postwar modern architecture still radiates its original splendour. Photo: Thyssen AG (1994).

The Thyssen Haus was built in the late 1950s and soon, the Düsseldorfers lovingly nicknamed it the Three-Slab-Building ('Dreischeibenhaus'). Even after 40 years, the high rise with its steel-and-glass elevation appeared ultimately modern. But time had

not passed by without leaving its traces.

A professional diagnosis was not quite encouraging. The facade did not meet current standards as regards building physics nor technology. Loud raps made one aware of the thermal expansions in the facades. After forty years, the air-conditioning system nor the fire security system came up to present requirements. Moreover, there were two complicating factors that were decisive in the preparation and execution of the renovation of a commercial building like this. The first was, that the works were to be executed while the building would be in use. The other was that the demands of the Department for Conservation had to be respected, since the building is listed as a historic monument. Permit procedures were therefore complicated and strict, but adequately anticipated while planning the project.

Historic elements

The elevations, the false ceilings with continuous ribbons of lightfixtures, the colour shades of the columns as well as the appearance of the entrance hall of this commercial building could not be changed as a result of its designation: a true challenge for any architect.

The renovation works were planned by the architect Thomas M. Fürst of Hentrich-Petschnigg & Partners KG from Düsseldorf, the firm that had originally designed the Three-Slab-Building in 1957. The ideas and architectural conceptions that had produced the original building were carefully traced back. Drawings were recollected from the company's archives and extensively studied. The aged architect who had originally designed the Thyssen Haus provided a unique source of information through a series of interviews.

On the other hand the range of defects that occurred in the building were recorded and analysed. The performance of the structure was compared to the various technical standards of today, that have gone through enormous changes since 1957. It turned out

that windows, air-conditioning, interior partitions, the complete systems for electricity and communications, as well as the underground parkings were completely to be renewed.

Functional environment

The renovation could only be successfully achieved by matching innovative technology with creative architecture. The integral design of the project allowed for an interaction between architecture and technology. Modern technology allowed all participants to take part in the planning process right from the start, without restricting the architects in their creative process. Their engineers calculated the light capacity, thermal balance as regards heating and cooling, and the conditions to maintain a comfortable interior climate, and provided the architects with the essential data to decide for a further increase of the building's functionality.

To ensure the appropriateness of numerous individual solutions, a series of detailed computer calculations and experimental tests were necessary, amongst others to verify the energy efficiency of the new facade. As a part of the test programs also the expected air circulation in the rooms was determined, as well as the temperature gradients, heating and cooling capacities, and so on. The engineers figured out how to design the infrastructure of the office floors in such a way, that office space might be rented out in small units in the future, without necessitating extensive changes in the building's energy and communicational systems.

Constructional defects

The steel frame of the building adds up to a total of 2,400 tons. Above all it is the way that the slender and tall structure, that has to withstand enormous windloads, is stabilized that stands out still today as a masterpiece in architectural and constructional terms. The 1,200 tons windload on the 8,000 m² main facades are transmitted to the foundations by cross-braces in the building's steel skeleton. These statically vital features have now been fire proofed with F90, a special product that is commonly used in offshore structures.

For the renovation, the complete structure was dismantled with the exception of the loadbearing steelframe and the four elevator shafts. By then, it was clear that both the steelframe and the reinforcement in the concrete floorslabs showed little corrosion, despite the far reaching carbonatation of the concrete and the resulting loss of a basic environment for the rebar. Still, the anchors attached to the concrete floors showed serious corrosion, most likely due to the occurrence of condensation within the facade construction.

With the restoration continuous vertical sticks have been mounted instead of the facade posts. When it had been calculated that these came up to static requirements as regards windloads and so on in

accordance with German Standards DIN 1055 File 4, the newly designed facade construction could be installed unconditionally.

The loads on the new posts are transferred to an existing secondary construction, that was occasionally reinforced where tensions were expected to exceed the tensile strength of the member concerned. The dimensions of the existing construction could then be verified and appeared to be sufficient as regards deformations of the posts through temperature changes and windloads, even if the avoidance of disturbing noises through deformations had to be taken into account. As a result, the occasional corrosion of structural elements could no longer affect the general stability of the building to a significant extent.

Facade

The facade had to be completely renewed. The entire construction of the new facade has been designed to meet strict requirements as regards building physics as well as the historic value of the building. The Thyssen Haus now features a completely new, flush aluminium-glass curtain wall composed of stick elements, with a structure and appearance that strongly refers to the design of the original facade. Vertical sticks in a rectangular pattern again form a primary grid for the curtain wall, while a secondary aluminium-glass construction has been applied as an infill. The aluminium construction of the facade has been designed with profiles with a thermal break and vertical tracks for the suspended scaffold of the window-cleaning installation. The existing installation for window-cleaning could be kept, although now the tracks are integrated in the mullions of the curtain wall.

Glass

The functional requirements for the renovation project meant, that a type of glazing had to be applied that would allow a minimum of solar incidence to enter the building. Yet it was agreed that the usage of a reflective coating should be avoided, in order not to disturb the architectural features of the original building.

The vision panels of the new curtain wall have been fitted with double glazing, the outer panel of which is heat protective Climaplust N with $K = 1,7 \text{ W/m}^2\text{K}$. The spandrels have been fitted with enamelled float glass, that was furnished with a special coating according to the results of a so-called Heat-Soak-Test.

Before the glazing has actually been put in place on site, an extensive computer simulation programme had again been passed.

The end facades of the building's three slabs are clad with Remanit, a relatively light yet durable metal alloy. Remanit is highly resistant to weathering and immission, and it is easy to maintain. Even after forty years of service, the condition of the corrugated cladding was satisfactory and replacement was

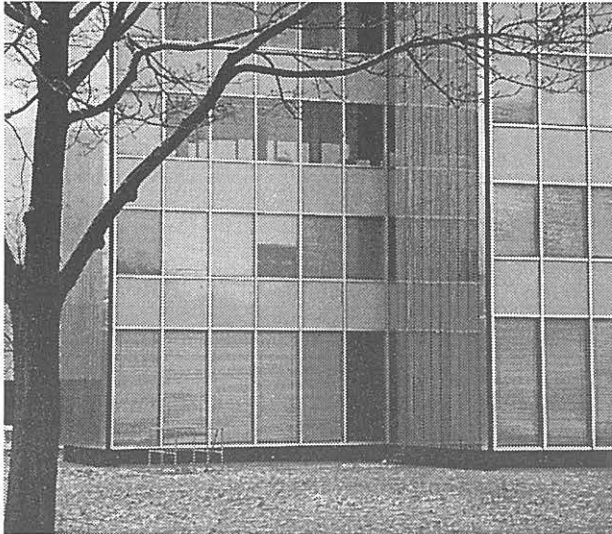
therefore unnecessary. The steel cladding has been taken off, and reinstalled after extensive checks and minor repair work. Today the minor dents in the remanit panels add an appealing flavour of authenticity to the perfect shape of the exterior of the renovated Thyssen Haus.

Climate systems

The sophisticated facades of the Thyssen Haus respond to changes in the outside climate, to optimize internal conditions for the users of the building. As a result, it is expected that also productivity will increase, while energy savings are anticipated to be significant due to a reduction of emission through the glazing.

The built-in ventilation supply-system features exchange of thermal energy between fresh and exhaust air, which again results in high energy savings in case of extreme climate conditions in summer and winter.

The built-in control units, that allow for individual



The replaced glazing features a reflective coating, but still displays a similar transparency as compared to the original facade. Photo: Wessel de Jonge (1996).

operation, proves to be a great advantage. In addition, relatively small inlets at the windows allow for individual ventilation of which the energy loss is beyond control.

This system ensures an easy and intelligent operation of the systems for heating, ventilation and cooling. Thanks to the sophistication in facade technique and climate control, an optimal balance was established between measures as regards weather-proofing, energy saving, sunshading and natural light, as well as the systems for heating, ventilation, air conditioning and lighting. Only this way, a comfortable interior environment can be provided, with lighting conditions that are suitable for working at screens, a minimal energy consumption and a maximum acceptance of the building by the users.

In order to achieve this, some of the already existing

technologies as regards building components and service systems, such as the sunshades, the ventilation, the heating and cooling systems, have been functionally refined.

Facility management

A vital issue in the whole process of rehabilitation was to secure the added value of the investment as regards the service and maintenance of the technical systems, but just as well with respect to the functional use of the house, that could only be accomplished through Facility Management. Typically, the costs of technical systems and services today add up to 40 % of the total investments for any building. These sophisticated features will only be worth the investments if they are carefully and regularly serviced, in other words: if they are continuously monitored by a professional party. Today, Thyssen's custodian is no longer in charge of monitoring, inspection nor the management for maintenance of the building.

Through the outplacement of these 'alien' activities,



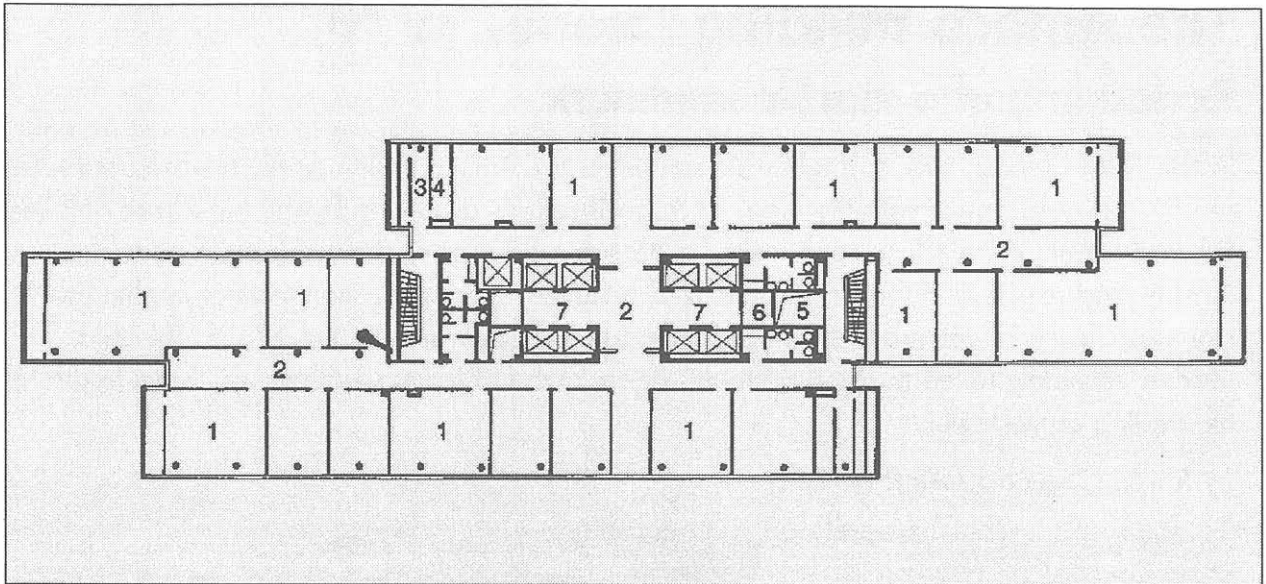
The dented Remanit panels on the end facade are witnesses of the past and add a pleasant flavour to the renovated Thyssen Haus. Photo: Wessel de Jonge (1996).

Thyssen opted for the only proper solution and decided to leave the service systems to external professionals.

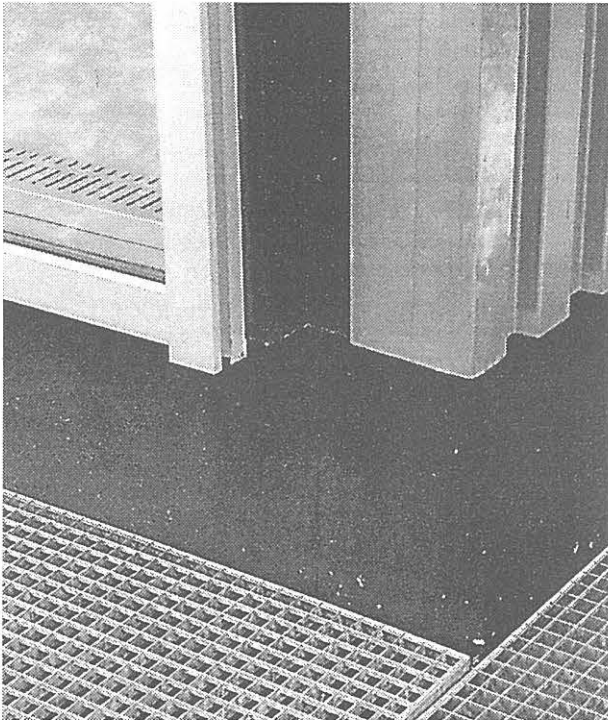
Video documentary

A rigid time schedule for the works could be adhered to, thanks to some special methods for mounting and finishing on site, that allowed for a careful planning of these works. Mounting time on site, which due to its dependence on weather conditions is one of the most risky stages in construction, was reduced to a minimum through a high level of prefabrication of components.

The high level of automation and quality that can be achieved under controlled conditions in workshops is another advantage of prefabrication. Also, it helped to reduce costs for packaging and transport, as well



Ground floor plan. Typical floorplan of Thyssen Haus after refurbishment: 1) Offices, 2) Corridors, 3) Kitchen, 4) EDV, 5) Service shafts, 6) Services, 7) Elevators. Drawing: HPP Architekten.

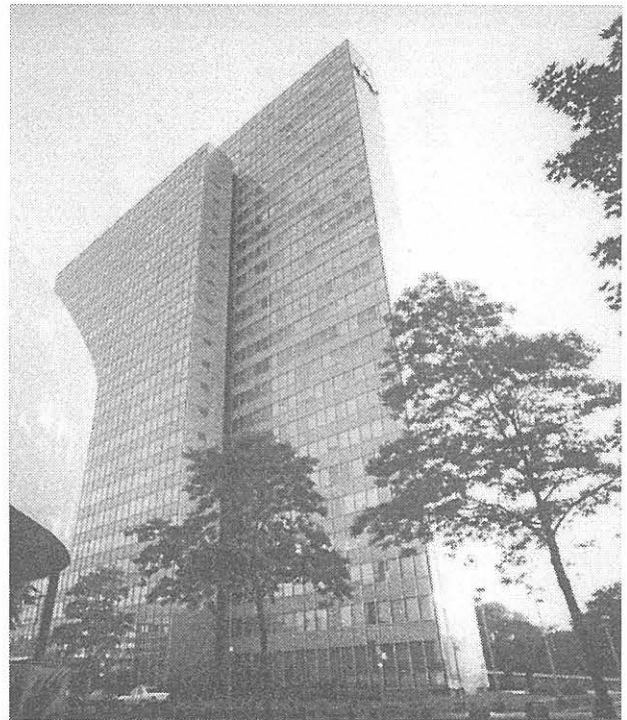


A corner detail displays the careful work of the renovation architects HPP from Düsseldorf. Photo: Wessel de Jonge (1996).

as to minimize storage on site. The project management of the renovation was commissioned by Thyssen AG to Thyssen Rheinstahl Technik, a division of Thyssen Handelsunion.

A rather unique decision was made by the contractor Hochtief to have the planning and execution of the works documented by means of a video documentary. This short visual report gives a stunning impression of the sophistication of the works in terms of logistics and professionalism in execution.

As a result of the renovation, the 'Dreischeibenhaus' regained its original splendour as well as a large



The Thijssen Haus in Düsseldorf, built in 1957, before refurbishment. Photo: Thyssen AG (1987).

appreciation by its users. Both are indispensable for a durable future for the building.

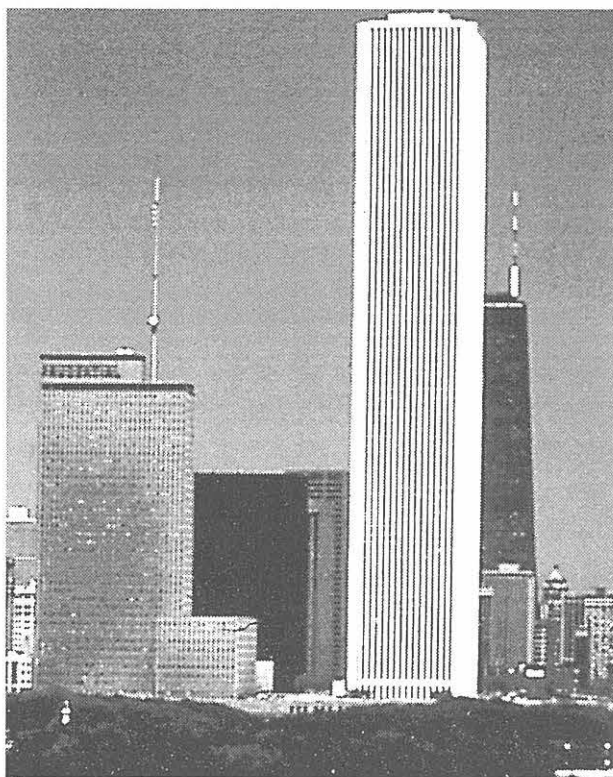
Eberhard Zerres is the project manager of Thyssen Rheinstahl Technik in charge of the renovation of the Thyssen Haus. Text translated from the German, enlarged and edited.

The Amoco Building (Stone, 1970)

Recladding of a marble landmark

In the USA, Chicago's second tallest skyscraper is the Amoco building which was constructed in 1972 in accordance with the plans and specifications drawn up by the New York architect Edward Durell Stone. Once completed the 82 story, 350 meter, Amoco building was the tallest marble clad structure in the world. It utilized a rather new construction technique: thin cut stone as a curtain wall material which first made its appearance in the 1960s. This thin marble ultimately failed to stand up to the rigors of the Chicago weather, which led to a total recladding of the tower.

by Ian R. Chin and Jack P. Stecich



A view of the Amoco Building from the south.
All photos: Wiss, Janney, Elstner Associates, Inc.

Groundbreaking for the Amoco building was in 1970, and the completed structure was occupied in 1972. The building is a steel tube structure with a center core design and column-free space between the core and exterior walls. The exterior wall was originally clad with 44,000 pieces of Alpha-Gray marble quarried in Carrara, Italy. The average marble panel was 127 cm high by 107 cm wide by 3 cm thick. The marble panels were suspended from the columns by a series of galvanized clips and stainless steel shelf angles. Kerfs were cut into the edges of the marble panels to engage the support angles. Each piece of marble was thus independently supported. The joints between the marble panels were sealed with sealant.

Accelerated distress

After the building was occupied, the building cladding was regularly maintained by Amoco personnel. The maintenance of the marble panels consisted of inspection of the panels, replacement of deteriorated sealant, and repair of cracks that developed in the panels. All work was performed from a suspended scaffold that could engage into vertical tracks that were incorporated into the facade. In 1979, the Chicago based consulting architectural firm of Wiss, Janney, Elstner Associates, Inc. (WJE), was hired by Amoco to perform an inspection of the exterior facade of the Amoco building in accordance with the City of Chicago's building facade inspection ordinance. During this inspection, all of the marble panels on the building were inspected. This 1979 inspection revealed the following:

1. Crescent shaped cracks at the kerfed connections in approximately 230 marble panels.
 2. Vertical, horizontal and diagonal cracks emanating from the kerfed connections in approximately 1,800 marble panels.
 3. Outward displacement of seven of the marble panels at corners of the building. The outward displacement averaged about 1.3 cm.
 4. Lengthening of some of the cracks in the marble panels that had been previously repaired.
 5. Outward bowing of some of the panels. The maximum outward bow was about 1 cm.
- The extent of the distress in the panels was not considered to be extensive in 1979. However, between 1979 and 1985, Amoco personnel observed that distress of the marble panels was continuing to occur at an accelerated rate. As a result of this observation, WJE was again hired in 1985 to perform an inspection of the marble curtain wall.

Exposure to sun

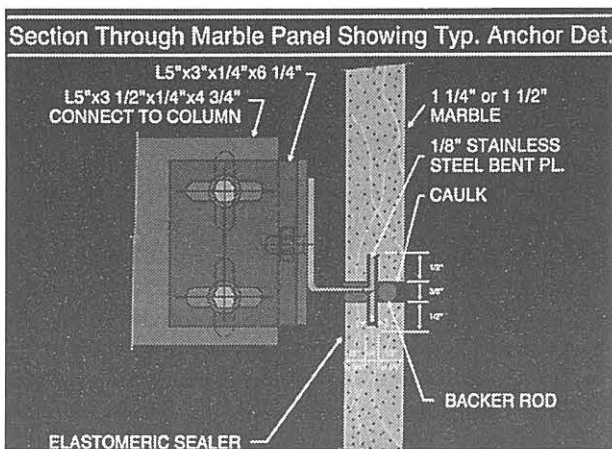
The 1985 inspection revealed the following:

1. Crescent shaped cracks in marble panels at connections in approximately 2,780 of the 44,000 panels on the building. This represented an

increase in this type of distress by 1,100 percent since 1979.

2. Vertical, horizontal, and diagonal cracks in marble panels emanating from connections in approximately 12 percent of the panels on the building. This represented an increase in this type of distress by 190 percent since 1979.
3. Outward bowing of marble panels of approximately 1.3 to 2.9 cm. This represented an increase in this type of distress by 200 percent since 1979.

Approximately 80 percent of the significantly bowed panels were located on the south and east elevations of the building, which, unlike the west elevation, have no adjacent structures to



Marble panels suspended from the columns by a series of galvanized clips and stainless steel shelf angles.

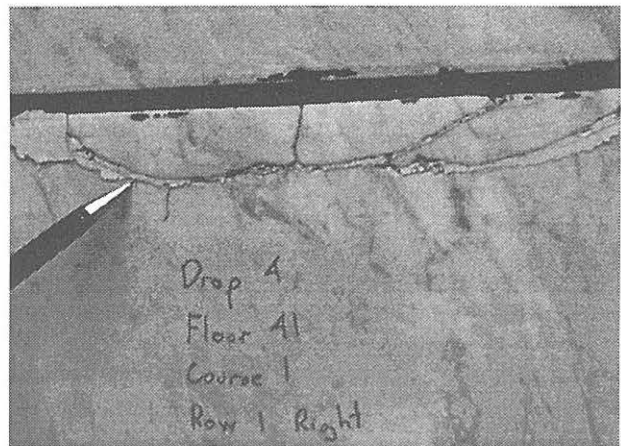
block exposure to the sun. The marble panels on the north elevation exhibited the least amount of outward bowing. The marble primarily consists of calcite crystals which are anisotropic.¹ This phenomenon is called hysteresis, and it often results in a permanent deformation in marble and accompanying strength loss. Hysteresis can cause marble panels such as those used on the Amoco building to bow when one of the faces of the panels is heated to a higher temperature than the other. This effect would cause the exterior side, which is exposed to the sun, to expand more so than the interior side. It was, therefore, not surprising to find that the vast majority of the significantly outwardly bowed panels were located on the sides of the building that were exposed to the rays of the sun, and that the panels with the least amount of outward bowing existed on the north side of the building that was least exposed to the rays of the sun.

Comprehensive investigation

The 1985 inspection confirmed the observations of building personnel that cracking and bowing of the marble panels on the building were accelerating at a rapid rate. When this information was presented to Amoco, it was decided to perform an investigation to

determine the causes of the cracking, the effects of the cracking on the ability of the panels to support design loads, and to recommend remedial action. The investigation consisted of laboratory testing of 96 marble panels removed from the building, laboratory testing of 10 original panels that had been stored in the basement of the building and never installed, and *in situ* testing of 48 panels on the building.

One of the objectives of laboratory testing performed on marble samples removed from the panels was to obtain a basis for estimating the present and future flexural strength of the marble. The laboratory tests included petrographic examination to determine the mineral composition; flexural and connection testing on full sized panels; testing of panel connection kerfs; flexural strength tests on rectangular prisms (ASTM



One of the marble panels with crescent shaped cracks at the kerfed connections.

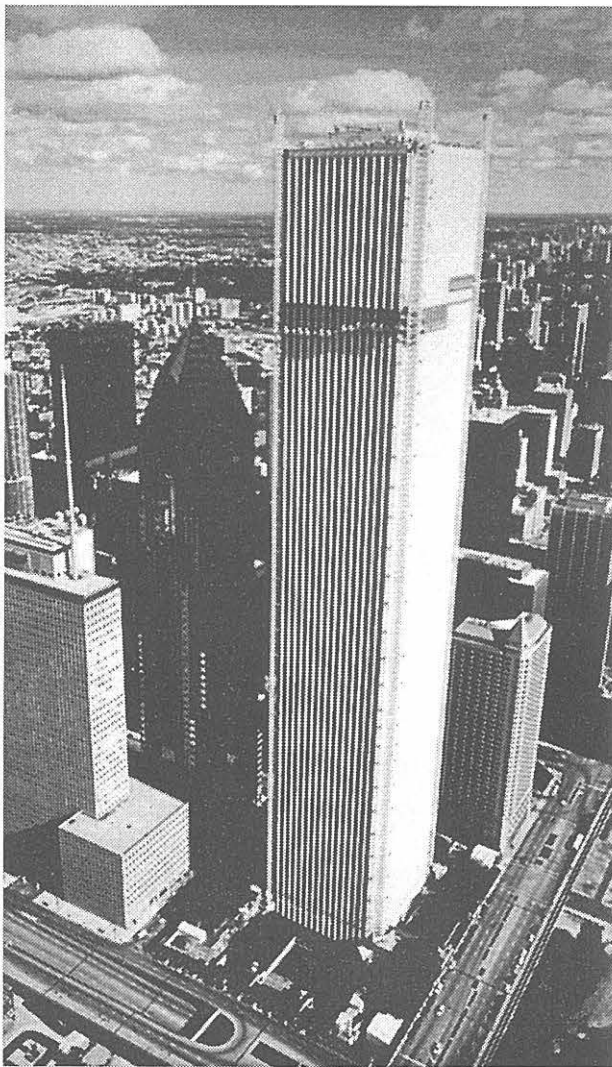
C880)²; compressive strength tests on cores (ASTM C170); permeability testing of samples; and absorption and specific gravity testing (ASTM C97). Another testing procedure was laboratory-simulated accelerated weathering test on rectangular prisms cut from the panels. This testing consisted of submerging the outside 1.3 cm of the prisms in 0.01 molar solution of sulfurous acid to simulate acid precipitation and exposing the prisms in this condition to 100, 200, or 300 cycles of an air temperature range of -23 degrees to 60 degrees C. The laboratory tests revealed that the marble had lost and would continue to lose significant strength due to its exposure to heating and cooling cycles, and that a marble panel with a large bow tends to have a lower flexural strength than a marble panel with a small bow.

In situ load tests were also performed on 48 marble panels on the building. The panels tested were selected based upon their location and extent of bowing. The purpose of the *in situ* load tests was to assess the ability of the marble panels and their connections, in their condition at the time of the tests, to support outward wind load. The *in situ* load tests revealed that under design wind loads the marble panels on the building did not have an adequate

factor of safety. The results of the investigation revealed that the marble panels could not support the design wind load with an adequate safety factor and that the marble panels would continue to lose strength due to exposure to weather. It was decided to remove all 44,000 marble panels and reclad the building.

Cladding options

As architect of the recladding project, WJE studied various potential recladding materials and systems from aesthetic, material, structural, and durability points of view. Among cladding options that were studied were panels of aluminum, marble, and granite. It was determined that granite quarried by the North Carolina Granite Company at their Mt. Airy quarry in the USA would be used. This granite, unlike marble, does not exhibit hysteretic behavior. It was



A view of the Amoco Building during recladding.

also determined that the stone panel thickness would be increased 5 cm and a special surface finish was developed to enhance the white color of the granite. A comprehensive structural analysis of the building structure was performed to evaluate the effects of the increased cladding weight. In addition, wind loads

specified by the current City of Chicago Building code were higher than wind loads specified at the time the building was designed. At the time the building was originally designed, the structural analysis was performed on a mainframe computer at the Massachusetts Institute of Technology. Using state-of-the-art computing at that time, engineers were able to model only one-quarter of the building. Because of improved computer technology in the 1990s, the analysis was performed on a model of the entire building using a desktop computer. The analysis revealed that seven columns at the lower levels on the north face were slightly overstressed when subjected to the most severe wind case. It was decided that these columns would be reinforced by welding new steel plates onto the existing columns.

Conclusion

As the recladding project proceeded, constructability, structural performance, and aesthetics were evaluated by the owner, architect, engineer and contractor on a weekly basis. Extensive testing of marble materials, connections, hardware, and of a fully assembled mock-ups of the recladding was performed. The testing performed was so extensive as to lead to improvement in standard ASTM testing procedures. Construction logistics were carefully planned to allow undisturbed occupancy of the building and to provide a safe work environment 350 meters above Chicago streets. The project ultimately led to the use of a strong, stable cladding material with a bright appearance for a major Chicago Landmark and world corporate headquarters.

Ian R. Chin and Jack P. Stecich are respectively vice president and senior consultant, and senior consultant at Wiss, Janney, Elstner Associates, Inc., Chicago. Text edited by Stephen J. Kelley from the Proceedings of the Seminar on the Recladding of the Amoco Building in Chicago, Illinois, edited by Ian R. Chin, Chicago Committee on Highrise Buildings, Chicago 1995.

Notes:

1. Anisotropic means that when the calcite crystals are heated, they expand in different amounts in different directions, and when they are subsequently cooled, they cannot return to their original position because the crystals interlock.
2. The American Society of Testing and Materials (ASTM) is a voluntary standards organization which is the basis for the majority of specifications for building construction.

Boots Factory (Williams, 1932)

Careful medication for a curtain wall

In 1989, the Boots Company set up a study to see how Owen Williams' D 10 building of 1932, could be refurbished to meet their future manufacturing requirements and the new EC standards for pharmaceutical production. It is now seven years on, and John Barks, manager of the Boots project team, and consultant AMEC, must be congratulated on receiving the Europa Nostra conservation award for the project.

However, to reduce solar gain the instalment of slightly sunreflective glazing could not be avoided. A significant loss of transparency is the side effect of a careful medication.

by James Strike



The Boots Factory with original glazing before renovation, with opening lights and structural mullions between the three window bays.

In the *Architects Journal* of 3 November 1994, Peter Fawcett, Head of School and professor of architecture, University of Nottingham, describes that 'the icon status of 'D10' stems from its progressive structure and the uncompromising curtain wall to its west facade': he comments that 'the restored facade is an unqualified success'. However, the refurbishment was not easy: Jan Sosna, Chief Architect of the AMEC team, recalls how 'it was the replacement of the fenestration that became the key issue with English Heritage'. This article looks at the story and the details of this replacement glazing.

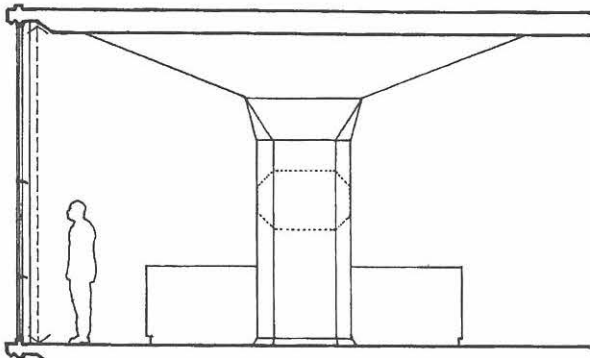
Hard edged meetings

Conservation of Modern Movement factories has its share of indifferent results and outright failures. It is therefore good news for the conservation lobby that this project work out well. The process of working on historic buildings takes account of the need to record before the changes are made, and to record the end product: a recognised system in archaeology. What is now clear is that the details of getting to the end product is also an interesting part of the process, but one that is not often adequately recorded. Perhaps we need a recognised system for recording for posterity,

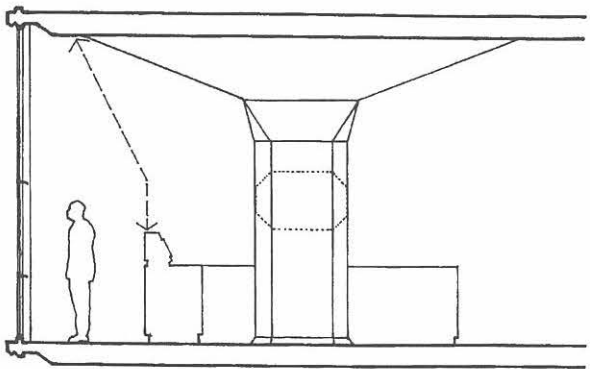
the actions of the design meetings, and the decisions taken on site. It is salutary to recall the meetings which lead, eventually, to the reglazing of the 'D10' facade. The early meetings were professionally hard edged. The optimum solution for English Heritage was to retain the original fabric, Boots required an efficient and practical solution, and AMEC wanted to solve the problem.

Continuity and transparency

Historic fabric is irreplaceable, and this glazing was particularly interesting in the way that Owen Williams used Crittall's standard range of 'medium universal' steel window sections to form storey height panels with minimal flat glazing bars to the external face. The 20mm wide T-bars, with small aluminium angles to fix the glass, gave minimal sight lines, portraying what



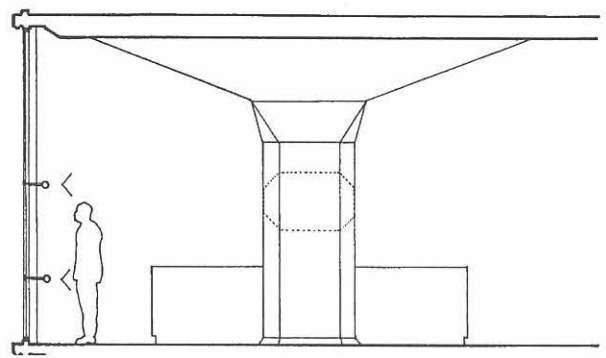
Existing glazing conserved and upgraded with the introduction of internal secondary glazing. All drawings: James Strike.



The environmental requirements of the building provided with the introduction of a glazed screen to the machinery or work benches.

Walter Gropius had described earlier as 'dematerialisation of the walling'. The glazing allows Owen Williams' large span flat concrete-slabs and supporting columns with mushroom heads to be clearly perceived through the external enclosure. The original storey height panels were fabricated in three window widths with a 100mm by 18mm structural steel mullion between the panels at 2.34m centres. Metal sections were at that time assembled with hammered tenon joints and the 4m high panels of the 'D10' building lack sufficient rigidity to withstand strong gusts of wind, often leading to

cracked panes of glass. Several initiatives were explored to save the glazing. Full conservation was examined. Anything is possible, but the cost of treating such large areas of rusting and warped glazing with the necessary studio based 'museum artifact' approach would have been exorbitant. Public opinion is undoubtedly moving in favour of such buildings and we may well need to consider such duty of care in future projects. A parallel problem in conserving the original glazing was the need for a satisfactory warranty; more of this later. The debate also confronted authenticity. It is common practice to conserve historic fabric 'as found', on the basis that the evolution of the building is part of its history. In the case of 'D10', this evolution consists of repairs, alterations, blank panels, and the random addition of extract fans and blinds. The important characteristics



New glazing based on standard W 20 sections with horizontal structural bars.

of this building, however, is in the edited simplicity of the structure and the continuity and transparency of the glazing; and this has to be demonstrated through an unsullied and coherent whole. Conservation of the original glazing would therefore require the removal of these many alterations and the use of patch repairs to the original profiles.

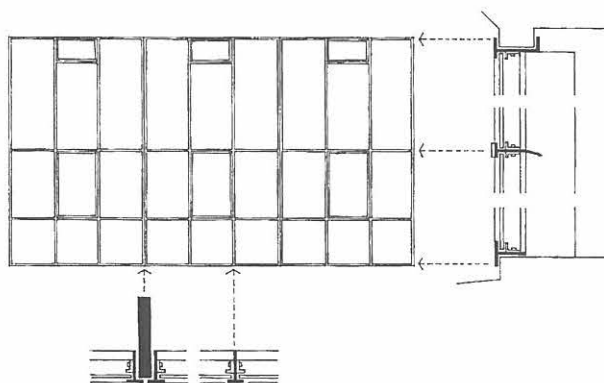
Secondary internal glazing was considered to overcome heat loss and the EC requirement of dust penetration.

Owen Williams designed the original glazing with the glazing beads and transom bar projections on the inside as part of the designed simplification of the external facade. Consequently, secondary glazing had to be movable or demountable to allow for internal reglazing the original system. However sophisticated, this additional line of secondary mullions would have created an unwelcome 'double image' of vision into the building. An alternative system was considered as modern glazing set back to the line of the machinery or laboratory bench. This could be perceived as part of the design language of the machinery, an overtly modern screen, visually separate from the historic fabric. The specific problems of this scheme, particularly in avoiding the structural mushroom column heads, prevented a satisfactory simple practical solution; however, the approach may be useful for some other project.

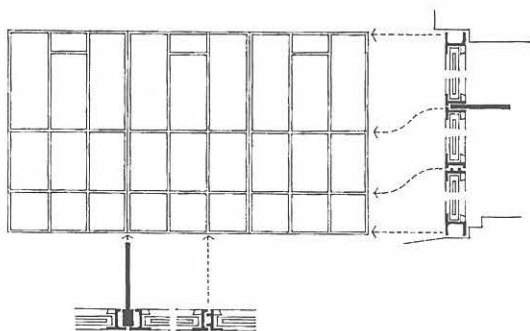
Two trial panels

At the same time, designs were produced for replacement glazing. One advantage of a new scheme would be a clean and consistent glazing plane; the fabric may be lost but the original coherent design would be retained, and even enhanced. It was established from the start that the new EC pharmaceutical standards would best be met through the introduction of internal air conditioning, and that opening lights would not therefore be required. Early criteria for the new glazing were to emulate the appearance of the original glazing, to reduce heat loss, and to overcome the wind loading. Two trial panels were constructed in a loading bay at the end of the building.

The first used Crittall standard 30mm T-bar sections,



Original glazing with opening lights and structural mullions between the three window bays.



Final scheme as constructed, with structural mullions between three bay windows, made of standard sections which incorporate a horizontal structural steel plate.

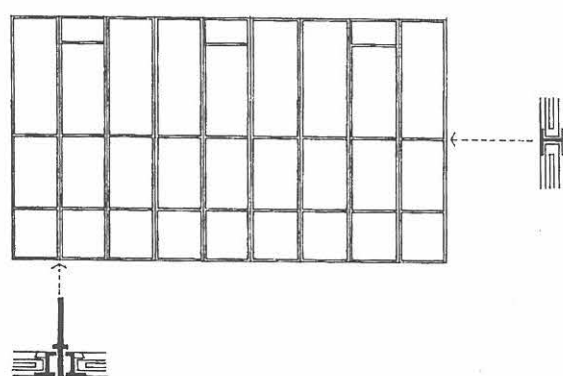
which are just deep enough to accommodate a double glazed panel, and vertical steel joining members between each window to give the required structural strength. The result was clean and coherent, it reflected the design ethos of minimal glazing but did not follow Owen Williams' solution. The second used larger Mellows sections. This followed the original pattern of the three window panel and the opening lights, but was thicker and visually more intrusive.

Crittall's standard sections

The meetings were becoming less productive, and we needed to reflect on our opinions. The schemes were

presented at English Heritage, to an invited group of people experienced in the history and conservation of Modern Movement buildings. Boots took the unusual step of producing a professional video showing the problems and solutions, and this, with a formal paper, were submitted to English Heritage Historic Buildings Advisory Committee. The advice was to retain the original three bay panels and the pattern of opening lights, and to seek the most suitable lightweight glazing system.

Crittall's were appointed to develop their thin standard sections into a three window structural panel between structural mullions. The problem of hot galvanising such a large panel was also explored. The 30mm T-bar was reconsidered with new internal rails configured as a structural horizontal trusses spanning



New glazing based on 30mm T-bars and a vertical structural jointing member between each window.

between the structural mullions. The final solution was visually and structurally more simple, with the introduction of a 90mm horizontal steel plate between standard Crittall's W20 window sections, and a 130mm steel mullion between the panels.

Duty of care

The steel work was hot dip galvanised and polyester-powder coated in dark green (RAL 6009) to match the original design. It is interesting to observe how the glazing bars have diminished in comparison with the recent white paint. The double glazed panels are 4mm-6mm-4mm to fit into the available internal width of the Crittall sections, fixed with snap-on beads. The vision panels have Pilkington HP Neutral outer glass and clear float inner glass, the lower and upper panels have Pilkington Vellum inner. Externally the system was treated with feathered black silicone pointing.

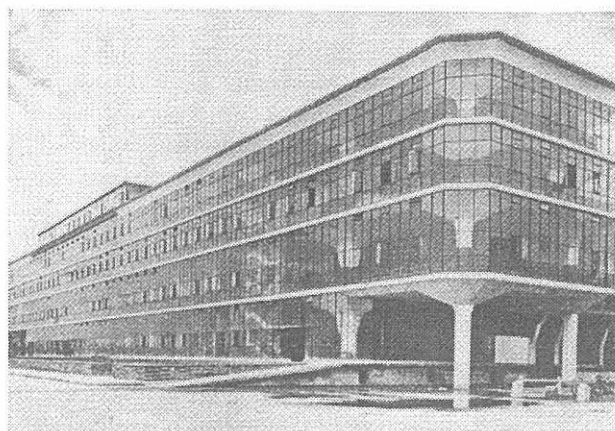
AMEC were faced with the difficult problem of the tolerance between the glazing and the concrete slabs which varied up to 50mm. Pressed steel sections with adjustable plates were made to restrict the silicone pointing to 20mm.

The question of warranties for work involved in saving these buildings has to be addressed. The conservation of a medieval cathedral or a vernacular timber barn would not be covered by a warranty. The boundaries

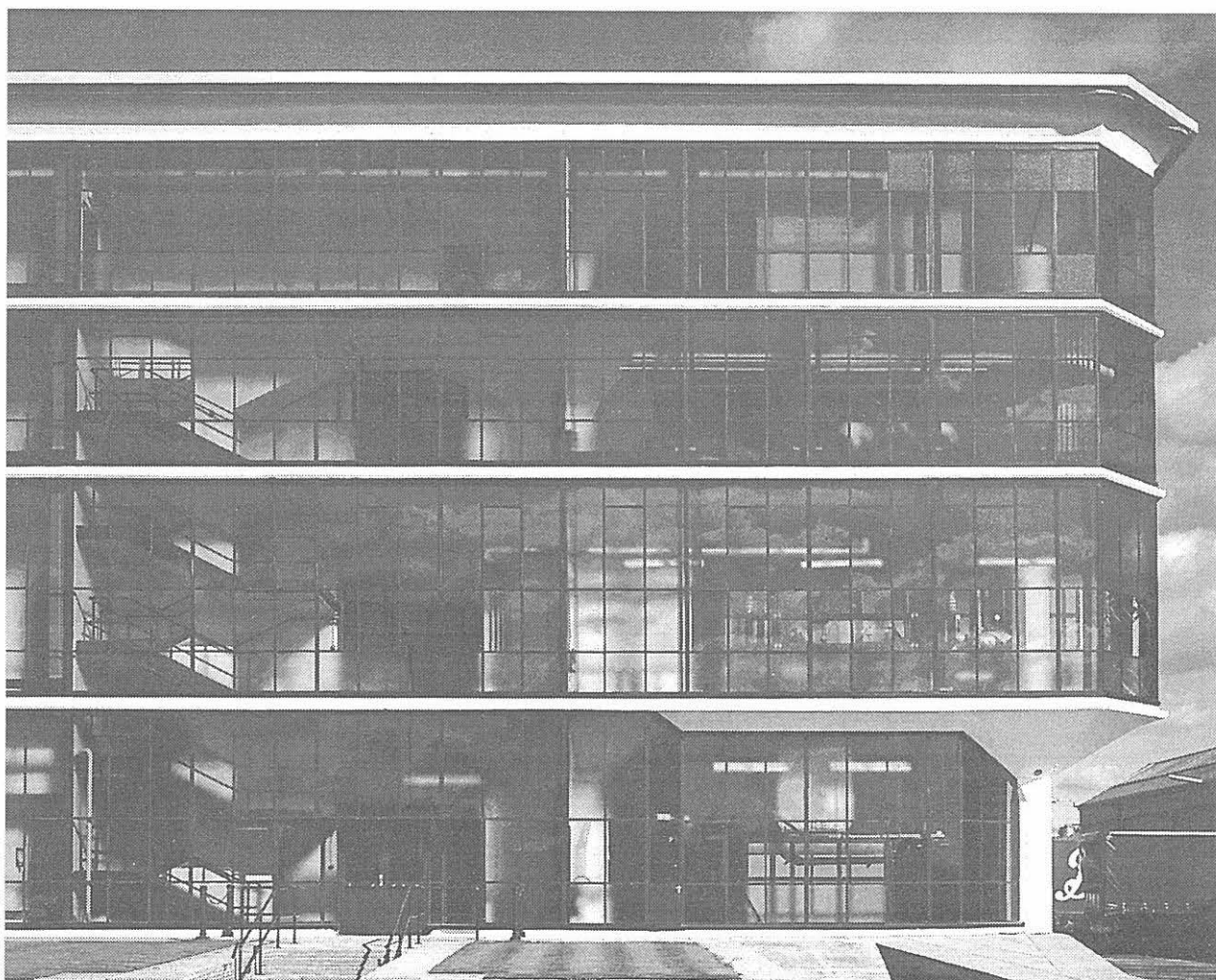
are blurred, and the ownership of the duty of care for the historic fabric seems to change with the age of the building.

Fortunately, a solution was found for the 'D10' building which used new standard, and proven, sections to overcome the problem. But the question is asked; would the conservation 'Authority', which requires the retention of historic fabric, take on such a warranty? The whole story evolved over many months; it was frustrating and time consuming. It is interesting to see, now, how it followed the familiar pattern that the design process takes in many fields, in that the elegant solution developed slowly out of many long discussions and abandoned drawings.

Boots were wise in their request for minimum publicity



Period photo of the Boots Factory. Photo: Crittall Windows Ltd.



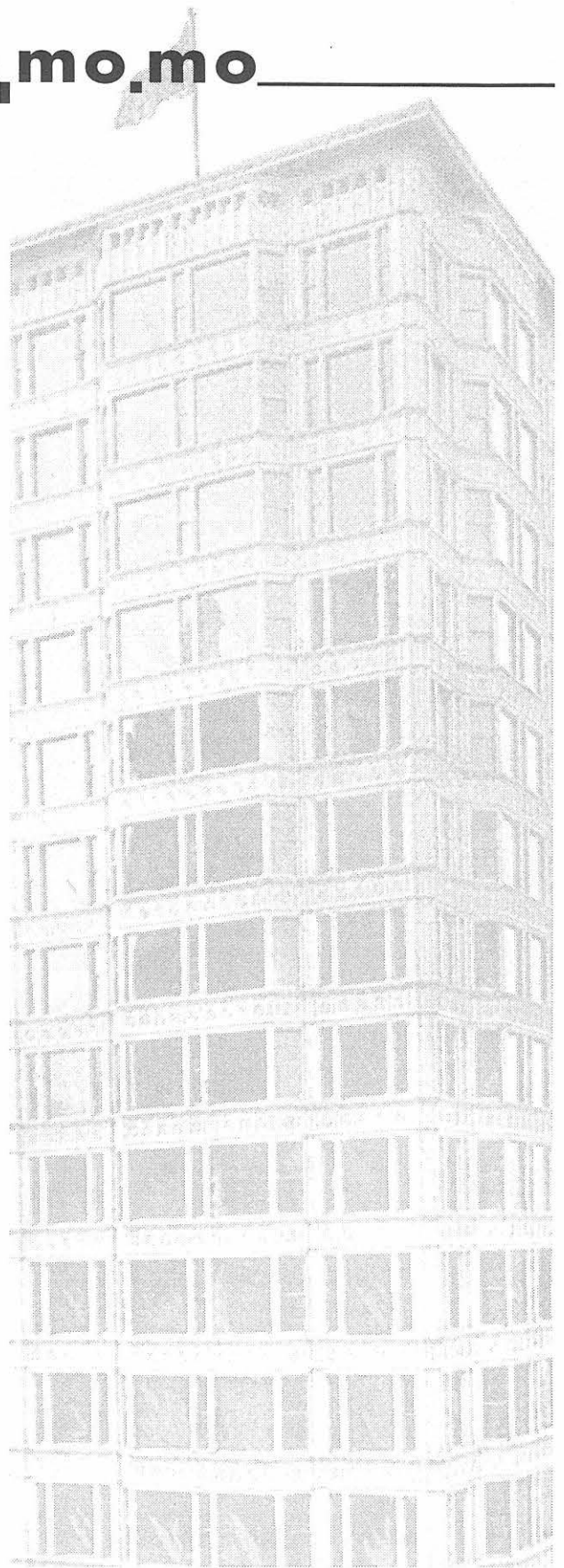
The completed scheme. The sunreflective glazing has a neutral grey tone of only 10%, but still results in a significant loss of transparency. Photo: Martine Hamilton Knight, courtesy of the Boots Company.

during the development stage; you need to be able to explore unproven ideas. It was particularly useful that Boots were willing to set up the trial panels and the video, to prove and disprove the issues. The scheme demonstrates the duty of care required, and hopefully, moves forward the level of expertise and expectation for the conservation of such Modern Movement buildings.

James Strike was the advisory architect to the Inspector for the refurbishment of Owen Williams' 'D10' Boots Factory in Nottingham. He now runs the Masters course in Building Conservation at Bournemouth University. He is author of Construction into Design, Butterworth Architecture, and Architecture in Conservation, Routledge.

APPENDICES

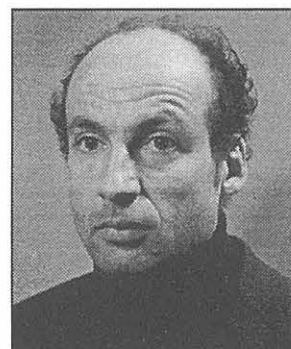
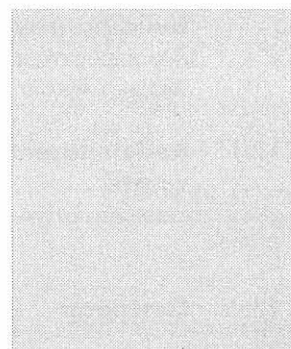
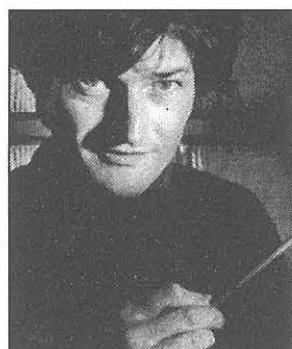
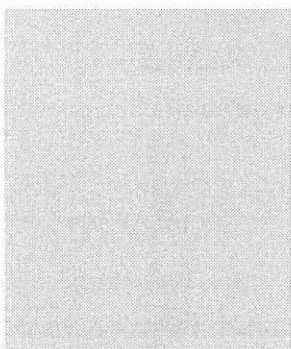
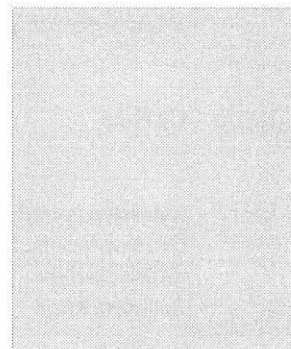
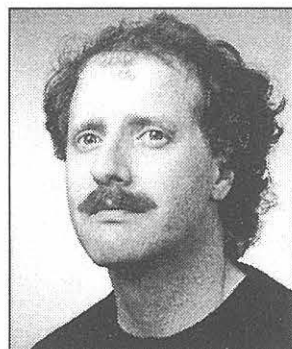
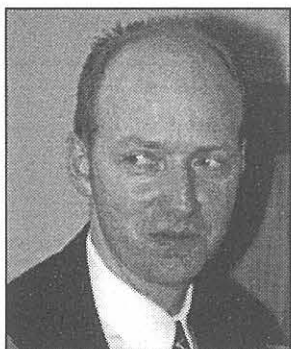
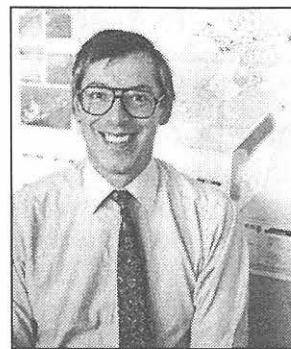
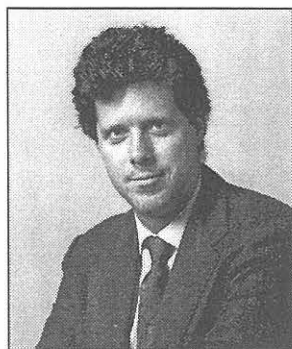
do.co.mo.mo



do.co.mo.mo_ Programme

- 08:45 **Reception**
- 09:15 **Opening**
Hubert-Jan Henket
- 09:30 **History and typology of curtain walls**
An image of modernity
Stephen J. Kelley
- 10:15 **Curtain walls in the Netherlands**
Refurbishing an architectural phenomenon
Wessel de Jonge
- 10:45 **Coffee**
- 11:15 **Curtain walls**
Developments, functional lifespan and refurbishment
Just Renckens
- 11:45 **Curtain walls as a system of building physics**
A perspective for refurbishment
Jacques Mertens
- 12:15 **Redevelopment of postwar real estate**
Hans de Jonge
- 12:45 **Luncheon**
- 13:45 **Natural stone in the context of ageing curtain walls in the UK**
John Redding
- 14:30 **Blaak 333 (Kraaijvanger, 1961) in Rotterdam**
A critical review of a second life
Dirk Jan Postel
- 15:00 **Video: Thyssen Haus (HPP Architects, 1957-60) in Düsseldorf**
A success story about architecture, corporate image and return
- 15:15 **Tea**
- 15:45 **Rijnhotel (Merkelbach & Elling, 1957) in Rotterdam**
An approximate image
George Köhlen & Leon Wolters
- 16:15 **Case studies from 'The Loop' in Chicago**
Preserving a Business District
Stephen J. Kelley
- 16:45 **Debate**
- 17:15 **Cocktail**

do.co.mo.mo_ **Resumé of speakers**



Hubert Jan Henket
Wessel de Jonge
Just Renckens

Stephen J. Kelley
George Köhlen
Dirk Jan Postel

John Redding
Jacques Mertens
Hans de Jonge
Leon Wolters

Hubert-Jan Henket is an architect with his own practice in Esch, the Netherlands. Among his most important buildings are the main office of the White Fathers in Dar es Salaam (Tanzania), the pavilion for the Museum Boymans-Van Beuningen in Rotterdam and the law court in Middelburg (The Netherlands). He is professor Renovation Technology at the Faculty of Architecture of the Eindhoven University of Technology, and co-founder as well as chairman of DOCOMOMO International.

Stephen J. Kelley is an architect and structural engineer with Wiss, Janney, Elstner Ass., Inc., specialized in the evaluation and repair of exterior claddings on existing buildings. He has special expertise with highrise buildings and was the job architect for the investigation and exterior renovation of several historic skyscrapers, including the Wrigley, Tribune and Rookery buildings in Chicago. Kelley is widely published on the subject of windows and curtain walls.

As a researcher for the Section Renovation Technology of the TU Eindhoven, **Wessel de Jonge**, specialized in specific issues concerning the restoration and refurbishment of 20th Century architecture. He is co-founder of DOCOMOMO International and chair of their International Specialist Committee on Technology. As an architect with LeedeJongearchitecten he is in charge of several prominent restoration cases of modern buildings.

After a 12 year career in facade construction **Just Renckens** started Renckens Consultancy for Facade Technology, in 1992. Renckens also works part-time for the Delft University of Technology, where he is preparing a book on facade technology. This reference work is a basis for a Ph.D. thesis on aluminium-glass facades, technology and organization, with an emphasis on new developments and performance in use.

Jacques Mertens is with Peutz & Associés, a group of independent offices of consultant engineers concerning acoustics, noise control, building physics and environmental technology. In the company's modern and well equipped building physics and acoustic laboratory, research is being done on, amongst others, physical qualities of facade systems.

In his capacity as a top manager for the Dutch Government Building Agency, **Hans de Jonge** has been in charge of a number of postwar office redevelopments. At present, he is director of Starke Diekstra Holding nv, a leading consultancy in real

estate development, as well as a professor in Real Estate Management at the Delft University of Technology.

John Redding is an engineering geologist with over 20 years experience of using natural materials in construction. He works for Ove Arup and Partners, an international practice of consulting Engineers and Architects and helped to launch the highly successful Arup Facade Engineering branch of the company. He is, amongst others, a member of the Natural Stone Working Group of the Centre for Windows and Cladding Technology. He has lectured and published widely on the subject of natural stone cladding.

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: innercity renovation, experimental research position, international school, rehabilitation of a large events- and exhibition building, industrial design and glass. His glass bridge (Rotterdam 1994) has been nominated for the Rotterdam Design Prize as well as a honorary mention in the Benedictus Award (Washington DC 1995).

George Köhlen is an independent architect in Maastricht. With **Leon Wolters**, director of the ASW facade construction company, he is in charge of the refurbishment of a prominent Reconstruction-period building in downtown Rotterdam: the former Rijnhotel. In close cooperation with their client and the planning authorities, the image of the original building could be respected in the replacement facade.

do.co.mo.mo_ List of participants

- Dhr./Mw. Aarden, De Groot & Visser, Gorinchem*
C. van Amstel, Vereniging Metalen Ramen en Gevelbranch, Nieuwegein
S. Baart, Gerrit Rietveld Academie, Amsterdam
M. Bakker, Misset Uitgeverij BV Redactie BouwWereld, Doetinchem
Dhr./Mw. Beemster, Arko Uitgeverij, Nieuwegein
H. Bergsma, University of Technology, Eindhoven
A.F. Boerefijn, Hermeta Gevelbouw, Asperen
M.D. Booy, Van den Broek en Bakema, Rotterdam
S. Bos, student University of Technology, Eindhoven
Dhr./Mw. de Bruijn, A.B.R. Projectmanagement, Maastricht
M.J.W. Buijtsels, Hurks Inducon BV Algemeen, Veldhoven
P. van Buijtenen, DOCOMOMO International, Eindhoven
J.J.A. Czabanowski, University of Technology, Eindhoven
C. Dean, DOCOMOMO UK, London, United Kingdom
F. Desmet, R.C. Systems R&D, Landen, Belgium
D. Dijk, student University of Technology, Eindhoven
A. Doolaar, DOCOMOMO International, Eindhoven
H.S. Duivenvoorde, Achmea Beleggingen Vastgoed, Apeldoorn
S. Duquesne, Catholic University, Leuven, Belgium
A. Eissens, student Art History, Catholic University, Nijmegen
D. Engel, Institut für Baukonstruktion, TU Braunschweig, Germany
P. Erkelens, University of Technology, Eindhoven
V. Etienne, student, Nijmegen
H.C. Faber, Novem BV NOGO, Utrecht
G.J. Florian, Advies Buro voor Bouwtechniek BV, Velp
F.P.M. Gremmen, student University of Technology, Eindhoven
N. Heeren, student University of Technology, Eindhoven
H-J. Henket, University of Technology & DOCOMOMO International, Eindhoven
H. Hinterthür, Topaz Architecten, Delft
H. Hoeben, student University of Technology, Eindhoven
E. van der Hoeven, Buro Monumenten dS+V, Rotterdam
J.M.P. Hoex, Bliita BV, Venray
J. Hoorn, Buro Monumenten dS+V, Rotterdam
J.P. Houx, student University of Technology, Eindhoven
C.J. Isendoorn, Façade, Eindhoven
C.H. Isselmann, Holst Glas BV, Enschede
Dhr./Mw. Jammers, A.B.R. Projectmanagement, Maastricht
D. Janssens, R.C. System R&D, Landen, Belgium
J. Jennes, Reynaers International NV, Technische Dienst, Duffel, Belgium
H. de Jonge, Starke Diekstra Holding NV, Nieuwegein
W. de Jonge, DOCOMOMO International, Eindhoven
J.A. Jutte, Tijdschrift Bouw, Delft
S.J. Kelley, Wiss, Janney, Elstner Associates Inc., Chicago, USA
V. Kerstens, Faculty of Architecture, Hogeschool Utrecht
H.J.J.J. Keulemans, Reynolds Architectuursystemen, Harderwijk
F.W.A. Koopman, University of Technology, Delft
J.T. Koudijs, Gevel Consult, Woerden
C.C. Kruit, Uitgeverij te Hage & Stam, Architectuur & Bouwen, Den Haag
H. Kuns, Natuursteen Magazine, Amsterdam
G. Köhlen, Architect, Maastricht
J.W. Köhler, Eisma's Vakpers, Nieuwekerk a/d IJssel
R. Körner, Stiftung Bauhaus Monument Preservation, Dessau, Germany
H. van Laarhoven, Hubert-Jan Henket BNA Architecten, Esch
A.W. Lolkama, Radeko Metaalbouw BV, Holward
H. van der Looij, Reynaers BV, Schijndel
S. Macdonald, Architectural Conservation, London, United Kingdom
J. Mertens, Peutz & Associés, Mook
M. Naaykens, student University of Technology, Eindhoven
A.N.H.M. van Oijen, Reynaers BV Directie, Schijndel
J. Peeters, Façade engineer, Eindhoven
G. Perquin, Peutz & Associés, Mook
J.M. Post, Post Ter Avest Architecten, Rotterdam
D.J. Postel, Kraaijvanger•Urbis, Rotterdam
J. Redding, Ove Arup and Partners, London, United Kingdom
J. Renckens, Renckens Consultancy, Malden
M. Rolloos, TNO bouw Binnenmilieu/Bouwtype/Installaties, Delft
Dhr./Mw. Rossen, Saint-Roch Glas, Nieuwegein
J.Th. Rutgers, Vereniging Metalen Ramen en Gevelbranch, Nieuwegein
J.A. Römelingh, Felix Glas BV Projektbouw, Waalwijk
H. Schmidt, TH Aachen, Karlsruhe, Germany
E. Schulte, University of Technology, Eindhoven
C.M. Schwencke, Schwencke Rosbach Architekten, Amsterdam
E. Slothouber, Gerrit Rietveld Academie, Amsterdam
W. Stigger, Buro op ten Noort-Blijdenstein BV, Utrecht
A. Tapper, Façade, Eindhoven
H. Thomas, Comité Wederopbouw Ontwerpgericht Onderzoek, Rotterdam
J. van de Ven, Metalen Ramen (MHB) BV, Herveld
M. Verdonschot, University of Technology, Eindhoven
A.B. Verheijen, Bliita BV, Venray
L. Verpoest, Catholic University, Leuven, Belgium
J. Vogelaar, Wilma Vastgoed BV Bedrijfshuisvesting, Nieuwegein
A. Westerhof, University of Technology, Eindhoven
W.F. Westgeest, Van Zanten Raadgevende Ingenieurs BV, Den Haag
J. Westra, University of Technology, Eindhoven
J. Weyts, Reynaers International NV, Duffel, Belgium
J.A. Wisse, University of Technology, Eindhoven
L. Wolters, Aluminium en Staalindustrie Wolters BV, Weert

international secretariat docomomo:

prof.ir. hubert-jan henket
ir. wessel de jonge

eindhoven university of technology

bpu postvak 8
p.o. box 513
5600 mb eindhoven
the netherlands

tel.: 31-40-247 24 33
fax: 31-40-245 97 41
e-mail: docomomo@bwk.tue.nl

ISBN 90-6814-069-8