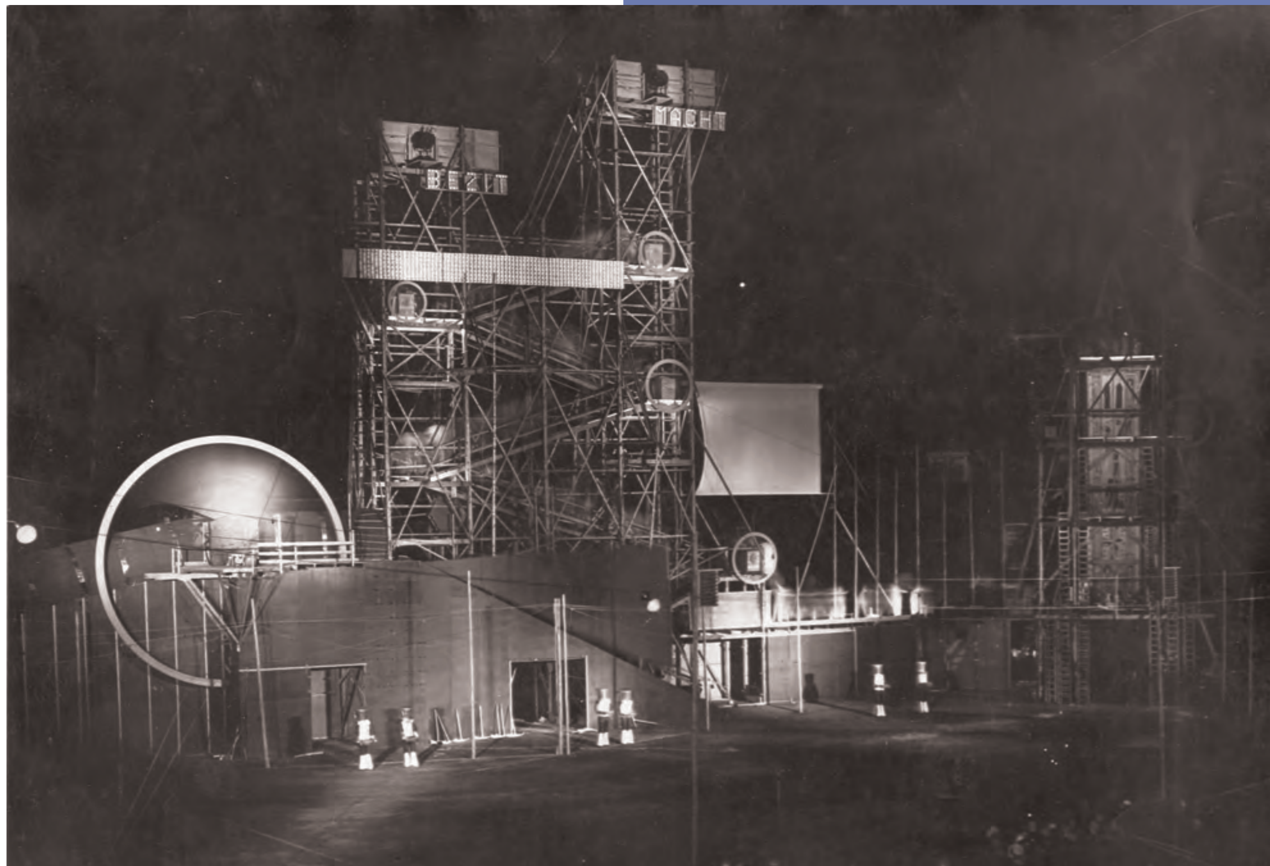

Based on international examples and expertise the 13. International DOCOMOMO Technology Seminar discusses the questions:

How was technology perceived by designing architects?

How was the collaboration with engineers and the selection of adequate building materials and systems as a part of the design process?

The seminar **Perceived Techologies in the Modern Movement** on January 25/26, 2013 in Karlsruhe, Germany, was organised by DOCOMOMO International Scientific Committee Technology (ISC-T) in collaboration with the Karlsruhe Institute of Technology (KIT).

It figures also as the 10. Karlsruher Tagung „Das architektonische Erbe“

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

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International working party for
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of buildings, sites and neihgbourhoods of the
modern movement

Perceived Technologies in the Modern Movement 1918 - 1975

preservation technology
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Perceived Technologies in the Modern Movement 1918 - 1975
proceedings of the 13th International DOCOMOMO Technology Seminar
january 25/26 2013, Karlsruhe

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The seminar figures also as the 10. Karlsruher Tagung „Das architektonische Erbe“. Financial support for the seminar and this publication has been provided by Beton-Marketing Süd

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Institutions involved in the organization of the seminar

Front cover picture of Arango House by John Lautner from the contribution of Frank Escher. Back cover picture of a unique student event 'Mensch en Machine', Delft 1-3 July 1928, from the contribution of Jan Molema.

International working party for
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Photos: Bernd Seeland

Contents

Welcome Address

Das architektonische Erbe / The architectural Heritage

Dear Ladies and Gentlemen, 10 years ago now, we discussed with the Faculty of Architecture of today's Karlsruhe Institute of Technologie (KIT) the possibilities of how outstanding architecture of the Modern Movement can be better protected. This includes in particular the refurbishment of the many buildings of this epoch in Europe and in other countries according to the most current knowledge and standards. Background of the discussion was the observation that many buildings of this era had sunk into oblivion, partly were in a very bad condition or were even already demolished. We agreed in the belief that in particular contemporary designing architects could and should engage themselves in saving this heritage.

This is why we decided to take up the issue of „Modern Movement Architecture" within the framework of a regular event to report and discuss about the actual conditions and developments and about good examples and best practices from several countries. In 2013 the conference series we started took part for the 10th time already and meanwhile it is not only supported by KIT and Beton Marketing Süd GmbH but also by DOCOMOMO Germany e.V. and the DOCOMOMO International Specialist Committee - Technology , the German Werkbund Baden-Wuerttemberg, the Association of German Architects (BDA) and Chamber of Architects Baden-Wuerttemberg, division of Karlsruhe.

The first conferences had a focus on different or comparable countries in Europe presenting their particular features and case studies. Next to the country specific developments other aspects became more important. Fundamental questions about the attitude and the value shift pushed their way into the foreground, represented by topics such as „Original + Replacement". Other recent conferences made the protection of „Authenticity" a subject of discussion and others had particular emphasis on the issues of „Perceived Technologies" and on „Energy" questions (2014).

The organizers of the 10th conference „Das architektonische Erbe" have the common goal of establishing a platform for actual discussions and developments related to Modern Movement architecture. They want to contribute to safeguard existing qualities in architecture in a professionally manner and to show ways and possibilities of how to take care of our architectural heritage in future in a meaningful, positive way. The producers of cement and concrete – represented by Beton Marketing Süd GmbH in the South of Germany – feel responsible and obliged to give their contribution to our building culture.

Ulrich Nolting
Managing Director
Beton Marketing Süd GmbH

Architecture and Technology

„*Architecture begins where Engineering ends*"
Walter Gropius

At any time TECHNOLOGY was one of the keys to ARCHITECTURE and in any time Architecture in its complex character was more than its parts.
Looking at the beginning of industrialisation 90 % of all technological innovations were invented in GREAT BRITAIN. Railway stations first in London, then in Paris became big, open, public spaces. Glass technology experiences of the greenhouses, the warehouses, the exposition halls and the iron constructions of wide spanned bridges, many steps of inventions, like these of Jean-Barthélémy Camille Polonceau, suspended beams, led to wide spanned roofs with great skylights covered with glass sheets giving a spectaculous lightness, saving enormous weight and material. - VISIONS BECAME REALITY.

And at any time ARCHITECTURE is not only referring to it's BEAUTY, the aesthetical quality and its values of SPACE that enriches the city or the landscape. At any time Architecture is also a POLICAL STATEMENT and a SOCIAL ACT.
So in 1958, when Germany had to built up a new future society and a new reputation in the world, the architects Egon Eiermann and Sep Ruf designed a light and transparent pavilion ensemble with new furniture and details as a masterpiece and an aesthetic demonstration for a new German Society and its new place in the world as a peaceful, democratic member of the Unity of States.

- In his very interesting publication „Geborgenheit und Freiheit“, Wend Fischer describes the enormous development of architecture, using technological innovations as a tool to develop new kind of architectural qualities.
It was 1973, the spectacular “Olympic Games in Munich”, when Günther Behnisch + Partners had designed a sport facility ensemble as a park. They invented a landscape instead of an arena. Together with the designer Otl Aicher a corporate identity for the OLYMPIC GAMES was developed, free of old fashioned ambitions. It was a strong cultural signal towards a new human future. The technologies for this architecture and design proposals did not yet exist but they developed it with experts like Frey Otto and his team of engineers and architects, the park together with landscape architect Günther Grzimek and their work altogether installed a new scale of ideas in Architecture and Design in a time of worldwide changes. Again ARCHITECTURE and TECHNOLOGY was able to demonstrate that it was possible to create not only a masterpiece and milestone of its time but something new for the whole society.
Again in the very remarkable exposition and publication in Munich „Die andere Tradition, Architektur in München, von 1800 bis heute“, 1981-82 designed by Otl Aicher, Wend Fischer demonstrated that the sophisticated design projects use technology both, as a basic part and as a motor for innovation and that this is still going on in the contemporary design.

MODERNITY was in each of its phase connected with development of innovative use of old and new materials, new instruments, new design. When the industrial design came up also lifestyle changed intensively, promoted by the dynamic of the film industry and its influence on the people worldwide and by the advantages of new materials in the mass production.
The INTERNATIONAL STYLE had become political correct in all countries, a new culture for homes was coming up, for example with Ray and Charles Eames furniture the light style of the case study houses, the bungalow, the apartment. A new smell and a new sound of a young generation had appeared, the world was changing. Verner Phanton’s chairs appeared together with the Flower Power and the POP generation and the design for flexible and universal use like for example the USM Haller Systems headed tendencies of minimalism. All these designers got pioneers of artistic and genius design by reflecting technologies and ideas of their time, which changed rapidly by social and political emancipation.

When in the eighty’s the British High Tech Architects widened the field, beside skin and skeleton, space and technology but also ecology was in the focus, looking for the conditions for the future, international projects, business, communication and mobility, spaces flexible for change and progress, expressing the essence of a powerful autonomous architecture. French young architects started to give new input by looking forward to new aspects of architecture like scenography. The research on glass technology led to new possibilities of being creative with this and with other materials. Together with the progress in calculating and designing constructions as membranes and new advanced methods like „finite elements“ a way to new solutions was realised in very short time.
It is easy to understand that in Germany, a country of few resources, energy-saving standards and methods and relevant technologies for ecological systems have come on the agenda and there is a big pressure to do as much as possible to minimise our ecological footprint.

Today the SMART MATERIALS are on the way to help us making our surrounding healthier, functional and particular and giving perspectives to a life cycle management and sustainability. Meanwhile the ALGORITHMS are ruling the world, not only in the financial market or in the computer-centres of the secret services. Simulation is first and in Science it is a third leg together with the Theory and the Experiment. So TECHNOLOGY in future will be also inside the tools to by creative and the tools to design, in the logistic and it governs the information, the communication and the way of thinking.

Looking at the architectural heritage it is worth to see and to understand very precise the conditions of the buildings, to do research deep into the substance of each project. It will help us fighting, discussing and finding out good professional solutions to give these buildings, urban ensembles or landscapes a future, to share the cultural richness.

Alex Dill
KIT - Faculty for Architecture
Institute Design, Art and Theory

Editorial Note and Preface

Jos Tomlow (ISC-T), Alex Dill (KIT), Uta Pottgiesser (ISC-T)

Introduction

Based on international examples and expertise the conference with the title PERCEIVED TECHNOLOGIES IN THE MODERN MOVEMENT discussed the following questions: *How was technology perceived by the designing architects? How was their collaboration with engineers and the selection of adequate building materials and systems as a part of the design process? Where did they find technical tools or where did they miss them, forced to improvise a feasible and economic solution? How and why did technology lead to the uniqueness of the innovative archtectural results?*

The 10. KARLSRUHER TAGUNG of the series DAS ARCHITEKTONISCHE ERBE[1] took place on 25th and 26th January 2013 at the Karlsruher Institut für Technologie (KIT) and was organised in cooperation with the INTERNATIONAL SCIENTIFIC COMMITTEE TECHNOLOGY (ISC-T) as 13TH INTERNATIONAL DOCOMOMO TECHNOLOGY SEMINAR.

The above characterised fundamental questions may lead to a new research topic. Not to many answers seem to exist, like one can derive from historic disputes, discussions and contributions or manifests by the Werkbund, de Stijl, CIAM and other organizations. Only by differentiation we, as descendants of the 20th century and reaching the 21th century, may find answers for such questions. Many buildings have been and are going to be analyzed and renovated and can serve as documents for the used technologies. Nevertheless modern architecture is still lacking a complete theory related to the cooperation of all professionals involved in the realization and materialization of a building.
As organizers and editors we sought for a suitable theoretical approach of the topic and for a good structure for the individual papers presented in the conference. It seemed to be interesting to depart from detailed studies of individual architectural works or of works generated by small groups of congenial individuals from different parts of the world – taking into consideratin climate, culture and biographies.

The careful selection of lectures and lecturers is based on a chronological and stylistic order. The inclu-sion of the specific architectural work into stylistic terms and definitions combines a general overview with an insight into the position of “technology” in a specific work. Although styles generally have been defined by art-historians – who sometimes lacked knowledge and interest for the historic role of technology – one may confirm that from a pragmatic view point, the incorporation of architectural work in styles may help to establish a certain historical order, also as a hypothetic dialectic path of thesis versus antithesis.
In the history of the DOCOMOMO community and its aims since 1988 the definition of MOMO (MOdern MOvement) slowly widened, in both the time perspective beyond 1950s (New York 2004) and in respect of tolerance towards and subsequent interests in other modernisms (Istanbul & Ankara 2006). Whereas in the beginning DOCOMOMO focussed on the “classic modern architecture” from 1924-1929 (or 1918-1932) subsequently the period was enlarged incorporating younger times till 1975.[2]
As a consequence, the initial black-and-white-view of moderns opposing conservatives shifted into a much more complex position. A high differentiation level, taking into account certain aspects – like time, place and climate, sociological circumstances, economy – may be thought necessary to proceed with a scholarly analysis of the Modern Movement, resulting in a fruitful conservation strategy.

The substantial historic extension to a period of 1918-1975 brought to light much more than a controversy between moderns and conservative: contradictions became clear between generations (Oedipus conflict, children versus parents, in the case of Team X inside CIAM), between political systems (East versus West versus Post-Colonial systems), in the sense of national identification (autarchy versus free trade) or between economies (local versus glob-al) between different climatic zones and others. Thus the lectures of the seminar should regard “technology” and discuss specimens of:

1 The architectural heritage.

2 Recently also younger times than 1975 are included. Older periods than 1918 as well as periods younger than 1975 are not considered here for specific reasons. The historiography of the influence of earlier styles like Art-Nouveau, Neo-Gothic rationalism, 19th C. engineering design, is well studied and common knowledge. After 1975 a multitude of new styles – many of them reform-styles of earlier tendencies – occurred within a pluralistic cultural framework. Other approaches like Post-Modernism, and Deconstructivism show playful and irrational concepts with anti-technological impact, thus obscuring certain MoMo aims. Future studies will have to take care of them.

- a main architect or condensed group of architects or style of the period 1918-1975;
- architectural works also from Non-Western world regions.

Finally in this publication eight of elven papers are published and are accompanied by an important statement of the Docomomo International Specialist Committee – Technology called “Matter and Time – Perspective of Technology”. The editors want to thank all who contributed either by co-financing or in other ways to the success of this research project. Special thanks for layout to Jan Fallgatter M.A., HSZG, and for printing and distribution to Grafische Werkstätten Zittau.

Conclusions

The final discussion was moderated by Wessel de Jonge, former ISC-T Chair and co-founder of DOCOMOMO International. Several assumptions with regard to technology were identified and served as a starting point for the discussion. It seems that new technologies were used for problems that where not possible to solve with old construction methods and thus they were often prototypical and never went into standardization. New technology was also being developed to enable change and adaptation in a functional sense, reducing construction time through prefabrication or implementing new materials.
By comparing the lectures it became clear that there was a close relationship between the architect and the engineer involved in the project. Or the architects were very open for new construction principles, materials or products. This curiosity allowed them to bring different influences together and to integrate them into the architectural design. It can be assumed that in both ways a real and true dialogue arised - between architect and engineer or between architect and producer. The design process was seen as a teamwork resulting in an integral and holistic design.

This finally led to an important topic that was not referred to in the presentations, but raised by Colin Davies: the concept of authorship. If architecture is a collabarative enterprise, involving the (urban) planner, the architect, the engineer, the client and the construction companies, the authorship cannot be claimed by the architect solely but should be a joint one. An approach that is clearly restricting the traditional self-image of the architect, supposed of being the master-designer and master-builder. A second relevant topic was raised at the end of the discussion about the relationship between craftman-ship and industrial production. As a result of the industrial revolution in the 20th C. more and more building components were produced as industrial components not designed – but developed for mass customisation. Product development is mainly depending on prefabrication and serial production. It might be seen as a pioneer work and success of modern movement architects of being open for this exchange – taking it as a challenge more than as a restriction. How can we – a hundred years later and under the pressure of dealing with radical climatic and demo-graphic changes – learn from our professional ancestors? The audience agreed on that every intervention needs innovation and invention to be convincing.

The challenge of the 21st C. is the re-use and adaption of the modern heritage dating from 1918-1975 to maintain a sustainable and authentic environment in the different continents of an increasingly globalized world.


The authors and organizing team

Matter and Time - Perspective of Technology

DOCOMOMO International Specialist Committee - Technology

Background

The DOCOMOMO ISC on Technology (ISC/T) has focused on building technology to explore many underlying and pedagogical philosophies which relate to the inception of building design and construction in the Modern Movement. We also ponder architecture as a social and educational framework and, over the years, the work of ISC/T has maintained an exploration of unique historical perspectives which focus on the evolution of technology and these applied innovations within the Modern Movement.

Statement

As practitioners and educators, we must identify, support, and foster methodologies to maintain the technology used to construct buildings of the Modern Movement. To this end, the ISC/T is exploring strategies to manage change over time.

Consideration

How can we allow and account for change over time of these buildings and the continued use of their construction systems? We may consider the following:

- Technology is a key element of the modern movement.
- Innovation has given way to buildings which utilize technologies representative of diversity in time and place from the modern movement.
- Skills and knowledge which were used to construct Modern Movement buildings must be identified and respected
- Various perspective also failures, can be identified in the construction of the past

Goals

The ISC/T has defined the following goals:

- To emphasize and share material research, case studies and knowledge, so that the greater body of work by the committee can be used to focus on current conservation strategies for practitioners and educators.
- Through the documentation and comparison of technologies of this era, we must be able to improve upon previous identified innovations as we conserve buildings of the Modern Movement.
- To build upon the solid foundation and work of the committee as well as carry out practical and rigorous discussions that relate to the construction of the buildings from the past. Our discussion of technology in the Modern Movement will go beyond just a historic account.
- To engage and collaborate with the broader interests of the working parties and specialist committees of DOCOMOMO and to participate in ongoing implementation of the best care and practice for the conservation of Modern heritage.
- To prolong and sustain the life of Modern Movement buildings and to recognize how historic technologies were used so that they can be balanced with adaptive reuse in the future.

The following are general comments raised by committee members during the last two meetings. We ask that the committee members confirm that the questions below have been sufficiently addressed by the statement above:

- What is the significance of Modern Movement, as Time, Matter and Idea?
- How do we discover, document and relate to conservation when it comes to technology of Modern Movement?
- How do we successfully document the evolution of technology?
- How is the experience of matter and idea for the architect/conservator shared as common interest?
- What does the practice/hands on work with material/technology mean to the committee?
- How does the ISC/T take a more active part in further analysis and study of materials and technology?
- How do we engage these questions and others at meetings among ISC/T members, how can we develop a forum for broader discussion of these issues within the context of upcoming seminars, and potentially the Journal.

The ISC-T Team:
Regino Antonion Gayoso Blanco, Paulo Bruno, Iveta Černá, Emanuelle Gallo, Franz Graf, Wessel de Jonge, Robert Loader, Ivo Hammer, Susan Macdonald (Secretary), Tapani Mustonen, Kyle Normandin (Chair), Mariël Polman, Uta Pottgiesser, Jos Tomlow, Jadwiga Urbanik, Ola Wedebrun, Yoshiyuki Yamana.

This text has been written in a first version by Ola Wedebrunn in 2009 and was finally reworked within the DOCOMOMO International Specialist Committee – Technology meeting at Brno Castle (Czech Republic) July 4th, 2011, and finally published in the minutes of the meeting on August 1st, 2011 by Kyle Normandin (Chair), Susan Macdonald (Secretary).

The *Grossmarkthalle* in Frankfurt/Main – An early reinforced concrete shell structure

Horst Peseke, Manfred Grohmann, Klaus Bollinger

1. Introduction

The idea of constructing a large wholesale market hall in Frankfurt dates back to the Wilhelminian era. After a first attempt which was interrupted by the outbreak of the First World War, the design and construction of the *Grossmarkthalle* (wholesale market hall) began in 1926 according to plans of Professor Martin Elsaesser. The city of Frankfurt aimed at improving the supply of fresh fruits and vegetables for the citizens of Frankfurt as well as expanding the area of influence of the city in terms of food supply at a regional scale, which explains the size and appearance of the market hall. The *Grossmarkthalle* was inaugurated in 1928 and the wholesale market stayed there until 2004.

The *Grossmarkthalle* today comprises of the following elements:

- the east wing building (former refrigerating storage building; L/W/H: approx. 60/18/29.75 m),
- the market hall (L/W/H: approx. 225/55/23.5 m),
- the west wing building (former office building; L/W/H: approx. 60/18/29.75 m).

The overall building ensemble originally also included two annexe buildings (East and West), the so called Importhalle (for southern fruit imports) and an extensive transportation infrastructure between the buildings. Those structures were removed in the meantime and do not exist anymore.

The Großmarkthalle is a listed building, which will be converted by the European Central Bank (ECB) as part of its new headquarters. In this context the structure of the Großmarkthalle was investigated and a concept of refurbishment was developed, respecting the requirements of the historic preservation authority of the state Hessen.

Figure 1: North façade.

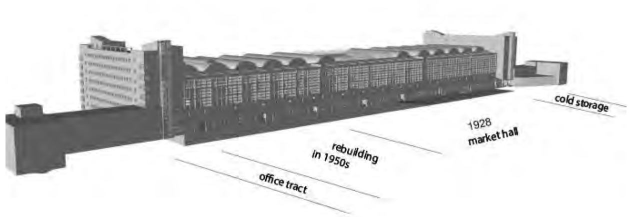

Figure 2: Overall view.

2. The *Grossmarkthalle*

The *Grossmarkthalle* encompassses approximately 235 000 m³. The market hall itself is divided into three sections with five reinforced concrete half-cylindrical shells each. The shells are built according to the "Zeiss-Dywidag" system, as roof shells with edge beams (constructed as box girdres) and endplates. The box-girders are supported by inclined columns, the latter are fixed into individual foundations, as described in Kleinlogel [5], [6] and in Dischinger and Finsterwalder [3], [4].

The envisaged geometry of the shells is based on a circle segment with a radius of 7.50 m. The shells' thickness ranges from 7 cm to 10 cm. The reinforcement bars are set in five different layers with respective dimensions of 12-8-12-8-12 mm. Their disposition follows a rhomboid shape based on the main stress trajectories. For the concrete, a high quality Portland cement (Dyckerhoff-Doppel) is used in proportions 1 to 4. The edge beams of the shells are designed as box girders with dimensions of 0.8 m width and 1.9 to

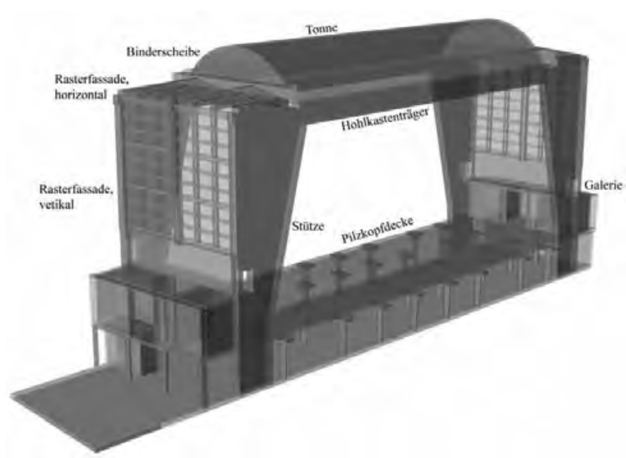

Figure 3: Segment of the Grossmarkthalle.

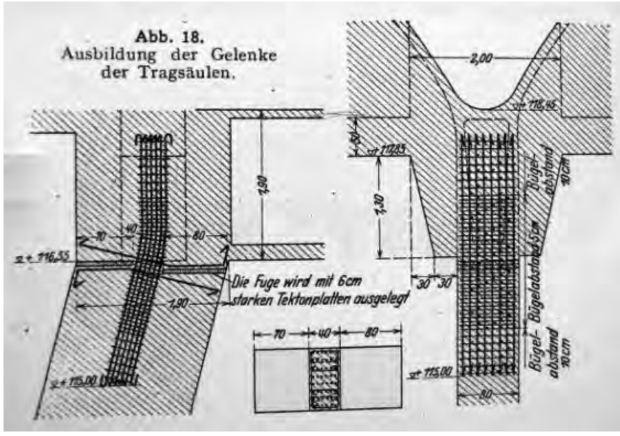

Figure 4: Concrete Hinge.

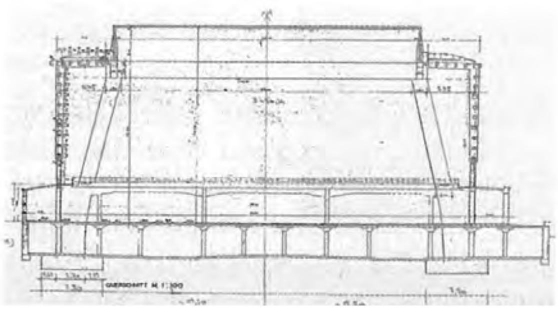

Figure 5: Cross section.

2.0 m height. The side of the box-section are 10.0 cm thick whereas the bottom of the box-section is 22.5 cm thick. The top of the box-girder is slightly inclined for drainage purposes. The columns of the *Grossmarkthalle* are 0.80 m wide and 1.90 m thick. The connection between the box-girders and the columns is articulated. The articulation is designed to transmit only horizontal and vertical bearing forces.

The façade of the *Grossmarkthalle* is supported on half frames and spans between the primary columns. The facade frames comprise three different sections in a regular pattern.
The floor above the basement is executed as a reinforced concrete plate supported by individual columns. Each column has a polygonal section and is locally reinforced at the connection point with the floors. The columns are supported on individual foundations. The perimeter walls are built with bricks.

3. State of the Art 1926

Three major lines of evolution converge into the design of the Großmarkthalle.

- The investigation of the composite behavior of reinforced concrete,
- The progress made in prefabrication techniques and
- The increasingly theoretical calculation methods

All three developments influenced one another and established in 1926 a state of the art, which regard to spatially curved concrete structures, which enabled the construction of the *Grossmarkthalle*.
Since the second half of the 19th century, bridges, industrial- and commercial-buildings were built as reinforced concrete structures. The use of reinforced concrete structures then gradually expanded to residential-, administrational- and academic-buildings, shown by Giedion ([4], pp. 220) and Müller-Wulckow [5]. An attempt to present its effectiveness and adaptability was the Monier-Broschüre by Wayss [14], which was therafter completed and updated in professional journals and publications of the different concrete unions. Even in 1929, the reinforced concrete construction was still an early stage of development.
The debate about reinforced concrete can be divided into three major themes:

- Characteristic data and behaviour of the material,
- Fabrication and manufacturing, as well as
- Applicability.

The structural performance of specific building elements formed the basis for the applicability of reinforced concrete, see Mörsch [9]. With time, more and more traditional building elements – from columns and beams to plates, frames and trusses - were constructed in reinforced concrete. The increasing knowledge of two-dimensional planar load transmission possibilities logically led to the creation of shell constructions. Material specific research and development began to form an independent field of construction science, e. g. the research of Bach [1].
Reinforced concrete constructions permitted to reduce thickness of sections in comparison to traditional masonry vault and arch constructions (see Mörsch [10], pp. 217 - 240). The tolerance for the formwork (shuttering) had to be dramatically diminished in order to meet the planned thrust line, as even the smallest deviations lead to considerable unplanned bending moments in the shell. The formwork was usually made of wood which required a lot of operating expenses, which was often subject to shape imperfections and which lead to dangerous stress states while stripping the formwork.
Walther Bauersfeld proposed a different approach for the realisation of reinforced concrete shells, described in Kurze [8]. The design of the planetarium for optical works in Jena in 1922/1923 was based on a projected spherical surface. The shell had to be supported by the existing roof due to a shortage of space and thus had to be quite light. In collaboration with the engineers Mergler and Franz Dischinger

from Dyckerhoff & Widmann, they accomplished to design a shell built in 1923 triangulated with a set of unique custom-built steel bars. The reinforcement is fixed to the steel bars to take up the forces in the shell. A climbing nine square meter wooden formwork is mounted on the inner side of the shell and shifted further after every concreting step. The concreting was conducted from the outside by means of sprayed concrete. Due to the high costs of the manufacturing of steel bars, the principle was developed further into a systematic formwork technique ([15], [16]), which was also used for the roof of the *Grossmarkthalle*. This formwork technique permitted to remain accurate to shape and the mathematical form-finding as well as to avoid hazardous mechanical states during the stripping of the falsework (see Kleinlogel [5], p. 12).

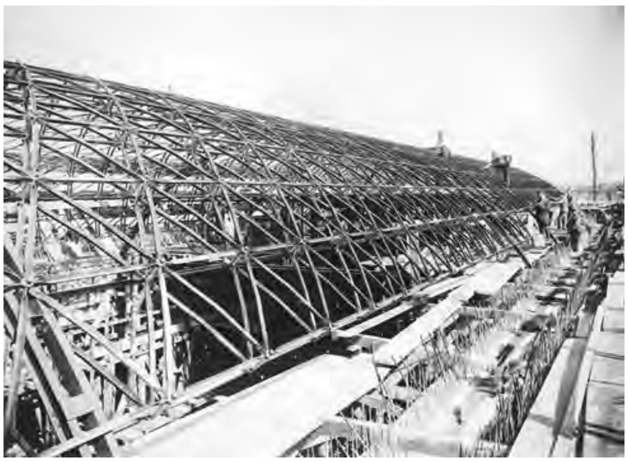

Figure 6: Formwork.

Figure 7: Concreting

The concreting was conducted based on the spread mortar technique ("Torkretverfahren"), which was introduced in Germany by Carl Weber. This technique emerged in the US in 1909 and was patented [17] in the German Empire in 1919. Pneumatic driven pipes spray the wet or dry cement mixture on the intended surface.

The applicability and practical use of these new construction methods were described by various building associations, who also developed the relevant codes (compare [13]). The structural safety concept of the *Grossmarkthalle* was based on a predictable and sufficient margin between the actual working load combined with the ultimate load and load capacity of the structure. The exhaustive experiments conducted by Wayss & Freytag formed the basis to develop new calculation methods which focused both on the structural behavior and on the cost-effectiveness of the material applicability. The calculations of the reinforced concrete section investigated the internal stresses equilibrating the external loads and established the necessary reinforcement to take up the tensile forces. The difficulty was to assert the inner stress states of the structure. In addition to the calculative approach of the market hall, a large scale experiment was also conducted. In parallel to the construction of the main hall, an experimental shell in a scale of 1 to 3 was constructed and gradually loaded between the 11th of April and the 4th of Mai 1927. The main goal was to obtain information on the stability of the cylindrical shell, clarified by Kleinlogel [5] (p. 15). He reports in [6] (pp. 25) the results of these tests. Corresponding to the testloads the deformation was measured with the measuring point in the centre line of the model.The experiment proofed that the structure possessed sufficient material behaviour and sufficient load resistance.

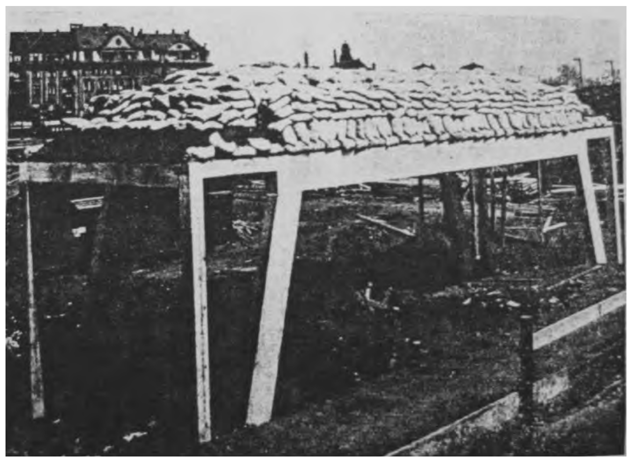

Figure 8: Experimental shell.

The building companies were responsible for the correct dimensioning of the reinforced concrete structure. Thus, they had an economic interest in the analysis of the existing internal stresses which postulated the respective reinforcement devices as well as the construction of the structure. By virtue of his experience in Jena, Franz Dischinger also used the "Zeiss-Dywidag-System" for cylindrical shells under

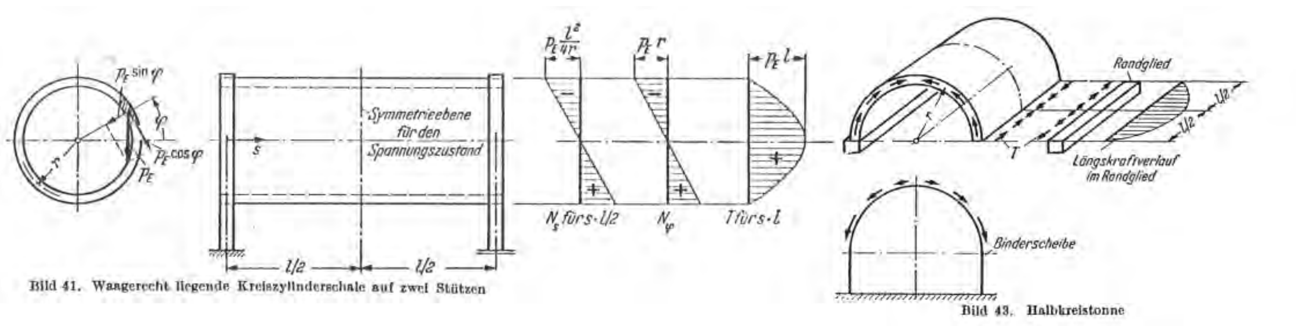

Figure 9: Loadbearing transfer.

the condition that binding elements or transverse beams were built at a certain interval and that the bending stiffness of the curved parts was sufficiently low. This formed the basis for the membrane theory of shells for the determination of the internal stresses. Bauersfeld wrote this idea out and put it into practice for the roofing of an industrial building in Jena in 1924, compare Kurze [8] (p. 68). The second pprototype was constructed on the “GeSoLei”-fair (Gesundheitspflege, Soziale Fürsorge und Leibesübungen) in Düsseldorf in 1926. Ulrich Finsterwalder who started

Figure 10: Market hall during refurbishment works.

to work for Dyckerhoff & Widmann in 1923, focused on the development of the shell theory for transversally stiffened cylindrical shells (see also Kurze [8] (p. 69)).

The then innovative structural concept of the market hall created the possibility for an integrative building concept thanks to progress made in terms of material technology, pre-fabrication and calculation methods. Prior to the start of the construction works in December 1926 the city of Frankfurt, i. e. the building department headed by Martin Elsaesser, designed a preliminary draft. The guidelines for the functional and architectural design were combined with a technical competition between the different material crafts represented by steel-, timber- and concrete-companies. The aim was to receive a structural concept which fulfils the architectural ambitions with economic and maintenance requirements. The call for tender showed that the City of Frankfurt was well aware of the technical challenges resulting from the preliminary draft of the *Grossmarkthalle*. The competition between the different material crafts resulted in a cylindrical reinforced concrete shell. The structural concept, the construction design and the calculation were drawn up by Dyckerhoff & Widmann and the

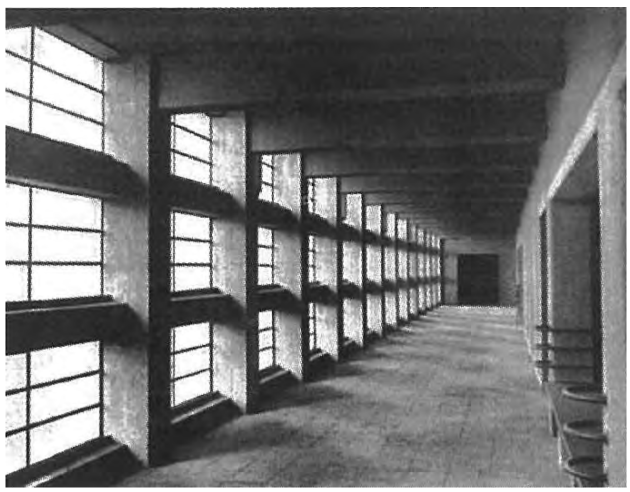

Figure 11: Corridor of the cashier station, 1928.

Figure 12: Cellar area.

Figure 13: Aspects of facade masonry.

final construction was conducted in a consortium with Wayss & Freytag. Both firms had a 30 year long experience in this technique and were actively participating in further material researches. In contrast to the well-established steel structures transferring spatially load had been made until the construction of the *Grossmarkthalle*.
Alf Plüger described in [12] a proposal for understanding the structural behaviour of the shells. A tube, which is supported by endplates, is divided according to length. The truncated part of the tube is replaced by edge-beams. The principal behavior of the shell is shown in figure 9.

These principles were further developed for the *Grossmarkthalle* and combined with the design by Martin Elsaesser into an ingenious prototype.

Figure 14: Design of the headquarter of the European Central Bank (ECB) in Frankfurt/Main by Coop Himmelb(l)au, 2008. The refurbished *Grossmarkthalle* has been added by a 200 m twin office tower and other additions.

Besides its dead load, Dischinger and Finsterwalder described in [2] and [3], that the load bearing structure had to transfer the loads from the roof covering, the variable wind and snow loads and thermal fluctuation damage-free and safely. The control of thermal expansion in the longitudinal and transverse direction was a key step of the process. In the longitudinal direction, the thermal expansion was given a reasonable limit through a division of the market hall structure into three main sections with respectively five half-cylindrical shells each. The façade, which was directly exposed to weather conditions, was subject to an additional partitioning. The three central fields of the facade were detached from the two edge fields of the façade. In the transverse direction, the shells were connected via a concrete articulation with the inclined columns.
The wind loads were taken in by the inclined frames of the façade in combination with the horizontal parts of the gallery and the fixed columns.

4. Analysis of the status quo of the *Grossmarkthalle* and the development of the respective concept for refurbishment

4.1 Concept for the analysis of the status quo of the *Grossmarkthalle*

In addition to the an available drawings of the reconstruction, documentation of the building applications for the renovations, the bill of costs of the maintenance measures as well as the transcripts of the inspections), on-site inspections proved to be mandatory in order to assess the status quo of the *Grossmarkthalle*.
On the basis of the results of these inspections a research scheme was developed. This research scheme takes into account the various construction methods and times, the various production methods of the involved construction companies, the aging of buildings in general and the minimal maintenance which was conducted throughout the years. This scheme was divided in view of methodical and temporal issues. Methodically was distinguished between objectives that allow a survey of the existing

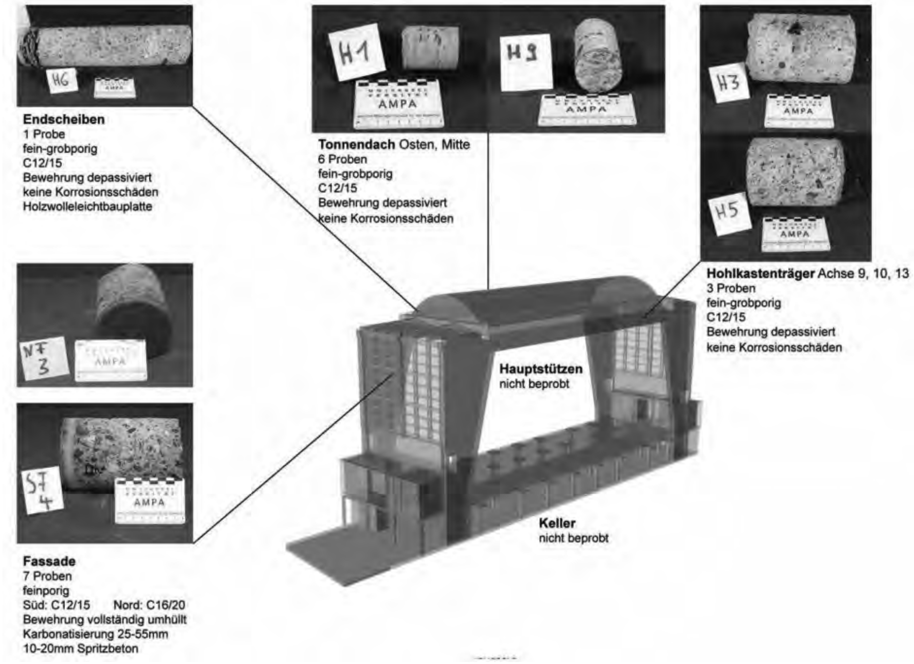

Figure 15: Results of the analysis of the status quo of the Grossmarkthalle, concrete samples..

Figure 16: Ribbed ceiling, before and after refurbishment.

condition and the refurbishment methods of object-specific design taking into account the character of a heritage building.

The objectives include the investigation of the structural compressive strength, Young's modulus, the concrete density, the pattern of cracks, the level of carbonation, the concrete cover above the reinforcement, the type of the existing reinforcement and its distribution within the concrete as well as the corrosion of the existing reinforcement.

The measures for the refurbishment take into account the surface textures, the degree of moisture within the concrete, the gas permeability and the tensile strength of the surfaces. With regard to the preservation of the *Grossmarkthalle* the colour and brightness of the concrete surface are analyzed and the surface textures and weathering are recorded.

The compressive strength of the various shell elements varies with 1,8 N/mm² as the lowest merit and 56,9 N/mm² as the highest with an average merit of 42,2 N/mm². The average value of the Young's modulus is 19406 N/mm². These results are based on 54 drilling cores. In historical design codes the requirements for the compressive strength amounts to 13 N/mm² and the requirements of the Young's modulus amounts to 14000 N/mm2.

4.2 Refurbishment of the *Grossmarkthalle*

The concept for the refurbishment of the *Grossmarkthalle* can be divided into two tasks. The first task relates to the structural refurbishment, the second task deals with the restorative renovation. Since the latter is based on the former, there is only a partial independence in the choice of material and the layer sequence.

The restorative renovation of the damaged listed *Grossmarkthalle* is based on

- Careful handling of the existing status quo of the

building,
- Selecting procedures with minimal intrusion depth, which are also tailored to the various cases of damage,
- Feasibility and reliability of repairs, few but multiple-use materials,
- Considering the scale factor (size and frequency of necessary measures),
- Preference of procedures, ideally depending only on a few parameters.
- In addition, the restoration renovation gives high priority to
- The careful integration of the architectural design
- The preservation of historically important areas and surfaces
- The sampling and demonstrating the design criteria of M. Elsaesser.

The various design elements were recorded. Their structure and their characteristics were described in detail. For the renovation, the possible inclusion about deviations and damages were discussed. While assessing the actual damages design rules and codes of the construction period and current design codes were compared. This led to a system of design features related to the type of construction corresponding with a classification of damages. Based on this damage catalogue various procedures were developed and applied to sample surfaces to

Figure 17: Principles of renovation, tested at one column.

test their adequacy. The objectives for the renovation were optimized, in a coordinated process of the building owner, the historic preservation authorities and the relevant experts.
Figure 17 shows the results of this testing-phase. The refurbishment of the concrete – including reinforcement-protection, new different concrete layers and a finish with a dispersion-silicate paint which – corresponds to the original surface.

The refurbishment measures were classified in three different groups, depending on the status quo regarding stresses and deformation:
- Measures of low-intervention depth. Changing the existing construction only to a limited extent, stress and deformation changes aren't expected (e. g. removing the layers of dirt, small spatial clinker repairs and joints).
- Measures of medium-intervention depth. Changing the existing construction in only small areas. Occurrence only for locally different stresses and no additional design elements will need to be added. (e. g. a local break out of concrete without exposed reinforcement, medium spatial clinker repairs and joints).
- Major intervention measures. Altering the existing structure by adding new independent design elements. A significant change in the designed stress and deformation state is necessary for the preservation of the market hall (e. g. local break out of concrete with exposed reinforcement, strengthening and new connections).

Based on these principles and the results of analysis of the *Grossmarkthalle* the design team has established four types of measures: maintenance, conservation, completion and replacement.
In addition to the damage occurring at isolated spots which can be clearly allocated, it is possible to define different damage classes. These classes are distributed in varying concentration (density) across the building. Every type of damage corresponds to a refurbishment measure and the density of damages is related to a concentration of measure. The basic tasks are in turn assigned to material related measures. With regards to the selection of procedures the type of damage determines the type of action (measure) and the degree of damage determines the denseness of action.

5. Conclusion

The chosen planning process allows for a risk reduction in terms of refurbishment measures for a listed building. In particular with regard to:

- The building owner’s now sound knowledge of available technology.
- The Coordination of procedures between the building owner, the design-team and the heritage authority.
- The determination of quantities of the measures required.
- The Limitation of the risk of errors during implementation on site.

The documents drawn up support site management in the supervision of the construction, enable cost controlling and presents construction companies a tool for carrying out the renovation successfully.

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On 26th January an site excursion was organized to visit the building site the new European Central Bank (ECB) building, which is an example of Re-Use of the former Grossmarkthalle / Central Market Hall Frankfurt/Main. The temperature measured -8° C.
Tour Guide: Thomas Rinderspacher, building division of ECB / P. R. division, in coordination with architects and structural designers. Photos Alex Dill.

Bauhaus and the new technologies for „home building and home furnishing"

Wolfgang Thöner

The Bauhaus is perceived as one of the most important institutions for the development of avant-garde architecture and industrial design of the first half of the 20th century. What made the Bauhaus, subtitled *Hochschule für Gestaltung* from 1926 onward, so special was not least its openness toward new trends in art, culture, science, technology, economics and society. The Bauhaus brought together a number of extraordinary architects, artists and designers of its time. In addition to being a pedagogically innovative educational institution it was also a production facility with its own sales department and a forum for international debates. Unlike almost any other school or institution, the Bauhaus addressed the question of manageability of the modernisation process by means of design while the industrialised society was facing crisis-laden times.

The conference asked for the onset and the effects of technological innovation in modern architecture during the period from 1918 to 1975. This is a genuine Bauhaus topic, since the school was an institution whose guiding theme was to have design – of any type - react to the challenges of new technologies (even if the school itself was not the origin of the technical innovation), a school that desired and anticipated the development of new technologies: "Art and technology – a new unity" Bauhaus founder and first director Walter Gropius demanded in 1922. The Bauhaus made an impact far beyond its time of existence from 1919 to 1933, which is the time period this article is limited to.[1]

The term technology as it relates to architecture typically conjures up a new design vocabulary or an architectural artefact and its production, i.e. constructional novelties, new materials, new building equipment. However, technology also applies to all of the equipment and methods used to regulate building services, in a narrow and a broader sense, particularly the climatic and lighting conditions in a building by means of new sources of energy and media: In the Nineteen Twenties, the modern home was inconceivable without the fact that it could draw on more and more external energy and material flows. With the industrialisation, all houses were successively connected into a network; they were perforated with water and wastewater pipes, gas pipes, electric power cables and telephone lines. With antennas, sometimes visible on the outside, the invisible waves of the new medium radio were received. At the

Fig. 1: Herbert Bayer, information leaflet about the Bauhaus building, 1925. Image rights: VG Bild-Kunst Bonn.

1 The Article Title Part "Home Building and Home Furnishing" / „Hausbau und Hauseinrichtung" refers to the Statutes Bauhaus Dessau, October 1926

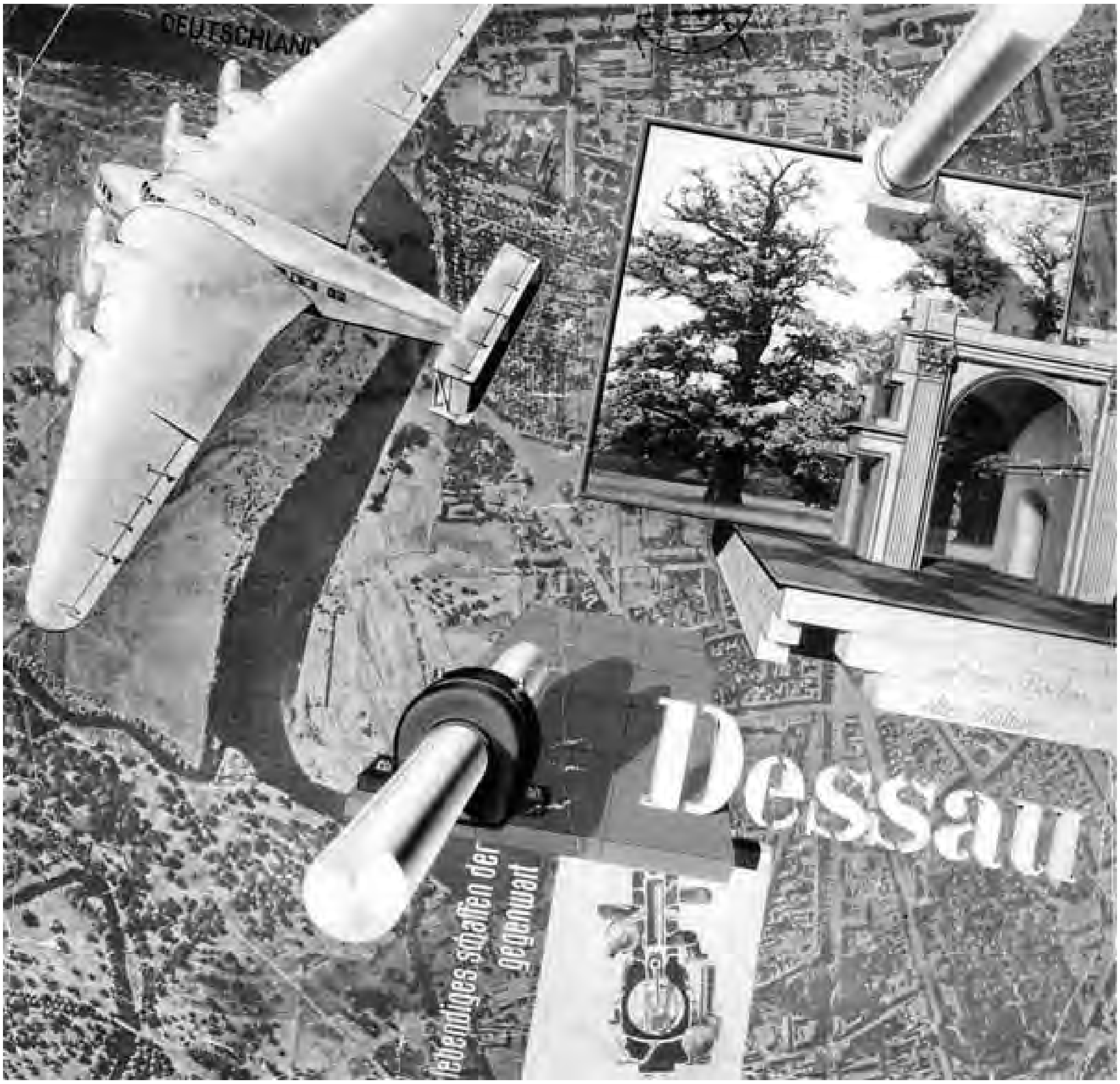

Fig. 2: Joost Schmidt, title of a brochure for the tourist information of the city of Dessau (Fremdenverkehrsamt der Stadt Dessau), 1931. Image rights: VG Bild-Kunst Bonn.

Bauhaus, the modern home and modern furnishing was perceived as a unit. In the new statutes of 1926 following the move from Weimar to Dessau, the Bauhaus focussed on two goals with even more dedication: firstly, on the „intellectual, craftsman-oriented and technical education of creative people for visual design work, particular for building construction", and secondly on „the execution of practical experiments, particular for home building and home furnishing as well as the development of prototypes for industry and skilled crafts"[2]. Contacts with the industry became more varied and were intensified. That same year, Gropius asked where the working fields of artists and engineers touch, for him the „hotspot between civilisation and culture". According to Gropius the artist holds the intellectual leadership; even if he/she could only achieve this by maintaining "a continuous connection to the production processes". The "artistic designer" should "learn from the technical inventor and constructor"[3] . This was only put into effect in the Bauhaus curriculum in 1927, when the fist regular architecture education was started and engineers became part of the teaching staff. Gropius successor Hannes Meyer then arranged the educational scheme of the Bauhaus to include degrees as artist as well as production engineer and construction engineer.

The following will provide an overview of how various

2 Ibid.

3 Walter Gropius, Wo berühren sich die Schaffensgebiete des Technikers und Künstlers?. In: Die Form, Berlin 1 (1926), p. 117-12, cited acc. to: Hartmut Probst / Christian Schädlich, Walter Gropius. Ausgewählte Schriften, Berlin 1987, p.101.

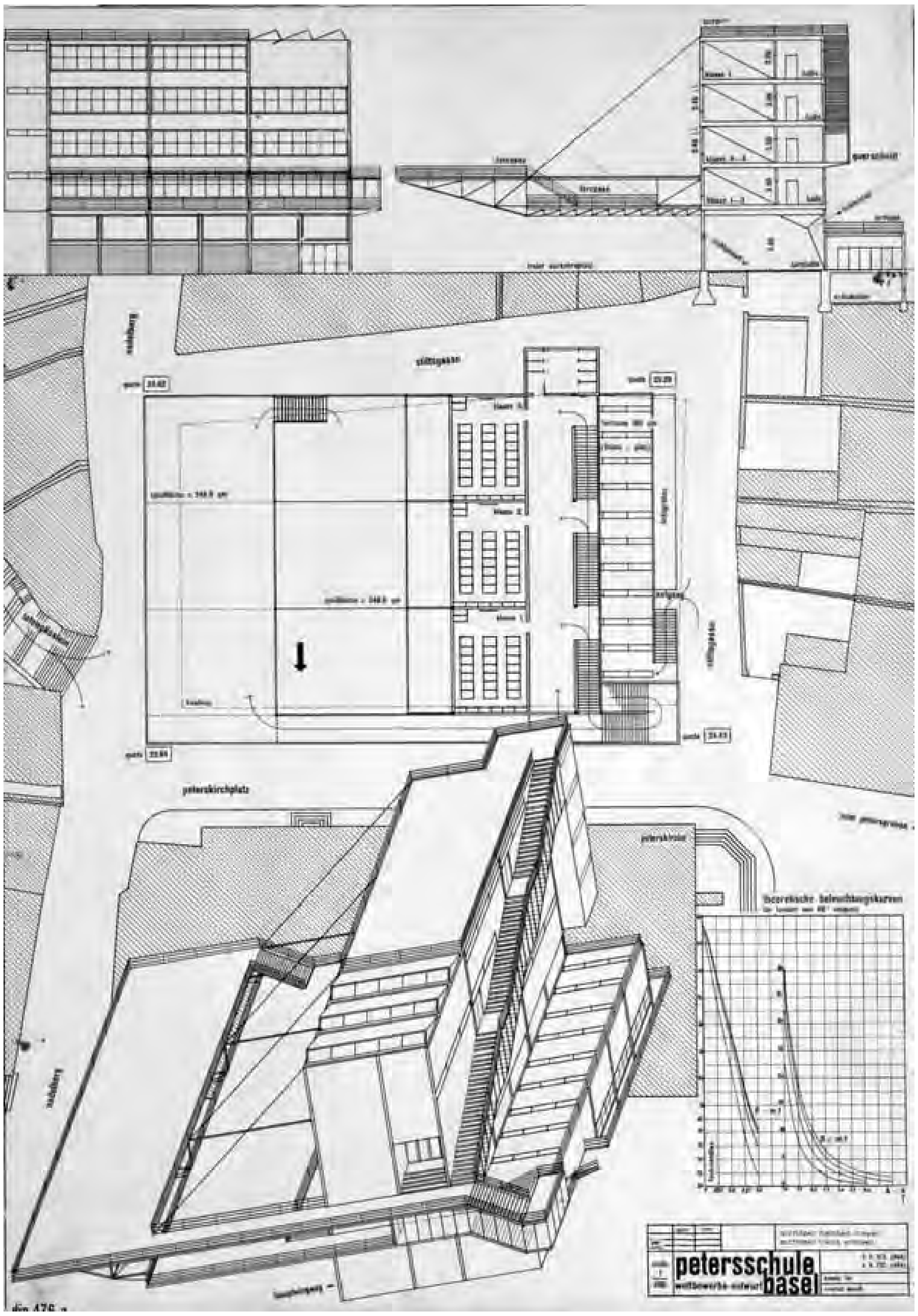

Fig. 3: Hannes Meyer and Hans Wittwer, Petersschule Basel, competition design, 1926, Bauhaus Dessau Foundation
Image rights: Bauhaus Dessau Foundation

new technologies were utilised to design and realise architecture at the Bauhaus.

New constructions, materials and methods for architecture

At the Bauhaus itself, no new technologies were developed to realise architectural projects, not even in direct collaboration with engineers. And the situation never occurred that projects evoked an architectural idea that advanced into areas that would challenge engineers to come up with new constructions. However, the architects at the Bauhaus adopted new constructions, materials and methods offered by the industry and the building craft, and explored them from a designer's viewpoint. Only a few designs, ones that were never realised, challenged the boundaries of the technical possibilities of the time.

The architectural avant-garde of the Nineteen Twenties focussed on uniformity, stemming from the cultural and particularly the economic thinking of modernity since the ages of Enlightenment and industrialisation, often connected to the strive for economic and aesthetic austerity that targeted social egality, and hereby contributed to homogenising the working, living and artistic worlds that, today, are discussed under the term globalisation. A fundamental aspect for the type of architecture that was theoretically and practically developed at the Bauhaus and which complied with the movement of New Building of the time, was the strive to design it as spatial and representational requirements of developing utilisation methods of a new life. Architecture was contemplated in terms of the analysis of its functions, i.e. the planned day-to-day use, as "conscious forming of life processes" (Gestalten von Lebensvorgängen)[4] . Artistic progress was to be synchronised with social and technological progress. For Gropius, those architectural functions for a new, modern life included predominantly intellectual aspects, which he primarily saw in new, transparent spatial concepts. Gropius considered the room, chiefly defined by its proportions, the highest goal of all of his efforts, superseding economical and other aspects: "Researching the nature of a building to give it its shape is limited by the boundaries of universal laws of technology, and to the laws of proportion. Proportion is a matter of the intellectual world; material and construction are its bearers. It is bound to the function of the building, gives testimony to its character with its own special language and bestows it with an own intellectual life beyond the building's useful life."[5] The parameters generated analytically from theoretic as well as practical experiments by architect, engineer and economist should, in the design work of the architect as the one responsible for „determining the master plan"[6] be synthesised in spatial qualities of the building that are largely disencumbered from the depictive/representational.

The example of the Bauhaus building shows how Gropius combined traditional and newly developed concepts. In fact, the building sits on a plinth that encompasses all parts and visualises load and bearing – even if in very abstracted form. The glass façade can be understood as a reverberation of the expressionistic glass constructions that Gropius referred to in 1919. In addition to engineering-oriented factory building structures, there are cantilever plates for balconies and entryways modelled after de Stijl, who introduced the topic 'floating' which in turn was a response to a "world of machines, cables and fast vehicles" (Welt der Maschinen, Drähte und Schnellfahrzeuge)[7]. The modular structure reminding of the seriality of industrial production is in some places counteracted by a composition that is oriented toward an enclosed shape following the proportions of the golden ratio. The underside of the bridge resembles the underside of a motor vehicle chassis of the time: the frame, the structural skeleton is shown "bare and shining" (nackt und strahlend)[8].

The heterogeneity of different requirements and influences was combined into a dynamic spatial unit through the aesthetics of a consistent abstract, geometrising form language. The cubes of the individual wings of the Bauhaus building resemble the

4 Walter Gropius, Geistige und technische Voraussetzungen der neuen Baukunst, in: Die Umschau, Frankfurt am Main 31, 1927, p. 909-910, cited acc. to: Hartmut Probst / Christian Schädlich, see note 3, p. 114.

5 Walter Gropius, Die neue Bau-Gesinnung, in: Innendekoration 36, 1925, p.134/136/137, cited acc. to: Hartmut Probst / Christian Schädlich, see note 3, p. 95.

6 Walter Gropius, Der große Baukasten, in: Das neue Frankfurt, Frankfurt am Main 1, 1926/27, p. 25-30, cited acc. to: Hartmut Probst / Christian Schädlich, see note 3, p. 111.

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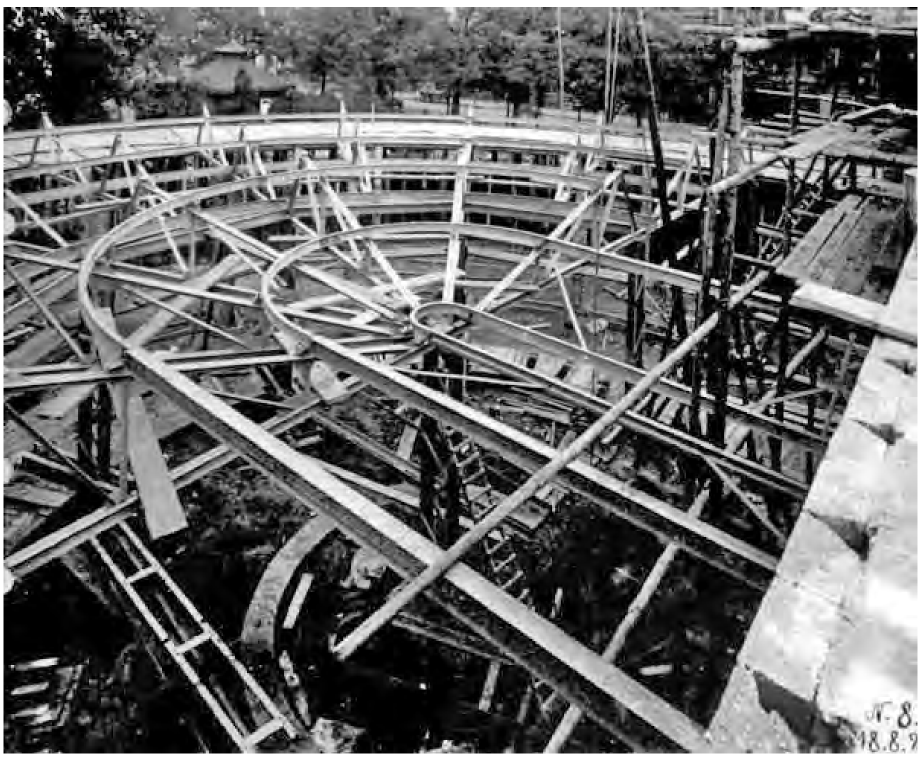

Fig. 4: Walter Gropius, employment office Dessau, construction site 1928, Bauhaus Dessau Foundation, unknown photographer
Image rights: VG Bild-Kunst Bonn

Fig. 5: Title Bauhaus book vol. 3: Ein Versuchshaus des Bauhauses, Munich 1925. Image rights: VG Bild-Kunst Bonn.

parts of a modular construction system. They all feature their own formative and spatial characteristics: The glazed curtain wall facade of the workshop wing – the most voluminous part of the Bauhaus building – eliminates any weightiness. The same is true for the large opposing stairways on either side of the bridge wing. A coloured embracement of the individual windows emphasises the possible combination of the spaces within the connecting structure to the atelier building; auditorium, stage and cafeteria can be re-dimensioned with the help of large door openings and folding walls. As with a vehicle chassis, joist elements on the underside of the bridge wing and at the ceiling of the auditorium interpret the structural skeleton and the penetration of the building cubes. In the northerly wing, ribbon windows indicate class rooms. On the far side of all this, the punctured façade on the eastern side of the atelier building emphasises the individual aspects of the modern communal life that developed there.

After the craftsmanship oriented early phase with buildings such as the Haus Sommerfeld in 1921 and the change of track in 1923, the buildings designed and realised by architects of the Bauhaus between 1919 and 1933 purposefully followed new constructional methods. The following will show this development with the most important projects. Many buildings were based on an iron skeleton which was used to realise the architectural concepts characterised by the Bauhaus building: large rooms with cantilevers and a minimum of supporting columns. Walter Gropius and his partner Adolf Meyer (until 1925) had gained according experience with industrial buildings, which allowed for different facade structures, from curtain wall to traditional punctured facades as well the cantilever of the workshop wing projecting beyond the plinth level. The second Bauhaus director, Hannes Meyer, and his partner, Hans Wittwer, also employed this technology for their projects such as the never realised design for the *Petersschule* in Basel from 1926. The design intended for an iron ferroconcrete structure to serve as the 'backbone' for a far cantilevering steel skeleton construction which was to be suspended from the core structure. Hannes Meyer and Hans Wittwer also designed the 'Federal School of the German Trade Unions (*Bundesschule des ADGB*)', realised in Bernau close to Berlin from 1928 to 1930; also with an ferroconcrete skeleton. From 1928 onward, Hannes Meyer was intent on avoiding to lapse into architectural formalism or building technical schematism. Similar to Gropius, he placed emphasis on serial elements in addition to traditional techniques. However, he stressed that technology must never be an end in and of itself: "No skeleton structure if this is too elaborate, no concrete construction if clay and brick are present onsite, no modern flat roof if a single-pitch roof receives more sun".[9] The balcony access houses built in 1930 for the Dessau Savings and Building Society (*Dessauer Spar- und Baugenossenschaft*) were constructed with conventional methods: building materials included bricks, ferroconcrete beams and hollow brick ceilings.

The steel skeleton was utilised by Walter Gropius from 1927 to 1929 in the employment office building (*Arbeitsamtsgebäude*) in Dessau. Here, he employed the knowledge of his staff member Richard Paulick, who had studied at the Technical University Berlin under Hans Poelzig, and technical possibilities available in Dessau: the steel beams were supplied by the Dessau Wagon Factory (Dessauer Waggonfabrik). Years earlier, Ludwig Mies van der Rohe, who joined the Bauhaus as director in 1930, had already designed steel skeleton constructions with glass facades as competition contributions, which at the time had not been realised. His block of flats in the development Stuttgart-Weißenhof from 1927 has a steel skeleton. One year later, numerous steel beams allowed for large column-free rooms and wide-spanning window edges with only a clinker layer showing

9 Hannes Meyer, lecture in Basel, 3.5.1929, manuscript, in: Hannes Meyer, bauen und gesellschaft. Schriften, Briefe, Projekte, Dresden 1980, p. 59.

Fig. 6: Walter Gropius, housing estate Dessau-Törten, construction site 1927, photography: Erich Consemüller
Image rights: VG Bild-Kunst Bonn (Gropius), Bauhaus Dessau Foundation (Consemüller).

in his Krefeld houses Haus Lange and Esters. Mies' pavilion for the German Reich at the world exhibition 1929 in Barcelona and the Villa Tugendhat in Brno, realised in 1930 shortly before his taking office in Dessau are buildings with extremely minimised steel columns and far-spanning ceilings.

The use of new materials and building elements was first employed at the Bauhaus in 1923 with the Haus Am Horn in Weimar (Georg Muche and Adolf Meyer). Rather traditional from a constructional point of view, it utilised so-called Jurko bricks and hollow brick ceilings.

With the housing estate Dessau-Törten, built from 1926 to 1928, Gropius entered uncharted waters by "determining the most socially and economically efficient plans, typifying and standardising entire buildings or parts thereof, applying new space and material saving techniques and materials"[10], particularly with the worksite operation Neuland that was organised after tayloristic and fordistic aspects.[11]

Cost reduced building processes and independence from climatic conditions by means of a quick and dry to assemble house were the main criteria for the experimental steel house by Georg Muche and Pichard Paulick, built from 1926 to 1927 in the vicinity of the housing estate Dessau-Törten.

Technology and "home furnishing"

"Home building and home furnishing" stood at the centre of the work at the Bauhaus from 1927 onward. In this unity, the purpose was not merely to achieve depictive spatial qualities in the sense of representation but rather, as described earlier to allow and even enforce a new way of living. At the Bauhaus this always included rationality. The household was embedded into a developing external technical network for climatisation, artificial lighting, nourishment, hygiene, transportation and utilisation of new media. Other conceptions for the household which a. o. included self-sufficiency by means of according garden design existed only in very rudimentary stages in the housing estate Dessau-Törten.

The Bauhaus' first building in this sense was the previously mentioned Haus Am Horn, which was a. o. equipped with central heating and continuous-flow gas heaters by the company Junkers from Dessau. The masters houses (Meisterhäuser) and the Bauhaus building were also equipped with a warm water central heating system by the same company. In addition, the director's house included an electric fan – also by Junkers – in the living room, which was meant to introduce prewarmed fresh air into the room in winter. The 'Arbeitsamt' building by Walter Gropius had central heating that also served to melt

Fig. 7: Advertisment by the company Junkers & Co. with the master house by Walter Gropius in Dessau, around 1929
Image rights: unknown.

potential snow loads on the shed roof, and even a climate control unit, again by Junkers. The piping and heaters were not hidden under some sort of cladding but openly displayed, sometimes even like sculptural building shapes in exposed areas.

10 As note 6, p. 112.

11 Cp. Andreas Schwarting, Die Siedlung Dessau-Törten. Rationalität als ästhetisches Programm, Dresden 2010.

Fig. 8: Walter Gropius and Adolf Meyer, director's room Bauhaus Weimar, 1923, photo of the reconstruction from 1999
Image rights: VG Bild-Kunst Bonn

Lamps in particular played an important role (as well as other devices), since they used electric power. At the time, electric power was distributed with above-ground cables. Even today, the masts of high-voltage power lines resemble associated constructional sculptures. Except for the architecture-oriented lamps by the office of Walter Gropius, Bauhaus designers such as Gyula Pap, Karl Jacob Jucker and Wilhelm Wagenfeld only started designing electric lamps from 1923 onward. The industry with its own planning offices was already farther ahead. At the beginning of the Twenties, electric lighting conquered the households, replaced gas and petroleum lamps and started becoming the standard in the flats of subsidised housing. Before World War I electric light was a luxury that only few households could afford; produced were mainly utilitarian lamps for street lighting, factories and display windows. Mass production for household lights began in "special lighting factories" as they were called in an article for the spring trade fair in Leipzig 1925.[12] Contrary to the utilitarian lamps which were designed specifically for optimum light yield and illumination of the rooms, the product portfolio consisted almost exclusively of decorative arts and crafts lamps focussing on a representative effect. In the beginning of the Nineteen Twenties, light planning for architectural lighting developed into an independent discipline. The institute for lighting technology was established in Karlsruhe, large companies such as *AEG* in Berlin or *Kandem* in Leipzig conducted ongoing research and development work. In 1926 Joachim Teichmüller, founder of the Karlsruhe institute coined the term of "lighting architecture". With this term lighting was understood as a material and thus included in the architectural design. The modern lighting architecture of the Nineteen Twenties was fed by two different traditions of spatial lighting design: light planning and stage lighting. The objective of light planning were well lit living and working environments whereas stage lighting conveyed very different impulses. Here, neither the intensity of light nor homogenous illumination was of interest but rather spaces consciously staged with lighting to create certain atmospheres and images. Lighting technician Teichmüller referred to efforts already made pre 1914 in the field of light planning and lighting design, and called the work of Peter Behrens exemplary, in whose Potsdam office Walter Gropius and Ludwig Mies van der Rohe gained first professional experience around 1910. The task to equip new architecture with electric light was first taken on by the Bauhaus for the project Haus Am Horn. Gyula Pap's floor lamp, a slender sculpture formed with clear geometric shapes celebrated the materials steel and glass and the series product incandescent lamp. The director's room designed by Walter Gropius in the school building by Henry van de Velde is equipped with rod-held tubular lamps; the grid in which they are arranged is one of the means that define the room. In 1925, the construction of the school building and the masters houses made it necessary to design lamps dedicated to workshops, offices, stairways, a stage and for living areas since the lights offered by the industry did in no way comply with the Bauhaus conception. Designers like Marianne Brandt, Hans Przyrembel and Max Krajewsky acquired the necessary knowledge at the companies Osram and *AEG* in Berlin. Thus from 1925 to 1929, with Gropius' Dessauer Bauhaus buildings there evolved an entire lighting program for the new architecture, closely connected to it. Aside of the disk-shaped lamps that melt in with the interior design it is mainly three geometric bodies that define the lamps in and on the Bauhaus buildings: the cube, the sphere and, in slender pipe shape the cylinder. From 1927 onward, Hannes Meyer made even more of an effort than Gropius to

12 Rüdiger Ganslandt / Harald Hofmann, Handbuch der Lichtplanung, Braunschweig / Wiesbaden 1992, p. 22 ff.

approach the lighting issue from a scientific point of view, and thus looked for contact with research institutes and leading companies. Classes dedicated to lighting design were based on e.g. "illumination intensity according to the specifications of the German Light-technical Society Berlin (*Deutschen Beleuchtungstechnischen Gesellschaft Berlin*)". Preserved student writings include notes and drawings referring to "optimum intensity of illumination for street plazas, interior spaces, shop displays, work places", to "Beleuchtung" (managing natural light) and "Belichtung" (using electric lighting).[13] Planning of electric lighting played an important role at the Federal School of the German Trade Unions (*Bundesschule des ADGB*) in Bernau/Berlin right from the start. And Ludwig Mies van der Rohe's buildings are inconceivable without the clever use of electric lighting. Regulating natural incident light and opening parts of the façade was partially realised with electric motors, such as for the shading mechanisms of the Bauhaus auditorium or the large retractable windows in Haus Tugendhat designed by Mies van der Rohe.

The home kitchen also saw the advent of new technology, particularly by the use of gas stoves. Electric cooling technology did not exist yet. Fast transportation by railway and lorry allowed the mass distribution of an increasing palette of food products; a prerequirement for the kitchen concepts such as in the masters houses. The workshop wing of the Bauhaus building even had a lift.

The technology of new media was also noticeable in the building sector. Hannes Meyer and Hans Wittwer's design for the *Palais des Nations* is coined by a large antenna as a symbol of modern communication. What in this case remained a vision became reality when an antenna spanned the space between the bridge wing and the atelier building of the Bauhaus.

Technologies for mass media and the „political economy of the sign“

The architecture developed at the Bauhaus was targeted on harmonisation of society; "home and home furnishing" in this context functioned as a unit. Objects and architectural details take on a subordinate role with regards to the space in an extreme reduction of formative vocabulary. From the mid Nineteen Twenties onward, the ideal was to model objects after industrial type and standard; conceived and designed to fulfil the needs in supposed social homogeneity over time. Longevity here does not only mean durability but particularly preventing wear due to changing fashion. The objective was to make qual-

13 Stiftung Bauhaus Dessau, archive, student notes by Arieh Sharon a. o. students of 'Baulehre zu Beleuchtungsfragen', Inv.-Nr. 16815- 16825.

Fig. 9: Edmund Collein, Bauhaus building Dessau at night, 1929, Bauhaus Dessau Foundation

itative and affordable products available to a broad group of buyers. The value in use was to be greater than the value in exchange. In 1930 Gropius stated this as follows: "Trouble-free, sensible functioning is not an end in itself but only the prerequisite to achieve a maximum of personal freedom and independence. Therefore, a standardisation of practical life processes does not mean enslavement of the individual but frees life of unnecessary ballast in order to allow it to develop creatively without restrictions."[14] In his 1926 paper "The new world" Hannes Meyer also took an optimistic look at a happy future enabled by new technologies.[15] From craft-oriented beginnings, the Bauhaus workshops developed into „laboratory workshops"[16], where product models were developed for serial mass production. Bauhaus proprietary products were manufactured by external companies. From 1926 onward the lamps designed for the Bauhaus building in particular proved to be a starting point for fruitful collaboration with companies such

14 Walter Gropius, 1930

15 Hannes Meyer, Die neue Welt, in: Das Werk, Zürich, 13, 1926, p. 205-224.

16 Walter Gropius, Grundsätze der Bauhausproduktion, Dessau 1927, p. 28.

Fig. 10: Advertisment by the company Saab with the Bauhaus building Dessau, 1999

as *Kandem* in Leipzig.
However, the Bauhaus had to face the reality of a consumer society still in its infant shoes. In this market, the Bauhaus products became mere ware. The minimalist form of the Bauhaus architecture and the Bauhaus products, which avoided regional or other specific aspects, suggested potential global marketability. Marxist influenced architects such as Hannes Meyer, Mart Stam or Ludwig Hilberseimer in particular were aware of this problematic issue. Hilberseimer for one demanded e.g. in 1929 in the Bauhaus periodical „a methodical economy in which production meets the needs of the people, not the profit seeking of a few“.[17]
On the other hand, during the entire time of its existence the Bauhaus maintained vigorous public relations for its own institution, which as of 1925 included advertising products that were marketed through a Bauhaus GmbH (limited company). Here for, the newest photography, film and print media technologies were used. Advertising and marketing was very successful even though it was one of the causes for the term “Bauhaus style” to become used, which the Bauhaus did not want to accept. But the development toward a brand “Bauhaus” could not be stopped in the developing consumer society. In hindsight, in which “the aesthetic and the useful seem to merge into one another and, at the same time, are subject to commercial interest”[18] Hal Foster has identified the role of the Bauhaus in this process in 2002 as follows: “If the first industrial revolution evened the grounds for political economy – i.e. a rational understanding of material production – the second industrial revolution, coined by the Bauhaus style, expanded the ‚regime of the exchange value to the area of signs, forms and objects‘, as Jean Baudrillard claimed years ago, in the ‚name of design‘.”[19] According to Baudrillard the Bauhaus stands exemplary for this qualitative jump from a political economy of the product to a ‘political economy of the sign‘, in which product and sign redefine and restructure each other so that both can circulate as a unit, as image-product with ‘sign/exchange value’, as is the case today. Naturally the Bauhaus masters, amongst which several Marxists, had something different in mind but such ‘bad dreams of modernity’ (as T.J. once called them) occurred more than once in the changeful history.[20]
This development concerned and concerns architecture in particular. Whereas the Bauhaus itself had indeed used its buildings for public relation work, it is exactly the Bauhaus building which has become a brand mark, still present in today’s electronic media as an icon of the unity of art and technology.

Translation: Usch Engelmann

17 Ludwig Hilberseimer, Handwerk und Industrie. In: Bauhaus. Zeitschrift für Gestaltung, Heft 2, 1929, p. 21.

18 Hal Foster, Design und Verbrechen. Und andere Schmähreden, Berlin 2012, p. 30.

19 Ibid. p. 31. The citation contained herein: Jean Baudrillard, For a Critique of the Poltical Economy of the Sign, transl. by Charles Levin, St. Louis 1981, p. 186.

20 Ibid. The citation contained herein: T. J. Clark, Farewell to an Idea. Episodes from a History of Modernism, New Haven 1999, p. 306.

The Buildings of Russian Constructivism (Moscow, 1919 - 32) and the Technology Transfer

Anke Zalivako

The specific situation within the economies and societies of Europe after World War I as well as in the young Soviet Union after years of civil war forced a rational approach in construction activities. In Europe this was to cause a revolution in building traditions that had not changed since the Middle Ages. Architects and engineers combined their aesthetics with the technical requirements of quick, easy and cheap production processes. The developing construction industry demanded more efficient results through standardization and typization. For the first time buildings became the result of the mechanisms of their production process and were erected with great precision. From today‘s point of view this revolution became the basis of today‘s construction technology consisting of a huge variety of complex composed building materials and methods.

The buildings of Russian Constructivism (1919−1932) were primarily made out of stone, metal, wood and concrete. They present a departure into a new and efficient construction technology in the Soviet Union: as cheap as possible and for the first time mostly out of artificial materials. After the revolution in 1917 Russia, traditionally an agricultural peasant state and therefore extremely backward in industrial terms, plunged into a self-imposed „Turbo“-modernization. In the early 1920s this industrialization began with a transfer of knowledge, but also with the physical transfer of materials, machinery, buildings and people into the Soviet Union discussed in this article.

1 The Situation after the Russian Revolution

While the European Construction had emerged in the organized structures of craft guilds since the Middle Ages and was supported by an organised production of construction materials since the late 19th Century, the new Soviet government could not resort to such a wealth of experience to address their most urgent task: a comprehensive supply of the population with housing. After years of civil war (1920−26) the consolidation of the Russian economy had virtually be resumed from scratch. The cement and brick production, but also the traditional wood industries were in a state of total disrepair. A Russian construction industry did not yet exist. Craftsmen in the European understanding were available only in the larger cities such as Moscow or St. Petersburg. Building in Tsarist Russia was a matter of the summer season, when the residents repaired their houses and in order to fix them for the next winter. This type of construction work in the country as well as traditional methods of building material production in manufactories was called *kustarnichestvo* which was perceived and criticized under the new conditions. Following this example of recruitment after the

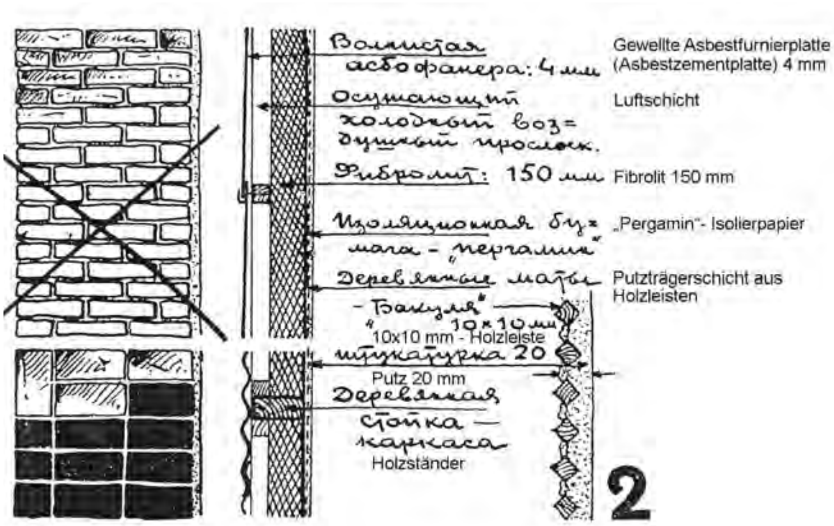

Fig. 1: Sandwich-construction of the external wall with cavity. Constructivist approach. Credit: Sovremennaia arkhitektura 1929, No.6, p.212.

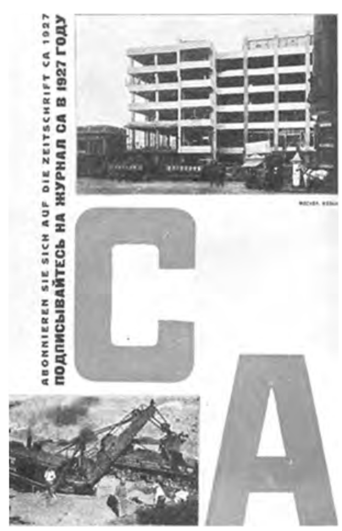

Fig. 2: GOSTORG - Ministry of Trade. Concrete-skeleton. Credit Sovremennaia arkhitektura 1927.

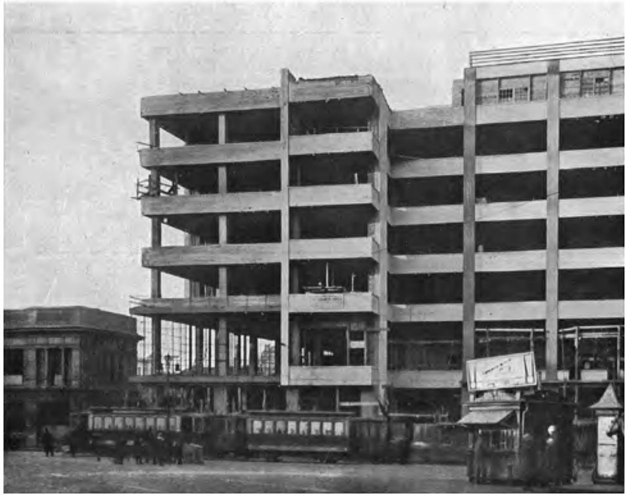

Fig. 2a: GOSTORG - Ministry of Trade. Concrete-skeleton. Moscow 1925–27. Credit: El Lissitzky (1930), Abb.75.

revolution, the new municipalities hired in summer mainly unskilled workers for the construction and then led them off again after the saison. Cheap but unskilled labor were available, because masses of unskilled workers, coming from the agricultural province, flocked into the cities to escape the threat of hunger in the country. They were learning on site by doing the work. This also benefited the construction industry, where many workers were needed for the production of building materials and to set up the falsework for concrete.

2 The Soviet Union as an emerging field of experimentation construction industry

The new Soviet government was faced with the task of inventing new construction techniques. For the first time it had to organize a functioning construction industry and also perform a mass number of tasks in practical construction in the shortest possible time in order to create a visible sign of the progressive construction of the new communist society. However, there was not only lack of skilled construction workers, but also on building materials. It was necessary to boost the production of new building materials instead of traditional wood, clay and stone, but equally efficient and above all, affordable building materials and to develop new structures for an efficient use of these materials. Any means and thus any approach was right to solve this problem. The dissolution of the traditional masonry brick wall into construction layers of different materials can be described as the most important change that has been introduced in construction by the Avant-garde of the early modern movement (Fig. 1 - 2a). The key savings opportunity that arose was in a greatly reduced wall thickness while maintaining the same or even improved insulation against the outside air. The search for new materials and structures was characterized primarily by the desire to achieve both, better insulation and simultaneously save on material.

The Soviet Union proved to be ideal testing ground for the development of new materials and construction methods. The government activated all available intellectual and financial resources. Starting point of all efforts was the first review of the already available natural materials to their conceivable innovative potential. The main task was to bring such materials on the market that could be easily produced in large quantities and without excessive demand for raw materials. It was hoped that the economy would rapidly transform from *Kustar manufacturing plants* to an industrialized mass production of building materials. Material Research Institutes and many other institutions within the construction industry were founded, including the most popular operating Soviet construction organisations in the 1920−30s, such as *GOSPROEKT, GIPROGOR, INDUSTROY, PROMSTROY,* to name just a few. Foreign developments set an initial guide for the work of these institutions. The organization process of the Soviet construction industry was completed in 1927 by founding of the State Research Institute for Construction *GIS* - modeled after the german State Research Society named *RFG* for the search of economical approaches in the field of construction[1]. It played the most important role among all research institutes established at that time. As a result of the experiments several new artificial materials have emerged: Materials such as slag concrete, thermal insulation of peat, wood shavings and other waste materials that would be described today as „recycled products“ characterize the fabric of the Russian Avant-garde buildings as well as buildings of the European Modern Movement. The newly established institutions sought foreign materials, but also developed their own solutions: The company *TECHBETON* specialized in the introduction of in situ concrete. The so called “Kossel”- slag concrete, named after the constructor Paul Kossel from Bremen, Germany, became famous in Russia. With his assistence in 1926 the German-Russian construction trust *RUSGERSTROY* built the Institute of the Red Professors on *Pirogovskaya Street* in Moscow with the same recipe for slag concrete which was used in Germany (1925−28, architect I. Osipov, A.M. Ruchljadev, Fig. 3, 3a).

Since 1927 the National Building Institute *GIS*

1 RFG - Reichsforschungsgesellschaft für Wirtschaftlichkeit im Bau- und Wohnungswesen e.V. (1927–31), and GIS – Gosudarstvennyj nauchno-eksperimentalnyj Institut grazhdanskich, promyshlennych i inzhenernych Sooruzhenij.

Fig. 3: Kossel-slag concrete, named after the constructor Paul Kossel from Bremen, Germany. With his assistence a German-Russian construction trust *RUSGERSTROY* built the dormitory of the Red Professors on Pirogovskaia Street in Moscow 1925–28. The same Kossel-slag concrete was used in different mixtures for the houses of Johannes Pieter Oud in the Weißenhof-settlement in Stuttgart in 1927. Photo 2005.

Fig. 4: Fibrolit–panels as interior insulation. NARKOMFIN–Commune House. Moscow 1928–30. Photo 2007.

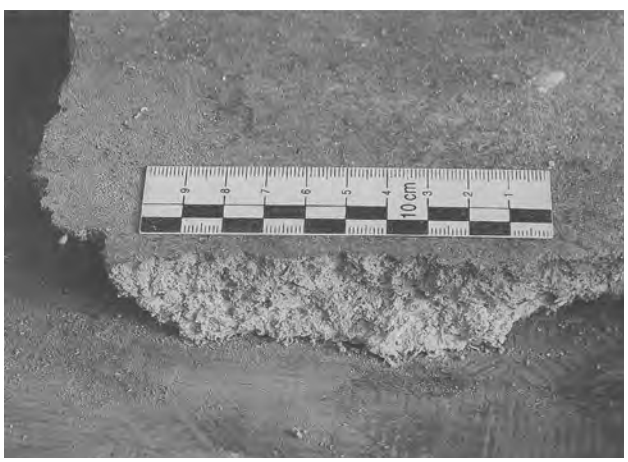

Fig. 4a: Woodcement–magnesite–flooring. NARKOMFIN–Commune House. Moscow 1928–30. Photo 2009.

researched the mixture of the Austrian *Heraklith*-insulation panel and developed a similar material named *Fibrolit*[2]. In most pilot projects of the Avant-Garde *Fibrolit* / *Heraklith*-insulation or *woodcement*-flooring were used (Fig. 4). For acoustic and thermal insulation purposes very small pieces of wood were mixed into the screed to make it warmer as well as to provide more soundproofing (Fig. 4a). This floor finish can still be found in some avant-garde buildings in Moscow as well as in the german Bauhaus-buildings. For these copies the insights into the local production gained on foreign trips were of inestimable value.

2.1. Scientific and technical exchanges with foreign countries

In order to exploit the knowledge of the capitalist countries, the Soviet government financed not only the deployment of Soviet specialists on field trips and training abroad, but was importing wide-ranging expertise in the field of industrial construction methods, in particular from the United States but also from Germany, the Netherlands and France[3]. Towards the end of 1928 the newly founded Central Office for Foreign Technical Assistance in Berlin, located at the Russian embassy, had to provide about 130 professionals, engineers and technicians ready to work in the Soviet Union[4] (Fig. 5). The government financed numerous invitations for foreign specialists and excursions abroad for their own experts. A popular excursion destination was the Werkbund exhibition in Stuttgart in 1927. In 1929

2 The *Österreichisch Amerikanische Magnesit Aktiengesellschaft* in Radentheim, Kärnten, produced and patented *Heraklith*. s. bibliography (1).

3 Bodenschatz, H. / Post, C. (2003), 36–43, 40.

4 Kazus, I. A. (2009), 308. Z*entralbüro für ausländische technische Beratung*

a Soviet government delegation was travelling to Frankfurt to visit the new housing estates. On this occasion Ernst May, chief architect in Frankfurt at the time, was invited to give lectures in the Soviet Union. Aleksandr Vasilevich Kuznetsov (1874−1954), an architect and engineer, who had completed his education partly in Germany, reported about the visit at the Berlin Torkret company in december 1927 in the journal *Stroitel'naia promyshlennost'*. He drew the conclusion, that Germany and the Soviet Union independently developed the application process for slag concrete[5]. He used Torcrete for the flat roofs at the Electrotechnical Institute in Moscow in 1929 (Fig. 6).

International competitions were announced and the Soviet architecture and construction journals extensively published on the state of construction activities in the West: The Russian Constructivists journal *Sovremennaia arkhitektura* published buildings of western architects (Fig. 7). The magazines *Stroitel'stvo Moskvy* and especially the *Stroitel'naia promyshlennost'* informed extensively about foreign developments. In Germany in 1923 the society called *Freunde des neuen Russland* published the magazine *Das neue Rußland*. Walter Gropius (1883−1969), Ernst May (1886−1970) and Bruno Taut (1880−1938) reported on Soviet architecture. Lazar' Markovich Lisickyj (in Europe known as El Lissitzky, 1890-1941) was an important mediator in

Fig. 5: Journal Das neue Frankfurt 1930, No 9. Front page Deutsche Bauen in der UdSSR.

5 Kuznetsov, A. V. (1929, №. 1), 48 and Kuznetsov, A. V. (1929, №. 2), 131–135.

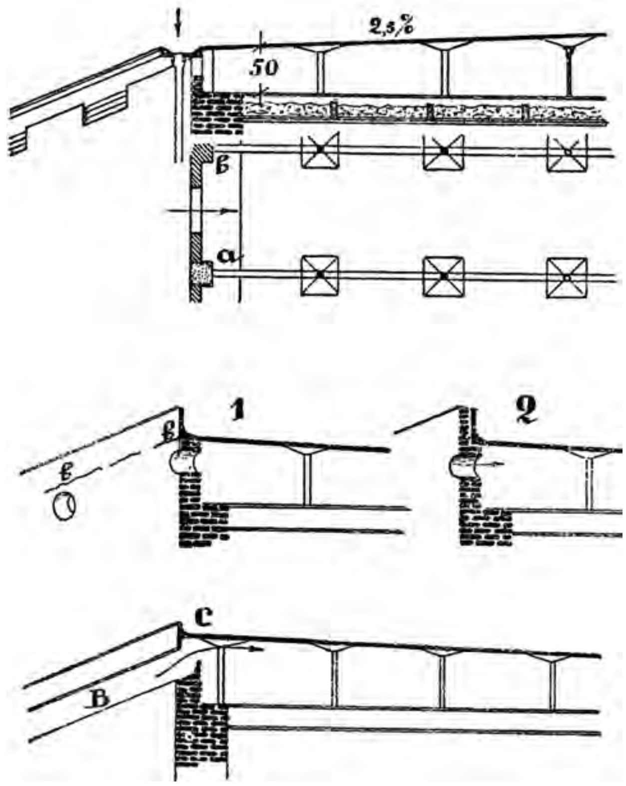

Fig. 6: Several options of ventilated flat roofs. Credit: Stroitel'naia promyshlennost' 1929, No.1, p.50.

АНКЕТА

О ПЛОСКОЙ КРЫШЕ

АРХИТЕКТОР ЭРИХ МЕНДЕЛЬСОН. БЕРЛИН

Fig. 7: Bauhaus-inquiry 1926 about the flat roof with an entry by Erich Mendelsohn. Anketa o ploskoi kryshe. Credit: Sovremennaia arkhitektura 1927, No. 4, p. 192.

Fig. 8: View on the plant *ChELJABTRACTORSTROY*. Cheljabinsk 1930–33. Credit Promstroyproekt / Fisenko 1936, p.324.

the relations with Western Europe. He promoted the exchange of information about the building process on both sides. The process of acquisition of foreign technology was also supported by the translation of numerous specific publications on construction technology in particular in the field of concrete construction, which gave the Soviet engineers and architects a valuable guide. Since the early 1930s the main foreign reference works were published in the Russian language, including books of Emil Mörsch (1872−1950) and Adolf Kleinlogel (1877-1958), by Franz Dischinger (1887−1953) and Friedrich Edler von Emperger (1862−1942). Another important role played the productive relations between the Bauhaus Dessau and the Moscow Vkhutemas School. They were based on the same aspirations of both schools in pedagogical training in their first years. In 1921 Vasily Kandinsky (1866−1944) became a teacher at the Bauhaus school in Dessau. The first contacts of both schools arose in the fall 1927,when *Vkhutemas*-students visited the Werkbund exhibition in Stuttgart and the Bauhaus in Dessau. In the same year, German architects presented an exhibition in Moscow organized by the association of modern constructivist architects OSA. In 1928 Bauhaus students travelled to Moscow. In 1931, an exhibition on the Bauhaus Dessau curated by Hannes Meyer (1889−1954), was held in the new Soviet capital. Because of his political views the Bauhaus director was released from the school in Dessau in the summer of 1930 and then moved to Moscow together with seven Bauhaus students. In Russia the group dealt primarily with the planning of industrial high schools and developed type projects for the soviet state building programs.[6]

6 Püschel, K., (1976), 468 and Schmidt, H., (1967), H. 3, 383–400.

2.2 Imports in order to develop the construction industry

1929 was a turning point for the further development in construction of the Soviet Union. With the global economic crisis in America and Europe the new courses for the further development were set. With the first 5-year plan (1928−32) the government favored the industry and urged the introduction of industrialized methods, standardization, typization and mechanization of construction and especially forced a non-seasonal construction. The standards of production and mechanization achieved in Western Europe and America were to be exceeded. Foreign production equipment and materials were imported as well as technical knowledge. In the field of industrial construction the Soviet Union focused on cooperation with the United States of America, in particular the automobile manufacturer Henry Ford (1863−1947) and his architect Albert Kahn (1869−1942). Henry Ford‘s production principles have been the model for the construction of soviet socialist industry. For the extension of the Stalin Auto Works Albert Kahn‘s brother Moritz founded a Moscow branch of their Detroit office *Albert Kahn Incorporates* subordinated to the Soviet building committee[7]. As a result the factories built under the first five-year plan in 1929 in the Soviet Union, are usually an acquisition of foreign construction methods. Foreign experts who had traveled along with the manufacturing facilities imported from abroad, had to pass on their knowledge to their Soviet colleagues particularly in the area of industrial building. For example the production halls for the tractor factory in Cheljabinsk, designed by *Albert Kahn, Inc.*, Detroit, were modeled after the Ford Motor Company River Rouge Plant in Dearborn/Michigan. After analysis of the American

7 Chmel'nickiy, D., (2005), H. 9, 102.

Fig. 9: Planetarium, Moscow 1927–29. Photo 1930s. Courtesy A. V. Shusev-Museum of Architecture, Moscow.

example, consisting out of steel beams with butterfly skylights, the Russian plants were erected in wood (Fig. 8). The knowledge gained by this scheme led to optimized results in wood and concrete. The results were published by the Soviet research institutes as a manual guide for the future. This transfer of technology from the United States to the Soviet Union, however, stopped on March, 1st in 1932 with the end of the consultancy agreement about American technical assistance[8]. Another example is the Moscow planetarium. It can certainly be called an acquisition of a foreign design (Fig. 9). Built in 1927−29 with the assistance of German engineers, it adapted the first German dome planetarium in Jena, a prototype of the Zeiss Dywidag shell construction completed in 1924, to the Moscow location.

The designers and engineers of the Soviet Union had no fear of height: This is proven by the Soviet experiment to build the then largest ribbed dome of the Soviet Union as reinforced concrete roof construction of the opera and cultural center of Novosibirsk (1931−1934). The concrete dome with a span of 60 m and only 8 cm thick remains a still extreme and admirable performance of the Soviet engineers[9].

2.3. The Experimental Programme of 1929

For practical verification of the new building materials and construction methods, these were tested by the Soviet government within a comprehensive experimental programme in Moscow since 1928[10]. The experimental buildings of this program included not only the well-known commune houses of Moisei Ginzburg and Ivan Nikolaev, but also the home and studio of Konstantin Melnikov, all in Moscow[11]. The unique structure of the Melnikov House was made as an attempt to include maximum space with a minimum number of brick, with the brick following just the loadbearing lines. The honeycomb windows allowed to save on window lintels. Both tricks made the house innovative.

Just as the Americans were consulted for the construction of industrial projects, the Germans and Dutch were leaders in the field of housing. „On the Russian side the results of 1924−31 ‚of the seven fat years of housing', operated by Bruno Taut, Otto Haesler, Walter Gropius and Ernst May in Germany, were of special interest for the Soviet government, not only because of the technically functional, but particularly because of the social aspects. The solution of the housing question was a central theme of the exchange.[12]" Research on the rationalization of the housing sector played a crucial role in the development of the new Soviet construction industry. Therefore the Council of People's Commissars of the building committee *STROYKOM* created a special section for typization in housing directed by Moisei Ginzburg (Fig. 10). Here the possibilities of industrializing the processes within residential construction by using new materials and methods were investigated.

3. The Narkomfin House in Moscow

The commune house for the employees of the newly

8 Bodenschatz, H. / Post, C., (2003), 40.

9 Zalivako, Anke, (2013), 124–139.

10 Postanovlenie Sovnarkom SSSR ot 27.3.1929 goda *O planirovanii opytnogo stroitel'stva i nauchno- isledovatel'skich rabot v oblasti stroitel'stva i o fonde ich finantsirovanja.*

11 The commune house on Gogol-Boulevard (1929–31, Michail Osipovich Barsh, Viacheslav Nikolaevich Vladimirov u. a.) and the commune house for the students of the Textile Institute on former Donskaia street (1928–1930, Ivan Sergeevich Nikolaev with Konstantin Michailovich Sokolov).

12 Schädlich, C., (1976), H. 12, 716–721, 718.

founded financial ministry at the People‘s Commissariat (*Narkomfin*) was built 1928−30 as part of the State Experimental Programme. Moisei Jakovlevich Ginzburg and Ignatius Frantsevich Milinis together with the concrete specialist of *TECHBETON*, Sergei Lvovich Prokhorov, designed the building with the support of the client and then Peoples` Commissar of Finance, Nikolai Aleksandrovich Miliutin (1889−1942). It served to test the newly invented materials (Fig. 11). In its entirety the *Narkomfin* house today represents a kind of „Encyclopedia of the building materials of the early Soviet modernism“.[13] Today the building can be considered symbolic for the transfer of technology and knowledge between Europe and the young Soviet Union and is thus a representative sample. Moreover, no other building embodies the early Soviet modernism, the design and conceptual intention of the constructivist architects in their design and technical implementation of innovative materials as consistent and clear as the *Narkomfin* commune house. Further to this the *Narkomfin* was built with international participation: In 1927 Moisei Ginzburg visited both, the recently completed Dessau Bauhaus school building and the Werkbund exhibition at Stuttgart-Weißenhof. Influences on *Narkomfin* are evident. The *Narkomfin* house was built on total analogy with the worker`s housing estate of the Bauhaus in Dessau-Törten. This refers to the way it was erected: with prefabricated materials produced in a field-factory on site. Furthermore, at *Narkomfin* adoption and adaptation of some details of the residential buildings in Stuttgart Weißenhof by Le Corbusier (1887−1965) are evident. The window mechanism of the sliding window is a vivid example of the analogy. The locking mechanism is almost identically with the one found in Le Corbusier‘s holiday home called „Le Cabanon“ in Roquebrun, France.[14] The color concept for the interior of the *Narkomfin* house was designed by Bauhaus master Hinnerk Scheper (1897−1957).

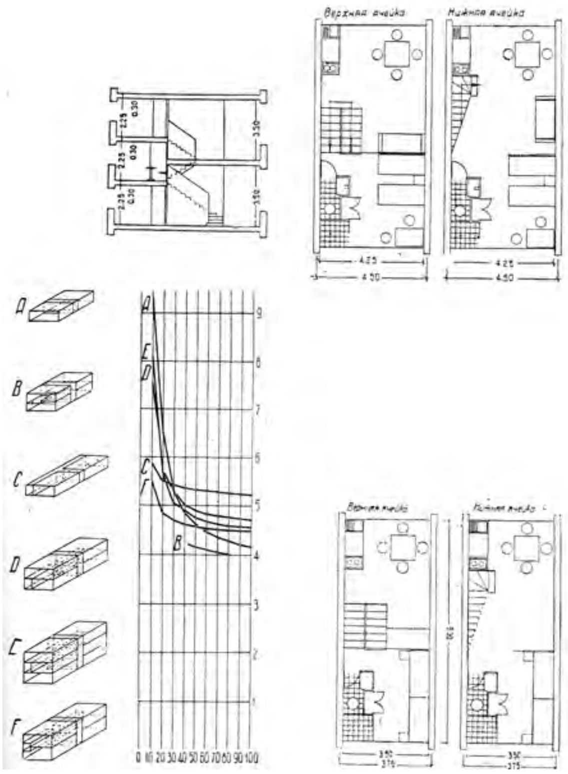

Fig. 10: Section for typization at *STROYKOM*. Credit: Sovremennaia arkhitektura

Fig. 11: NARKOMFIN Commune House. Southside. Moscow 1928–30. Courtesy A. V. Ginzburg, Family archive.

13 Cramer, J. / Zalivako, A., (2013).

14 For Le Corbusier, Moscow was his first foreign construction site. The construction for the *CENTROSOYUZ*-Central Union of Consumer Cooperatives (1928−36), later the People‘s Commissariat for light industry (*NARKOMLEGPROM*) and today Federal Service of State Statistics of Russia on Miasnickaia Street in Moscow, is an inseparable part of the Soviet avant-garde. It was created in collaboration with Pierre Jeanneret (1896−1967) and the Soviet architect Nikolai Jakovlevich Kolli (1894−1966), who was responsible for the working drawings. During the planning phase, Le Corbusier met Moisei Ginzburg (1892−1946), who devoted a lot of his time to the theme of collective living. Based on the pilot project for collective living realized in *Narkomfin*, Le Corbusier developed decades later his concept of the vertical city, his *ville radieuse*. In some aspects the *Narkomfin* house in Moscow can be considered as a prototype for his Unités d‘Habitation in France and Germany (Berlin type). From *Narkomfin* Le Corbusier took as well the height of 2.26 m for his later developed Modulor-theory of proportion. This dimension corresponds exactly to the clear ceiling height in the common corridors of *Narkomfin* commune house.

Together with his student Erich Borchert (1907−1944) Scheper worked in Moscow in 1929−1930 as head of the consulting department for architectural surfaces of the organization *MALJARSTROY*, a company that was specialized in painting, glazing and plastering. Both were among the 132 German engineers sent by the Central Office for Foreign Technical Advice in Berlin.[15]

The basic material for the *Narkomfin* house is concrete. Reinforced concrete was considered as main building material of the future. Moisei Ginzburg and the engineer Sergei Prokhorov were among the advocates of rational construction methods with for the time remarkable early almost industrially prefabricated building materials. They set up a field factory for the production of insulating cinder hollow blocks on site. First experience with such a production Sergei Prokhorov had collected in 1924 during the construction of the Moscow settlement *DUKSTROY*. In this case, the production of cinderblocks had been tried at the same time with the European countries, maybe even earlier. The *Narkomfin* house was built with both in-situ concrete as well as with artificial cinderblocks. The loadbearing system of the house is built with the help of a cinderblock concrete skeleton. The *Narkomfin* house is probably the only building from the 1920's in Moscow which has slabs made of cinderblocks, covered with a 5 cm layer of in situ concrete. The system is known from European reinforced brick slabs such as the German *Klein*-System (1892). It was most likely the model for the construction of the slabs at *Narkomfin*. Here it was carried out as a special type of reinforced concrete ribbed slab system: The cinderblocks were used as filler between 10 cm wide ribs, reinforced with iron rods pairs, without static efficiency. Further to this, the hollow blocks were used for the external walls as well as for partitioning between the flats. In situ concrete was used for the galleries within the maisonettes and in the bridge between the two main building structures. The windows of the *Narkomfin* house were carried out on analogy to the Swiss method as concrete frame structures with wooden sliding panels. In the roof area, the architects tested the prototype of an external thermal insulation composite system, which already comes very close to our present-day thermal insulation composite systems (Fig. 12 or 12a). In some areas the walls are covered with Kamyshit-matting and plastered, a very innovative method at the time. Moisei Ginzburg and Sergei Prokhorov may be regarded as the inventors of the external thermal insulation system and proved the term „avant-garde“, in this case even more ahead of the time than their western colleagues.

Fig. 12: Plastered *Kamyshit*–matting. Prototype of an external thermal insulation composite system. *NARKOMFIN* Commune House. Moscow 1928–30. Photo 2009.

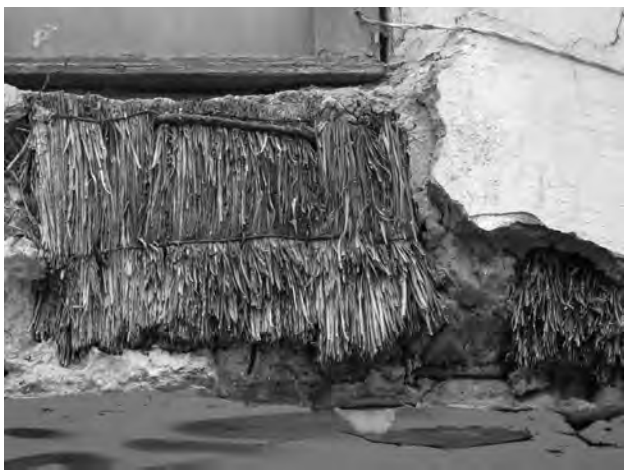

Fig. 12a: External wall with plastered Kamyshit–matting. Prototype of an external thermal insulation composite system. Housing complex of the employees of *URALOBLSOVET*. Sverdlovsk / Ekaterinburg 1931–33. Photo 2010.

4. Conclusion

The transfer of technology into the Soviet Union can be characterized mainly as a process of catching up and copying. The close cooperation with foreign experts and organizations manifests in the analogy of the buildings of the Soviet Avantgarde to the buildings of European Modernism. The strongest overlap in the materiality and construction techniques with other European countries and the United States can be classified for the experimental buildings erected between 1925 and 1929. Some of these buildings in their materiality partially take the character of „copies“. However, it is essential to note that the Soviet designers have certainly accomplished remarkable pioneering achievements in individual areas of the construction industry: The construction with cinderblocks prefabricated on site, the prototype of a thermal insulation system on top

15 Compare footnote 4.

of the *Narkomfin* house (1928−30), the minimalized design concrete dome with 8 cm thickness at 60 m span of the opera and cultural center of Novosibirsk (1931−34) are illustrative examples of the innovative power of the Soviet avant-garde architects and engineers in technical terms. In these areas, the Avant-garde designed at the level of the time. The audacity of their daring designs in some cases was even superior to the buildings of the colleagues from the West.

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The text is based on the research results of the author within the project *Die Bauten des Russischen Konstruktivismus (Moskau, 1919−34) − Baumaterialien, Baukonstruktion, Erhaltung* founded by the German Research Society DFG, Technische Universität Berlin, published as Vol. 9 in the series Berliner Beiträge zur Bauforschung und Denkmalpflege, Michael Imhof Verlag, Petersberg 2012.

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Fig. 13: Zalivako, A., *Die Bauten des Russischen Konstruktivismus Moskau 1919–32 Baumaterialien, Baukonstruktion, Erhaltung*. Berliner Beiträge zur Bauforschung und Denkmalpflege, Band 9. hg. von J. Cramer und D. Sack, Michael Imhof Verlag, Petersberg 2012.

New Movement and Technology in the Netherland

Jan Molema

Subject

Is it wise to treat a broad subject as New Movement and Technology in the Netherlands in a short period of less than an hour?[1] Even if I restrict myself to what happened in the Netherlands in architecture between 1922 and 1936?[2] These were my inmediate questions, when I received the invitation to speak at the forum in Karlsruhe. My answer: I prefer to come with two questionable aspects of construction by two befriended architects in two of their famous buildings, two real icons of modernity (Fig. 1, 2).[3]

Fig. 1: Maison de Verre at night (Photo source unknown)

Introduction

From their toddler years around 1930 till well after World War II there was almost no interest in two of today highly esteemed architectural monuments of the first half of the XX-th Century: a refurbished house in a Paris backyard and a brand new complex on a Dutch heath. Far apart from each other, the two were realized by two befriended engineer-architects: the first one in an old side street of the St.-Germain-des-Prés Boulevard on the south bank of the Seine, the other outside Dutch radio city Hilversum. A greater difference does not seem possible, yet the two became closely related through their authors: Bernard Bijvoet, maker of the plans for the 'Maison de Verre' and Johannes Duiker, who – after having worked with his companion on the preliminary designs for Zonnestraal during several years – finished the definitive plans at almost the same time. Whilst since

Fig. 2: Zonnestraal Sanatoria complex, main building after the restoration. (photo from the south west by Arie den Dikken, Huizen).

the nineteen sixties both Zonnestraal and the Maison de Verre have been described repeatedly – and in some cases extensively – in modern architectural literature, I know of no intent to bring the two together in one tale. I have ventured to attempt this for an extensive book about Bernard Bijvoet, Jan Duiker and Jan Gerko Wiebenga, triumvirate of the Dutch

1 Instead of *Modern* Movement I prefer to use *New* Movement as Shirley B. Wainwright coined it in the Decorative Art 1929 edition of the 'The Studio' Yearbook.

2 In 1922 J.G. Wiebenga designed his famous schools in Groningen, which opened in 1923. In 1936 Bijvoet finished Duiker's Grand Hotel and Theatre Gooiland in Hilversum.

3 Modernity is today generally called modernism, a term I very much dislike (and even more modernistic). Modernity is not restricted to any period. It is not a style, but an attitude. Wikipedia says: (It is) „readiness of the psyche to act or react in a certain way" (Jung, C.G., *Psychological Types*, in: *Collected Works*, Volume 6, Princeton. 1971: par. 687 (1921)).

New Movement in Architecture during the Interbellum.[4] Here I will especially pay attention to two remarkable structural aspects of these glorious icons that I discovered recently: one in the steel skeleton of the Glass House, the Maison de Verre (I rather call it Maison de fer/ faire) and one in the reinforced concrete skeleton of Zonnestraal. But, please allow me firstly to give some personnel information about Bijvoet, Duiker and Wiebenga.

Good company.

Bernard Bijvoet (Amsterdam 1889 - Haarlem 1978), son of a merchant, and Johannes Duiker (The Hague 1890 - Amsterdam 1935), son of a school director, met in Delft, presumably at the very beginning of their study there, and were friends for life from then on.[5]
They graduated from Delft Technische Hoogeschool as building engineers on one and the same day in 1913.[6] Delft Polytechnic was still small in those years, so it was not difficult to know everybody in the department.
Jan Duiker and Jan Gerko Wiebenga (Soerakarta 1886 – The Hague 1974) knew each other already from their high school in The Hague, which they finished on the same day. Wiebenga graduated in Delft as civil engineer in 1912 (January 26), but with the strong wish to become an architect. [7]
While Wiebenga had gone to Delft directly after high school, Bijvoet and Duiker, being still very young, firstly spent a year in workshops in furniture making and building practice. After taking their engineer's exams in Delft, Bijvoet and Duiker were employed by their erstwhile professor, Hendrik Jorden Evers, and worked with him on his design for the Rotterdam town hall.[8] Wiebenga had already found work in southerly Breda with IGB, a firm specializing in reinforced concrete structures and products like concrete building blocks.[9] The three would meet again in 1917, when Wiebenga did the structural part of their entry for the Rijksacademie (State Academy) competition in Amsterdam.[10] From then on Wiebenga would work with Bijvoet and Duiker in several occasions, one well-known project being the Nirwâna apartment building in The Hague, another the final design for the Zonnestraal Sanatoria main complex.[11]

Theory

In July 1926 Bijvoet and Duiker had an article published in *Het Bouwbedrijf* from which I like to select the following phrases:

> *According to recent insights in physics, "matter" is a geometrical property of space.'*
> *If one considers the universe according to these views as a system consisting of mass particles, influenced by each other's gravitational field, one may perceive the entire universe geometrically. Seen in this sense, order and regularity flow from a state of motion, in equilibrium or functional, in these gravitational fields, which together build the world order.'*
> *'In nature, that which we behold as decorative, is to be regarded as a system of forces visible as mass particles, as an equilibrium in a part of these gravitational fields.'*
> *'Seen in this way building technology is still in a desperately infantile stage, though in utility works, the domain of the engineer, something is beginning to dawn that looks like a purifying of principles. Man, [as] the meaningless fantasy, is placed here in the background, resulting in a intenser and more decorative appearance of the building than the architect can achieve in his decoration of the second order with coarse, non-relating envelopes.*
>
> *Irs. S. Bijvoet en J. Duiker.*[12]

Some years later Duiker would produce, this time without Bijvoet, a longer, but more comprehensive text in a small book, *Hoogbouw* (High Rise).[13] There-

4 Molema, J., *Maison de Verre / Zonnestraal* in: *Cuadernos de Notas* 14, Madrid 2013, p. 98-132. Generally the Maison de Verre is attributed to the furniture and interior designer Pierre Chareau, who indeed had been asked by Annie (Dalsace) Bernheim to design her new house. In my opinion, it was not really Pierre Chareau who designed the Maison de Verre refurbishment, but the engineer architect Bernard Bijvoet. This I have discussed with Kenneth Frampton amongst others.

5 This friendship was dearly remembered in Bijvoet's letter to Jaap Franso on 04.03.1964: 'In a (indeed very small) circle of students Duiker and I were somewhat "isolated" but, between us, inseparable with our ideals and busy with our rather personal "experiments".' See: Molema, J. a.o., *J. Duiker, bouwkundig ingenieur*, Rotterdam 1982, p. 8.

6 Nowadays Technische Universiteit Delft.

7 His father was against this idea, as he was of the conviction that an architect would never be able to support a family, as Jan Gerko Wiebenga's daughters told me.

8 As the position was not defined by law, anybody could call himself architect. Apart from night-time education in some places, Delft was the only higher educational institute in the Netherlands were one could be trained as an architect, receiving the title of engineer. Both building and civil engineers (essentially those who choose the dry sector) have worked in what Germans call *Hochbau*. Civil engineer Sybold van Ravesteyn f.e. was the architect of the Dutch Railways (Nederlandse Spoorwegen); he designed amongst more, the main station of Rotterdam, now demolished and some control posts.

9 Internationaal Gewapend Beton Maatschappij Stulemeijer & Co.

10 Maybe before, in the first months of 1916, when Bijvoet and Duiker still lived together as paying guests at Essenburgsingel in Rotterdam. Wiebenga lived shortly nearby in the same street and must have met Bijvoet and Duiker, but we have no proof.

11 About Wiebenga: Molema, J., P. Bak, *Jan Gerko Wiebenga, apostel van het Nieuwe Bouwen*, Rotterdam 1987. Also in the various publications about Duiker from my hand.

12 The complete article has been translated for me by Anna Ghijs, whom I thank for her confidence. It will be inserted in the book to come. S. Bijvoet must be read as B. Bijvoet.

13 Ir. J. Duiker, *Hoogbouw*, Rotterdam 1930. Duiker wrote the text between November 1927 and 1929. He presented in *Hoogbouw* the Nirwâna highrise as the common work of Wiebenga and himself. Interesting though is that the pertaining drawings are signed with the combined

Fig. 3: Zonnestraal under construction, summer 1927 (Photo collection Jan Molema)

after he would even become a prolific writer of clearer and cooler articles, mostly in *De 8 en Opbouw*, till his untimely death on 23.02.1935. Bijvoet, to my knowledge, never published anything (theoretical) anymore.

We may want to investigate how the article in *Het Bouwbedrijf* reflects Bijvoet and Duiker's buildings from then on and for that matter, those of Wiebenga.[14]

The remarkable feature of this sole common 'scientific' article of Bijvoet and Duiker is the coincidence in time with the plans and the start of the materialization of the Maison de Verre and Zonnestraal, on which we concentrate here.

Machine and Man, Man and Machine

It all happened in a period dominated by the debate about The Machine: the universe as a (unlimited) machine, the human body as a machine, the house as a machine. This would lead to a hefty dispute in the thirties between the so-called moderns, as united in *De 8* (Amsterdam) and *Opbouw* (Rotterdam), on one side; and what after the war would be termed Delftsche School on the other.[15] It is clear who would propagate the machine.

It is also clear where Jan Duiker stood. Bèr Bijvoet seems to have been less provocative, less wanting and willing to express himself as a reformer in writing, more in building.[16] Maybe this was precisely the characteristic, that made him -when being back in The Netherlands directly after WW II- a prolific designer of a whole series of theatres, the last one being the Opera in Amsterdam with all it's machinery the final element of Bijvoet and Duiker's oeuvre, the real Building-Machine.[17]

The summer of 1928 witnessed a few events that are not known as in some way related. There was, to start with, the opening ceremony of Zonnestraal on June 12, where Duiker and his (second) wife and Bijvoet were present.[18] Two weeks later the first

initials of Bijvoet, Duiker and Wiebenga! NB the first request for a building permit for the Maison de Verre dates 23 November 1927. See for some more dates in the text to follow.

14 Wiebenga was the editor, who had urged Bijvoet and Duiker to send him their text in a letter.

15 It would bring us too far from my aim here, but there is still a lot to investigate about this controversy in which we see calvinism versus catholisism, socialism versus conservatism. Very few modern buildings were built outside what we call now the Randstad.

16 Wiebenga certainly was the most provocative of the three.

17 This project would, after Bijvoet's death, be realized as a part of what became known as the STOPERA. The Viennese Wilhelm Holzbauer, winner of the competition for the town hall, had to cooperate with Dam, doing his own piece.

18 Hermine Franken had divorced Jan Duiker in september 1926, and had moved a year before with Bijvoet and his wife and baby to Paris. After the war Bijvoet married her, after having divorced Jacoba Ezerman. Duiker had married his neighbour Lucie Küpper in November 1926. We are not sure about Wiebenga's presence. Jan van Zutphen, as one of the initiators of Zonnestraal did mention him in his openingspeech, but we

Fig. 4: 'Mensch en Machine', Delft 1-3 July 1928. (Photo Archive DSC, Delft)

meeting was held of the Congrès Internationaux d'Architecture Moderne (CIAM) in La Sarraz, June 26 – 28. Here we see Pierre Chareau, from France. Interesting, but why was he there? Chareau was nót an architect![19] Can it be because Bijvoet could not be there? Bijvoet was an architect and Bijvoet became the secretary of CIAM France.[20] On July 1 till 3, an extraordinary event took place in Delft: "Mensch en Machine". Then there were the Olympic Games in Amsterdam in the new stadium of Jan Wils from July 28 till August 12. Can it be that Bijvoet and his family spent their holidays in the Netherlands? For sure he was in Hilversum at the opening of Zonnestraal as we can see on a photograph, and Duiker and Bijvoet may have had an interest in the highly interesting Mensch en Machine open-air play in Delft. It has been as far as we know the biggest constructivist open-air theatre happening ever.[21]

can not find him on the group picture taken that day.

19 There is no proof, that the furniture designer and interior decorator Pierre Chareau ever designed a building himself without the presence of an architect or a draughtsman.

20 Or at least: Bijvoet was the only one mentioned with address and having paid in a letter to S. Giedion. Chareau is not in that list.

21 Neither Duiker nor Bijvoet were members of this students club; Wiebenga though was. For "Mensch en Machine" read: Molema, J., S. Leemans, *Jan Albarda en De Groep van Delft. Moderniteit in een behoudende omgeving*, Heiningen 2010. Jan Albarda was the son of the social democrat leader Johan Willem Albarda, who had been neighbour of Jan Duiker (and his sisters), who was also party member. The Albarda's were members of the Delftsch Studenten Corps, organizers of the play. They represent two generations of left-wing Delft engineers within the mostly right-wing Delftsch Studenten Corps, DSC.

Zonnestraal

We always have had two questions about Zonnestraal without a satisfying answer: Why those big spans, even under the ground floor of the buildings; and why the use of concrete? Why a skeleton and no supporting walls? As the complex was supposed to be temporarily, it did not seem logical to us to choose concrete as the basic building material. And as many of the spaces in the buildings, specifically in the pavilions are quite small, the patient rooms for instance being just 3,00 x 3,00 m in plan, it seemed that the spans could easily have been limited to normal floor and beam proportions.

Both questions have been repeatedly discussed. Answers were: big spans make a building flexible, fit for different uses. With sanitation tuberculosis would disappear as a killing disease; the complex would loose it's function and a new one could then easily be encountered as the buildings by their flexibility could house a variety of purposes. This fitted our concept of Duiker and his companions as rational architects, which they were. But here we misled ourselves. We did not think of Duiker, Bijvoet or Wiebenga having


Auteursrecht voorbehouden.

Uitgegeven 15 Mei 1926.

Dagteekening octrooi 16 Februari 1926.

OCTROOIRAAD

NEDERLAND

OCTROOI N°. 14521.

KLASSE 37 a. GROEP 5.

BERNARD BIJVOET en JOHANNES DUIKER, beiden te Zandvoort en JAN GERKO WIEBENGA, te Groningen.

Werkwijze en bouwelement voor het optrekken van gebouwen in gewapend beton.

Aanvrage No. 25593 Ned., ingediend 14 November 1923, middernacht; openbaar gemaakt 15 October 1925.

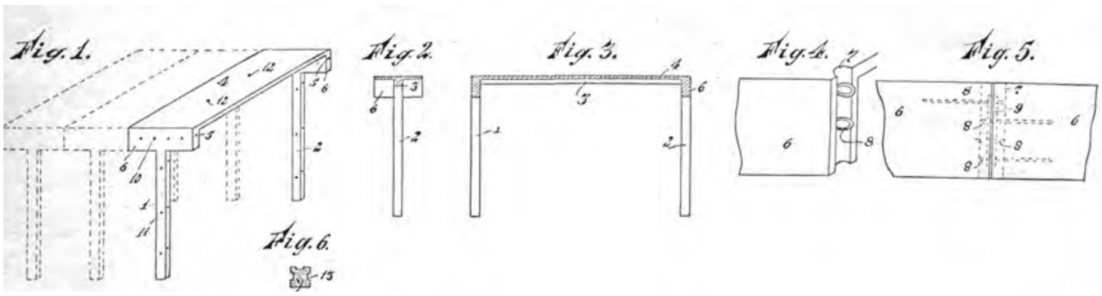


Fig. 5a+b: A patent by Bijvoet, Duiker, Wiebenga for a building system and assambly part in reinforced concrete.
(source: Forum, nr. 5/6, 1972)

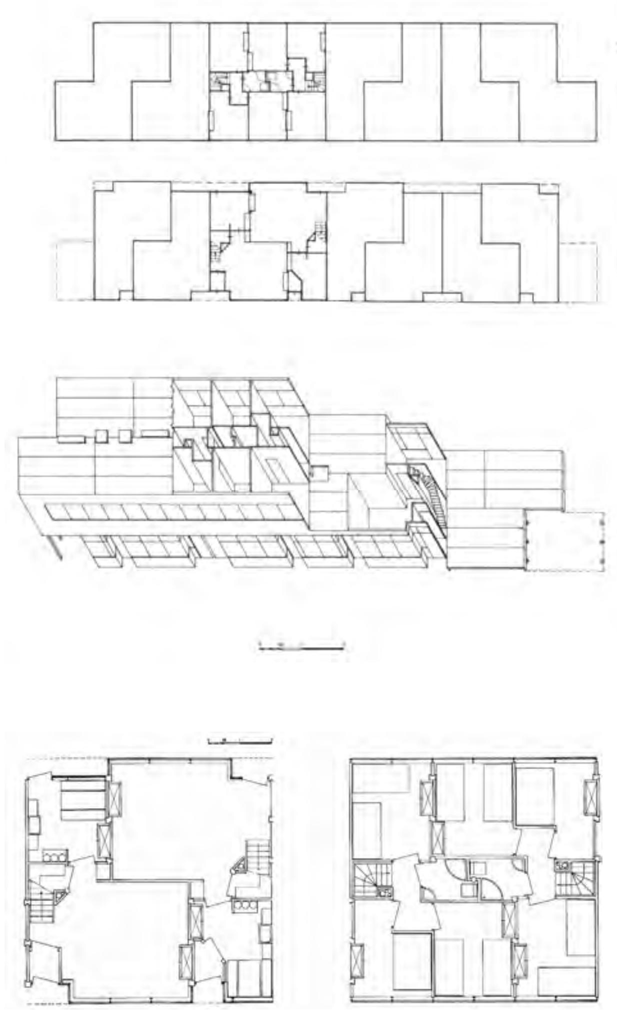


Fig. 5c: Design of row houses in the patented system of prefabricated reinforced concrete elements. The two-storey houses were interlaced with entrances on both sides of the block. (Molema, J., a.o., *J. Duiker, bouwkundig ingenieur*, Rotterdam, 1982)
From top: scheme plan top floor, scheme plan first floor, axonometry, left: interlaced plan first floor, right: second floor.

certain 'castles in the air' and a strong will to get these castles built. What was the dream castle to be built?[22]

Zonnestraal and some preceding theoretical projects

From 1919 on Bijvoet and Duiker had made several designs for the sanatory complex of Zonnestraal, yet nothing important had been built there.[23] But on June 7, 1926, a few months after Bijvoet had found work in Paris with Pierre Chareau, and there being very busy indeed, the two received the commission for the complex as it would be built. This is why generally is thought, that Duiker was the only architect of Zonnestraal.

Whatever the case, just three weeks before the Zonnestraal commission they had received the approval of a patent, which Bijvoet, Duiker and Wiebenga had applied on 24 november 1923, a patent for a system of prefabricated reinforced concrete elements. These elements were rather queer, as can be seen in the accompanying drawings: they seem to be very unhandy, if not impossible to transport. The element is a T-beam with two T-columns at either end. The span would be limited as these elements were essentially meant for terraced housing with dwellings of 5,00 meters wide or less, as we see in a later theoretical project.
Combining two elements would provide them stability.

22 When we did our Duiker investigation and later on our Wiebenga research, we split up the works to be studied. Each building for a group of four students. Purely analyses of the buildings, mainly their construction and function, not the design method. Not the possible relations between the buildings. Had we done so, we would have understood long ago, what I saw recently, what their pipe dream was in 1926.

23 As far as I know, Wiebenga got only involved in the definite project.

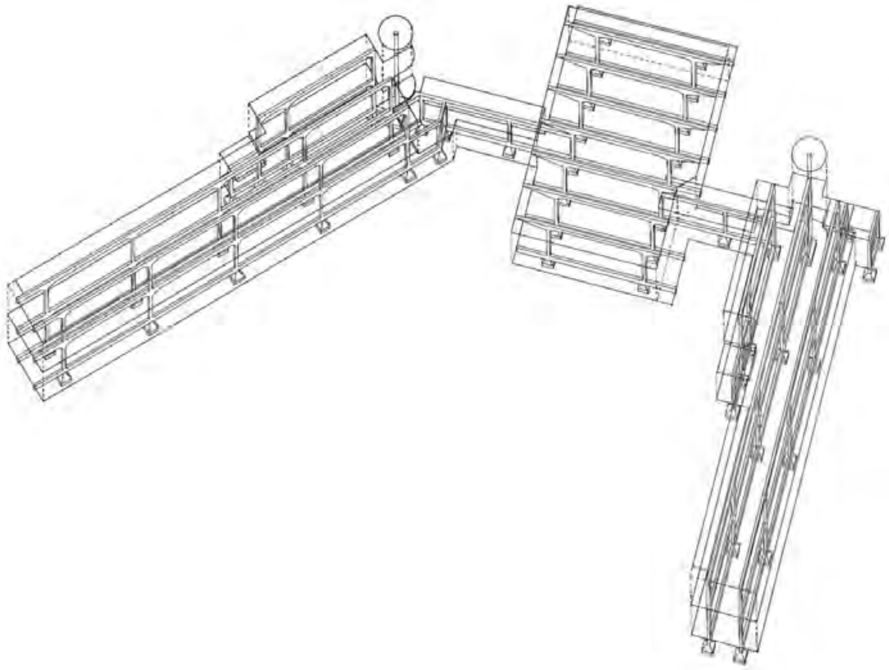


Fig. 6a: The pavillon complex shows interesting varieties of the principle. (isometric drawing by Duiker Group Delft: Wessel de Jonge).
Fig. 6b: A Zonnestraal pavilion under construction.
Fig. 6c: Detail of 6a with tappering floors between high beams. The big console beam to the right, carries one of the spiral stairs.

The section of the T-beams shows a thinning from the rib to the sides of the slab. This is a static device, which we see everywhere in Zonnestraal. The cantilevering floor slabs ánd beams all do contain as little material as possible, and a T-beam works very efficient indeed.[24] Why do we not see prefabricated elements in Zonnestraal? Well, there are plenty; the exterior ‘walls’ are an array of prefab elements; Zonnestraal was a sort of laboratory, an experimental place. But the concrete skeleton was made in situ. My feeling is, that against the desire of the architect stood the restricted possibilities of the contractor. We have no details of it, but we know that there were problems with the building contract; in the open tender even the lowest contractsum was too high. Therefore the assignment was in second instant accepted by another contractor under certain conditions. But on the other hand, the patent speaks of the possibility, that these elements could be made as a whole or as a beam and two columns to be ‘bound together’ to form a frame. This is nearer to the chosen solution of pouring the whole in situ.

Whatever the case, when we take a special look at the pavilions, we see that it is absolutely clear, that the patent is reflected in the double T-beams, but with a much larger span of 9 meters, the ribs at distances of three and with cantilevering slabs of 1,50 m.[25] We can see on photographs taken during the construction, that the slabs, indeed as on the drawings, have a deminishing thickness from 12 to 8 cm!

Surprising is, that even the beams under the groundfloors have the same spans, where in fact nobody can see them and there are no serviceable spaces there. A calculation of needed material is desirable to know whether this continuation of the principle was efficient.[26] We may suppose this, as Wiebenga was known for his daring slenderness.[27]

24 The applicants refer to loading platforms in Empergers Handbuch, Band VII, p.192-193.

25 Emperger shows prefabricated T-beams of 7,00 m.!

26 (Reinforced) concrete slurry was comparatively expensive.

27 See for instance: Robert van Venetie, De tienduizend rozen van

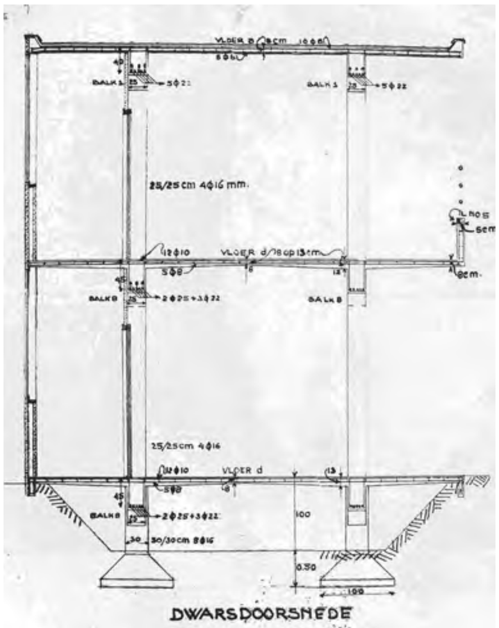


Fig. 7. The double T-beam construction in Zonnestraal. Section through a pavilion. NB the contract drawings did not show yet the tapering of the floors.

Their ultimate dream?

It was to make design more scientific, to rationalize and industrialize the building process:
Jan Duiker in 1933 in *De 8 en Opbouw*: 'Het huis van dr. D'Alsace (sic!) in de Rue St. Guillaume te Parijs. Architecten P. Chareau en ir. B. Bijvoet.' [28]
'This is what we need: there should be an architectural science, a science not only containing the usual technical, mathematical, and physical subjects, but also medical, philosophical, economical, biological subjects; then no hostile newspaperman or any principal would dare to open his mouth. He still might say: "I don't like it", but his judgment would leave us cold just like the statement of a patient that he does not like the taste of his medicine. (….) This architectural science should contain natural history, but certainly not art history and not modelling, not the art of ornamentation, not architectural geometry … not decorative art ... not … But we will discuss this later.'[29]

The House of Glass / La Maison de Verre

31, Rue St.-Guillaume is a whitewashed unremarkable noblemen's house from 1780. The house had a deep garden, in which around 1860 another house has been built.[30] Between the two is a courtyard. The new house had two floors, a basement and an attic. As far as I could trace there were two apartments, as measured drawings show two kitchens in the basement. When the Dalsace Bernheim couple bought the house, and as the anecdote wants to tell it, an old lady living in the attic was unwilling to leave her apartment.[31] So what they had to do was to plan a refurbishment of the rest of the house, instead of taking down the whole and build something totally new.[32] It was at this moment, that Bijvoet came to rescue the situation.

Fig. 8: Courtyard façade of the Maison de Verre before the refurbishment by Bijvoet and Chareau (Photo probably 1925-6, source unknown)

Two aspects

The Maison de Verre is a famous example of modernity of the Nineteenthirties. Several books have been published, in which we find descriptions, some drawings and sometimes beautiful photographs.[33] Entering the building, after being impressed by the all glass façade, going up the elegant and easy stair, one is flabbergasted by the fabulous space of the living hall, and the built-in furniture.

And the tall, slender red steel columns! There is something strange in these columns, which has not been described in any book.[34] When I revisited the house after many years, I saw to my surprise, that the consoles at the head of the columns were cut,

Wiebenga, in: Jan Molema en Peter Bak, Jan Gerko Wiebenga, Apostel van het Nieuwe Bouwen, Rotterdam 1987.

28 J. Duiker, *De 8 en Opbouw*, 18, 2 September 1933, p. 155-164. To be found in an English translation in Jelles and Alberts' Duiker 1890-1935, Forum, nr. 5/6, 1972, p.142.

29 I also must reveal, that Duiker wrote this around the time that he had undergone the medical investigation, that would prelude his untimely death in February 1935. Duiker's illness has been described by his stepson, doctor Arthur Hofmans in Herinneringen aan Jan Duiker, Lelystad 1990.

30 This I have been able to deduct from several scources such as old maps around 1780, the Atlas Vasserot (1810-1836, 'le cadastre par îlot') and a cadastrial map (aprox.1870). See for details: Jan Molema, A tale of two buildings, in Cuadernos de Arquitectura 14, Madrid 2013.

31 This anecdote does not contribute to a report in a highly scientific way, but I can not lay it to rest. I guess, that her kitchen was in her attic.

32 In fact it has been far more complicated, but apart from several unclear aspects, it would take too far for this article to explain.

33 Montes, F., *Maison Dalsace.* GA houses, 1977, 46 and B. B. Taylor: *Pierre Chareau Designer and Architect*. Taschen Verlag, 1998.

34 Maybe in some article in some language in some magazine, that I do not know of?

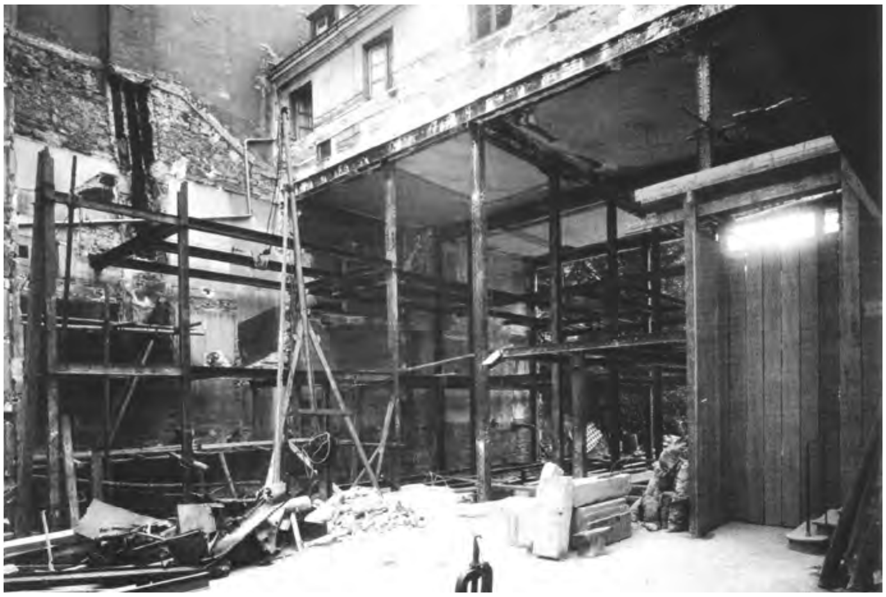
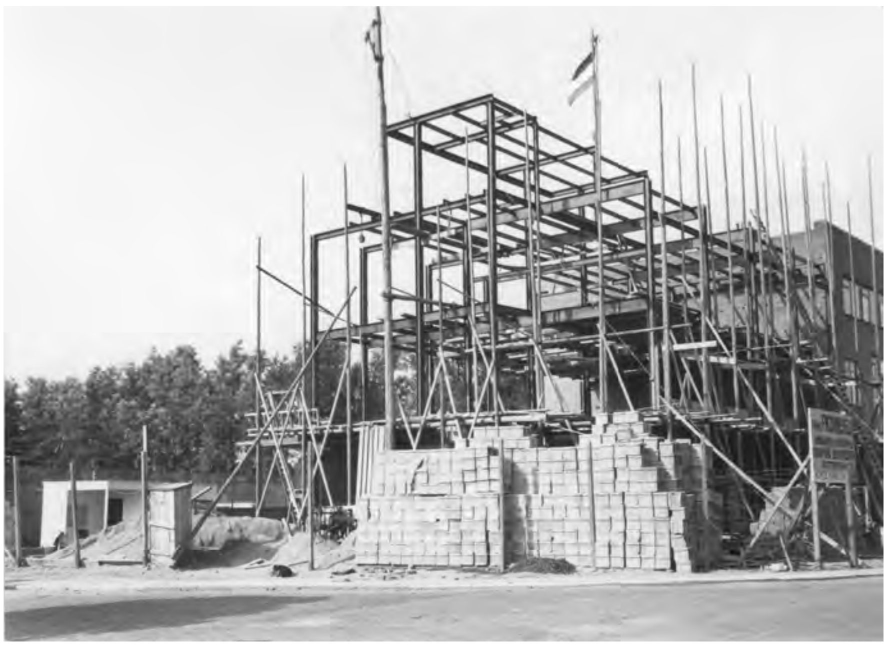


Fig. 9: The Maison de Verre during the refurbishment (photo source and date unknown).



10. The building of the modern skeleton of the Van der Leeuw House, Rotterdam 1928 (Photo source: unknown).

very roughly, totally contrarious to the refinement surrounding me.[35] I could and can not imagine Bijvoet and or Chareau having done this on purpose. Add to this the junctions in these columns at different, undefined height with their varying bolts; add to this the rivets holding together the composing L-profiles and plates to form the I-section. 1928! Already in 1909 full I-profiles, so-called DIN, were common, and as a German source says, composed columns were not used anymore in these dimensions (± 22x19cm).[36]

Writers all tell the same story about the steel frame: it was inserted in the late nineteentwenties, during the refurbishment by (Bijvoet and) Chareau.[37] This may be so for minor additions, but must be incorrect for the main structure. My supposition is that, apart from the old reluctant lady upstairs, there was already -at least partly- a steel structure from between 1860-1870 and 1900-1910.

There are no photographs known of the mounting

35 The owner of the house gave me the opportunity to see the Maison just by myself, having all the time to see every detail. I am very grateful to him fot this exceptional position.

36 Das Handbuch des Bautechnikers ; Bd. 9. Die Eisenkonstruktionen des Hochbaues, R.Schoeler (Bearbeitung), Hans Issel (Herausgeber).

37 It is more and more admitted that Bijvoet was the real architect, not Chareau, although the commissioners, the couple Annie Bernheim and dr. Jean Dalsace, must have asked Chareau in the first place. The question is why Chareau choose Bijvoet to help him out; why not André Lurçat, brother of Jean, schoolfriend of Dalsace, why not Mallet-Stevens, friend and companion in work of Chareau, or any other Parisian. One serious Dutch source says ‘Bernard Bijvoet werkte in januari en februari 1926 voor Robert Mallet-Stevens‘ (www.erzed.nl Zoetbrood). In fact any building of Bijvoet with Chareau we know of was a commission from the Bernheim family, the Maison de Verre being the last; Papa, uncle and nephew Bernheim paid for these commissions. Bijvoet was the perfect one. Molema, J.: Maison de Verre / Zonnestraal, in: Cuadernos de Notas 14, ETSAM, January 2014, p. 98-132.

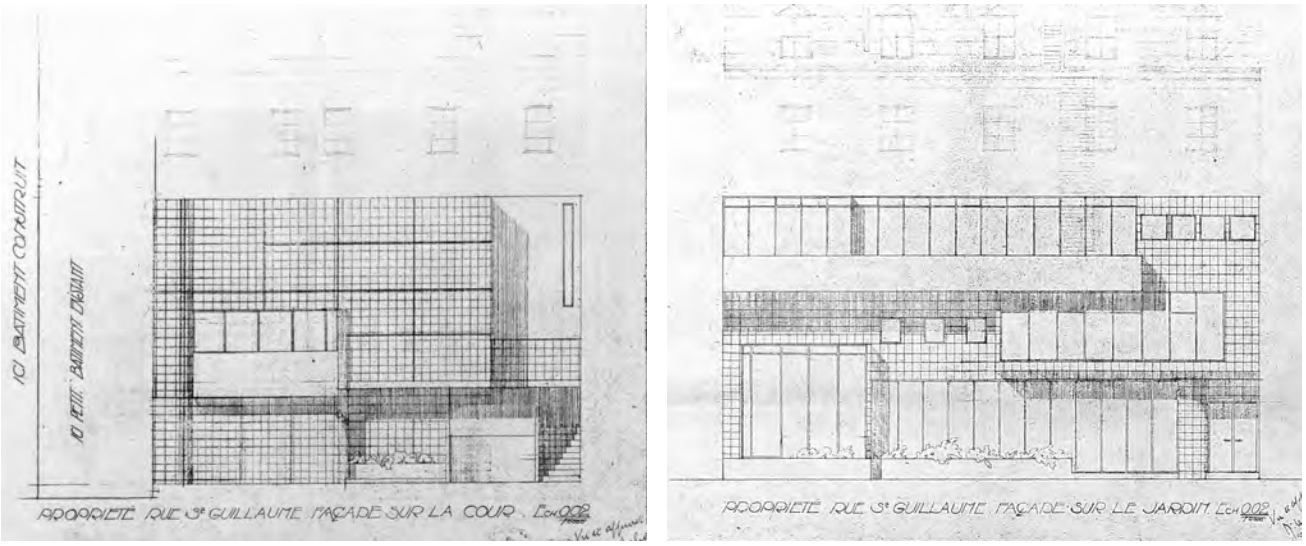


Fig. 11a,b: Maison de Verre. Facade court and facade garden, possibly drawn by Bijvoet. (Source: Molema 2014)

of these elements, though those moments must have been literary spectacular. And there is another strange fact: before demolishing the existing facades they were stripped of their plaster, and windows taken out; but not the frames, as we can see in two pictures. Why did they do this, if they wanted to take them down? Could it be that during the removal of certain elements an existing, but hidden steel structure was discovered, which gave the architect the possibility of making what he really dreamed of? Was this when Bijvoet came to the fore?

Questions that still have to be answered.

Fig. 12: Console of one of the columns (Photo Jan Molema 2012).

Fig. 13: Interior of the Maison de Verre (Photo Jan Molema 2012).

The glass façade and the heating system of the Salvation Army "City of refuge": from conception to restoration

Vanessa Fernandez, Emmanuelle Gallo

Introduction

When a historic building is renovated, it is generally a question of technical update as well as material conservation and restoration. The architects and engineers are entrusted with the task of implementing the least destructive and noticeable intervention while complying with today's building standards. In this respect, the technical equipment such as electrical wiring, plumbing and heating is subject to frequent updates. The same goes for the façade: the glass and the window frames of old buildings cannot be reproduced today and are frequently replaced by up-to-date products.

But what happens when the technical devices are an integral part of the historical value of the building? It is the case for the ongoing renovation project of the Salvation Army "City of refuge" built in Paris in 1933 by Le Corbusier. For decades, this icon of modern architecture, a well-known pioneer building in glass façade and environmental control, has undergone a slow degradation due to improper maintenance and transformations contradicting its nature. The project we will discuss here shows that the approach to the conservation and restoration of historical monuments in France is constantly evolving. Today, our knowledge and sensitivity to issues of technology allows us to adopt a more scientific method and develop a greener project at the same time.

The historical research we conducted as experts of the 20th century construction history helped the restoration team led by the French architects François Chatillon and François Gruson. It enabled us to understand and evaluate the innovations that were originally implemented in the building. Since few of the original materials and devices remain today, it was a real challenge to appreciate and describe the systems. The archives provided by the Le Corbusier Foundation comprising hundreds of drawings, correspondence and pictures coupled with on-site investigations have revealed the richness and sophistication of the façade construction and the heating systems of the City of refuge. It is to be noted that we relied on existing historical research that was extremely helpful[1]. However, the thorough analysis

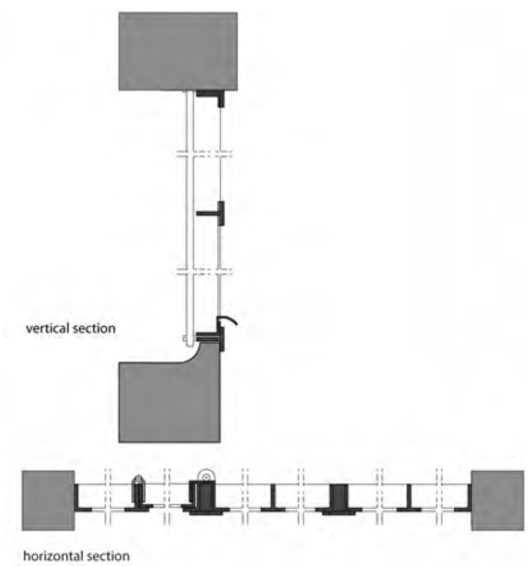


Fig. 1: Atelier Ozenfant (1922). Plan and vertical section of the horizontal window on the 1st floor. The frames are formed of assembled standard angles and T-shapes. Thicker steel mullions support the casement bolt and strengthen the frame. Flat sheets screwed on this mullion reconstitute a rabbet. Drawing VF according to the working drawing FLC07830

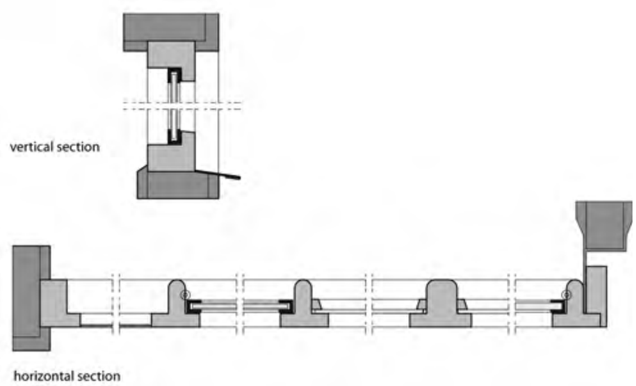


Fig. 2: Window detailing of the Cook villa (1926-29), showing the wooden mullions that replaced the steel profiles probably for economic reasons. The operable glass pane is simply rimmed with a thin folded steel sheet shaped in a U. In this case, the glass is not considered as the filling of a frame but as the structural element. Drawing VF, according to FLC08315

1 A book was particularly useful and saved us a lot of time and energy: Taylor, B. B. (1980). Le Corbusier, La cité de refuge Paris 1929-1933.

Fig. 3: Photo of the façade, Salvation Army City of Refuge, architect Le Corbusier, 1933. ©Archives de la Fondation Armée du Salut

of the as-built drawings compared to the contractors' estimates, had never been conducted before, and it is the primary documentary source of this study.

In this paper we will share our findings and answer the following: How were the original technical devices of the building executed? How would they perform? How innovative were they regarding the technological context? What were the origins of the devices in Le Corbusier's work? Why and when were they modified? What were the options of the ongoing restoration project regarding this matter?

THE GLASS FAÇADE

The origins of the glass façade in Le Corbusier's 1920-1930s work

In the years 1920-30, Le Corbusier developed two types of openings for façades freed from the load bearing part by the use of post-and-beam structure. On the one hand, the "ribbon" window allowed a better distribution of light in the room and a better view towards the outside. This can be seen in the "purist" villas built during this period[2]. On the other hand, Le Corbusier also developed the "pan de verre" or glass wall. As this "pan de verre" was inherited from the traditional façade of artists' workshops, it was natural that Le Corbusier first used it for this purpose, in the Ozenfant painter home and studio (1922). This project displayed the same window frames that were generally implemented in workshops and factories. The posts and transoms of the "ribbon" windows and the large glass façades were made of the same industrial 25 and 35 mm L-, T- and U-shaped hot-rolled steel profiles. Due to their large dimensions, the frames of the large windows of the studio had to be reinforced by 20x80 mm-thick steel mullions[3].

Shortly after, Le Corbusier used the same industrial products for the large window of the Villa La Roche. But the "ribbon" window implemented in this house differed in design and material from the Ozenfant system. The steel stiffener was replaced by a wooden 35 mm T-shaped profile. This served as a rabbet for the fixed glass panes and the French window casements. These were made of a single sheet of glass having a thin U-shaped profile on the edges. The replacement of a metal part by a piece of wood is a crucial step in the search for the innovative and inexpensive building methods that Le Corbusier

Paris: L'équerre.

2 See Benton, T. (1984). Les villas parisiennes de Le Corbusier. 1920-1930. Paris: Ph. Sers / éditions de La Villette.

3 This part of the research is based on the book by Ford, E. T. (1991). The details of modern architecture (Vol. 1). Cambridge,MA: The MIT press, supplemented by an analysis of different projects that served for the article: Fernandez, V. (2012). "The simplification of the window frame: windows experiments in the work of Le Corbusier in the 1920s". In A. Guillerme, Nuts and bolts. Proceedings of the 4th International Conference Construction History (pp. 203-211). Paris: Editions de la Villette.

had led since the mid-1910s [4]. In this project, he also defined the dimensions of the “standardized window” he promoted in the 1925 “Call to the Industrialists”[5]. This combination of fixed and operable sashes would be often implemented in the following projects, such as the “Quartiers Modernes Frugès”[6].

Le Corbusier went on with the idea of a “mechanical”, mass-produced window. Eventually, he patented a wooden “standardized” sliding window. This device was executed in all the villas built between 1926 and 1931. They were produced by the same craftsman; a woodworker named R. Louis and had the same dimensions. But all the efforts Le Corbusier attempted towards the industrialists in order to mass-produce these windows failed. This type of window was completely abandoned after the construction of the Villa Savoye (1931).

In 1931, on the occasion of the 3rd CIAM meeting in Bruxelles, Le Corbusier suggested an exhibition of steel sliding windows. He did a hard work to adapt his patented model to this more challenging material[7]. He finally exhibited two models, one made of an aluminum alloy by the Swiss firm Neuhaussen and one made of steel by the Parisian locksmith Barriaux. One model was also sent by E. Wanner, the Swiss commissioner and builder of the Geneva Immeuble Clarté. Finally, Le Corbusier implemented metal sliding windows were in the large “pans de verre” of the Pavillon Suisse (1932) and the Immeuble Molitor (1933) but not for the Centrosoyus (completed in 1936), where wooden sliding sashes were maintained for economic and technical reasons. Le Corbusier experimented with the “mechanical” system for the large bay window of the Villa Savoye. The opening mechanism was driven by a crank and a chain recalling the double hung window also called Descommuneaux system in France, or the metal shutters of the shops.
In fact, Le Corbusier’s real purpose was to simplify the construction of the façade. He thought this part of the building should be fully industrialized and executed by a unique trade, removing the joiners from the worksite. This streamlining explained why the decision was made of an entirely glazed, airtight façade at the City of refuge, as we will see further.

The development of the glass façade in Le Corbusier’s projects dates back to the early 1920s. In the project for a 3-million-inhabitant contemporary city, widely taken up in the 1925 and 1929 Plan Voisin for Paris, and the 1935 Radiant City project, the large glass façade have been extensively used. The shape of the glazed buildings evolved through all these projects. Initially, they had a cross shape, then a “hound’s-tooth check” shape, which limited the North orientation that provided no sun in winter. Eventually, the shape of the glazed buildings became a sort of “greek border” facing East and West. After the war, Le Corbusier promoted the “Cartesian” skyscraper, a simple, rectangular building facing East and West.

In this respect, the City of refuge was a pioneer building. For the architect, the glazed façade was the key element of the modern city. It enabled one to triple the width of the building and thus save up on ground distribution and networks. Adapting this conception to the Parisian context, he laid out the different parts and functions of the City of refuge such as a childcare center, individual rooms, and dormitories in a very original manner. He implemented the main block perpendicularly to the street, clearing a complete glass façade facing south, 82 m long and 25 m high. This unique envelope sheltered various functions, as we will see later. The rationality of the distribution set in a central block, enabled approximately five hundred people to live, sleep and work behind the glass façade of this “factory for well-being”[8].

Description of the original glass façade of the City of Refuge

The choice of an entirely glazed, airtight façade can be easily understood in the context of the 1930s, when the search for hygiene was prominent[9]. The reason was deeply rooted in the fear of shortages of fuel and energy, consecutive to the First World War.

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4 On many occasions between 1915 and 1930, Le Corbusier recalled the importance of the issues raised by the window: he identified it as an element intended for mass-production in order to reduce the construction time and costs. Thus, in 1915, the windows of the Dom-Ino house are industrial elements. They are supposed to be built before the walls. In 1923, in his book Towards a New Architecture, Le Corbusier emphasized the importance of the mechanism of the widow using the example of trains and cafés, where opening systems allowed not only an airtight closure, but also the sash to vanish while open. The window was attached to the industrial and the transport imaginary, enabling one to see and control the indoor environment. About the Monol houses (1922), Le Corbusier wrote “windows and doors are adjusted at the same time as the cells of asbestos cement. The house is made by a single trade”.

5 “The call to the Industrialists” was issued in Le Corbusier. (1934). Oeuvre Complète, volume 1. Zurich: Girsberger.

6 Benton, T. (2004). "Pessac and Lège revisited: standards, dimensions and failures". Massilia.Annuaire d'études corbuséennes, pp. 64-98.

7 It should be noted that the welding was recently improved by the use of the acetylene.

8 Justin Godart, Speech delivered at the inauguration ceremony of the “City of refuge”, FLC J1-20-20.

9 Many research focus on the topic of hygienist urbanism. See for example: Traisnel, J.-P. (1997). Le métal et le verre dans l'architecture en France, du mur à la façade légère,. thèse de doctorat, université de Paris-VIII-St-Denis, sous la direction d'A. Guillerme or Harzallah, A. (2007). Émergence et évolution des préconisations solaires dans les théories architecturales et urbaines en France, de la seconde moitié du XIXe siècle à la deuxième guerre mondiale. thèse de doctorat, Ecole polytechnique de Nantes: sous la direction de Gérard Hégron.

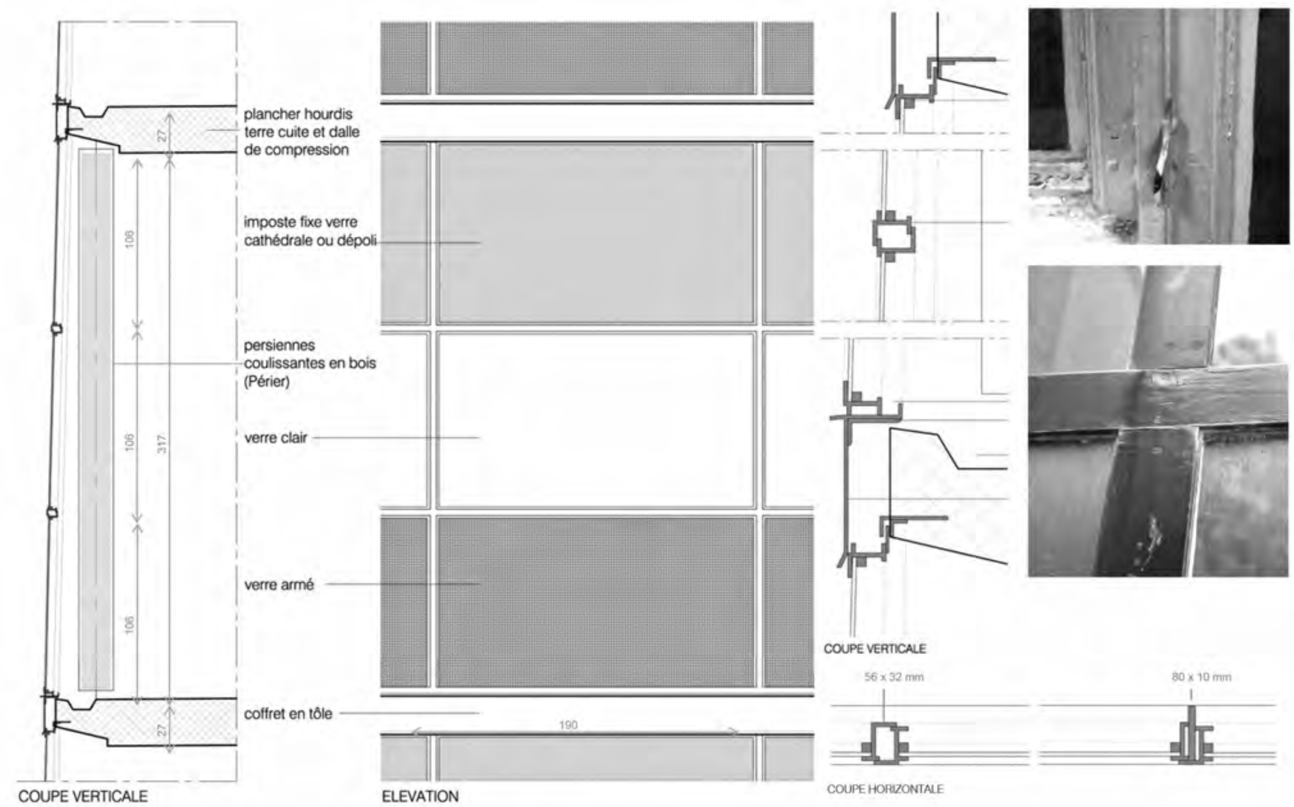


Fig. 4: Reconstitution of the 1933 façade detail.
©Vanessa Fernandez, according to contractor's drawings.

For Le Corbusier, the airtight glass façade was an easy way to provide thermal comfort and save energy thanks to the greenhouse effect. Eliminating the operable windows was a means to protect the interior of the building from atmospheric pollution due to the coal coming from the nearby railways, to prevent residents with fragile health from air draughts by keeping the inside warm. Le Corbusier warranted its "advanced solutions" to the Army on the ground that the glass façade would allow for the light to reach the far opposite section of the building despite its width (10 m). It also allowed for increased fuel economy and prevented detrimental localized cooling spots[10].

The glass pane was sold as an economic solution[11],used to increase solar gains in winter and easy to protect by shutters in summer. Moreover, glass was also considered a clean material. Smooth and easy to clean materials were appreciated in a society that considered the joint as a pathogenic place by excellence. The glass also allowed for translucence and transparency, providing a complete reading of the building, of its structure and of its effects of light at night[12]. A kind of morality and social control was associated to transparency[13], which enabled sight of the interior of the building from the exterior.

This extensive use of glass provided little intimacy to the residents, in spite of the different types of glass: frosted or clear in the central part of each floor depending on the program and the altitude, wired glass for the spandrels, and patterned glass for the clerestory. This monumental glass wall was technically possible thanks to the recent innovations in glass fabrication such as the Slingluff process (glass drawing process patented in 1921) and the inauguration of a Saint-Gobain factory near Paris in 1930 where a new machine that polished both sides of plate glass at the same time was installed[14].

Based on summary sketches made by the Le Corbusier's office in 1931, several firms tended for the construction. Two of them were retained, Menuiseries Métalliques Modernes from Reims (MMM estimated the job at 200 000 F.) and Dubois & Lepeu from Paris (D&L), the latter being also in charge of the glass façade of Le Corbusier's Swiss Pavilion. The fenestration contract was split into two: on the

10 FLC J2-15-103.

11 "The glass panel such as we conceived it, is a technical achievement that led to the economic solution, when it is not about complicated steel and windows opening inside the room, but simply a large metal frame with fixed glass panes. There is a wise economy". Le Corbusier, letter to Commissioner Peyron, 08.03.1931, FLC J2-15-103.

12 See E. Garda, « Le matériau comme manifeste. Les années trente en Italie et les contradictions du rationalisme », 1992, in Philippe Potié, Culture constructive, Paris, Parenthèses, pp. 111-116.

13 Jean-Pierre Traisnel, Le métal et le verre dans l'architecture en France, du mur à la façade légère, PhD thesis, Université Paris 8, 1997.

14 The book Camoreyt, P. (1971). Emplois et mises en oeuvre du verre dans le bâtiment. Paris: Eyrolles sums up the early 20th century techniques for the production of glass.

one hand, “the large frame” of the Cantagrel Street attributed to MMM, on the other hand, the façade on Chevaleret Street, given to D&L. The main difference between the two contractors laid in the profiles they used: the standard U-, L-, T- and Z-steel profiles for D&L, and a special 32 mm hot-rolled steel profile, more expensive but more resistant, for MMM[15].

We assumed that the windows and metalwork elements were pragmatically distributed between the two contractors, following imperatives of visual unity and cheapest cost, in spite of their apparent randomness. Originally developed for smaller windows, the 32 mm “special” steel profiles were adapted to the story height of 3.20 m thanks to a frame of vertical steel stiffeners, distributed every 3.80 m. Each unit was divided twice vertically to match the 1.90 m width of each room and three times horizontally in modules of 1.06 m. The system was held at each floor by embedded bracket and covered by a sheet-metal coffer. Adding complexity, the curtain wall was inclined to respect the urban planning bylaws. Apparently, this curtain wall met the expectations of the users in terms of solidity and protection against air and water, since no complaint appeared in the archives, contrary to the D&L’s frame, which had to be stiffened afterwards[16]. This description was confirmed by the fact that we discovered one original window frame in the building. Located in the basement, under cover, it had been protected from corrosion.
It should be noted that entirely glazed buildings were still very scarce in the early 1930s. The City of refuge glass curtain-wall was one of the first of this size (1000 m²) built in Europe. In the context of a country in economic crisis, this technological achievement deserves to be highlighted.

The solar and light protection was added after the client’s complaints. Wooden sliding shutters, similar to those of the Swiss Pavilion, were implemented in the interior of the dormitories, and curtains were installed in the other rooms. The efficiency of these devices in terms of solar protection was insufficient, as we will develop further.

THE HEATING AND VENTILATION SYSTEMS

The origins of the environmental control systems in le Corbusier’s work

According to several authors, the first experiment Le Corbusier conducted in the field of environmental control laid in the villa Schwob, built in La Chaux-de-Fonds in 1916[17]. Together with the Sulzer company, he installed a hot water heating device in the cavity of a double window in order to reduce the cold wall effect induced by large glazed façade. It also limited the condensation and avoided air draught. In the single family home of the Weissenhof Siedlung built in Stuttgart in 1927, Le Corbusier also split the “glass wall” but did not implement the heating device in the cavity.

Le Corbusier also experimented with the double masonry wall. In the 1922 “houses for craftsmen” projects, the Pavillon de l’Esprit Nouveau and the Fruges town houses built in Pessac in 1925 he tried to implement the double-wall “isothermal” technique devised by Raoul Decourt. It was a double wall of projected cement (cement-gun) 4cm thick, with an air gap or a board of solomite (compressed straw) interleaved. The attempt to resort to this building technique for the Fruges project was unsuccessful[18].

In the 1925 “Call to the Industrialists” Le Corbusier stated that the glass walls were designed to illuminate and not to ventilate. In this respect he acknowledged that the ventilation should be mechanically controlled and elaborated on this in his projects for large buildings. The synthesis of the technical approaches of the 1920s, large glass façade, controlled ventilation and insulated double-wall, was carried out in the project for the great assembly hall of the League of Nations Headquarters, in 1927. The side walls of this room were fully glazed and the cavity created between the two membranes was utilized not only to isolate, but also to retrieve the stale air. Le Corbusier collaborated with Gustave Lyon, who was the acoustician and thermal engineer of the salle Pleyel, for the development of a ventilation and heating system they called “aération ponctuelle” (spot ventilation).

15 Special hot-rolled profiles appeared in France around 1925. The steel bars are first hot-rolled by multiple passes in a rolling mill that stretches the molten metal. The products are then either finished or semi-finished. In the latter case, they are processed anew in an oven at a lesser temperature and are stretched by rammers that push the metal, or pushed through the press. Stretching is used to calibrate the product precisely. It is for this reason that special profiles are more sophisticated than the standard elements such angle, flat, L or U. The air and waterproofing are improved by a double rebate (rabbet) and the setting of glass panes inside with screwed beading instead of putty. The fact that MMM originated from Lorraine, a coal and steel region that was occupied by Germany until 1918 might explain why their steel technology was better developed.

16 January 20, 1933, Pierre Jeanneret will ask D & L to estimate 335 meters of “36-42 protection bars secured by brackets 0.30 m distance from the cross piece of the large glazed wall side Cantagrel facade and facade Chevaleret” , estimates D & L, FLC J1-18-263.

17 See for example Alazart, J. (1961). De la fenêtre au pan de verre dans l'œuvre de Le Corbusier. Paris: Boussois, PVP

18 Rosellini, A. (2011). "Charles-Édouard Jeanneret, consulente tecnico della Société Française de l’Everite, 1917-20". Massilia. Annuaire d’études corbuséennes, pp. 8-29.

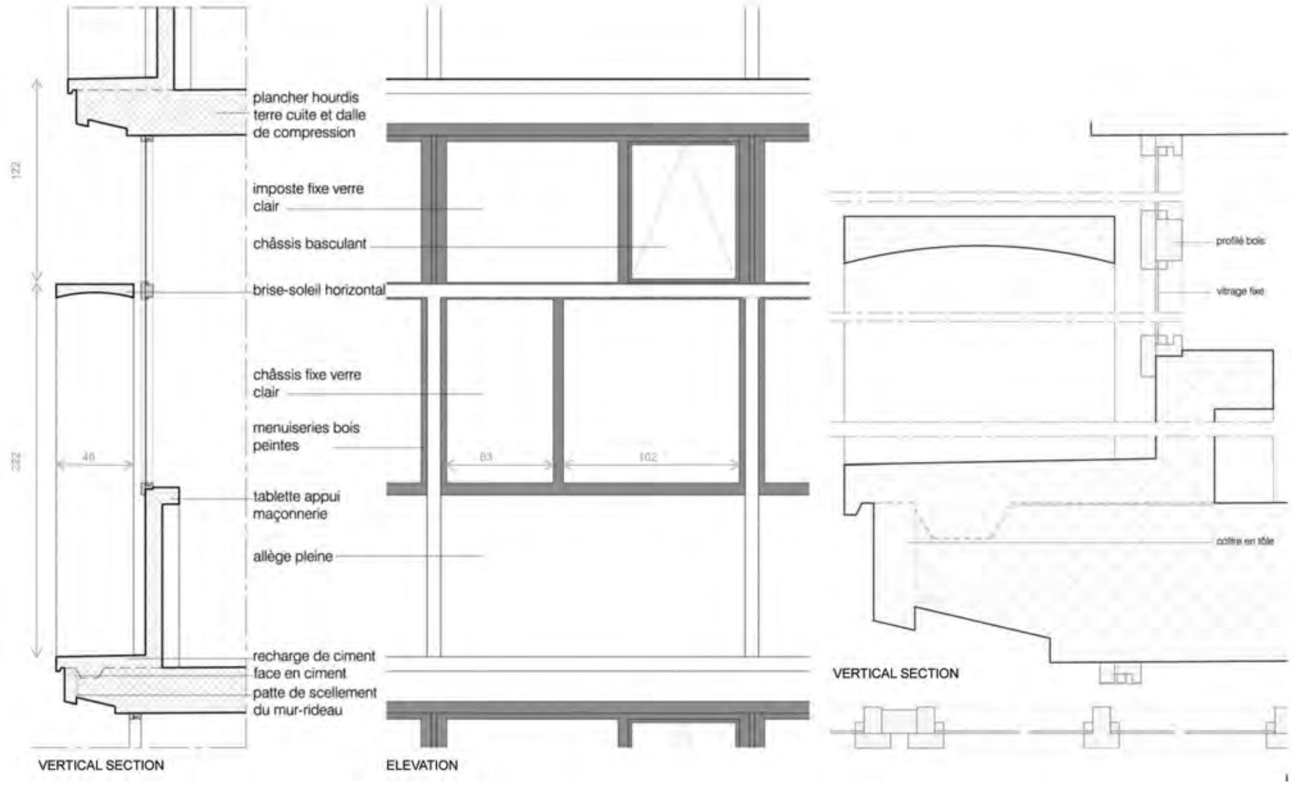


Fig. 5: Reconstitution of the 1952 façade detail. ©Vanessa Fernandez, according to the measured drawings elaborated in 1975 by P. Verrey.

For the Centrosoyus building in Moscow in 1931, Le Corbusier proposed to circulate air, warm in winter, cool in summer in the cavity of a double ”pan de verre”, hermetically sealed from the inside and the outside. He called this system the “neutralizing wall”. Once reduced the radiating and thermal exchanges through the envelope by this “wall” repeated at each floor, a mechanical ventilation system, inspired by the system used by Gustave Lyon at the salle Pleyel, was implemented. This so-called “exact breathing” system provided each one with 80 liters of air per minute at the constant temperature of 18 °C[19]. At the Centrosoyus, the principle of double facades has been accepted, with difficulties however, the commissioners preferring “ribbon” windows to the fully glazed wall. Le Corbusier yielded on the creation of sliding windows in the “neutralizing wall” and the “exact breathing” system was never implemented.

But what Le Corbusier called his “inventions” were in fact the reuse of traditional techniques. Indeed, the double wall with heated air cavity, although energy consuming because of the heat losses, already had a long history in the 19th century. Although the systems were not invented by him, the interest of the Le Corbusier’s solutions lied in the fact that they could be split-up.

In the description of the systems published in Précisions in 1930[20], it appeared that they were intended to be used in all orientations and all latitudes. Le Corbusier hoped somehow standardize the internal environment, thanks to the double airtight façade and ventilation at 18 °C. The building was inspired by the functioning of a lung, the city working as an organism.

At the City of refuge, despite Le Corbusier’s discourse, there was no evidence of a projected “neutralizing wall”. Presumably for economy reasons, technical feasibility and considerations for the French climate[21], Le Corbusier quickly replaced the “neutralizing wall” with a single curtain-wall. Nevertheless, in June 1931, Le Corbusier had the “neutralizing wall” tested by the glass company Saint-Gobain. The conclusions of this experiment were that, the heated cavity of the “neutralizing wall” needed to be isolated by a second layer of air created by an extra glazing in order to be effective.

A version of the “exact breathing” system, a forced-air heating system, was however implemented at the

19 Le Corbusier, Une maison, un palais : A la recherche d’une unité architecturale, Paris, G. Crès et Cie, 1928.

20 Le Corbusier, Précisions sur un état présent de l'architecture et de l'urbanisme, Vincent-Fréal et Cie : Paris, 1930.

21 Le Corbusier featured “neutralizing walls” for the projects exposed to harsh climate such as Switzerland (Villa Schwob, 1916 and League of Nations Headquarters, 1927) or Russia (Centrosoyous, 1931) but not for those located in Paris, apart from the Draegger printing shop in Montrouge (1929).

City of refuge, with great pragmatism over means and conditions (the initial contractor bankrupted during the construction). It should be noted that the air conditioning and the mechanically controlled ventilation were still rare during the interwar period in France, which explains why they were only partially implemented at the City of refuge.

The projected heating and ventilation systems

In 1931, several companies, Leroy, Sulzer, Tunzini, Zaniroli, Castiaux, explored solutions for the central heating and cooling systems. Construction having already begun by this date, the location and size of the service spaces were fixed, including that of the two chimney flues and of the six ventilation ducts. Le Corbusier wrote: “The contractor shall take into account the shafts (floor openings) that have been laid out in the floors for ducts and pipes. He will provide installation based on these crossing points. The ducts and pipes laid horizontally or vertically, in any kind and in any form whatsoever, shall in no case be hidden in the masonry wall, they will be rather clearly disconnected, especially visible and accessible on the ceiling that is to say, suspended”(FLC J2-15-114).

While heat engineer Victor Maubras declined the offer to work on the project[22], his colleague Auguste Beaurrienne provided documentation on his invention: the “Calopulseur” system he recommended for heating large spaces such as workshops[23]. Heating companies Leroy, Sulzer Tunzini, Zaniroli Castiaux were consulted to offer alternatives and submit estimates of costs[24].

Sulzer, Leroy and Tunzini proposed four different solutions, from traditional radiator heating to complete air conditioning systems[25]. The architect and the client chose at first Zaniroli and Castiaux. They finally selected Castiaux, probably because the simplified system it proposed, at 470.000 francs, was the least expensive. By contrast, for their air conditioning systems, Sulzer had asked for 1.640.000 francs, Leroy 1.250.000 francs and Tunzini 978.000 francs. As B. B. Taylor pointed out in his study on the building, these figures were out of proportion with the building budget that oscillated between 4 and 5 million francs[26]. After Castiaux faced financial difficulties, the Compagnie de Chauffage par le Vide, or CCV, took over the project[27]. It implemented a sensible solution that privileged mixed heating: a vacuum-driven, low pressure steam circuit fed cast iron radiators directly and, indirectly, forced air heaters.

Context of the time in the field of heating

The forced air system proposed for the Salvation Army building was relatively reliable at that time in France in domestic architecture. The vacuum-driven steam was a heat transfer fluid, still rare, coming from North America where it was implemented mostly in high-rise buildings. However, its handling was taught by the heat engineer André Missenard in his lectures at the l’École Spéciale des Travaux Publics from 1932 to 1942[28]. The principle was to maintain throughout the installation a pressure less than one atmosphere, using a vacuum pump. Then, the heaters were always saturated with steam at a relatively low temperature between 45°C and 95°C. This heating system allowed for the use of standard heating units: boilers, radiators and pipes of current section. It had many advantages: very low inertia, a setting as accurate as for hot water heating, suitable for intermittent use[29]. The risk of frost being discarded, its effectiveness allowed for making savings during operation. Associated with modern skyscrapers, vacuum-driven steam heating irrigated this innovative building.

It is to be reminded that the warm air systems (without mechanical propulsion) dating back to the eighteenth century in France developed during the nineteenth century in theatres, auditoriums, libraries and luxury homes. The forced air version, subsequent to the introduction of the electric motor, after 1880, spread predominantly in the industrial sector[30]. The forced

22 Victor Maubras, Traité pratique de fumisterie, chauffage, ventilation et chaudronnerie concernant le bâtiment avec de nombreux exemples, tables et résultats pratiques (Treaty practice of fumisterie, heating, ventilation and boiler for the building with numerous examples, tables and practical results), Paris, G. Fanchon, 1908. The author is also the author of a contribution to the first congress of the heating and ventilation of residential buildings in Strasbourg about: what are the current methods that seem to be required for the ventilation of large rooms, p. 146.

23 Victor Maubras and Auguste Beaurrienne represented important figures from the community of thermal engineers. The latter, who visited the U. S., was a member of ASHRAE (American association of heating engineers) and regularly reported from overseas technical developments, such as air conditioning.

24 Le Corbusier worked with the company Castiaux in Pessac and the company Zaniroli has made sanitation facilities and the heating in the “Palais de la femme”, Palace of woman, in Paris 11th district, a building owned by the Salvation Army. André Leroy was president of the trade association of heating by water and steam, the company Tunzini found in 1906, executed the heating and ventilation system of the Printemps department stores. Sulzer is one of the largest heating companies in Switzerland, settled in Winthertur, founded in 1841; they owned at that times several offices in France.

25 These three firms were very well known at that time, there were member of the Union Chamber of heating system manufacturers.

26 B. B. Taylor,op.cit., p. 96.

27 FLC J1-18-207, FLC J1-18-31.

28 André Missenard, Chauffage et ventilation, 1932, 166 p., manuscrit lectures.

29 Most part of the building was intermittent heated.

30 The Glass House by Pierre Chareau (1883-1950) in Paris (1928-1931) also used a forced air heaters, a direct system. Le Corbusier often visited the construction site. (B. Bijvoet collaborated in this project. Note of Ed.)

Fig. 6: Photo of the façade, Salvation Army City of Refuge, 2010
©Vanessa Fernandez

warm-air heater embodied an effective comfort and the image of the machine in the hygienist universe of the Salvation Army's building.

Le Corbusier's idea of heating his building with warm air at a constant temperature in order to minimize cold drafts also initiated in 18th century in France. In 1777, Jean-Simon Bonnemain, the inventor of hot water heating system, had first implemented this system for hatching eggs and rearing chickens in all seasons, a task that required constant temperatures. Le Corbusier apparently followed the recommendations of the marquis de Chabannes who, in his first book on heating of 1815, advised "the purification of the air, the prevention of dampness, the equality of temperature and suppression of draughts of air"[31].

The heating system of the City of refuge

At the City of Refuge, eight steam heating circuits were planned but only four, longer were implemented. Three oil burning boilers, a vacuum pump, and hot water tanks occupied the basement. The fresh air coming from the roof, after being filtered, was distributed by forced air heaters into the rooms. The larger spaces in the building, the dormitories, the dining room, the hallways, the meeting room, were also heated by forced air heaters "Thermon". The blowers were located either inside the space to be heated or underneath the floor with registers, as it was the case in the circular entrance pavilion, the hall at the pilotis level, the meeting room, and the elderly women dormitory. Two blowers placed on the first floor heated the entire staircase. Blowers located at both ends of the corridors heated the individual rooms for mothers and their children and the child-care center. The ducts were inserted into a counter ceiling along the corridors and registers were placed in the wall above the door in the rooms[32].

The offices, apartments, the room for supervisors,

31 Jean-Baptiste Chabannes (marquis de), Explanations of a new method for warming and purifying the air in private houses and public buildings, Schulze & Dean, London, 1815, p. 5-8.

32 Le Corbusier's quotation, see note 14, FLC J2-15-114.

the room dedicated to the Princess of Polignac (the principal donator) were equipped with standard cast iron radiators heated directly by steam. Most of these small spaces had opening windows[33]. The chosen fuel was oil, supposed to be the “modern” clean fuel, producing no waste and that did not require staff. This fuel was “almost” gainful because of dramatic increases in coal prices in the aftermath of the First World War[34].

The heating system seemed to function properly, even if the Salvation Army thought the consumption of oil and electricity was too important[35]. Most of the issues, however, occurred during the summer with the airtight glass façade.

We can establish a social interpretation of the distribution of spaces between radiators and hot air blowers; radiators served offices, rooms and apartments dedicated to the staff and the Princess de Polignac. Radiators, devices well known by the privileged classes, were socially “valued” and recognized as an effective system. Le Corbusier’s choices of thermal comfort for the City of Refuge as seen through the eyes of the "hosted" must have been quite different from those of the Salvation Army staff. Indeed for this population, continuous thermal comfort throughout the building is something quite new. They were unlikely to have had access to a central heated place unless they had been in prison or had been hospitalized. The modest population’s heating means at this time remained the fireplace, fitted or not, and industrially produced stoves, like Godin stoves. Similarly, primary schools were mainly heated by stoves, as well as cafes and other community spaces accessible to popular population. The heating in the small bedrooms, dematerialized due to hot air, should have been seen as a little "magic" by this population accustomed to cold and damp rooms. In the dormitories, the presence of “pulsairs” blowers was probably surprising, but probably more by their efficiency than as technical objects left uncovered.

Indoor climate issues

Without an air conditioning system, considered too expensive, blowers, disconnected from the heating system, were supposed to provide ventilation during the summer[36]. Rooms were thus given fresh air coming from the roof, although, Le Corbusier suspected that the Salvation Army disconnected the blowers in order to save electricity[37]. How the air circulated in the large spaces, such as the dormitories, was simple but maybe insufficient. On floors 3 to 6, single rooms served by a corridor, were ventilated by registers above the doors, creating some overpressure. The air left the room pushed under the door into the corridor and exited the building through grilles set in the walls of the small courtyards. This system was apparently not sufficient as well. In the childcare centre on the 5th floor which, unlike the dormitories, is used during the day, the temperature could rose to 33°C[38]. With a glass curtain wall, the replacement of the air conditioning system by forced air ventilation may have made sense financially, but certainly did not technically. Beyond technical issues, the negative reception of the hermetic wall can be explained from social and cultural points of view: the possibility of opening windows appeared necessary for some residents as it did to the administration. It might have been an expression of what is called now the sick building syndrome. Furthermore, one can easily imagine the problems that people, with fragile mental states, faced in airtight spaces.

The Salvation Army complained bitterly to Le Corbusier about the excessive heat, each party supported by its own team of experts[39]. After numerous exchanges they decided to find a solution, consulting engineers proposed a water cooling system that unfortunately proved to be too expensive[40]. In the end, as claimed by B. B. Taylor, forty sliding windows were opened in the glass wall[41].

THE TRANSFORMATIONS

The façade and the “brise-soleil”

In 1944, a bomb destroyed the glass façade completely, giving way to a new façade project, developed by Le Corbusier in 1950-52. This project enabled him to explore new solutions with regards to

33 B. B. Taylor, on the contrary, wrote that all rooms equipped with radiators had opening windows.

34 The difficulty of finding staff added to the rising price of coal.

35 Mr. Lavergne wrote: “The heating during the winter period is entirely satisfactory both from the economic point of view as well as regards to the ventilation that is established simultaneously with the heating”, FLC J2-5-233.

36 Le Corbusier wrote: “The renewal of the air volume will vary depending on the power of the blowers (pulsairs) between 2 and 3 1/2 times per hour, but a renewal of a minimum of two times per hour in the summer will be insured”, FLC J1-18-25 to 30.

37 The architect wrote: “The directors of the refuge, wanting to save money at all costs, only rarely do the fans turn”, FLC J1-20-257.

38 Former Commissioner Peyron wrote: “Do you know that in summer the temperature rose to 33° and the children dragged on the ground questing for air?”, FLC J2-5-37.

39 FLC J2-5-3 to 6, FLC J2-5-238 to 41.

40 More than 100.000 francs, FLC J2-5-232 and 233.

41 B. B. Taylor, p. 123, “the architects have agreed on the principle of practicing various openings in the façade of the nursery. Hence, the experiment can be made if this method is positive or negative”. Similarly, “mothers and children rooms and the child care will possibly be ventilated by the establishment of small horizontal blinds; one room has been fitted this month”. FLC J2-5-233.

reducing solar heat gains. In 1950-52, Le Corbusier offered to repair the façade destroyed by the bombing, and designed a new façade were he experimented with concrete sunshades or “brise-soleil”.

The story of the “brise-soleil” device is now well known through several publications[42]. Le Corbusier developed a system of opaque protections for the glass wall associated with natural ventilation for Barcelona, Algiers and Rio de Janeiro in the late 1930s. After the war, Le Corbusier did not completely abandon the idea of the “neutralizing wall”, as evidenced by its proposal for the UN headquarters in New York in 1947. But he learned from his mistakes and incorporated a solar protection to the façade of the City of refuge. This awareness can also be attributed to its collaboration with André Missenard[43]. In the inter-war years, scientific publications had reported thermal studies under the guidance of professional associations, including a study on solar heat gains in residential buildings[44]. Le Corbusier would widely use the shading devices in the post-war projects, such as the “Unité d’habitation” in Marseilles or at the convent of La Tourette, etc.

It is therefore not surprising that, offering his services to the Salvation Army to renovate the building, Le Corbusier made a project that incorporated a concrete “brise-soleil” on the South facade. Iannis Xenakis, then collaborator of Le Corbusier’s office, studied the depth of the device with graphic solar studies[45]. Despite an initial geometric blueprint that defined the optimal depth of the shading device to 70 cm, the executed protections were only 46 cm deep. The large glass panes of the two façades were fully replaced by new wooden frames laid on light masonry spandrels, set back from the edge of the floor. The design of this façade differed from the original one. The geometric divisions of each panel created a square in the center, filled with fixed glass, and an operable casement in the clerestory. Le Corbusier also advised the Salvation Army for the polychrome façade, supposed to recall the colors of its flag.

We know that as the result of this work, Le Corbusier ceased his “friendly participation, begun 20 years before”. It is because of the lack of compliance with his recommendations, especially the yellow color painted on the 7th floor façade panels which he did not like.

Slightly modified during the 1975 renovation, the wooden frames were replaced by aluminum sliding sashes in 1988, and the spandrels were covered with aluminum sheet panning. This alteration changed the appearance of the façade, in spite of the designation of the building as a Historic Monument in 1975. The last two floors of the building kept their original steel frames, odd and modified, until 1975. They were then replaced by new steel frames rather similar to the original ones, apart from the masonry spandrels. They were still in place before the 2013 renovation work.

The original heating plant and the distribution networks have been totally destroyed at an unknown date and replaced by the company Delbost-Metz & Cie[46]. The implementation of the current radiator system negated the architectural qualities of the building. Since 1992, the City of Refuge is heated by the Parisian district heating system (CPCU) using low pressure steam. This technology might facilitate the return to a system closer to that used originally. Despite the destructions , it is still possible to find significant traces of the ventilation ducts around the building such as filled-up floors openings, grilles, and registers[47]. Those traces confirm that the original system was close to the technical specifications and the few changes described in the letters exchanged between the architect and the CCV. They point to a captivating history of technical innovation.

The ongoing restoration project

The ongoing restoration of the City of Refuge allowed for an interesting debate on the façades and heating -ventilation systems restoration. Despite the fascina-

42 Le Corbusier himself told the story of the “brise-soleil” in Le Corbusier. (1946, janv-fév). "Problèmes de l'ensoleillement. Le brise-soleil". Techniques et architecture, pp. 25-28. Reyner Banham considered the “brise soleil” as a major invention in the field of architectural device for controlling environment. Banham, R. (1969). The architecture of the well-tempered environment. London: London press. Daniel Siret analyzed the genealogy and the efficiency of this device. Siret, D. (2002). "L'illusion du brise-soleil par Le Corbusier". Langages scientifiques et pensée critique. Cerisy and Siret, D. (2004, Octobre). "Généalogie du brise-soleil dans l'oeuvre de Le Corbusier : Carthage, Marseille, Chandigarh". Cahiers thématiques(n.4), p.169-181.

43 A thermal engineer with whom he developed the “climatic grid” tool that was used for Ahmedabad and Chandigarh projects in the 1950s. André Missenard, Polytechnician, taught thermics in different high schools, while running a business (Missenard-Quint) and a study desk. Author of educational resources, responsible for professional associations, he is the only French to receive the plate Rietschel in 1938 for his contributions to the theory of the resulting temperature. In 1955, with Le Corbusier’s office, he will develop the climatic grid for the projects in Ahmadabad and Chandigarh.

44 Jeanne Mouret, André Nessi, Étude des apports de chaleur par insolation dans les bâtiments habités (Rapport n°5), Comité technique de l'industrie du chauffage et de la ventilation, section du chauffage et Société industrielle d'imprimerie, Paris, 1946, 94 p.

45 The sunshades were studied mainly by Iannis Xenakis. The project was entrusted to Pierre Jeanneret, who had supervised the building's construction from 1931 to 1933. Finally Mr. Guardian and Mr. Pollack supervised the renovation project after P. Jeanneret’s departure for India.

46 Plans, Salvation Army archives.

47 Successive visits to archives and the building enabled us to find its traces.

tion the original glass façade may have inspired, the "brise-soleil" was acknowledged as an original part of the building, showing Le Corbusier's capacity to readapt his initial concept and experiment new solutions.

The materiality of the façade has been in debate for several months. The city of Paris historic commission, the Ministry of Culture conservators and Le Corbusier Foundation experts issued conflicting advice on what to do: should the replication of the original steel profiles or the wooden frames be preferred? Both techniques are very maintenance intensive. The decision was finally made to restore the main façades in the 1952 state with wooden sashes. The attic and ground floor levels that still retained the 1975 metal frames were to be restored to their 1933 state with metal profiles. The adopted approach integrated new insulated double glazing to all the windows. The documents found and analyzed were extremely important for the restoration. Fortunately, abundant layouts, descriptions and pictures enabled the architects to reestablish the original design of the windows, the railings and many other devices destroyed and reconstructed differently over time. This attention for the slightest detail, the exhaustive documentation of what is done will allow for an "archeological" approach to the restoration project. An interesting group of experts was created to help the architects solve many issues of preservation. The topics of the meetings are as diverse as the choice of the colors of the main façade, the compliance of the details with the original documents, the furnishing of the three bedrooms that will be restored to their original features, etc.

It is to be recalled that only the façades, the roof and the hall are designated as historical. The committee only elaborates upon these locations. The polychrome façade was a challenging question: photos dating from this period are in black and white, they do not provide valid sources for restitution. The probes taken on the spandrels, the correspondence and contractor's estimate of costs, letters from Le Corbusier were discussed to find a solution. The same goes for the restitution of the internal polychrome painting in the hall. The colored glass tiles of the porch – "verre Désagnat" of which not a single tile and very few information remained are to be reinstalled. But the model of the elaborated lighting fixture, called "X-ray" one of which we finally discovered after one year's research will not be restored.

Unfortunately, the building must undergo a very deep transformation. The bedrooms are considered too narrow in respect of today's standards, 1.90m instead of 2.50 m. Therefore, all the internal partitions will be demolished, a heavy decision since the façade rhythm is paced on the dimensions of the rooms. But this transformation will enable the owner to keep the original use of the building and this is very precious. In order mitigate the loss of the original layout, three historic bedrooms should be conserved and furnished according to the 1933 state. During the demolition, our historical team will perform an archeological survey and some original devices will be stored for a future project of a visitor center.

The projected heating and ventilation systems do not intend to reactivate the original air system, the hot water radiators being more cost-effective. Nevertheless, the new circuits will not disfigure the space anymore and archaeological evidence related to this innovation will be preserved as part of a comprehensive and global project.

More generally, a relevant improvement of the renovation process should introduce the study of technical devices (through back and forth research between archaeological evidence and archives) as well as other historical research for preserving the buildings of the twentieth century. This is especially true when comfort perception and innovation were important for the quality of the project.

CONCLUSION

As a conclusion, we hope that we pointed out the historical significance of the technical endeavors of the Salvation Army City of refuge. The ongoing restoration project took this aspect into account and developed a design that will allow for everyone to rediscover one of the icons of Modernity. At the same time, an archeological approach will certainly reveal other historical evidences and enable us to learn more about this building.

Brazilian Engineering and Joaquim Cardozo's contribution to Oscar Niemeyer's Architecture

Danilo Matoso Macedo, Elcio Gomes da Silva

> I shape my projects characterizing them whenever possible by the structure itself, which is never based on the radical impositions of functionalism, but on a search for new and varied solutions, logical, if possible, within the static system. Therein I fear no contradiction of form with technique and function, for the lasting solutions are those that are beautiful, unexpected and harmonious. To reach this aim, I accept every artifice, every compromise, convinced that architecture is not just a matter of engineering, but an expression of soul, imagination and poetry.[1]

The work of Oscar Niemeyer (1907-2012) can be divided in at least three main stages. The initial works, from 1935 to 1955, characterized the so-called *Brazilian style*, skillfully articulating independent structure, glass curtain-walls, roof-gardens, with free-form plans, curved vaults, sun-shading devices, colorful cladding, integrated to an exuberant tropical landscape design.[2]

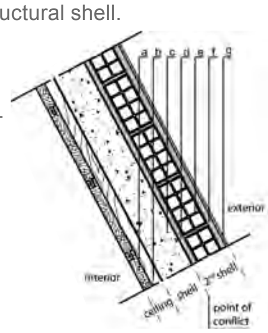
From the mid fifties on, starting mainly with the works in Brasilia, he progressively *cleaned* his architecture, preferring, in his words *compact solutions, simple and geometric*, in buildings that *no longer [would be] expressed through their secondary elements, but rather through the structure itself, duly integrated within the original plastic conception.*[3] Finally, from the seventies on, the structure became almost completely subordinated to free-forms, no longer determined by static or geometric principles. The relationship between form and structure – or the lack of it – is in the core of this process, and therefore the dialogue between architect and structural engineer should also be considered as determinant. In this field, Joaquim Cardozo (1897-1978) was certainly the closest partner – if not in number of works, certainly in their importance. Cardozo not only calculated and designed the architect's formal solutions. He established a true collaboration vastly documented in the projects and in the several texts he authored on engineering, aesthetics, art history, and, of course, on

Fig.1a: Pampulha Church, 1943. Oscar Niemeyer, Architecture. Joaquim Cardozo and Ruy Moreira, Structural Engineering. Photo: Danilo Matoso

Fig.1b: Model of possible structural scheme of the parabolic and circular vaults. Drawing: Danilo Matoso

Fig.1c: Detail of a possible shell-section. Drawing: Danilo Matoso

a – ceiling of cherry boards, variable width.
b – joist for fixation of the ceiling.
c – reinforced concrete structural shell.
d – plaster.
e – brick filling.
f – plaster.
g – cladding of blue porcelain tiles 20mm x 20mm, set at 45º. White grout.



1 Oscar Niemeyer, "Forma e função na Architecture = Form and function in architecture," Módulo 4, no. 21 (dez 1960): 2–7.

2 See Zilah Quezado Deckker, Brazil Built: the architecture of the modern movement in Brazil (London: Spon Press, 2001), 160–161.

3 Oscar Niemeyer, "Depoimento = Testimony," trans. Stanley Howling, Módulo 2, no. 9 (fev 1958): 2–6.

architecture. The historical background and details of their relationship brings new keys to understand the development of Niemeyer's work and its reverberation in Brazilian Architecture.

Architecture and engineering where not legally distinct in Brazil until 1933, when these professions where regulated. Niemeyer and Cardozo belonged to a tradition in which *Beaux-Arts* architects had a solid technical training, and Polytechnic engineers had strong *humanistic* credentials. As late as in the fifties, Classical theory and architectural history deserved some chapters in Brazilian construction manuals[4]; conversely, structural detailing and foundation design was a part of treatises on architectural philosophy.[5] In colonial times, before 1822, most of the formal architectural training in Brazil was provided by the Military Engineering Academies, established in the main cities since the late seventeenth century. The social prestige of engineering increased during the second half of the nineteenth century because of the demand for trained professionals for the construction of railways and telegraph networks. Contracts with foreign companies also stimulated the immigration of European engineers who, in exchange, opened the doors of European universities to Brazilian students. Antônio Francisco de Paula Souza (1843-1917) was one of these. He was graduated at the *Technische Hochschule* in Karlsruhe in 1867, and founded in 1893 a research institution named *Office for the Strength of Materials* in São Paulo, pioneering several tests on concrete dosing. Reinforced concrete was adopted for bridges and buildings in Brazil since the first decade of the twentieth century, through foreign companies with representations in the country, such as the French Hennebique or the German Wayss & Freytag, who worked with the help of local laboratories for adapting the technology to Brazilian context. With that academic and practical background, the following decade saw the work of a new generation of Brazilian structural engineers specialized in reinforced concrete. Emilio Baumgart (1889-1943), for example, was responsible for relevant achievements such as the largest straight span bridge in the world in 1930, the twenty-four storey *A Noite* building in Rio in 1928, also acting as a consultant at the twenty-four-storey *Martinelli* building in São Paulo, considered the tallest skyscraper with concrete structure in the world when it was completed in 1934. In 1943, at the former *Office for the Strength of Materials*, Lobo Carneiro (1913-2001) developed the so-called

4 João Baptista Pianca, Manual do construtor, 5 vols., 9th ed. (Porto Alegre: Globo, 1977). 1st. edition: 1955.

5 Adolfo Morales de Los Rios Filho, Teoria e filosofia da Architecture, 2 vols. (Rio de Janeiro: A Noite ; Borsoi, 1955).

Fig.2: Casa do Baile, Belo Horizonte, 1940. Oscar Niemeyer, Architecture. Albino Froufe, Structural Engineering. Marquee with flat ceiling and inverted beams. Photo: Alexandre Brasil.

Fig.2b: Hall with waffle slab and flat gypsum low-ceiling. Photo: Danilo Matoso (during renewal in 2002).

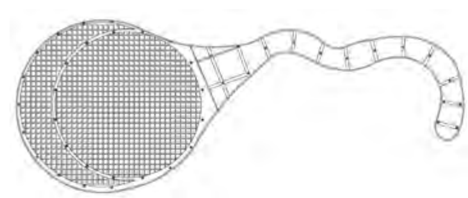


Fig.2c: Possible structural plan for the Casa do Baile – based on surveyed documentation. Drawing: Danilo Matoso

Brazilian Test, for the concrete resistance to tensile stress. The prestige of Brazilian structural engineers brought to the country foreign researchers, that also established a fruitful dialogue. The German editor of the *Beton und Eisen* magazine, Adolf Kleinlogel, came to Brazil to research and publish Baumgart's works in 1937, and Arthur Boase, editor of the North-American *Engineering News Record*, also came in 1944, intrigued by the slenderness of Brazilian structures, to produce then a special series on Brazilian calculation standards.[6]

6 For a history of these achievements see: Augusto Carlos Vasconcelos, O concreto no Brasil : recordes, realizações, história, vol. 1 (São Paulo:

Fig.3a: Alvorada Palace, Brasília, 1957. Oscar Niemeyer, Architecture. Joaquim Cardozo, Structural Engineering. Photo: Danilo Matoso.

Those where the principles that later would be used as a basis for the investigations on *chaos theory* and *fractals*. In another lecture that same year, he explained that in his works of Recife he thought out *space structures for achieving pure forms that can be shaped only with concrete, and which are solutions freer and more perfect than, for example, the column and the architrave, or the ribbed vault.* He claimed to have used, *for the first time* in his state, *the "flat-slab" and the "Zeiss-Dywidag" vault.*[8] The close contact with the Brazilian intellectual elite brought Cardozo

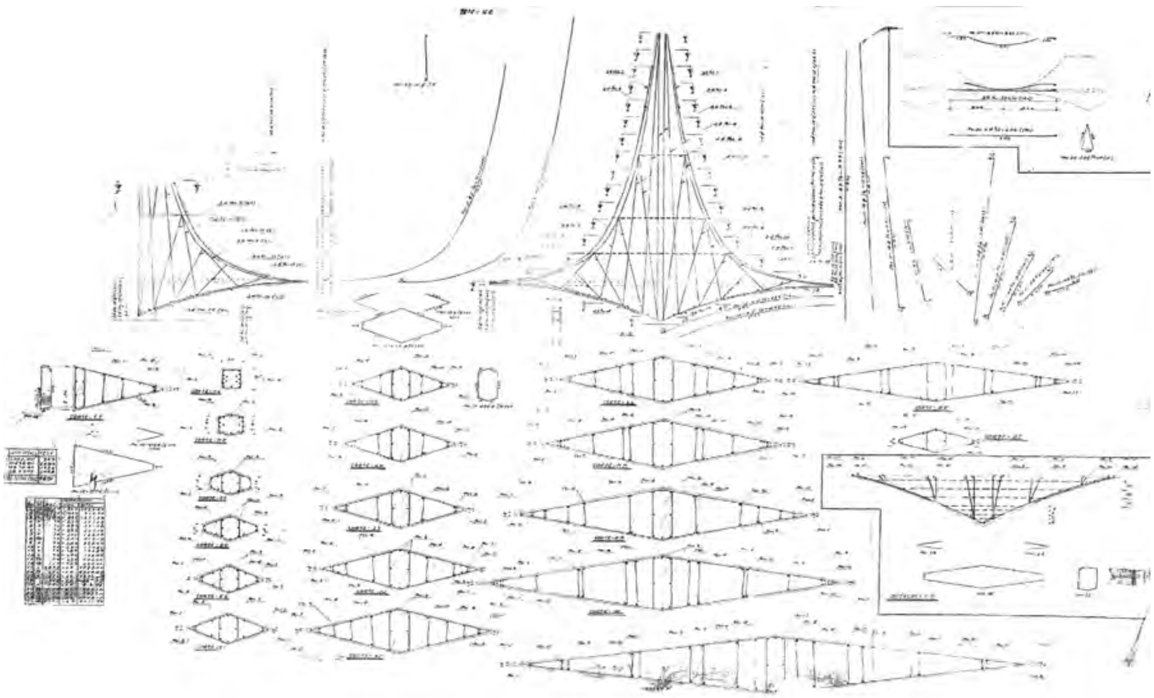


Fig.3b: Detail of the reinforcement of the external columns. Joaquim Cardozo, Structural Engineering. Source: NOVACAP Archive.

to Rio de Janeiro in 1939, to work as a historical researcher at the newly created National Historic and Artistic Heritage Institute, where Lucio Costa (1902-1998) and Oscar Niemeyer acted as architects.

Niemeyer graduated as architect in 1934 at the Escola Nacional de Belas Artes, but started to work in 1930 as a trainee at Lucio Costa's office. He participated in Costa's team that worked with Le Corbusier in 1936 in his visit to Rio de Janeiro in order to develop a project for the campus of the University and the Ministry of Education and Health building. With the departure of the Swiss architect, the same group ended up designing the building, with a concrete skeleton designed by Emílio Baumgart. It would become one of the first Modernist skyscrapers in the world.

The *Escola Livre de Engenharia* in Recife was founded in 1904. Before graduating in civil engineering there, in 1930, Joaquim Cardozo – himself a literary author – was already part of a local group of poets and painters that started one of the first Modern Movements in Brazil. In that city, he was in charge of the structural projects for architect Luis Nunes's designs, as part of an avant-garde county program for public buildings, with peculiar solutions such as the one for the *Alberto Torres* School, with a ramp stayed to a pair of arches. In a lecture in 1939 at the course of engineering, Cardozo made strong remarks on the importance of a solid mathematical basis for an engineer, quoting recent findings by Georg Cantor, Sierpinski and Luzin, among others.[7]

Copiare, 1985).

7 Joaquim Cardozo, "Discurso de paraninfo: Engenharia," in Forma estática - forma estética : ensaios de Joaquim Cardozo sobre Architecture e Engenharia, ed. Danilo Matoso Macedo and Fabiano J. A. Sobreira (Brasília: Câmara dos Deputados, Edições Câmara, 2009), 59–64.

8 Joaquim Cardozo, "Aula magna: Escola de Belas Artes," in Forma estática - forma estética: ensaios de Joaquim Cardozo sobre Architecture e Engenharia, ed. Danilo Matoso Macedo and Fabiano J. A. Sobreira (Brasília: Câmara dos Deputados, Edições Câmara, 2009), 53–58.

Fig.4a: Planalto Palace, Brasília, 1957-1958. Oscar Niemeyer, Architecture. Joaquim Cardozo, Structural Engineering. Photo: Danilo Matoso.

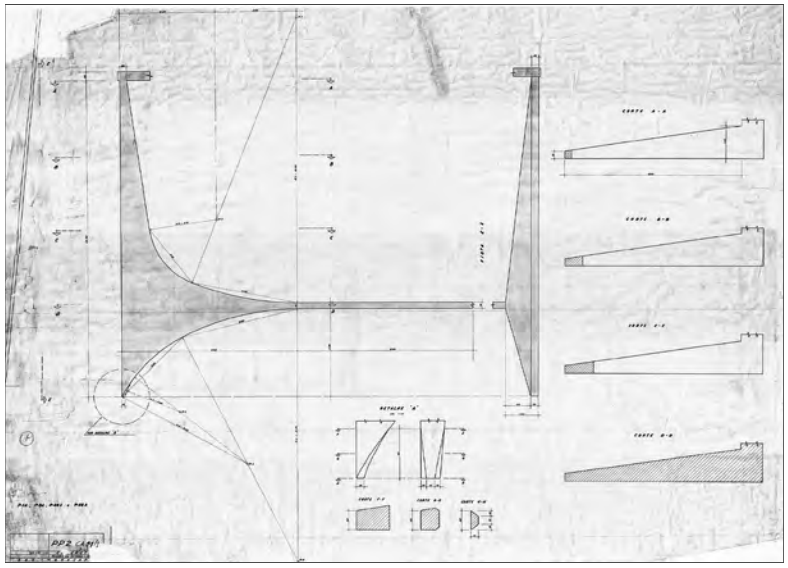


Fig.4b: Pillars of the façade – formwork. Joaquim Cardozo, Structural Engineering. Source: Arquivo Público do Distrito Federal.

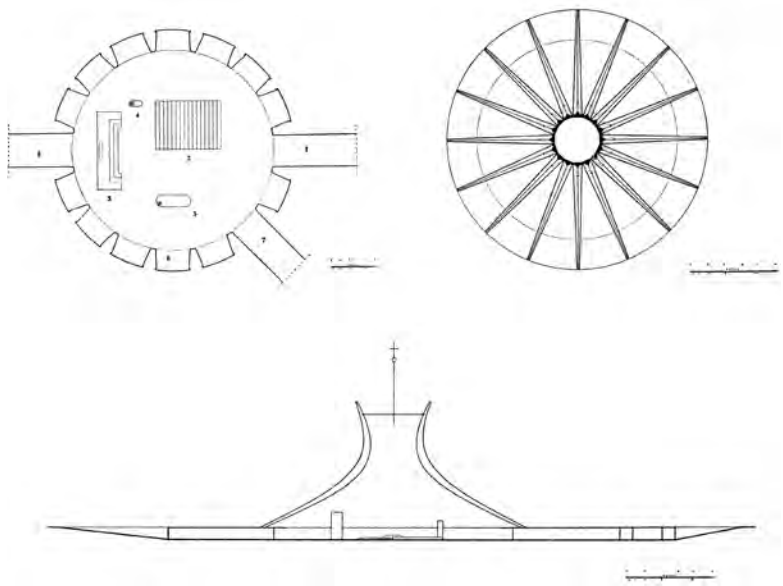
Joaquim Cardozo and Oscar Niemeyer started their partnership in 1940, with the Pampulha Casino and Church, in the city of Belo Horizonte. By then, Brazil had a solid base on reinforced concrete technology, and both professionals had experience with innovative solutions through teamwork. However, while Niemeyer would only start writing his ideas on a regular basis more than a decade later, Cardozo was used to publish his poetry and articles on art and literature. While the architect privileged practical and specific explanations for his designs, the engineer's speech was always more idealistic and *platonic*, maybe due to his deep mathematical knowledge. While Niemeyer had always an anti-intellectual form of writing, Cardozo populated his texts with references to authors – most of them Russian, German and East-European – that had driven him in a specific thought, quoting them in the original language. When Niemeyer invented his early architectural vocabulary with thin pillars, flat slabs, vaults and free forms, based on structural ideas, it was Cardozo who developed them into geometrical and mathematical shapes. He did that in a way not to subordinate the architect's invention to it, but rather to extract maximum performance from the visibly coherent static forms, also helping to conceal the adjustments that – although structurally necessary – would *stain* the pureness pursued.

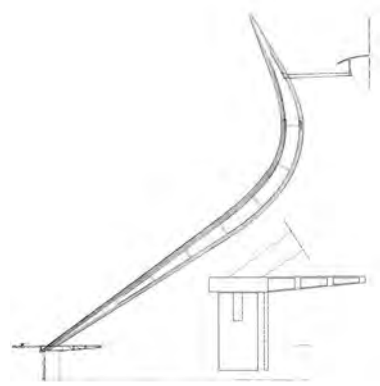
Cardozo in fact had employed parabolic arches at the *Alberto Torres School*, and it is arguable that he may have contributed decisively for the adoption of a parabolic vault at the world-known Pampulha Church, designed in 1943. As pure as the geometrical composition of this church may seem, it hides several expedients to make it a buildable and a suitable building. The small vaults are not parabolic, but circular arches locked with beams concealed in the walls. The large vault supports the choir, and part of the frontal marquee, which generated local stresses that also had to be compensated with a concealed steel reinforcement in the shell. The concrete shell, in fact, has its thickness enhanced by external layers of thermal isolation, water-proofing, porcelain tiles, and internal covering with wood boards. It is, in fact, an elaborated constructive device resembling a

Fig.5a: Brasília Metropolitan Cathedral, 1958. Oscar Niemeyer, Architecture. Joaquim Cardozo, Structural Engineering.Photo: Joana França

Fig.5b: Preliminary design: plan and sections. Oscar Niemeyer, Architecture. Source: Módulo, n.11, p.14, dec.1958

Fig.5c: Reinforcement of the columns. Joaquim Cardozo, Structural Engineering. Source: Módulo, n.26, p.22, dec.1961.





pure form – as desired by the authors (fig.1). As a general rule, the flat ceiling made up of a slab without beams was pursued in most of their works, in order to ensure the visual continuity through the glass walls. Whenever the span was too wide to allow for mushroom slabs, the most common solution were inverted beams with suspended floors. Waffle-slabs were also largely used, both with bricks at the voids and, when the grid was larger, with gypsum low-ceilings (fig.2)

By then, Niemeyer's buildings were object of careful detailing. A vast palette of materials and colors was duly harmonized with the surrounding landscape through glass-walls protected with sun-shading elements, such as *brise-soleil* and hollow bricks. This novel richness of textures and free forms being adopted by Brazilian architects contrasted to much of European Purism and created a new synthesis, becoming part of the *Brazilian style*. An architecture that provided the world with a way of integrating Modern tendencies until then seen as irreconcilable, as Rationalism and Organicism: a clear, rational, structural system that would also allow for more flexible plans e unusual shapes, not only independent from the structure, but articulated with it in ways that allowed secondary elements and materials to be part of the composition. Of course, this is a harmony hard to be obtained without strict supervision by the author. Niemeyer himself would admit later that, at a certain point, he *took too many projects, executed them hurriedly* relying upon his *ability and powers of improvisation*.[9] In the first half of the fifties, strong criticism and the charge of formalism came upon Brazilian architecture, and on Niemeyer. It came from

9 Niemeyer, “Depoimento” 1958.

quite opposite factions, from stern left-wing radicals, as Bruno Zevi –, for whom the free-form approach seemed frivolous and unwarranted – to stickler purists, as Max Bill – who could not accept anything but ideal prisms. Of course, the criticism had much of the ethnocentrism that still today contaminates architectural historians that analyze that period.[10]

For Brasilia, Niemeyer was hired by a state company – Novacap –, responsible for the construction of the new Capital of Brazil in only three years and a half. There is a shift in his architecture between 1955 and 1958, both as a reaction to problems encountered earlier in his experience, and as a design strategy in order to answer to the tight schedule and the call for symbolic power of such an enterprise. And in more than twenty works by him, Cardozo was in charge of the structural project. The engineer's abstract way of thinking was decisive in that turning point, as described by Niemeyer himself in 1958:

> The works in Brasilia together with my project for the Caracas Museum mark a new stage in my professional activities. This step is characterized by a constant quest for conciseness and purity, as well as greater attention to basic architectural problems.
>
> This stage, which constitutes a change in my design method and, mainly, in the way I develop my projects, did not break through as a different formula demanded by new problems. It sprang from a cold and frank review of my work as an architect. (…)
>
> I have become interested in compact solutions, simple and geometric: problems of hierarchy and of architectonic character; the fitness of unity and harmony amongst the buildings and, further, that these no longer [would be] expressed through their secondary elements, but rather through the structure itself, duly integrated within the original plastic conception.[11]

Niemeyer then turned his efforts to *classical principles* of order underlying composition, and on how to demonstrate them through rhythm, form and transparency.[12] Although still present, detailing was drastically reduced to the way elements would be articulated (stereotomy, window framing etc). Even structural elements turned out to be only schematically represented in architectural drawings – after to be exhaustively developed in Cardozo's drawings, where mathematical formulas determined the exact shapes to fit the original profile.[13]

Such is the case at the columns for the Alvorada Palace – the presidential residence. This colonnade has a double stiffening on the point it touches the floor slab. A straight transversal one, and the longitudinal parabolic profile that conforms the peristyle of the building. Cardozo precisely defined the formula of that curve as a fourth-degree parabola, and reinforced it with an interesting diagonal layout for the steel bars. The base, below the floor level, also form an articulated link (fig.3). The columns for the Planalto Palace – the presidential office – had similar treatment, although they were actually constructed with the correlation of circular curves and straight lines (fig.4). The domes of the Palace of Congress were also mathematically defined. The smaller thirty-nine meters dome, corresponding to the Federal Senate, is a paraboloid of revolution with a second-degree parabola as generatrix, that has to withstand only compression stresses. The larger dome, for the Chamber or Deputies, is a much more complex composition. The outside visible shell is an ellipsoid of revolution combined with an inverted cone, with sixty-two meters of diameter on top and a sixteen meters cantilever. It was covered by a lowered compression secondary low dome which supports, through a small-span concrete grid, both a hanging low-ceiling and a flat concrete ring above. Niemeyer frequently recalled in his memories the phone call by Cardozo, to celebrate the finding of the curve that would make the inverted dome seem tangent to the platform bellow. At the Cathedral, also defined by Cardozo, a set of sixteen parabolic pillars with diamond section and a profile described by him as *a series of tangent surfaces: truncated cone, zone of pseudo-sphere, two internal arched zones and, at the higher part, a zone of hyperboloid of revolution*.[14] While a constructive solution for the glassing was searched for through the sixties, the building was only a skeleton, conveying one of the most impacting

10 See: Nelci Tinem, O alvo do olhar estrangeiro : o Brasil na historiografia da Architecture moderna (João Pessoa: Manufatura, 2002). and Danilo Matoso Macedo, Da matéria à invenção: as obras de Oscar Niemeyer em Minas Gerais, 1938-1955, Arte e cultura 5 (Brasília: Câmara dos Deputados, Coordenação de Publicações, 2008).

11 Niemeyer, "Depoimento" 1958.

12 We have demonstrated some of those principles in: Danilo Matoso Macedo and Elcio Gomes da Silva, "From open plan to open design: architectural principles in Niemeyer's Palace of Congress," in The survival of modern – from coffee cup to plan (presented at the 12th International Docomomo Conference, Helsinki: Docomomo Finland, 2012).

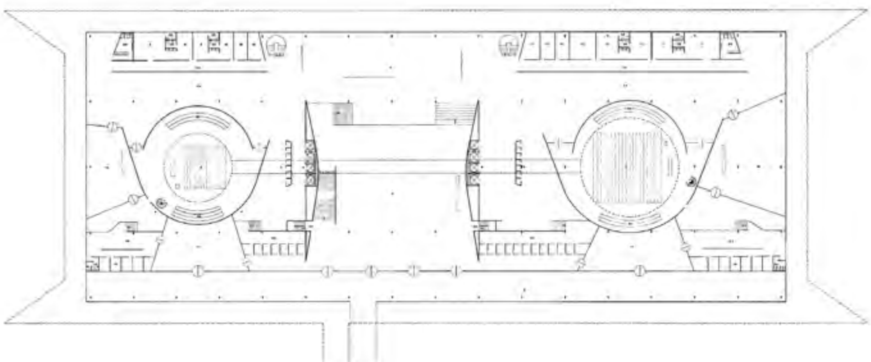
13 For a thorough analysis of the structures of the Palaces of Brasília, see: Elcio Gomes Silva, "Os palácios originais de Brasília" (Tese de Doutorado, Faculdade de Architecture e Urbanismo, Universidade de Brasília, 2012), http://repositorio.unb.br/handle/10482/11159.

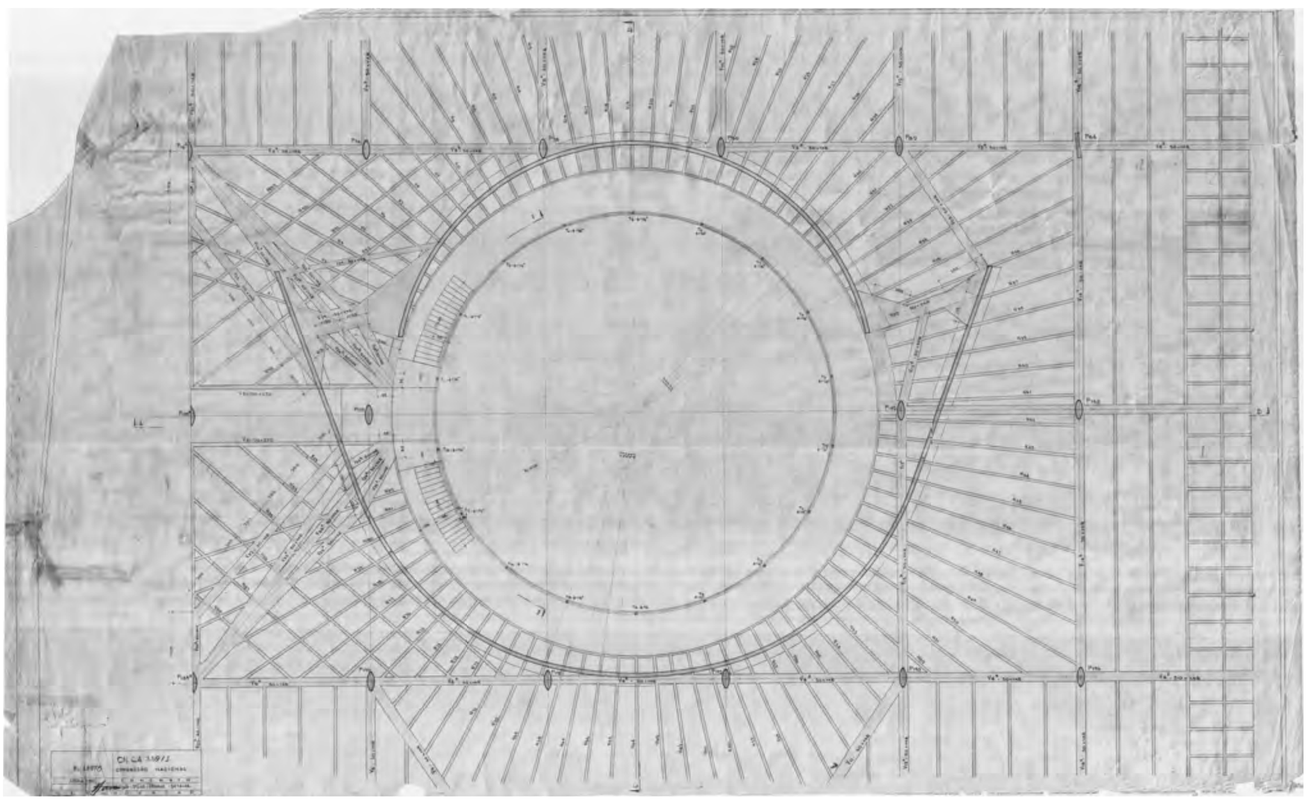
14 Joaquim Cardozo, "A construção de Brasília," in Forma estática - forma estética : ensaios de Joaquim Cardozo sobre Architecture e Engenharia, ed. Danilo Matoso Macedo and Fabiano J. A. Sobreira (Brasília: Câmara dos Deputados, Edições Câmara, 2009), 177–179.

Fig.6a: Palace of Congress, Brasília, 1957. Oscar Niemeyer, Architecture. Joaquim Cardozo, Structural Engineering. Photo: Joana França

Fig.6b: Preliminary design. Upper level of the horizontal building Oscar Niemeyer, Architecture. Source: Technical Archive of the Chamber of Deputies.

Fig.6c: Detail of the formwork for the platform slab. Joaquim Cardozo, Structural Engineering. Source: Technical Archive of the Chamber of Deputies.





images of Niemeyer's work (fig.5).
These visible examples in Brasília seem to materialize Cardozo's theoretical formulation:

> we are concerned no longer with a Cartesian geometry, dominated or led by algebraic formalism, but with another, more modern, that has cast off systems borrowed from other sources and restricting its field of existence. The use of this geometric reality (…) brings us nowadays to a criterion of moldings, of the proportions and outline (…). A molding more intrinsic to the lines, surfaces and volumes that constitute architectonic space, one that is defined by the use of fields of tangency, and curvature, or contacts of a higher order between these geometric entities (...). The question then arises: what about the solutions of equilibrium for these forms? They are to be found in experimental physics, in the optics of rheological states, and in photo-elasticity; between the polarizer and the analyser the lines of stress and deformation will spring into evidence, particularly the isoclinics, isostatics and isochromatics, three families of curves that are the natural example of that geometrical **object** discovered by Veblen and which likewise belong to the field of **Geometrie der Gewebe**, geometry of fabrics, i.e. the textile geometry created by Blaschke.[15]

Some of the most intriguing effects of this philosophy are revealed when we analyze the hidden beam layout of the hollow or waffle slabs of the palaces. Since all of them have regular grids of pillars, a set of equally distributed ribs reinforced the slabs. Wherever an asymmetrical load was added, or a larger spam was needed, a set of diagonal beams, resembling vegetal *branches*, would distribute the new stresses through the structure. The Palace of Congress external platform, for instance, have the weight of the domes distributed through beams like *roots* that reach the supports (fig.6).

Since close teamwork and full-time assistance in the construction site allowed it, in all those buildings structural elements were reduced to a simplified representation in architectural drawings, to be fully developed only by Cardozo. That was the case with the Palace of Congress pillar sections, represented only as rectangles in architectural drawings, later detailed by Cardozo as ellipses. Close relationship with engineering allowed Niemeyer to state, years later that

> (…) in the palaces of Brasília, that would be my choice, characterizing them by their structures, within the conceived shapes. Thus, minor details that compose rationalist architecture would dilute themselves into the dominating presence of the new structures. When one examines the Congress building in Brasília, or the palaces there built, one realises that, once the structures were finished, architecture was already present.[16]

Cardozo's reflection on those phenomena would go even deeper. In 1965 he wrote *On the problem of being and architectural structuralism*, where he associated the lightness of the new structures and materials, their new physical properties, with new aesthetic values: *one feels in all the prevalence of the logical thought, of rational thought; however, it is always implied some sentimental thought, affective, some mythical though, that thought that insistently turns up, through Plato, even in the rigid Socratic Maieutic*.[17] Praising the new complex geometry of Niemeyer's works, in 1968 Cardozo would describe it as a new *chant of surfaces* – paraphrasing Perret's quote that *Architecture is the art of making supports sing*, where architecture and structure would reach a new unity, and the whole building would become a single structural element *following the supports*. In a third moment in his career, Niemeyer would work with many other talented structural engineers – amongst them Bruno Contarini and José Carlos Sussekind. However, the fine balance between Cardozo's abstraction and Niemeyer's resourcefulness would not be repeated.

References

This paper was developed within an institutional program of documentation and conservation of the Palace of Congress – listed as National Monument in 2007 –, where both authors work as architects. The program comprises documental organization, historical research, physical diagnosis, restoration, a preventive conservation plan, as well as a master plan for future developments.

15 Joaquim Cardozo, "Algumas idéias novas sobre Architecture = some new ideas about architecture," Módulo 33 (June 1963): 1–7.

16 Oscar Niemeyer, As curvas do tempo: memórias (Rio de Janeiro: Revan, 1998), 265.

17 Joaquim Cardozo, "Sobre o problema do ser e do estruturalismo arquitetônico," in Forma estática - forma estética : ensaios de Joaquim Cardozo sobre Architecture e Engenharia, ed. Danilo Matoso Macedo and Fabiano J. A. Sobreira (Brasília: Câmara dos Deputados, Edições Câmara, 2009), 153–159.

John Lautner (1911 - 1994)

Frank Escher

About one hundred years after John Lautner's birth (1911) and twenty years after his death (1994) his place in 20th century American architecture may be best summed up by two observations: Frank Lloyd Wright (who Lautner worked with from 1933 to 1939) considered his celebrated pupil to be the 'Next-Best Architect on Earth' (Wright himself, naturally, being the Best); and Frank Gehry, as a student, considered John Lautner to be 'a God'. There are, of course, great differences between these three architects: Lautner achieves an elasticity of form and fluidity of space that Wright doesn't; Lautner conceives his buildings as 'space' rather than as 'objects', as Gehry does. Nevertheless, between Wright and Gehry, Lautner is the missing link.

Two buildings, the Pearlman Mountain Cabin and the Arango residence best illustrate Lautner's ideas of space and structure, and their relationship to each other: The modest cabin is a small, circular wooden building. Two thirds of its perimeter are solid walls; one third is a faceted glass screen. The roof, with a flat circular center, folds down to the wall at the back and crimps up to the large opening in the front. Across this opening, the roof rests on a row of actual tree-trunks. Enormous sheets of glass, set directly into these logs, form a delicate screen, through which one gazes at the panorama unfolding beyond. It is an idea of great beauty: the trunks, both the roof's structure and frames for the windows, echo the trees of the site beyond and unite the little space with its expansive, sylvan setting, spatially extending the architecture to the 'borrowed landscape' - a spatial concept we know from Japanese gardens.

The Arango house, built 17 years later high above the bay of Acapulco, is one of the most extraordinary houses of the twentieth century. A driveway curls down the hill, cuts through, slips out and then back under the roof, an immense arc sweeping out from the hillside. The approach ends in a vast carport. From the entry, the house appears surprisingly small: the shorter inner edge of the curved roof is here at its lowest, sloping up towards the perimeter, fore-shortening the ceiling and almost entirely removing it from view; the bridge connecting into the house lifts one even closer to the ceiling. It is not possible to understand the scale, until one moves further into the house, and it expands to its dramatic dimensions. A large living area opens to the air and view, bordered by a continuous meandering body of water. Visually and conceptually, this moat, the boundary of the living platform, becomes one with the ocean beyond, extending one's space to the sea and sky.
Growing out of the precipitous site is an enormous plinth, into which the private rooms are tucked.

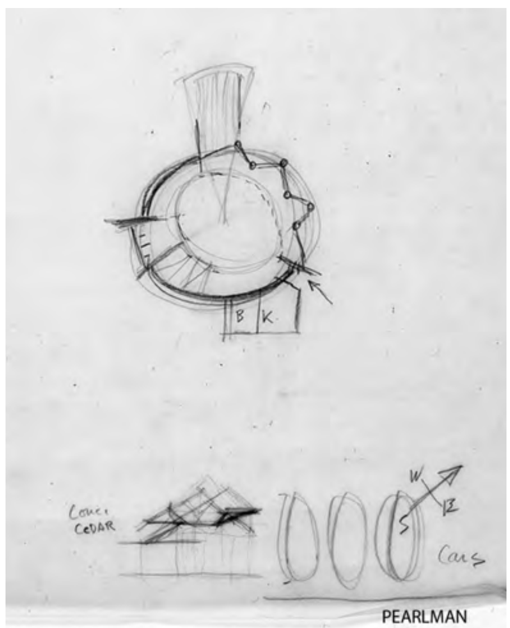


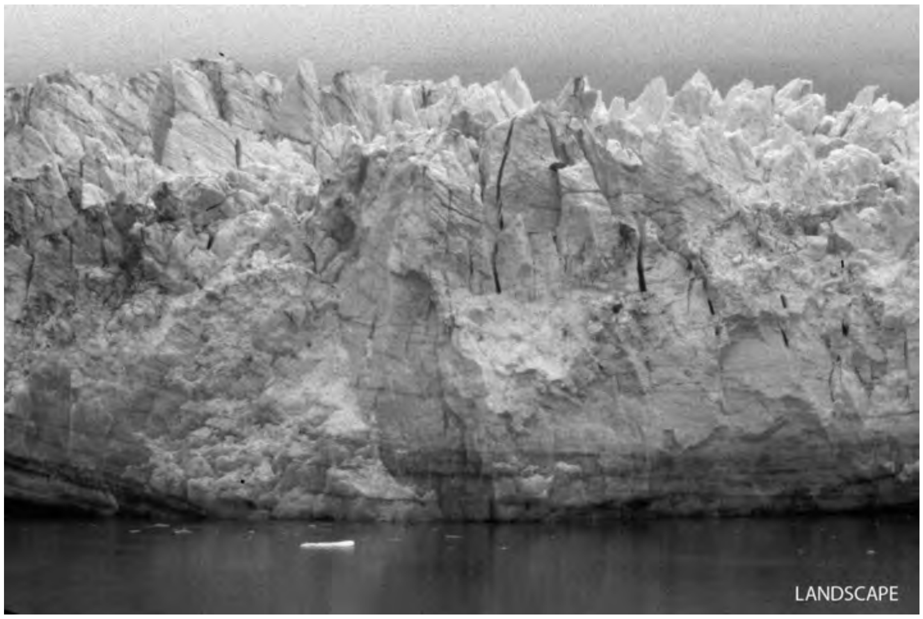
Fig. 1a,b: images Pearlman photo, Pearlman cabin; caption: Lautner's first sketch for this project, which contains the seed of the building

Fig. 2a,b,c: Arango plan, photos.

These two houses, in many ways, define the boundaries -- or breadth -- of Lautner's work. They represent different stages in his career, different geographical and cultural settings. Their scale, budget, and, more importantly, their means of construction could not be more different: the Pearlman Cabin, like many of Lautner's earlier projects, is a simple wood construction, while the Acapulco house is one of his most ambitious concrete forms.

But the tree-trunks of the Pearlman Cabin and the moat of the Arango house serve the same end: they are the natural element that conceptually, visually and spatially mediates the transition from the architectural space to the surrounding landscapes. By incorporating elements from the surrounding landscape into his buildings (as Lautner frequently did), rather than extending the architecture out to nature (as in the work of Richard Neutra or Mies van der

Fig. 3: Landscape study, John Lautner.



Rohe), Lautner created a most unusual manifestation of a key principle of modern architecture: the connection of the architectural space to its surroundings.
An additional example is the Goldstein office, a small space for one of Lautner's most important clients in the last years of his career. The small space - a jewel box formed from sloped and folded planes of stone, wood, glass and copper - looks north towards the hills above Los Angeles. The sun setting in the west, then, daily reflects a golden light off the folded copper wall and into the space, blurring the boundary between inside and out. To further this idea of blurring, Lautner originally intended to install along the window a planter of moss (which would have echoed the grass beyond). This, however, was not executed.

Lautner's architecture is conceived first as space, then developed from inside to outside – from his clients' needs to their sites. His work shows his extraordinary, almost seismographic, sensitivity to the nature of his settings. Arango, Pearlman and other house demonstrate his ability to absorb the features of a site, and then, through his architectural interventions, make others see what he sees and emphasize what might otherwise go unobserved --- rocks, bodies of water, precisely framed views. One can imagine Lautner thinking his spaces out into their surroundings, and those surroundings pulsating back, and the complex geometries of his buildings emerging from a ground plane along these intersections.

Fig. 4: Lautner drafting tent, Taliesin.

Lautner was a keen and careful observer of landscape, geology and topography, and he used his camera in the way that other architects use a sketchbook. His photo collection contains thousands of studies of formations of rocks and clouds, waves and caves, and - again and again - aerial views of vast landscapes. These images reveal and document much of his spatial and formal interests.

Lautner was the son of an academic and an artist – his mother was a painter, more or less self-taught, with an interest, among other things, in Fauvism, born in Marquette, Michigan, a small University town at the shores of the 'Great Lakes' in the Northern US. A seminal experience for the young boy was a summer cabin designed by his mother, built by his father and, years later, decorated on the inside with a ceiling painting of a blue sky. From Marquette, Lautner joined Wright in 1933, one year after the founding of Taliesin. Lautner came to Los Angeles in 1937, but continues to work with Wright, overseeing the construction of two Wright projects in the city.

Lautner's first built project was a small tent to work

Fig. 5a,b: Carling building site and interior.

and sleep at Taliesin: an extraordinary structure created with three elements – a roof; a wall; and a cactus. The small, light, almost insubstantial, and long since destroyed building, anticipates much of Lautner's architectural interests: the relation of space to enclosure and structure; the expression of material; and a surprising spatial experience of two, interlocking spaces. The roof sheltered the drafting space from the harsh desert sun and opened to the horizon, while the folded wall enclosed the sleeping area with the cactus which drew one's eye up to the night sky.

Lautner was deeply interested in "how things are put together." He had an earnest respect for good craftsmanship, technical skills and relied greatly on a process of interacting with and manipulating a construction. He constantly experimented with new industrial processes and materials, and characteristic of his work is a congruence of construction technology and architectural form: His formal vocabulary developed with the construction technologies used and the possibilities they offered. His oeuvre, then, can - very boldly - be divided into a first group of small and low cost residences, built in wood (1939 - mid 1950s), the predominant method of construction in Southern California. While he developed spatial and structural complexities in this first group of buildings, the wood construction itself is here used in a fairly conventional manner. Into this group belong his own house, the houses for Bergren, Foster or Schaffer (his first real masterpiece, a composition of planes of glass and wood, where space and structure weave around the existing oak trees and into the site).

A second, smaller group of buildings completed in the years after the war (1946-1949) with prefabricated steel and wood roof structures includes the Carling, Polin, Jacobson, Gantvoort and other

Fig. 6: Schaffer interior.

houses. At the Carling House, a hexagonal steel structure suspended from three steel trusses covers the main space. None of the walls bear loads and are either glass or independently moveable: a large sheet of glass retracts across the pool and an entire side of the hexagon opens like an enormous hinged door over the terrace, converting the enclosed space into an open garden pavilion.

From the mid-1950s on, Lautner began to bend and shape wood, working increasingly with pre-fabricated, glue-laminated wood technologies. Into this group fall the small office structure for Speer (the builder of many of Lautner's early projects), Henry's Drive-In at Pomona, a structure resembling an up-turned boat, or the small independent roof structures of the Midtown School.

The Chemosphere, arguably one of John Lautner's and the city's best-known houses, is a brilliant and radical structural solution: one support planted in its precipitous site. The house was occupied by its original owners until the early 1970s, after which subsequent owners made careless and disastrous changes – removing built-in furniture, changing surface materials and allowing general decay.

It is important to note, though, that the Chemosphere was not completed as envisioned: design revisions and changes were made during construction, mostly due to budget constraints; materials planned by Lautner were replaced by materials donated by companies (which then used the house for advertising purposes); plans were modified while new infrastructure systems were added. It made little sense, then, to return the house to its 1960 condition, when in 1990 our office, Escher GuneWardena Architecture, was commissioned to restore the house. To develop an architectural strategy that would respect historic fabric while visibly introducing changes, the restoration project addressed the needs of a new owner and his family, as much as Lautner's original intentions. This lead to discussions with original clients, project architects and builders, as well as researching

Fig. 7a,b,c: Chemosphere, interior and exterior.

Fig. 7: Peters House, model.

documentation: the original seven drawings neither reflected built conditions nor did they show much detail - interior elevations were schematic, at best. Changes made - replacing floor and wall materials, installing frame-less glazing, re-constructing old and introducing new built-in furniture – were carefully considered, as were repairs, restoration and reconstruction of abused or missing elements of the original house.

Lautner was deeply fascinated by the engineering and economic possibilities of mushroom structures, and had used these structural concepts beginning in 1948. Most of these projects were unbuilt (Abbot apartment and Ross Residence, both 1948), with the one built exception being the Sheats Apartments in West Los Angeles (where a series of "mushrooms," central concrete columns supporting 35' diameter platforms, step up a hill). Following Chemosphere, Lautner continued to apply this structural strategy: in the Alto Capistrano development, Lautner envisioned entire forests of mushroom structures growing on the hills, leaving the terrain untouched, while in the Peters House, concrete mushrooms were stacked to reduce the structure of the house to its most elegant minimum. Floor-to-ceiling glass walls enclosed what would have been an extraordinary building.

From the early 1960s on Lautner started to get larger commissions, allowing him to explore new materials and ways of construction. Silvertop of 1963 marks a turning point in his career. It is the first house in which he uses the material he is now best known for: reinforced concrete, a construction technology rarely used in residential architecture in Southern California and the muse of his later experiments in plasticity and flow.
Lautner's work in concrete, as with timber construction earlier, describes a development arcing from

Fig. 8: Silvertop.

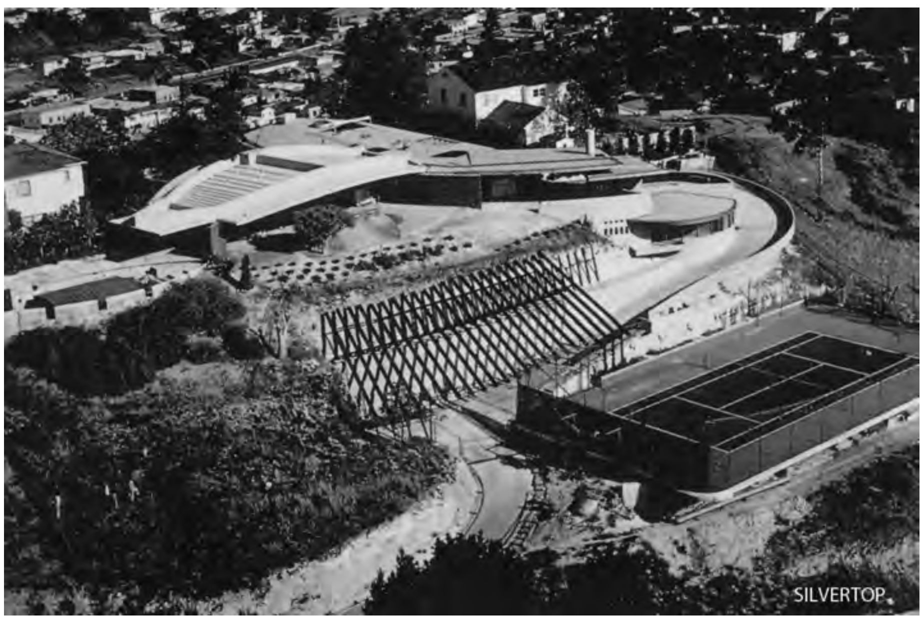
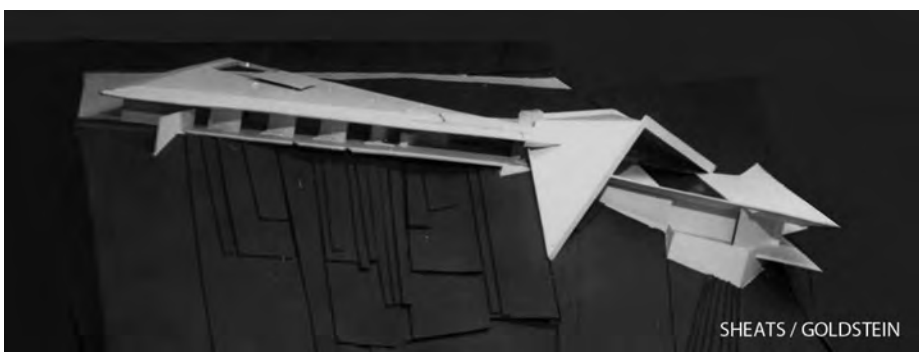


Fig. 9: Sheats model.



simple symmetrical structural concepts, flat beams and slabs, to shapes of single curvature, and, finally, to double curves, asymmetrical systems, and forms of enormous geometrical complexity. Lautner drew on an understanding of engineering that was not simply intuitive but thoroughly educated: he prepared structural calculations on many smaller projects himself.

It is difficult to imagine Lautner's work outside of the context of twentieth century structural engineering. As the discipline slowly moved from symmetry towards fluid and undulating shapes, Lautner increasingly explored highly complex geometries: surface, form and structure melt together, space and structure intertwine. One forms the other.

Throughout his career, Lautner collaborated with a number of interesting local structural engineers: Edgardo Contini engineered the pre-fabricated roof structures in the years after the war and Andrew Nasser worked with Lautner during his last twenty years of practice. On Silvertop, it was T.Y. Lin (who effectively introduced advanced pre-stressing and post-tensioning to the United States) who introduced Lautner to these concrete technologies.

At Silvertop a great vault of concrete, supported on four columns only, spans across sixty feet of the central space. Two walls of brick slip under the roof and curve back out towards the views, screening off and separating the bedrooms from the main space. The Sheats (now Sheats/Goldstein) House is a composition of triangular concrete elements forming an enormous cave sitting on a ledge above the city, with the first wing of bedrooms attached to one, and the second wing, one level lower, attached to the other end. Finally, at the Elrod House, large slabs of concrete radiate from a center and are held together by a concrete tension ring, creating a shallow, large dome hovering over the main space.

Fig. 10a,b: Elrod.

Fig. 11: Franklin, model.

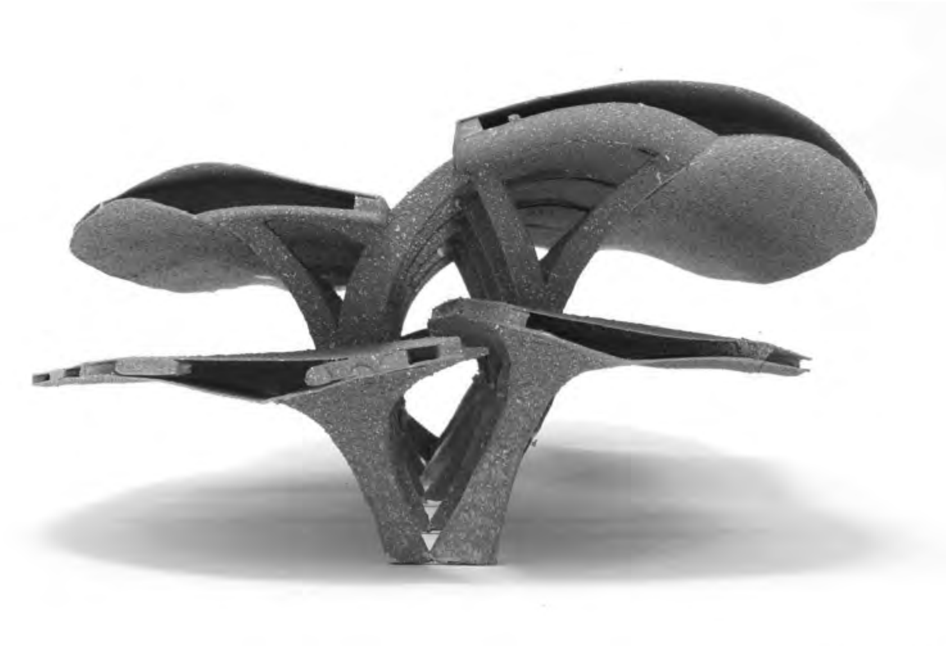


Fig. 12: Hope, model.

In addition to the engineers already mentioned, Lautner studied in great detail the work of Eduardo Torroja and Robert Maillart (in particular his ideas for 'mushroom slabs'). He traveled to Italy to examine Nervi's work (photographs exist in the archive), he knew Frei Otto's work, his explorations of asymmetrical systems and Otto's study and observation of nature and natural forms, and Lautner visited the roof structures for the 1972 Munich Olympic stadia.

But in Felix Candela especially, Lautner recognized a fellowship. He knew Candela and his work since the mid 1950s and would eventually collaborate with Candela on the first, sadly un-realized proposal for the Hope residence, a project intended to push the formal possibilities of concrete construction. The idea of the original house was a huge mound that re-shaped the topography of its site by adding a form that echoed its mountainous surroundings, and sheltered within a cavernous open space.

With the idea of the building as a topography, Lautner began at the end of his career to explore an architectural concept that only now, a generation later, has received greater attention.

John Lautner died in October of 1994. His family set up The John Lautner Foundation, which maintained the Lautner Archives, until these were acquired by the Getty Research Institute in 2007, where they now are.

Foster and Rogers – The start of British High Tech

Colin Davies

The application of new technologies to everyday building construction is a major theme in the history of twentieth century architecture. Louis Sullivan and Auguste Perret used steel and reinforced concrete frames in otherwise traditional office blocks and apartment buildings, preparing the way for Mies van der Rohe and Le Corbusier to give these materials full expression in a new Modernist architecture. This was the architecture of what Reyner Banham called the First Machine Age, the age of the railway and the factory, the ocean liner and the power station. But by the mid century, machinery was taking on a new character. The typical machine was no longer a steam engine, but an automobile, no longer the exclusive concern of specialist engineers working for industry or government, but available on the open market for ordinary people to buy and use. Even the domestic environment was being transformed by small machines like refrigerators, electric cookers and vacuum cleaners.

The Second Machine Age had dawned. How should architecture respond? In the early 1960s a group of young architects recently graduated from London's Architectural Association school began publishing a small circulation magazine called Archigram. It served as a justification for continued project-making of the free, futuristic kind that the group's members had enjoyed as students. Some of these projects have since become famous – Peter Cook's Plug-in City of 1964, for example, and Ron Herron's Walking City of the same year. No-one, least of all their authors, envisaged actually building these cities. They were pictorial provocations not too different from scenes in a science fiction comic. But they were inspiring because they questioned the most basic assumptions about the nature of architecture, especially the assumption that it was an art of static formal composition. Plug-in City, despite its monstrous scale, was based on a dynamic and fundamentally individualistic idea: that dwellings would take the form of living 'pods', not too different from automobiles, that would be mass produced in factories, sold on the open market and plugged into a three-dimensional service infrastructure. Walking City was also dynamic, in a more obvious and literal way.

So was Archigram showing the way forward for an architecture of the second machine age? The irony is that conceptually its projects were already a reality. American trailer parks, for example, can be seen as examples of dynamic urban form combining communal infrastructure with factory-made living pods. And mobile cities had existed for a long time in the shape of ocean liners. These existing forms, however, did not count as architecture. They needed to be brought into architecture's cultural field before they could begin to influence actual buildings. This was the service that Archigram performed. It encouraged practising architects to look beyond the construction industry, borrowing technologies from other fields and allowing those technologies to influence the look of their buildings. In the event, Archigram's influence would be as much aesthetic as conceptual.

Among Archigram's approximate contemporaries at the AA were Richard Rogers, Michael Hopkins and Nicholas Grimshaw who, for the next three decades, would inject something of the spirit of those science fiction fantasies into the real architecture that came to be known as High Tech. But it was a fourth architect, Norman Foster, from a less privileged background and trained at Liverpool school of architecture, who gave High Tech its steely sense of purpose. It was not a 'movement' exactly, though its protagonists were all known to one another and often collaborated, especially in the early years of their careers. It would be more accurate to say that High Tech was a 'style', though the superficial connotations of the word seem inappropriate for an architecture that was based as much on concepts and principles as on aesthetic preferences.

The main features of the style were as follows: the use of synthetic materials like steel and glass rather than natural materials like wood and brick; an almost moralistic code of honesty of expression with no sham structures or false facades; a preference for prefabrication rather than on-site construction, and the expression of that preference in the form of the building; and a tendency to ignore functional and social distinctions, combining different human activities in large, flexible spaces. Note that the High Tech style had nothing to do with what we would now regard as high technology – that is, digital technology. High Tech was pre-digital, inspired by the physicality of machines, not the virtuality of the internet. The typical High Tech building was a factory on an open site, like Reliance Controls, near Swindon in the west of England, which is generally recognised as the first High Tech building. Completed in 1967, it was designed by Team 4, a partnership between Richard Rogers and Norman Foster with Su Rogers and Wendy Cheeseman.

Reliance Controls did not look much like an Archigram fantasy. The direct influences on it were more mainstream, in particular the Cummins Engine Factory at Darlington in the North of England by Kevin Roche and John Dinkeloo, completed just a few years earlier. Roche and Dinkeloo had been associates of Eero Saarinen in America, but Mies was the obvious influence on this elegant glass-walled, flat-roofed factory with its exposed steel frame in pre-rusted 'Cor-Ten' steel. One small technical detail of the building – the neoprene gaskets used in its glazing – was adopted by Team Four and was to play an important part in the story of High Tech. But if Reliance Controls was essentially Miesian, it was also a cheap and practical building, a simple shed combining production and office functions in the same space. Only the external cross-bracing of the steel frame gave any clue to the structural expressiveness that would later become a prominent feature of High Tech.

Another candidate for the title 'first High Tech building' is a glass-clad spiral of plastic bathroom 'pods' attached to the back of a Victorian house in London as part of its 1967 conversion into a student hostel. It was designed by Nicolas Grimshaw, then in partnership with Terry Farrell who would eventually defect from the High Tech camp to become an important Post Modernist. The concept of a plug-in service tower which was itself an assemblage of plug-in units was like a small fragment of Peter Cook's urban vision.

The partnership between Rogers and Foster did not last long. Soon each was designing simple sheds on his own account in subtly different interpretations of the High Tech credo. Foster's earliest solo efforts were object lessons in the conversion of unpromising clients' briefs into high-class, not to say historic, architecture. The first of these was an office and amenity building in the London Docks for the Fred Olsen shipping line, built in 1971. London's dockers were used to insecure employment and poor working conditions. Clients and users alike might reasonably have expected some cheap temporary or portable buildings to accommodate the necessary toilets and showers. What Foster gave them was a two-storey building wedged between two warehouses which combined facilities for both dockers and office workers in unprecedentedly egalitarian juxtaposition. Its front wall was made entirely of storey-height mirror glass sheets held in structural neoprene gaskets. British architecture had never seen a wall like it. Foster had flown to America to discuss its detailed design with the specialist supplier, establishing the principle of collaboration between architect and manufacturer that was to characterise his practice in the years to come. In the same year, Foster, now working with Michael Hopkins, converted a similar unpromising brief, this time from the giant computer company IBM, into a single storey, deep-planned, glass-clad office and amenity building of extreme simplicity. It was meant to be a mere stop-gap before the completion of a new headquarters building on an adjacent site at Cosham in Hampshire, but the 'temporary' building stands to this day and is remembered as one of the milestones of early High Tech.

These early Foster buildings, for all their slickness, were rather calm, quiet presences. Richard Rogers was more willing to be expressive, adopting for a time a vehicle-like style with round-cornered windows fixed in lightweight panels by neoprene gaskets. In 1968 he designed a 'zip-up' house for a competition sponsored by a newspaper. It took the form of a highly insulated yellow tube, like a big refrigerator, on pink telescopic legs. Its low energy technologies were prophetic. The drawings indicate a roof-mounted wind generator and a small electric car plugged into the house for re-charging. Nicholas Grimshaw also saw the potential of lightweight panels and neoprene gaskets. The walls of his Hermann Miller furniture factory at Bath, finished in 1976, could be dismantled and re-attached in different configurations by unskilled labour in response to changing functional needs. In practice, this rarely if ever happened, but flexibility and indeterminacy, even if only theoretical, were important principles of High Tech.

By the mid 1970s Norman Foster's 'simple shed' manner was being adapted to suit prestige buildings on sensitive sites. His headquarters building for the insurance company Willis Faber and Dumas, completed in 1975, was proof that High Tech and the city were not incompatible. The three-storey building in the centre of Ipswich has the expected open floor plans, unified by a central atrium and a cascade of escalators. In effect it is one large flexible volume. A rooftop restaurant and a basement swimming pool (now altered) complete Foster's vision of a new kind of workplace – open, collaborative and social. The continuous, serpentine, frameless glass external wall, literally reflecting the urban context, is only the most visible innovation in a building that set a new standard in the design of office blocks. It was universally admired, won several architectural awards and is routinely listed among the most important British buildings of the century.

While Willis Faber was being built, Foster was planning a prestige building of a different kind: the Sainsbury Centre for the Visual Arts on the campus of the University of East Anglia. It was a bold step to imagine that a flexible, factory-style plan might be applicable to an art gallery, a building type traditionally organised as an enfilade of classical rooms. But there was some sense in the idea. A modern art gallery has to accommodate temporary exhibitions that are more like installations than traditional picture 'hangs'. This is not too different in principle from the periodic reorganisation of a factory production line. But the Sainsbury Centre is not only factory-like in its plan, it actually looks like a factory – a big, open-ended shed on an grassy site near Denys Lasdun's famous 'ziggurat' student residences of ten years earlier (see Chapter ??). A Foster building is almost always analysable into two basic categories of space: 'servant' and 'served'. The distinction is usually attributed to Louis Kahn (see chapter ??). At the Sainsbury Centre, the servant spaces – plant rooms, toilets, air ducts, switch rooms and so on – are all contained in a thick external envelope formed by the side walls and roof combined. The 'served' space is the plain, uninterrupted, seven metre high rectangle contained by this envelope. Aluminium and glass panels held in neoprene gasketed frames form the outer layer of the envelope.

Willis Faber and the Sainsbury Centre mark the culmination of the first stage in the development of High Tech. It might have ended there with these proofs of the efficacy of flexible plans and demountable enclosures had not Richard Rogers, in partnership with the Italian architect Renzo Piano, won the 1971 international design competition for a new arts centre on the Beaubourg site in the centre of Paris. The completion of the Centre Pompidou in 1977, and its phenomenal success as a public attraction, boosted High Tech's credibility and took it into new territory. Pompidou is like a six-storey version of the Sainsbury Centre – a rectangular slab of served space flanked by linear servant zones. The building occupies only half of the Beaubourg site, the other half being left open as a sloping piazza, never without some kind of street entertainment. In early versions of the design, the elevation facing this piazza was an interactive electronic billboard; in the actual building, a flight of escalators in a glass tube snakes diagonally across it. On the other side of the building, facing the relatively narrow Rue du Renard, a close-packed row of brightly coloured service ducts explodes every preconception of what a street façade should look like. This is the Archigram comic-book vision made real, although it probably owes more to a 1961 paper project called 'Fun Palace' by another denizen of London's Architectural Association, Cedric Price.

High Tech's preference for flexible plans was taken to an extreme in the Centre Pompidou. The client's brief included a library, a museum of modern art, another of industrial design, a theatre and a cinema, not to mention all the cafés, restaurants and shops essential to any modern cultural venue. But the brief hardly mattered because, in principle, anything could happen anywhere. Every arrangement was to be provisional. Achieving this degree of flexibility required engineering on the scale of bridge-building. Steel trusses spanning the whole width of the building were too heavy to be supported on simple columns. Their weight had be balanced by pivoting brackets known as a Gerberettes (named after their inventor, Heinrich Gerber) anchored to the ground by tension rods. The football pitches of fully-serviced space that this structure created have proved over the years to be less a source of joyous freedom than of expensive awkwardness. Interior spaces still had to be created, suitable for human activities such as sitting in an audience, walking round an exhibition or drinking a cup of coffee, and this proved more difficult in practice than in theory. The heavy engineering was also problematic, requiring frequent renovation. Fire proofing, for example, was a headache from the start. In a road or railway bridge, steelwork can simply be painted to prevent corrosion, but the steel frame of a building must be covered in some form of insulation so that it doesn't weaken and collapse in a fire. A few years after completion of the Centre Pompidou, spray-on insulation could be seen slowly dropping off the building in great grey globs. An internal frame would have been easier to fireproof, but this frame was exposed to the weather; its 'expression' was an essential part of the architecture.

And here we come to an important aspect of the High Tech style, indeed the aspect with which it is most associated in the public eye: the exposure of structure and services – the bones and guts of the building – on the outside where everyone can see them. It may have been Renzo Piano who initiated this trend, in his Italian Pavilion for Expo '70 in Osaka, which featured a tensioned external steel structure not unlike a miniature, single-storey version of the Pompidou frame. As we have seen, Norman Foster, and his then partner Michael Hopkins, had been content to tuck structure and services away neatly behind slick skins or louvred screens. But after Pompidou came a rash of otherwise straightforward industrial buildings made into eye-catching architecture by external steel frames, often painted in primary colours. Richard Rogers' 1982 Inmos microchip Factory in Newport, South Wales (a convergence of 'High Tech' in the stylistic sense with 'High Tech' in the digital sense) is perhaps the best example. Its plan, naturally, is a plain rectangle, single storey, with external walls of square, detachable panels. These walls are hardly noticeable, however, beneath the elaborate apparatus that looms overhead. Structure, services and circulation are all combined in a central spine. Air handling units, important to create extra-clean manufacturing conditions, are lined up on the roof of the spine between tall steel frames from which the exposed tubular roof trusses are suspended by tension rods. The whole arrangement is like a functional diagram – symmetrical and perfectly legible. All steelwork is painted blue.

Norman Foster's response to this challenge was the Renault Distribution Centre in Swindon, completed in 1983. Its steel frame is arranged in square bays with masts at the corners from which slightly domed roofs are suspended. This time the steelwork is painted bright yellow. Red was also a popular colour, for example in Richard Rogers' 1981 Fleetguard factory at Quimper in France and Nicholas Grimshaw's Ladkarn factory in London of 1985. The bright colours soon went out of fashion but the roof suspension structures, now painted black, lived on in, for example, Grimshaw's Oxford Ice Rink of 1984 and Michael Hopkins' Schlumberger Research Centre in Cambridge of the same year.

Hopkins, leaving the Foster office in the mid 1970s to set up in practice with his wife Patty, produced some of the most inventive and refined High Tech buildings, beginning with his own London house of 1976. Essentially a homage to the Eames House in California of 1949 (see p??) it is a rare example of a domestic application of the style. Perhaps only architects can live comfortably in a box made of profiled metal and glass. The Schlumberger research centre, built for an oil exploration company, is the most spectacular of Hopkins' industrial buildings. Two parallel, single-storey, linear, Miesian blocks with exposed roof trusses house offices and laboratories. Between them rises a tent like the big-top of a three-ring circus. It shelters two drilling test pits and a 'winter garden' which serves as a meeting place for the researchers. The choice of a tent rather than a solid building to cover these quasi-external spaces was inspired. Its steel frame is external and equipped with all the raking struts and tension rods that had by the mid 80s become de rigueur in a High Tech building. Fabric structures of this kind, sheltering inside/outside spaces, became something of a Hopkins trademark, even after he had undergone a mid-career metamorphosis, replacing steel and glass with brick and timber as his default materials. This transformation began in the new Mound Stand at Lords cricket ground, completed in 1991. For construction planning reasons, it made sense to preserve and renovate the old brick arcaded base of the stand before erecting a steel superstructure crowned by a fabric canopy. Hitherto unfamiliar with brick as a material, Hopkins seems to have fallen in love with it. He proceeded to build a series of important buildings for British establishment clients, including Glyndebourne Opera House, completed in 1994, and the new Parliamentary Building in Westminster, completed in 2000. These can no longer be classified as High Tech, though they share at least one important characteristic of that style: its insistence on complete honestly. A brick wall in a Hopkins building is always a real, loadbearing structure, not just the facing of a steel or concrete frame.

In 1978, perhaps re-assured by the success of the Centre Pompidou, another British establishment client, the Lloyds insurance market, engaged Richard Rogers to prepare a development plan for the organisation's various premises. Unsurprisingly, this brief eventually turned into a proposal for a new building in the City of London. It was to be one of the two culminating masterpieces of High Tech completed in 1986, the other being the Hong Kong and Shanghai Bank (see below). Whereas Hopkins' style altered and softened as the establishment commissions began to arrive, Rogers stuck to his High Tech principles even for the bowler-hatted gentlemen of this three hundred year old institution. The basic idea was simple: the market or trading floor, traditionally known as 'The Room', would be accommodated in a single, multi-storey, rectangular space surrounding a central atrium with escalators. This would be the 'served' space. Everything else – all the 'servant' elements, including lifts, toilets, escape stairs, mechanical plant and ductwork – would be fitted to the outside.

The complex visual outcome of this strategy is shockingly like a piece of pure engineering, an oil rig perhaps, or a power station. The clarity of the underlying diagram is further obscured by the stepping down of the Room on the south side, exposing the glass barrel vault over the atrium like a fragment of every High Tech architect's favourite nineteenth century building, the Crystal Palace. Every element conforms to High Tech principles: lift cars are fully glazed wall-climbers; toilets are housed in separate metal-clad pods with round windows; escape stairs are boldly articulated; plant is contained in modular towers like stacks of containers; air ducts, both horizontal and vertical, are tubular, with dimpled silver casings. The main structural frame is concrete, not steel, to avoid the fire-proofing problems of Pompidou, but it is nevertheless cast in steel-like profiles, with cylindrical columns, brackets and diagonal bracing.

Meanwhile, in Hong Kong, Rogers' friend and rival Norman Foster was talking to another venerable institution, the Hong Kong and Shanghai Bank. The bank had occupied its 1 Queens Road Central site since 1865. Its current building, designed by Palmer and Turner in the mid 1930s, was well loved, especially for its Art Deco banking hall, but was short of office space. The brief to Foster was simple, therefore: stay on the same site, keep the banking hall, and build a skyscraper to accommodate the offices. It is worth remembering this original brief when looking at the completed building. Why does it look like a multistorey suspension bridge? Because it was originally designed to bridge over the preserved banking hall. At some stage in the development process it was decided that the banking hall could go after all, but it was too late to rethink the bridge idea. But perhaps the bridge idea also appealed to Foster for other reasons. That preference among High Tech architects for open, flexible spaces is hard to satisfy in a conventional skyscraper because the central structural and service core leaves only a relatively narrow strip of usable floor around the perimeter. Foster therefore rejected the central core plan and instead gathered the servant spaces and vertical structure on either side of the served space – an arrangement that naturally implied a bridge-like structure. Having created an open space on each floor, he then tackled the other unsatisfactory aspect of the conventional skyscraper: that every floor is spatially divorced from every other floor. To move from one floor to another, one must pass through an intermediate enclosed space, either a lift or an escape stair. Space, in other words, is discontinuous, and flexibility of use is compromised. Foster's solution was to unify the served space by means of escalators, as he had done on a smaller scale at Willis Faber, and indeed as Rogers was doing at Lloyds. These two innovations – the bridge like structure and local circulation by escalator – amounted to a re-invention of the skyscraper.

Many alternative designs based on these principles were produced during the development period, including the so-called 'Chevron' scheme which structurally treated every individual floor as a suspension bridge, resulting in a proliferation of diagonal tension members. The final building is less radical but revolutionary nevertheless. Bridge-like horizontal structural elements occur at intervals in the height of the building, with between seven and nine floors hanging from each one. Continuing the multi-storey suspension bridge analogy, there are really three of them, like three towers placed side by side, each rising to a different height. This creates the impression that the building is unfinished, that the two lower towers might one day be extended upwards to match highest. The form is partly the result of local regulations to prevent overshadowing. Floors are also set back in the other direction, between the massive composite steel masts. But the indeterminate look is quite deliberate. It is as if the building were a system temporarily configured for a particular situation rather than a fixed, finite form. Nobody believes that the lower towers will ever actually be 'finished' or the missing sections of floor filled in, but the unfinished look is in tune with High Tech's flexibility principle.

So, if the structure is essentially a bridge, what does it now bridge over? The answer is nothing, just an open paved area which, paradoxically, has become one of the building's best loved features. Accessible to the public at most times, it is a popular shady picnic spot. It is also the very unconventional main public entrance to the building. A pair of angled escalators appear to have been lowered onto this pavement from above like gangplanks. Taking the up escalator one rises through the glass 'underbelly' of the building into a cavernous ten storey high atrium that has been created by simply omitting the lower floors of the central multi storey bridge. The 'front door' of the building is therefore a horizontal shutter closing off the escalator when not in use. It could hardly be more different from the grand classical portico that one traditionally associates with bank entrances.

In the design and construction of the Hong Kong and Shanghai Bank, Foster's habit of collaborating with building component manufacturers became standard procedure. It was even given a name, though a rather dull one: 'Design Development'. Representatives of the Foster office were sent out to work with specialists all over the world. The structural steelwork came from Britain; the external cladding, including the very complex aluminium sheathing of the fireproofed external structure, came from the US; the prefabricated toilet and plant modules stacked up in the service towers came from Japan. Every element of the building was rethought from first principles. Almost nothing was taken from a standard catalogue. The result was one of the most technically advanced buildings of the twentieth century – and one of the most expensive.

In the Lloyds Building and the Hong Kong and Shanghai Bank the principles of High Tech were triumphantly vindicated. Those buildings marked a high point but also a change of a direction. The style's main protagonists, now firmly established, began to explore new architectural territory. Already in the mid 1980s Norman Foster was designing a Mediatheque in Nimes in the south of France, for a site opposite the well-preserved Roman temple knows as the Maison Carree, in very un-High Tech materials: concrete, bronze and local stone. A note in Foster's handwriting on an early sketch states: "No diagonals in structure – must not look industrial". Richard Rogers began to take an interest in traditional urban form, a topic remote from the usual concerns of High Tech. Eventually, in 1997 he wrote an influential book on the subject called Cities for a Small Planet. Even Nicholas Grimshaw, most dogmatic of the group, showed signs of shifting his interpretation of High Tech principles. The cluster of geodesic domes at the Eden Centre in Cornwall, completed in 2000, suggest an organic rather than a technological inspiration. They appear to have grown spontaneously in their disused quarry site, though in fact they were painstakingly constructed on a mass of temporary scaffolding.

One late High Tech building, completed in 1991, deserves special mention because of its enormous international influence. Stansted Airport (London's third, after Heathrow and Gatwick) marks a turning point in the design of airport terminals. Norman Foster brought to the job a personal interest in flight (he is an experienced pilot) as well as his by now formidable analytical design skills. The main idea, following the usual High Tech preference for spatial simplicity, was to house all of the public functions – departures and arrivals – in one big room. Passengers would be able to see where they were going and would no longer be completely reliant on stress-inducing signs and announcements. But the most influential aspect of the design was the lightweight, billowing roof. All mechanical plant is consigned to an undercroft, relieving the roof of the usual clutter of ducts, access walkways and suspended ceilings. Air, water, electricity and artificial light are supplied to the space via the four-strutted, tree-like steel columns. Following publication of the building, tree-like columns almost instantly became an architectural cliché, cropping up in forecourts, bus-stations, and railway platforms everywhere. But more importantly, the example of the big public hall with an unencumbered roof admitting daylight to the heart of the building was followed by airport designers around the world, from Richard Rogers in Madrid, to Kisho Kurokawa in Kuala Lumpur and Renzo Piano in Kansai, Japan. Foster himself refined the form in Hong Kong's Chek Lap Kok airport, opened just as the colony was being handed back to China in 1997, and at Beijing's huge Terminal Three, completed before the opening of the 2008 Olympic Games. These later versions, with their flowing, computer-generated forms, make little Stansted look almost primitive, like a pre-war biplane.

By the turn of the century the High Tech style had lost its distinctive identity, but the architects associated with it – Rogers, Foster, Grimshaw and Hopkins – now feted and honoured, continued to run large international practices. They were turning into the grand old men not just of British, but of world architecture. A 2014 BBC television series devoted to them was called "The Brits who Build the Modern World".

This text is a chapter of a forthcoming publication of the author.

Frei Otto – Executing High Tech concepts

Christine Otto-Kanstinger

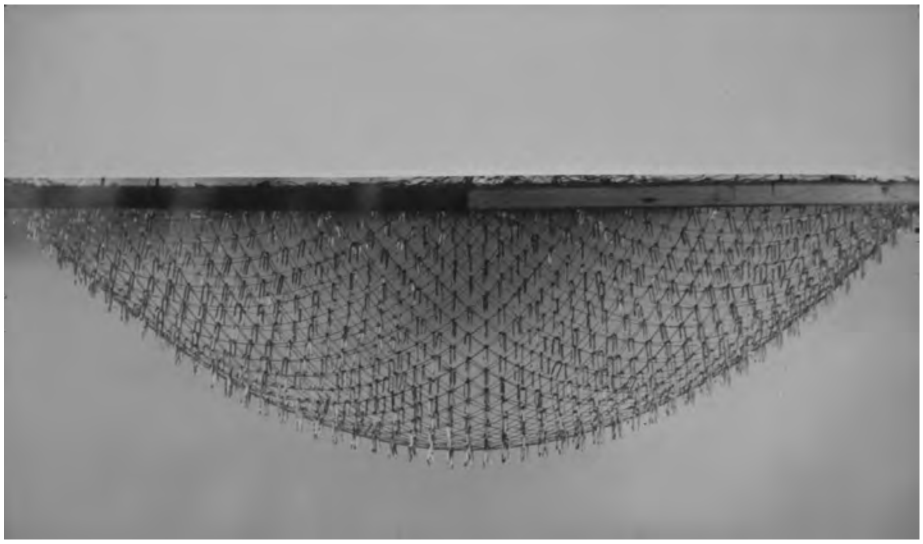


Fig. 1: Essen DeuBau. Hanging model as design method for the first grid shell. (Photo Frei Otto 1962).

The first part will arrange Frei Otto into the context of the Modern Movement.
The second part refers to the design process, details and materials of the exemplary buildings Essen 1962, Montreal 1967, and Mannheim 1975.

Frei Otto was born 1925 in Siegmar near Chemnitz. His father Paul Otto had studied at the Academie of arts in Dresden, worked as a sculptor and was part of the management of the German “Werkbund”. In his father´s workshop young Frei saw how to work with stone, but as well how to do models from fabric and gypsum. He also delivered letters and papers to members of the “Werkbund” living nearby and so he knew their names. When the German “Werkbund” was banned in 1934, Paul Otto could not work any longer as a free sculptor, but he wrote a book for stonemason. 1937 the family went to Berlin. Frei learned to fly sailplanes. He invented and built lightweight planes. He was still very young when he knew that he wanted to become an architect.

Fig. 2: Essen DeuBau. First grid shell model. (Photo Frei Otto 1962)

When he had his university-entrance diploma in 1943 he signed at once to study Architecture, but he was not allowed to. He was drafted into the labor force, then for military service. He was trained as a pilot and then became a prisoner of war. He stayed two years in a camp near Chartres. It happened, that he worked there as an Architect. This was a very instructional pre-study work experience. He got to know men with special skills in building. As they had nearly no materials, the question of minimizing was always very present.
Back in Berlin Frei Otto studied Architecture at the TU. 1950 he got a granted travel to the United States of America. He wrote to Walter Gropius and asked for a recommendation, whom he should see in the USA. So he went to Ludwig Mies van der Rohe, Ludwig Hilberseimer, Frank Lloyd Wright, Charles and Ray Eames, Richard Neutra, Erich Mendelsohn, Eero Saarinen and Fred N. Severud. When Frei Otto met Ludwig Mies van der Rohe in Chicago, he told him, that he could not find the famous Expo Pavilion in Barcelona. Ludwig Mies van der Rohe was quite happy, that the pavilion was dismantled after the expo because he assumed that it would have been shabby now and the roof leaky. A model of the Raleigh arena in Fred Severuds office in New York stimulated Frei Otto to his thesis “The hanging roof”.
In this context he went to see Peter Stromeyer, famous german tent builder. This turned out to a

Fig. 3: Essen DeuBau. Second grid shell. (Photo Frei Otto 1962)

Fig. 4: Essen DeuBau. Second grid shell shaped on pneumatic structure. (Photo Frei Otto 1962).

productive cooperation and a lifelong friendship. They created a series of new tents – especially for the national garden exhibitions in Kassel 1955, Cologne 1957 and the Interbau Berlin 1957. Frei Otto founded the „Entwicklungsstätte für den Leichtbau Berlin“ and built his first own Atelier in 1958. It was one room, glazed all around with lightweight sliding elements. Many of Frei Ottos buildings have to do with textiles, but some of them do not show this at once. Permanent sealing of flat roofs is difficult. Due to this fact some buildings of Modern Movement got additional pitched roofs. Remembering his discussion with Ludwig Mies van der Rohe, Frei Otto wanted to avoid leaking of his flat roof. So he used a prefabricated coated tent membrane, delivered in one piece, gravel on top against wind suction and for UV protection. Later he used the same technique for his house and Atelier in Warmbronn, unchanged since 45 years.

Frei Otto did many experiments with different form finding methods. In hanging models the form is forced by the earth´s gravitational force on the hanging elements. If these elements are stiffened, the form can be turned around and shows a vaulted compression structure.

1962 Frei Otto got the chance to do some experimental buildings at the first German Building Exhibition in Essen (DeuBau), two of them he did as shells. In preparation a fiber net with squared meshes was used to form a hanging model. Staples at each crossing point simulated the own weight of the construction. The length of each thread was measured. The results of the measurements were used to cut little spruce strips with a profile of 2 by 3mm² for an upright model in a scale 1:20. Using little brass screws the wooden laths were connected to a squared grid and bended to a grid shell.

On the real site in Essen timber planks were fixed to the ground with long steel pegs forming a ring with a diameter of about 15 meters as the lower bearing for the whole structure. Just as in the model wooden laths were laid out to a grid with squared 48 cm meshes. It was knotless Oregon pine with a profile of 4 x 6 cm. In the beginning the bolts at the crossing points were not tightened. The crossing angle of the laths had to change during the montage. A truck-mounted crane was used to lift the structure to the right position with a summit level of about 5 meters. Then the bolts at the crossing points were tightened and the dome went stiff. It was spanned with foil and the meshes around the entrance opening stiffened with wooden panels.

The second dome in Essen 1962 was a smaller trial structure with a diameter of about 8 meters and a height of about 3.5 m. An airtight translucent polyester membrane with PVC coating was blown up with a compressor like a balloon. The membrane was then stiffened from inside with 2 mm glass fibre reinforced polyester and with approximately 20 mm Perlite palatal, using a spraying equipment and three-component blast pipe. Working from the inside made this coating process nearly independent from weather. The membrane served as a watertight outer surface. At last the inner pressure was blown off and a door opening was cut off. The form of this shell was formed by the difference of pressure between inside and outside. It is not really an optimum for the given

Fig. 5: Montreal Expo 67 Construction of cable net. In foreground grid shells covering the auditorium (Photo Frei Otto 1966)

loads on site.

Other key aspects in Frei Ottos research were of course questions of membrane structures, how to build wrinkle-free tents, what would be the optimum way to span membranes and how forces get from the surface over edges and supports into the ground. Membrane structures are curved, flexible structures. They are tensioned in all areas and they cannot take compression forces. They get their form only by tensioning the edges, sometimes by additional supports in the surface. They have to be double curved in opposite directions. Each point in the surface can only be hold in position if forces are inversely arranged. A tent membrane could be used best, if it has nearly same tensions all over.

In search of the best forms for this since the 1950s Frei Otto experimented with diverse cloths, elastic threads, springs, rubber skins and so on. On or about 1961 he had the idea to use soap films, which proved to be an ideal method for form finding. Given that the surface tension in the soap film has to be equal in all areas, they form minimal surfaces self-acting and cannot take tension peaks. A minimal surface is the smallest possible face between any edges. Membrane structures should be close to minimal surfaces.

It has always been from special interest, how to get point loads into thin surfaces, since most thin materials can only take very small tension peaks. A soap film can be deformed with threads and wire rings. When Frei Otto studied the options, in 1963 he found a new world of forms with the so called eye loop, which has an equal curvature in space. The soap film was now replaced by a thin cloth and a model with alternating high and low points was built to find out something about a nearly continuous spanned membrane system.

This model became important, because it inspired the design for the German Pavilion in Montreal for the world expo 1967, done in a cooperation of Rolf Gutbrod (1910-1999), Fritz Leonhardt (1909-1999) and Frei Otto.

A cable net spanned over approximately 8000 m². It was supported with 8 masts and anchored at three inner low points and 31 outer edge points. Underneath the cable net was a membrane. The design idea was to create an exposition landscape on different levels where people would feel happy and free, with lightweight platforms and free access from all sides.

During the process of form finding the team did seven overall models and numerous detail models. In the first model in a scale 1:200 a fisher net with about 1 cm squared meshes was used to represent the membrane structure. The aim of this first rough form finding was to find the boundary conditions, to find the best places for masts, low and edge anchor

Fig. 6: Montreal Expo 67, Interior of German Pavillion. (Photo Frei Otto 1967)

Fig. 7: Montreal Expo 67 as a children's paradise. (Photo Frei Otto 1971)

points.
The form was then improved and refined in three more models in the scale 1:200, using fine lattice tulle with circa 2 mm meshes.
The form was influenced by the following constructive requirements: the whole roof should be producible from a homogeneous net with equal meshes that would be squared before the deflection; each part of the net had to be double curved in opposite directions; the curvatures should be as small as possible to reduce the pretension; there should be no horizontal areas to avoid accumulation of snow and the tension should be equal in the whole net.
Unfortunately it is not possible to create exact minimal surfaces with a standard net with equal meshes, the aim is of course to get very close to.
The models showed quickly, that the whole pavilion would not be producible from one single continuous net. Edges and ridges with options for joints were brought in.
Another kind of model was built not for the design process, but to find out about presumably wind loads. It was done from plywood in a scale 1:150 and was tested in a wind tunnel, measuring the respective pressure in multiple small boreholes.
The net is a highly undefined structural system, in which the distribution of forces is basically affected by deformations. With methods of this time it was incalculable.
So a special measurement model in a scale 1:75 was built. Fine steel wire with a diameter of 0.15 mm represented each forth rope of the planned net. The tension in each wire was measured. In a manual iteration process the form was manipulated until all tensions were balanced. To achieve this, some areas got double ropes and the sizes of the meshes at the edges were adjusted. To investigate deformations from wind and snow loads the model was loaded with little weights in different combinations. This was documented with double exposure photography. To find out the lengths for the real net, each tensioned model wire was measured exactly. In a next step the cutting pattern for the membrane underneath the net was determined.
One part of the pavilion was tested in original size. For this 1:1 test structure with approximately 460 m² as well several models from cloth and steel wires and a measurement model in a scale 1:75 were built. On a site of the University Stuttgart in Vaihingen the montage was studied, details were tested, and design assumptions verified by measurements.
Net and membrane for the real pavilion were prefabricated in several parts at Stromeyer in Konstanz, shipped to Montreal and joint on site.
For reasons of security the distance between the knots was defined to be 50 cm. This width was good for montage. The workers could easily climb on the net, but they could not fall through. The galvanized iron steel wire ropes of the net had a diameter of 12 mm and at the edges 54 mm. For the crossing points especial rope clamps were developed. The amount of joints for the edge cables was reduced as much as possible to avoid thick fittings.
The pavilion in Montreal was planned to stand only during the Expo, but it was used for another six years until it had to make room for the sports facilities for the Olympics 1976.
The test structure in Stuttgart-Vaihingen was sort of building waste immediately after the Expo. Frei Otto bought it for the University. In January 1968 the net was taken down with a crane, was brought to a site nearby and was re-erected. Instead of a membrane

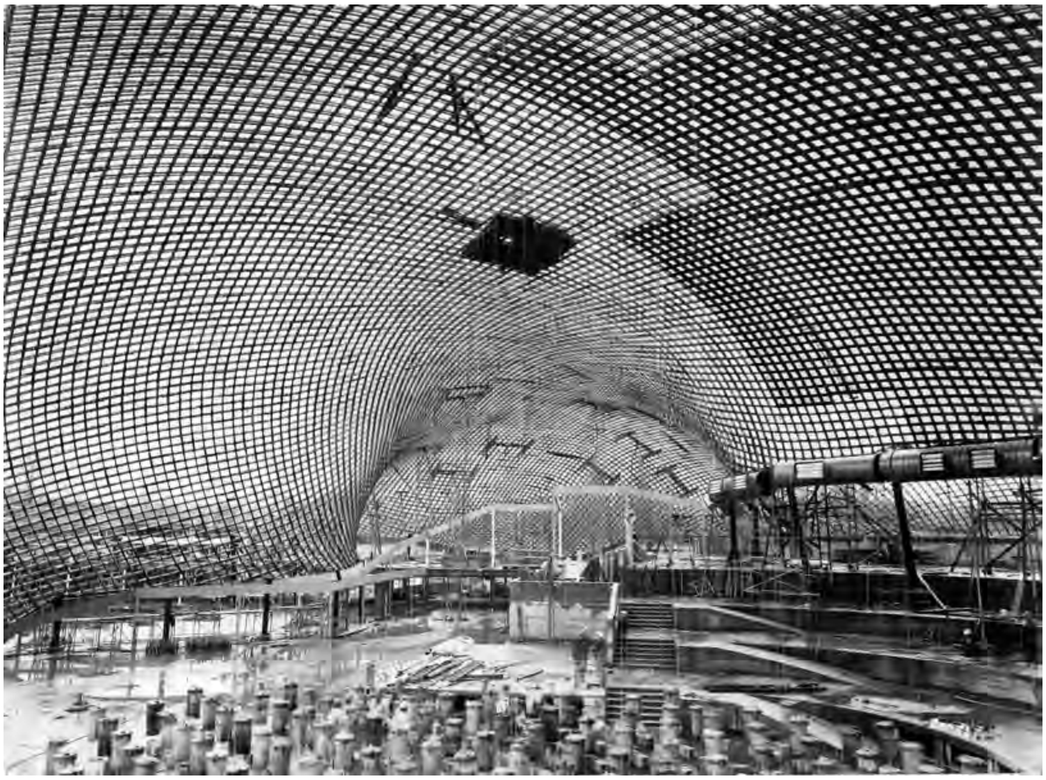


Fig. 8: Mannheim Multihalle construction site with real load test. (Photo Frei Otto 1975)

underneath the cable net it was now covered with wooden planking, insulation and shingles, the eye shaped opening in the roof was closed with acrylic sheets and the outer walls were formed by tilted windows all around. From then it served as home for the Institute of lightweight structures at the University of Stuttgart (IL directed by Frei Otto until 1991). Today it is a listed building.

It is less known, that under the well known cable net roof in Montreal two grid shells were spanning together over 365 m². The auditorium had 250 seats and was about 13 x 17 m, the foyer 5 x 20 m. As well as the grid shell for Essen the form was found in a hanging model. The second model was in a scale 1:20, the wooden laths were 2 x3 mm. As the strips had an own stiffness, a small change of the form occurred. The measured dimensions from the model served directly for fabrication. This structure was as well tested near Stuttgart before the transport to Montreal, to see the deformations of the laths. It was a 50 cm grid as well. The profile of the knot-free Canadian Hemlock pine laths was 33 x 42 mm. For the Transport the grid was pushed together and placed into a long box. On site in Montreal the wooden grillage was laid underneath the cable net and pulled

Fig. 9: Mannheim Multihalle wooden grid shell. The picture shows border divisions of the grid shell held by a cable between standing posts (Photo Frei Otto 1975)

up with cables. Additional laths on the fixing points during montage helped to divide the point loads and to prevent breaking of the laths. It was settled on reinforced concrete walls and brought to the preset shape. It got very stiff, when the loose bolts at the crossing points were tightened and plywood plates were nailed to the laths. Soft fibre boards and PVC coated cotton cloth came on top.

The socalled „Multihalle“ opened 1975 for the national Garden Exhibition in Mannheim. The Team Mutschler, Langner, Otto and Happold designed a covered market and a multifunctional hall. It was based on the experiences with the wooden grid shells in Essen and Montreal, but it was a great leap forwards in dimensions: from less than 20 m to 80 m largest span.

The distance between the knots was again well-proven 50 cm, the profile of the Hemlock pine about 5 x 5 cm, 2 layers at small spans, 4 layers at large spans. Additional to the wooden grid there are 6 mm thin steel wires in a diagonal 4.5 m grid. A new detail in Mannheim was, that in large areas the edges do not come to the ground or to a stiff concrete construction, but are standing on cables.

Calculation methods had developed since Montreal and were used elaborately for this large span dome structure, but nobody really wanted to rely on. Inspection engineer Fritz Wenzel recommended in an early stage to do a real load test on the finished structure, to convince all that especially snow loads can be carried. Thus 500 m² in the large hall were loaded using trash bins each filled with 90 l water hanging on each ninth knot of the grid. 79 mm was the maximum measured deflection. This astonished the involved persons. Sure enough the calculations had predicted 80 mm, but nevertheless all had anticipated larger deformations.

The “Multihalle” was only planned for the time during the garden exhibition 1975 and had a calculated life expectancy of at most 20 years. It is still there today 38 years later and is a listed building. Building with textiles did not count as Architecture for a long time. Today the term “textile architecture” is kind of fashion. Is a tent Architecture, if it was designed by an architect? Are the shown examples of constructions high-tech, mid-tech or may be simple-tech?

Lightweight constructions are very linked to the particular detail. The best details look simple and plain, but it takes a long time to develop them. Often people wonder whether Frei Otto is Architect or Engineer. This is probably because his working methods are untypical for both of them. The former builder “Baumeister” was architect and engineer in one person. Today´s classical division of labor between architects and engineers is that the architect is giving the form and the engineer is calculating this given form. Frei Ottos approach is different. He does not force a form, but he searches for the form. He does not care about whether the form could be calculated, but he cares if it can be built. He does not ask what form looks good – he asks what form is good?

Fig. 10: Institute of lightweight structures, Stuttgart University (Photo Christine Otto-Kanstinger 2011)

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1989 Workshop, Hooke Park, Dorset, England (with Burton)
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Architect. At the time Employee at the Berlin city adminstration (Senatsverwaltung für Stadtentwicklung und Umwelt, Oberste Denkmalschutzbehörde und Werkstatt Baukultur), co-responsible for monitoring and Periodic Reporting of the Berlin World Heritage Sites and for building culture in the urban space. 2005-2011 she was scientific assistant at Faculty VI – Planen, Bauen, Umwelt, Technical University Berlin, directed by Prof. Dr.-Ing. Johannes Cramer, managing a research projekt funded by the Deutsche Forschungsgemeinschaft „Die Bauten des russischen Konstruktivismus (Moskau 1919–34) – Baumaterial, Baukonstruktion, Erhaltung“ and published on Narkomfin-Haus in Moscow as Volume 9 and 11 of *Berliner Beiträge zur Bauforschung und Denkmalpflege*. After studying Architecture at Stuttgart University and Diploma degree at RWTH Aachen she worked in architect offices in Hamburg (Schramm, von Bassewitz, Hupertz und Partner, Alsop und Störmer) and in Moscow as well as in Berlin. 2000-2003 Dissertation *Zur Erhaltung der Bauten der 1920er Jahre im Vergleich Bundesrepublik-Russische Föderation (Moskau) unter besonderer Berücksichtigung der baukonstruktiven Voraussetzungen* (TU Berlin, Prof. Johannes Cramer). Member of Docomomo Germany and DOCOMOMO International. Member of the Deutschen Nationalkomitee von ICOMOS as well as Expert-member of ISC20C for 20th C. Buildings. She organized numerous activities and conferences, presented lectures, promoting the care for Russiona Avatgarde buildings, in favor for listing them as World Heritage Sites, in cooperation with ICOMOS Germany and International. She is ICOMOS-Monitor oft he World Heritage Site “Fagus-Werk in Alfeld”.