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Restoring Postwar Heritage

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View of the United Nations Campus, c. 1953.
Photo courtesy of the United Nations Archive.

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Import/Export: Postwar Modernism in an Expanding World, 1945-1975
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View of United Nations, c. 1952. Courtesy United Nations Photo Archives

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CONTENT

Restoring Postwar Heritage: Selections from the 2004 DOCOMOMO US Technology Seminars (New York)

Introduction

In the fall of 2004 the VIIIth International DOCOMOMO Conference titled *Import-Export: Postwar Modernism in an Expanding World, 1945-1975* took place in New York City. This was the first International DOCOMOMO meeting fully devoted to the postwar period and the first to evaluate the reciprocal relationship and its consequence between modernism and preservation. The ubiquity of modernism in postwar architecture is a sign of its significance and to achieve meaningful preservation requires the creative exploration of the on-going tension between design, preservation and materiality in modern structures.

In conjunction with this international conference DOCOMOMO US saw the need to address separately the much neglected or misunderstood technological challenges presented by modern architecture. A series of technical seminars was organized around the conference's general theme but focused specifically on technology. While the international conference was hosted at Columbia University, the technical seminars occurred at Baruch College in midtown Manhattan from September 30 through October 2. The program consisted of five different components. Aside from several general introductory presentations, four separate seminar tracks addressed technical issues quintessential to the understanding and preservation of modern architecture and its technologies.

Focusing on postwar building technologies and their particular technical and conservation issues, professionals from different parts of the world presented their expertise and experience within the four technical topic areas, which were titled: The 20th Century Metal and Glass Curtain Wall, Concrete Restoration in Modern Buildings, Stone and Technology in the Modern Movement and Chroma: Color and Conservation in Modern Buildings. Most of those papers are included in this dossier.

These seminars as well as the conference would not have been possible without the help of a large number of institutions and individuals, all of whom have been identified in the various appendices at the end of this dossier. The preparation of this dossier presented an additional challenge stretching out over several years. That publication would not have been possible without the help of many but particularly of Flora Chou, Olivia Klose and Deirdre Gould. The editors are extremely grateful for their insights, perseverance and diligence.

This publication was financially made possible through a grant from the Getty Foundation, the sponsorship of the firm Conproco and the generous support of Brent Harris.

Theodore H. M. Prudon and Kyle Normandin
Editors

Plenary

The following papers illustrate the preservation challenges and commensurate opportunities presented by large collections of modern buildings. In the case of the Zollverein Coal Mine Industrial Complex, designated a World Heritage Site in 2001, a balance was struck between new design to accommodate new uses and maximum retention of historic fabric. Since the 1932 steel-and-brick industrial complex was never intended to outlive the heavy industry that called it into being, the new program of uses responds to the idea and spirit of technological production in a 21st century sense by transforming interior and exterior spaces into venues for creativity in industrial design, the arts, cuisine, and cultural heritage education. At the University of Chicago's campus, where the purpose of the academic buildings dating from the World War II period remains the same, an initiative is underway to apply maintenance guidelines appropriate for the innovative building technologies and materials represented in buildings designed by Eero Saarinen, Ludwig Mies van der Rohe, and Edward Durrell Stone, among others.

University of Chicago Preservation Guidelines for Contemporary Architecture

Harry J. Hunderman, David S. Patterson, Richard C. Bumstead

After World War II, the University of Chicago and similar institutions faced a different social, economic, and educational climate than had existed during the 1920s and 1930s. Within a changing urban context, the university began planning for the physical expansion of its campus and the design of its new generation of buildings. Ten of the contemporary landmarks on the University campus, designed by renowned architects and constructed between 1949 and 1974, were selected as the subject of a study to develop preservation guidelines for contemporary buildings on the campus. Many of these buildings were designed and built using the innovative technologies, materials, and systems of their era, and thus present a wide range of preservation challenges as they age. The guidelines incorporate both philosophical preservation recommendations and specific technical recommendations for repair, conservation, and maintenance of the building materials and systems. The ultimate goal of the project is to assist the University in preserving the buildings of the modern era while allowing them to accommodate continued and changing uses.

Introduction

The contemporary buildings of the University of Chicago campus were designed and built using innovative technologies, materials, and systems of their era, and stand as a collection of architecture embracing the new economic, social, and educational trends in the United States at the time of their construction. The buildings of this period and the technologies that made them possible are now entering middle age. The university's goal is to maintain these buildings as functional parts of its physical plant, while recognizing them as an important part of its architectural heritage, complementing the Collegiate Gothic structures generally associated with the campus. Broader awareness of the significance of buildings from this era demands sensitivity to their value as architectural and historic artifacts, as well as technical sophistication in their maintenance, repair, and renovation.

The Preservation Guidelines for Contemporary Architecture were developed to provide a basis for future decision making for contemporary campus buildings. The project, funded by the Getty Conservation Institute Campus Heritage Grant Program, was undertaken to provide university administration, maintenance staff, building users, and outside design professionals and contractors with a better understanding of the architectural significance and the nature and condition of the materials and systems of these buildings. The ultimate goal is to preserve the contemporary buildings of the campus as they age. While particular features will require updating to meet programmatic and technological demands, accessibility standards, and new energy efficiency criteria, the architectural integrity of these buildings will be respected and as the technical challenges of preserving modern materials are met. The University selected the following buildings on the main campus for inclusion in this study: the Administration Building (Holabird and Root, 1948); Laird Bell Law Quadrangle (Eero Saarinen, 1959); Pierce Residence Hall (Harry Weese and Associates, 1960); University High School (Perkins and Will, 1960); Kellogg Center for Continuing Education/New Graduate Residence Hall (Edward Durell Stone, 1962); Laboratory for Astrophysics and Space Research (Skidmore Owings Merrill, 1964); School of Social Service Administration (Ludwig Mies van der Rohe, 1965); Henry Hinds Laboratory for Geophysical Sciences (I.W. Colburn, 1969); Joseph Regenstein Library (Skidmore Owings & Merrill, 1970); and the Smart Museum-Cochrane Woods Art Center (Edward Larrabee Barnes, 1974).

The administration building (Holabird and Root, 1946-1948) was the first building to break with the Collegiate Gothic style.

The Laird Bell Law Quadrangle (1959) designed by Eero Saarinen.

The study included archival research, field survey and condition assessment, analysis, and development of preservation guidelines. Original construction materials, systems, and details of the buildings were researched using the extensive collections of the University of Chicago Library, Special Collections Research Center. Available information about past maintenance and repairs was also reviewed. A visual survey of the buildings was performed to assess and document the existing condition of the materials and systems of the building envelope to identify conditions of concern and evidence of past repair work. The condition assessment included masonry cladding, curtain walls, windows and doors, roofing, and other building envelope components. In addition, significant interior spaces and materials were identified and assessed

Based on the research of original construction; evaluation of reported problems with the subject buildings; research on historic performance of these materials and systems; and the results of the condition survey, issues and characteristic problems were identified. The study addressed issues related to original construction, subsequent repairs, current building performance, availability of original materials and components, appropriateness of substitute materials, and authenticity. The analysis served as the basis for development of the preservation guidelines. The guidelines were prepared to address the subject buildings, with the understanding that these guidelines will be applicable to other buildings with similar construction detailing on the campus. The guidelines incorporate both philosophical preservation and specific technical recommendations for repair, conservation, and maintenance of the building materials and systems of these icons of contemporary architecture.

History

The University of Chicago was founded in 1890 by the American Baptist Education Society with support from John D. Rockefeller. The site in Hyde Park was a suburban area recently annexed to the City of Chicago that had developed rapidly with construction of the nearby fairgrounds in Jackson Park for the 1893 World's Columbian Exposition.

The first buildings in the initial campus plan were designed by Henry Ives Cobb in an architectural style that came to be referred to as Collegiate Gothic because of its associations with American universities. The University campus was planned as a series of enclosed cloisters facing a larger central quadrangle. The architects who followed Cobb in the 1900s, 1910’s, and 1920s based their designs on past European precedents of the Gothic style. Over these decades each subsequent building followed the concept of the initial campus plan, using a consistent style, building massing, and similar materials.

A decisive break in design and planning for the university came with the Administration Building, designed by Holabird and Root, and constructed in 1946–1948. The building is located on the Main Quadrangle, within the area of the original 1890’s campus plan, and was originally to be similar in style to the earlier campus buildings. The decision to abandon the Collegiate Gothic style came about in 1945 after Herbert P. Zimmermann, a member of the Board of Trustees and chairman of the committee responsible for the building design, happened to attend a lecture at the Art Institute of Chicago given by Joseph Hudnut, Dean of the Graduate School of Design at Harvard University. Hudnut, who in 1937 had been responsible for recruiting Walter Gropius to lead Harvard’s architecture department, commented in correspondence with Zimmerman that the Gothic designs implemented at the University of Chicago missed the essential spirit of Gothic architecture as well as the modern needs of the university. While accepting the past Gothic buildings as a permanent feature of the campus, Hudnut urged that future buildings should be planned “in a modern spirit, each unit scientifically adapted, in accordance with modern techniques of planning, to its specific purpose,” while noting that new designs would need to be compatible with the existing Collegiate Gothic structures. (Letter, Joseph Hudnut, Graduate School of Design, Harvard University, to Herbert P. Zimmermann, University of Chicago, 7 March 1945). Hudnut’s opinion, together with financial considerations, persuaded the Board to abandon the earlier designs and proceed with a modernist building that represented the decisive break with the Collegiate Gothic style at the campus. While the horizontal emphasis and minimal details of the Administration Building facades reflect modernist design principles, the use of limestone facades and a sloped clay tile roof refer to the older Gothic buildings on either side.

After World War II, the university began planning for physical expansion of the campus, and like other similar institutions it faced a different social, economic, and educational climate than had existed during the 1920s and 1930s. An overall shortage of housing in urban areas like Chicago was compounded by deferred maintenance of existing structures during the years of depression and war. The postwar economic expansion created the opportunity for thousands of middle class families to move to new suburban housing, leaving behind in urban neighborhoods the poor or elderly living in antiquated housing stock. The University of Chicago had to consider whether to remain as an urban institution or to follow the exodus to the suburbs. Ultimately, the University decided to stay in the city and to play an active part in rebuilding the neighborhoods that surrounded its campus. For its own master plan the University engaged Eero Saarinen, who worked on this effort from 1955 to 1959. To design the new generation of buildings, the university looked to some of the leading modern architects working at the time, including Holabird and Root, Eero Saarinen, Harry Weese and Associates, Perkins and Will, Edward Durell Stone, Ludwig Mies van der Rohe, Skidmore Owings & Merrill, I.W. Colburn, and Edward Larrabee Barnes, among others. These firms were responsible for the design of the ten buildings selected for this study, which were constructed between 1948 and 1974. The buildings of this period on the campus reflect a restrained modernist style that refers to the Collegiate Gothic architecture through the use of materials such as limestone and through building massing, rather than through ornament and detail.

Issues in Preservation of Contemporary Architecture

Some of the issues involved in preservation of contemporary architecture are primarily philosophical and aesthetic, such as consideration of the buildings as architectural masterworks and the development of material patina. Other issues are primarily technical, such as lack of redundancy in construction and the use of materials with limited durability, traditional materials in new applications, and innovative materials and techniques. Other issues are related to building use and function, such as energy efficiency and code considerations.

Architectural Masterwork

The concept of a building as an architectural masterwork demands consideration of the significance of the original architect's intent as compared to the significance of the building as it has evolved. The design of a renowned architect may be significant as an example of trends in architectural theory and history, or for its place in the body of work of that architect. However, alterations made after construction may affect the building's aesthetic and obscure the original design intent. In some cases, it may be appropriate to recommend that changes be reversed to restore the original design intent. In other cases, changes may have gained their own significance over time. For buildings of recent construction, can changes be correctly evaluated in terms of significance if little time has passed since their implementation? All of these questions apply to consideration of the buildings in this study.

An example of existing alterations within a building of this study is the Laird Bell Law Quadrangle, designed by Eero Saarinen. Additions to the Law Quadrangle completed after construction include the addition to the library (1985–1987) and the Kane Center (1998), which included an addition to the seminar wing. Both of these additions were designed to match the original building elevations closely in materials and details, and expand sympathetically upon Saarinen's original massing concept for the complex.

Material Patina

The effects of material weathering, defined as the material's patina, may be considered desirable on hand crafted materials but is perhaps less acceptable on highly machined materials typical of modern buildings. While the weathered appearance of traditional buildings is generally considered tolerable or even desirable, some modern buildings may demand cleaning, refinishing, and repainting to achieve a consistently new appearance. Synthetic materials such as high performance organic coatings and early generation anodized finishes may change appearance more drastically in weathering than traditional materials, creating potential aesthetic problems.

An example of these issues is seen at the Administration Building, where the bronze curtain walls of the main entrances on the east and west elevations have been continuously refinished and polished over the years and have therefore never attained a patina. In contrast, the exterior railings at the stairs to each entrance were not refinished and polished, and have been allowed to patinate. It is not known at this time whether the contrasting patination of the railings and non-patination of the curtain walls were part of the design intent, or whether it was intended that all bronze materials retain a consistent appearance.

Lack of Redundancy

Modern thin claddings and glass and metal curtain wall systems experience complex problems that were not historically of concern, in part because of the lack of redundancy of contemporary wall construction. While traditional masonry wall construction could tolerate some water leakage without damage to the building envelope or interior, water leakage problems from failure of sealants or improper design are more significant in buildings constructed with these less forgiving curtain walls. Water penetration in small amounts, a condition which may be of little consequence in a building with massive masonry walls, becomes immediately apparent and detrimental to interior finishes in a modern curtain wall clad structure. Issues of stone strength loss and panel anchorage deterioration are also of greater concern in a modern curtain wall.

As modern wall construction typically contains many standardized facade components, a problem with one component, such as leakage at a window mullion, is typically repeated many times throughout the facade. In addition, buildings of the modern era typically require more frequent monitoring and maintenance than traditional masonry construction. Thus, if newer materials such as joint sealants or insulating glass units are incorporated into a facade of more traditional construction, then the maintenance cycle for these components is more frequent than for other materials such as brick and mortar that are present in the same wall system.

Material with Limited Durability, Traditional Materials in New Applications, and Innovative Materials

Many contemporary buildings incorporate materials and systems that were known to have a limited life span at the time of construction. An example of such a material is joint sealants, which are anticipated to require replacement in a fixed time period (e.g., ten years) that is substantially shorter than the service life of many older building materials such as mortar. Change occurs frequently in product formulations and production processes of modern materials such as joint sealants, coatings, and chemical cleaning systems. The standards established for selection of replacement materials are more difficult to define for materials that are constantly changing. For materials of shorter service life and where products and properties change, it is also difficult to identify and replicate the original aesthetic intent (color, profiles, etc.), especially if such materials have already been replaced several times on a given building.

Traditional materials present different concerns when used in non-traditional applications on contemporary buildings. For example, several of the subject buildings are clad with thin stone panels. Thin stone cladding systems can be vulnerable to corrosion of steel anchorage and support systems, loss of strength, bowing and cracking of the stone panels, and other distress conditions not typically encountered with this same cladding materials in traditional, thicker applications.

Practical and economic difficulties exist in obtaining materials that were originally produced with large-scale industry but for which industrial processes have changed. Changes in production have rendered some materials obsolete and difficult or impossible to duplicate exactly. In some cases, production that occurred for many units may not be feasible where only a few replacement units are required, and hand craftsmanship may be needed to replicate something originally created with high tech industrial means. The question of when substitute materials should be used is relevant to this issue. Although preservation philosophy favors maintaining the authentic original materials whenever possible, and replacing unsalvageable materials in kind, it may be acceptable to use a mass-produced substitute material to replace a mass-produced original material in several situations. This approach may be appropriate when the original aesthetic intent can be maintained with the substitute material and where the original material is not currently produced, available as salvaged or warehoused material, or reproducible using current production techniques. In other cases, lack of availability of mass-produced products may require the limited custom fabrication of “out-of-date” components in order to replicate missing or damaged historically significant features.

Preservation of modern structures often includes preservation of innovative materials, systems, details, or components that were new and untested at the time of construction, and which may have failed to perform as intended. If the problematic features are architecturally significant, they may warrant preservation both based on technical uniqueness and in order to preserve the original architectural intent. An example of this issue is the bi-fold aluminum windows of the Administration Building, a key component of the building's appearance, which require frequent maintenance due to problems with operation and breakage of the operating mechanism during use.

*Energy Efficiency and Code Consideration*s

Modern buildings constructed before energy conservation became a major concern during the 1970s and are often problematic in terms of energy efficiency. While traditional buildings of masonry construction were often massive enough to be somewhat energy efficient, buildings with thin claddings and extensive curtain walls and glazing are more problematic in terms of energy efficiency. Changes to architectural features or mechanical, electrical, and plumbing systems to provide for improved efficiency need to be sensitive to the original architectural character and significant features. For example, replacement of window and curtain wall glazing may not be feasible within existing frame and sash, and alterations to permit installation of insulating glazing units may affect the appearance of the building envelope. Changes to roofing systems can affect perimeter and coping details that can be seen from grade. Mechanical system alterations may render obsolete significant original features such as ventilation grilles or radiator enclosures. Contemporary high-efficiency lamps such as compact fluorescent bulbs may not be compatible with original lighting fixtures.

Building codes are constantly being revised, and any older building is likely to have some features, details, or spaces that do not comply with the requirements of contemporary codes. This applies to life safety features, accessibility for the disabled, and building mechanical systems. Many of the subject buildings have experienced alterations designed to enhance accessibility or to address contemporary egress requirements. Code and performance requirements for building mechanical systems also require consideration. Although heating and air conditioning units are not generally considered historically significant features, original mechanical system features such as ventilation grilles or radiator screens should be preserved when systems are upgraded. Similarly, original elevator doors and elevator cab finishes should be preserved, although elevator motors and controls likely require replacement or reconditioning to comply with modern codes and performance requirements.

Preservation Guidelines

The goal of the preservation guidelines is to provide a structure for the preservation, conservation, repair, and maintenance of the contemporary buildings of the university campus. The study provides specific direction for appropriate measures for the conservation, repair, and maintenance of the contemporary buildings at campus. Further guidance on preservation, repair, and maintenance of the materials included in these buildings, and discussion of specific issues relevant to each of the individual buildings in the study, were also addressed in the study report. The ten guidelines are as follows:

1. Identify buildings of architectural significance.
2. Identify significant features and materials of each building, including exterior and interior elements.
3. Evaluate how original construction materials, systems, and details of the buildings have performed over time. Identify current problems and issues related to deficiencies and deterioration.
4. Identify modifications that have taken place to address technical problems or programmatic changes. Evaluate how these modifications have altered significant features and materials. Consider how these modifications have performed over time. Identify current problems and issues related to deficiencies and deterioration.
5. Identify current and projected programmatic needs and related modifications that may be required. Take

into consideration how these modifications will affect significant building features and materials. These considerations should address both the building envelope and significant interior spaces.

6. Identify needed ongoing maintenance procedures. Determine appropriate maintenance measures that are sensitive to the architectural significance of the building and preserves significant features.
7. Identify needed repairs and determine appropriate repair measures. Identify repairs that are sensitive to the architectural significance of the building and preserves significant features.
8. Identify critical performance requirements that necessitate major changes to significant features. Select the approach that involves the least adverse effect to significant features and is the most reversible. In general, major changes that affect the architectural character of the building should be avoided. However, if performance requirements necessitate modifications that strongly affect significant features, those changes should be carefully designed to minimize adverse effect.
9. Analyze and design maintenance, repairs, and modifications to preserve significant features wherever possible.
10. Document observed conditions, maintenance, repairs, and modifications as work is performed.

Application of the Guidelines

Examples: Stone Cladding

Thin stone cladding is present on the exterior of many of the buildings, with specific problems observed at the Laird Bell Law Quadrangle and the Laboratory for Astrophysics and Space Research. The spalls and displaced panels on the seminar wing of the law school and similar distress conditions observed on the laboratory building are related to the corrosion of steel members supporting and anchoring the thin stone panels and to unaccommodated thermal movement in the stone.

The thin stone panels on the Laird Bell Law Quadrangle are deteriorated due to corrosion of the steel anchors.

When repairs are implemented to these facades, some techniques appropriate to traditional stone construction may be aesthetically or technically unacceptable for thin stone cladding. For example, for thin limestone veneer panels, repairs with traditional dutchman units may not be appropriate for technical or aesthetic concerns. If the veneer is extremely thin, it may be technically difficult to install a dutchman unit properly, and the presence of a dutchman unit may be considered overly intrusive to the appearance of a thin panel that is designed to be an uninterrupted stone surface. Although it would be desirable to retain as much original fabric as possible, it may be necessary to replace entire panels rather than portions of panels. In contrast to the Law Quadrangle and Laboratory for Astrophysics and Space Research, the Administration Building is constructed with a relatively thick stone cladding in a self-supporting masonry application. Therefore, the use of dutchman repairs to address localized spalling is appropriate if implemented properly, using dutchman units of carefully matched stone type, color, texture, and finish, with very narrow perimeter joints so as to minimize visual obtrusiveness.

Examples: Windows and Curtain Walls

The School of Social Service Administration has experienced glass breakage from corrosion of adjacent steel elements, which is related to condensation on the interior and water infiltration through open joints in the framing and glazing. The use of glass units in steel frames and the associated problem of glass breakage from corrosion of adjacent metal is not unique to this design or to modern buildings of similar design and materials. However, the problem is complicated here because of the large size and extent of the glazing units, and their importance to the design intent and original aesthetic. Any changes to the materials or details of the window frames glazing would affect the appearance of the facades. The curtain wall glazing on the Law Quadrangle Library has been replaced previously with insulating glazing units to provide improved energy efficiency. The similarly extensive curtain wall at the School of Social Service Administration retains its original single glazing, and alteration of these units would likely not be acceptable.

The School of Social Service Administration (Ludwif Mies van der Rohe, 1965) has experienced glass breakage from corrosion of steel elements.

The unusual bi-fold windows at the Administration Building require frequent repairs. Parts are no longer available

Contemporary codes do not allow plate glass of the sizes and thicknesses used in some of the subject buildings. At Hinds Laboratory, this issue has been addressed by replacing the original glass units in the corridors with new glazing subdivided by an additional mullion; this change has not noticeably affected the appearance of the facade. In contrast, such a change at the School of Social Service Administration would dramatically alter a feature of primary architectural significance. Laminated or tempered glass may be required when glass units are replaced.

At the Administration Building, the unusual bi-fold aluminum windows require frequent repair due to breakage of the operating mechanism. The windows are no longer manufactured and the university has considered various options ranging from replacing the windows with new operable units to retrofitting the existing units as fixed units, rather than continuing to repair and maintain the existing window units in operation. These options present different implications for maintaining the design intent and aesthetic of the building facades, and for meeting varying requirements of the university program, building users, and facilities staff.

Examples: Roofing

Unlike existing facade components, many of the roofing systems on the subject buildings are replacement systems and are not original to the buildings. Also, with a few exceptions, the roofing systems are not visible from grade. Therefore the preservation issues are somewhat different for roofing than for other building envelope components, as there is less need to conserve original materials and also less concern about the effect that changes to existing systems will have on the overall architectural character of the building. However, when modifications are made to improve roofing performance, consideration should be given to careful detailing at the roof perimeter so that the result is consistent with the original design intent. Future repairs will provide an opportunity to correct visually obtrusive modifications such as those made at the coping of School for Social Service Administration.

Conclusion

The Preservation Guidelines provide a structure for evaluation, documentation, and care of the contemporary buildings of the university campus. The study report, which could be used as a basis for a historic structure report for each of the subject buildings, is an important tool for preservation, maintenance, and future planning. This work will need to be supplemented by annual inspections and with more frequent monitoring may be required for buildings where significant distress appears to be ongoing. The process of performing and documenting inspections is facilitated by the development of a database to record existing distress, repairs, and changes in conditions since the last inspection.

Ultimately, the best preservation practice is to maintain these buildings as a useful part of the University as classrooms, offices, libraries, and residence halls. Functional demands on these buildings likely will require alterations such as improved handicapped accessibility, increased communications capability, and changes to security needs. While these changes may be necessary for these buildings to remain part of the vibrant life of the university, modifications should be made carefully with respect to both the historic fabric of these buildings and the original architectural intent

Restoration and Rehabilitation of the Zollverein XII Coal Mine Complex: Strategies, Problems, and Perspectives for a World Heritage Site of the Modern Movement

Juliane Pegels

The mining ensemble Zollverein was one of the largest coal mines in the Ruhr area of western Germany. In the 1930s it was praised for its enormous productivity. Although the region's heavy industry suffered from serious crisis and eventually disappeared in the late 1980's, Zollverein survived as a regional landmark; as a well preserved testimony of the industrial past; as a unique cultural center; as an architectural jewel; and, thanks to these qualities, as a World Heritage site. The fact that we praise Zollverein today as an exemplary project is the result of an almost 15-year transformation process. Complex structures in thinking and building had to be changed. Most of all, the public had to learn to acknowledge the industrial past as part of Germany's regional identity; professionals had to learn how to find new uses for old buildings, adapting industrial structures to modern requirements. The experience gained during this process enables us to present a unique project and to share important intellectual, practical and constructive insights.

Zollverein as Miracle of Rationalization

The mining complex Zollverein consists of several sites hosting facilities necessary for mining, refining and processing coal (known popularly as "black gold"). One of the most important structures of the mine was the shaft for lifting the coal from far below and transporting the workers down to their workplaces. Equally important were facilities for processing the coal: coking, heating, and transformation plants; cooling towers; workshops; and a variety of infrastructural elements. All these facilities of the Zollverein complex are spread over several sites in the northeastern part of the city of Essen, directly linked by railways and transportation bridges and connected to the regional railway network.

Among the several pits of Zollverein, whose history as a mine dates back to the 1840's, Shaft XII was the last site to be added to the mine. It began operations in 1932 and shortly afterwards was characterized as "a miracle of rationalization" because of its extraordinary productivity: four times the average output of coal typical for that time. Its daily output of 12,000 tons was as much coal as some older mines had produced annually.

Furthermore, Shaft XII differs from the other pits on the site because of its impressive architecture. All the buildings of Shaft XII are characterized by their own formal language, entirely free of ecclesiastical or feudal elements. This was the accomplishment of two architects, Fritz Schupp and Martin Kremmer, who were commissioned to design a cover for the highly perfected technical facilities of Shaft XII. As still visible today, they created a very integrated and aesthetic whole in terms of urban layout as well as architectural perfection. Committed to the cubic language of Bauhaus architecture, not just in the buildings' skin, a post-and-rail construction with brick infill was perfected. And in order to create a true monument of rationalization, Schupp and Kremmer spent as much attention to the urban design of the mine. In 1929, Schupp referred to the ensemble as a "proud symbol of labor" and a "civic monument every citizen can show visitors with as much pride as he would show the public buildings of the city."

In 1986, Zollverein was one of the last mines to be closed in Essen. Not much later it was put on the city's preservation list as a monument of historic importance. It was valued as a testimony to the area's industrial past, but it also became a monument symbolizing the transience of technical progress: 50 years after it had been praised for its technical perfection, Zollverein became obsolete.

Zollverein's Architecture and Urban Design

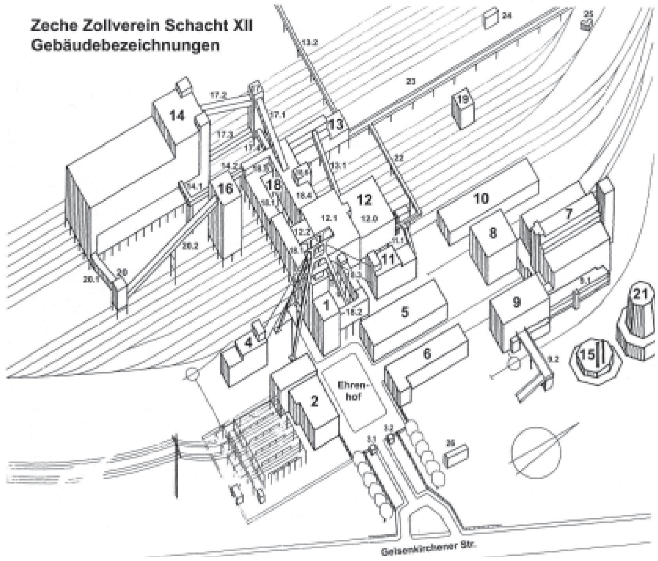
Entering the site of Shaft XII through the main gate, workers then and visitors today are welcomed by an impressive winding tower. This large steel structure with its parallel geometry is by now a well-known symbol of Zollverein. Not only does the height of the tower make the mine a recognizable landmark of Essen's skyline, but its double-legged symmetrical geometry and its visible aesthetic perfection distinguish Zollverein from the large number of other mines in the Ruhr area.

But it is not only the tower that is impressive to visitors. A large central court –"honor court" – flanked by workshop buildings on the north side (Hall 5 and Hall 6) and a switching house on the south side, welcomes entering visitors. This central open space functions as entrée or "stage" for the winding tower and as endpoint to one central axis. Perpendicular to this axis is another axis with the boiler house (Hall 7) and its tall chimney at the end. This second axis was also carefully integrated into the scene. Every effort was made to create an impression of infinite size. The two workshop buildings, the symmetrical layout of the boiler house, and eventually the tall chimney at the axis's end are meticulously arranged.

Even the layout of the lanterns received special attention. Supporting the idea of infinite length, the architects placed the lanterns at intervals of decreasing distance. The closer the lanterns get to the axis's end, the wider they stand apart. This little detail, this optical illusion, exemplifies the perfection of the architects' work.

The architectural details of Zollverein's Shaft XII are as refined as the ensemble's urban design. Three materials dominate: brick, steel and wire glass. The buildings' outer skins consist of a steel post-and-rail framework filled with either brick panels or bands of translucent glass.

The proportions of the outer skin are as reduced as the number of materials. The brick infill panels are horizontal rectangles of approximately 6.0 meters in length and 2.5 meters in height. As standardized modules, they can be found in almost every building. In cases where the panels are not filled with brick, they are further subdivided vertically into steel sash windows measuring approximately 0.6 by 2.5 meters. The load bearing structures of the buildings are similarly standardized, although it is not visible from the outside. With few exceptions, all buildings consist of a skeleton structure of steel portal frames rising to the full height of each building. Floors and roofs are made of steel beam constructions with concrete cappings.



Axonometric drawing of the Shaft XII site.

Today, more than 70 years after Zollverein's construction, Shaft XII is still admired for its architectural qualities. An industrial ensemble that was only meant to last 30 to 40 years – as short as the expected technical life of the mine – Zollverein is now undergoing a comprehensive process of renovation and rehabilitation. While the neutral character of the primary skeleton structure is ideal for integrating new uses, the facade construction has suffered substantially from weathering and other harmful influences. The task of renovating a historic curtain wall that was not designed to last longer than 30 to 40 years constitutes one of the largest challenges.

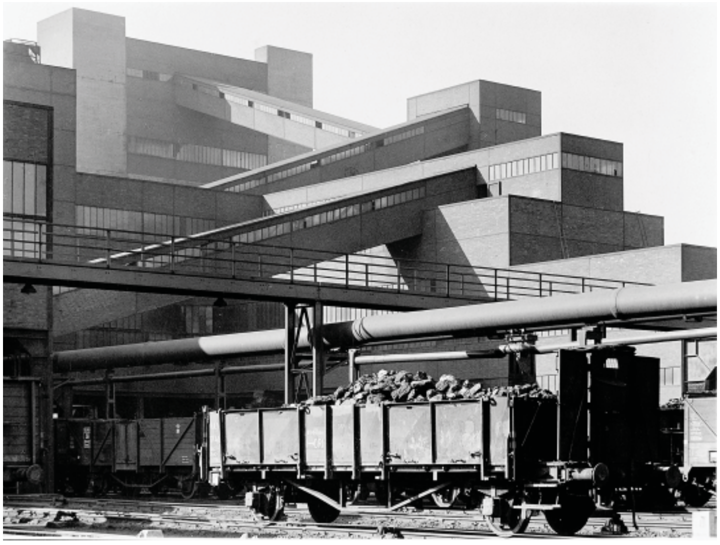
Detail of renovated curtain wall.

Enabling Zollverein to Survive

In 1989, three years after mining operations ceased at Zollverein, the architects Heinrich Boell and Hans Krabel were commissioned by North-Rhine Westfalia's development company LEG as trustee of the federal state and the city of Essen, to renovate Shaft XII. It was a difficult task to rehabilitate such an architectural jewel and to adapt this industrial architecture to new uses and the requirements of today's society. These architects described their job as an unusual challenge since they had to subordinate themselves, to listen to historic preservationists, and to draw conclusions from the existing structures, all while expressing contemporary architectural thoughts. Before being commissioned for the Zollverein project, Boell and Krabel had gained experience in similar, though smaller, projects, where, as Krabel describes it, they learned not to reconstruct, but to "enable the existing to function again, to make the ruinous usable, and to help fallow land become urban or natural landscape,".

The idea to rehabilitate and renovate industrial sites was a product of, and happened in the context and the "zeitgeist" of the International Building Exhibition Emscher Park (IBA). This German building exhibition was unlike most of its predecessors in that it was not meant to focus on new and single buildings. The IBA Emscher Park was a ten-year program focusing on restructuring and revitalizing a 70-kilometer-long industrial region along the river Emscher. The building exhibition's projects varied from the reuse of sewage plants and gas tanks to the preservation of railway stations and miners' housing estates, and from the conversion of coal mines and steelworks to the promotion of new workplaces and business centers. In summary, the IBA Emscher Park focused on the urban, ecological and economic renewal of a heavily industrialized region. When the IBA finished its work in 1999, the list of projects and visible signs of change was impressively long. But the changes in perceiving, understanding and appreciating remnants of the industrial past as cultural assets was even more striking.

Rehabilitating the coal mine complex Zollverein was one of the most important projects of the IBA program. As the main site for the IBA's final presentation in 1999, Zollverein presented itself as a forum for industrial culture, providing a wide range of facilities including a center for visual arts, theater and music; institutes for media and research; restaurants and rooms for social events; a museum of industry; and North-Rhine Westphalia's Center for Design. When the IBA started its work in 1989, it was clear that within a ten-year period the region's change could only be stimulated by the work. Zollverein proved exactly that: It changed substantially over the ten years even though the ensemble was not yet completely rehabilitated.
In 2001, an important next step towards developing an environmentally and economically sustainable concept for Zollverein was made by the Office



Hall 12, Hall 18 and the coal washery seen from the north side, 1930s.

of Metropolitan Architecture in Rotterdam. Its master plan suggested bringing design-oriented, productive life back to Zollverein. The Zollverein School of Design and Management, the design-oriented business park DesignStadtZollverein, the Entry-Exhibition and the Ruhrmuseum are some attractions planned to enliven the site.

Parallel to this effort, North-Rhine Westphalia's Ministry of Urban Development and Housing, Culture and Sports worked on an application to UNESCO (United Nations Educational, Scientific and Cultural Organization) to list the "cultural industrial landscape of Zollverein" as a World Heritage monument. As the title indicates, it was not only the buildings of Shaft XII designed by Schupp and Kremmer that were considered to be of special value. All features and infrastructurel elements of the entire mining ensemble, dating to 1847 – all shafts, the coking plant, the slack heaps, the adjacent open spaces, the surrounding neighborhood with its historic housing estates, and social facilities – were recognized and put under special protection. The intention was to preserve and foster the characteristic features of Zollverein, which presented the rise and fall of traditional heavy industry from its beginnings in the middle of the 19th century to its decline in the first half of the 20th century. Shaft XII was recognized as an exceptional embodiment of Modern Movement design principles applied in an entirely industrial context. The region surrounding Zollverein is considered a significant cultural landscape because of the workers' housing complexes, villas, churches, and public buildings associated with the rise of the coal mining industry.

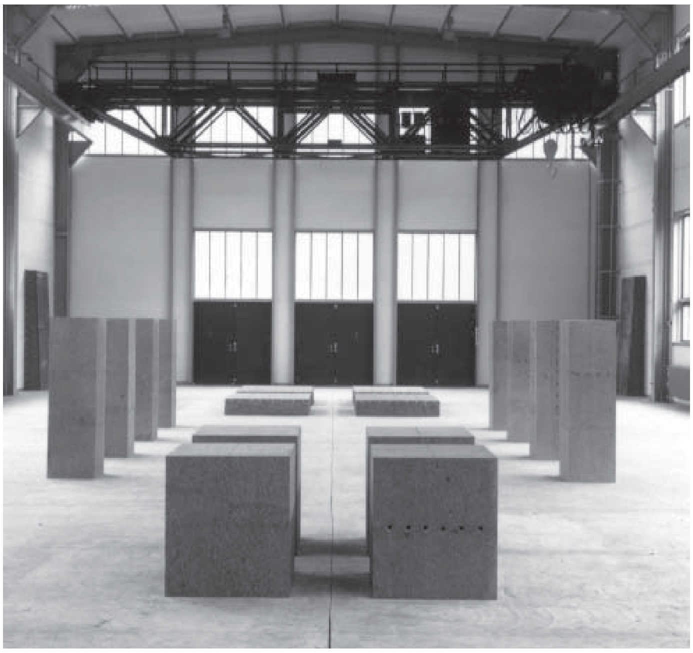
Since 1998, every effort has been made to keep the special character of the mine alive, and to enrich the ensemble with new developments in the fields of culture, cultural identity, design, entertainment and tourism. For example, railway tracks between Zollverein and other industrial sites have been converted to bicycle paths. Until 2010, the Ministry of Urban Development and Housing, Cultural and Sports application committee plans to secure the status and to extend the activities in order to foster Zollverein as a platform for design-oriented activities, as a background for a world design exhibition and as a site for a museum of industrial culture. Next to measures that specified uses for various buildings, the committee detailed a management plan and a management agency that would coordinate all activities. Zollverein is currently managed by two non-profit organizations, the Zollverein Cultural Heritage Foundation and the Industrial Monument Maintenance Foundation. According to the World Heritage nomination report, a "Craftsmen's Guild" has been organized by the town of Essen whose responsibility is to perform ongoing maintenance on industrial structures and to offer training in conservation techniques and practices. In 2002, UNESCO declared "the cultural industrial landscape of Zollverein" a World Heritage site.

Zollverein as World Heritage Site

For Boell and Krabel, UNESCO's decision was a signal to continue the rehabilitation strategy for the ensemble that they had followed so far. They maintained their circumspect approach that avoided all sense of competing with the existing architecture; they kept up their effort to apply simple solutions wherever feasible; and they continued to design while reflecting and respecting the significance of the location. Although these general guidelines and intentions were pursued, each building and every situation required very individual and detailed solutions. The following examples exemplify different solutions.

Hall 5 - From Central Workshop to Exhibition Space

The renovation and conversion of the central workshop into an exhibition hall shows one approach in adapting the historic structure to modern use requirements. The portal steel frames of the load-bearing structure needed only rustproof coating. But the workshop's outer skin required substantial renovation. Since the existing steel post-and-rail framework of the curtain wall had suffered from intruding rainwater, it was corroded heavily, and the curtain wall had lost its stability. One method to repair this damage would have been to dismantle the facade to the bare skeleton and to replace the corroded parts. However, Boell and Krabel applied another method. Instead of dismantling completely, they retained the original steel structure with its brick infill panels and its bands of wire glass, added a completely new corset structure of auxiliary rails from the inside, and anchored to it the existing post-and-rail-framework with its brick infill. It was, however, necessary to renew the existing post-and-rail structure near openings such as windows and doors; this was done by replacing single pieces and applying a rustproof coating.



Interior of Hall 5 today.

As a result of these actions, the outer skin regained stability and was able once again to resist the pressure and suction forces. The applied method of renovating did not interfere with the appearance of the historic curtain wall, and it also helped to avoid stripping and recoating the post-and-rail construction completely, which ultimately would have involved dismantling the facade to the bare skeleton. From the inside, the spaces between the auxiliary rails were filled with vertically perforated bricks with a plaster finish.

Due to this minimal intervention, the interior of the hall retained its austere industrial character, but was sufficiently updated to facilitate the change from workshop to exhibition space, both uses demanding rather similar thermal and acoustic conditions.

Hall 6 - From Electrical Workshop to Exhibition and Office Space

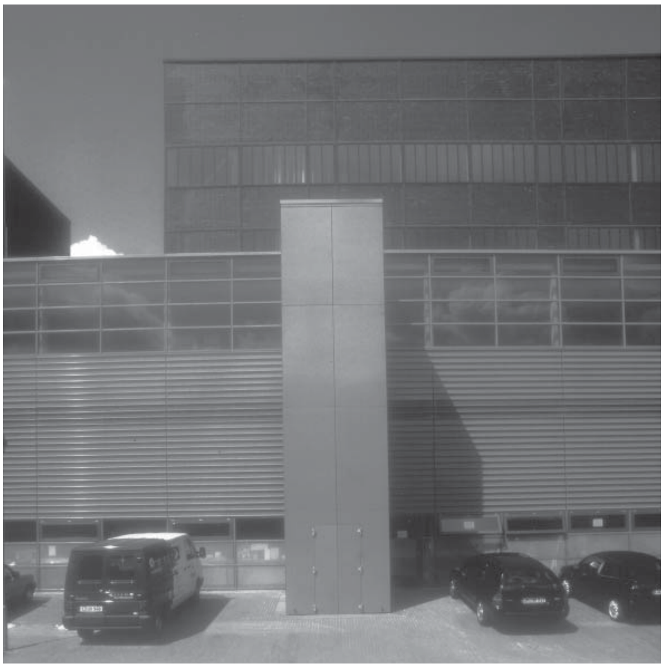
Similar to the method applied in the central workshop (Hall 5), the electrical workshop underwent only a few changes. The electrical workshop needed to be adapted to the new climatic needs and the fire protection requirements of an exhibition and office space. The outer skin underwent some cleaning and repair work and the curtain wall regained its stability with the introduction of the same auxiliary corset structure from the inside as with Hall 5. Since the new use required better thermal insulation, an existing pumice-concrete inner skin was removed and replaced with a better-insulating plaster wall construction. The use as exhibition and office space also required additional interior partitioning walls. Here again, the existing original structures were updated and only in some cases supplemented according to the new needs.

Hall 10 - From Storage Building to Workshop and Office Space

Hall 10 shows another approach of rehabilitation. According to the 'house within a house' principle, an independent structure was built inside the Hall. The new use as office space required thermal requirements that would have been very expensive if the historic structure were to be updated. Therefore Boell and Krabel constructed an independent, self-sufficient "inner house," which benefited from the protection of the surrounding hall. Again, in this building the genuine structure of Zollverein was not altered. The Hall's outer appearance remained untouched, while the Hall was adapted for a new use.

Hall 9 - From Compressor Hall to Restaurant

Another approach to the rehabilitation retained important internal structures, fixtures and machines. In Hall 9, massive reinforced concrete



Kitchen added to Hall 9.

Link between Hall and Office Area, Hall 10.

New entrance to Hall 9.

supports for air compressors were preserved. The retention of these giant structures did not create any drawbacks; rather, the columns help to subdivide the restaurant space into well-proportioned partitions, each fitting a pleasant number of seats. In addition, the concrete's rough surface adds to the special interior atmosphere of the location.

On the outside, Hall 9 needed an extension to house the restaurant's kitchen. Consistent with the overall approach requiring that all extensions and new work remain visible, as such, the kitchen building was fit into the structural rhythm of Zollverein's architecture. It adopts the formal language of the historic ensemble with its clear-cut cubic forms, but it also remains clearly distinguishable in material and orientation. Limited to two materials (aluminum panels instead of brick, and glass instead of wire glass), it presents a contemporary interpretation of Schupp and Kremmer's original ideas.

Hall 12 - From Tipper and Sorting Hall to Assembly Space and Workshops

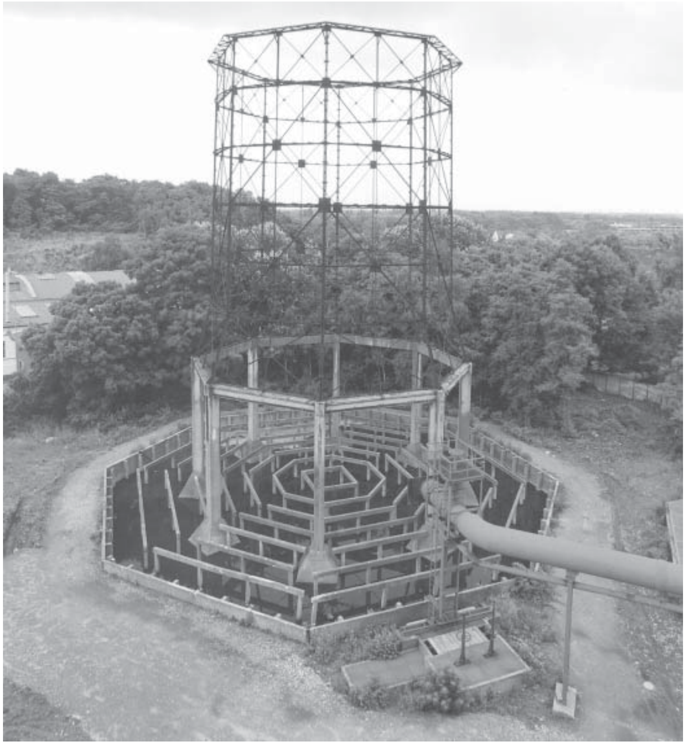
Substantial alterations had to be made to Hall 12. Functioning originally as a bridging structure with tracks on the ground floor, it allowed railway wagons to enter to be loaded with coal from above. To reuse this open ground floor, its front elevation had to be glazed. The horizontal orientation of the new glass panels contrasts with the typical vertical bands of wire glass.

The former railway tracks suggested the idea of preserving public access to the building. Therefore the railway tracks were converted into a sidewalk that leads into the building and functions as a lobby to workshops, offices and a multi-purpose hall on the upper floor. Upstairs, where 900 square meters of space were converted into an assembly room, the historic fixtures of the tipper and sorting machines were preserved and remain visible behind a glass wall, giving testimony of the building's original function.

Hall 12 Concert space.

From Cooling Towers to Heating Plant and Media Institute

Following the idea that, if new buildings were added or new uses integrated, this was to be done with very careful regard to the historic context, the water basin of one of the two old cooling towers was converted into Zollverein's new heating plant. The original steel structure of the cooling towers had been destroyed, and only the foundations of these impressive towers were intact when Boell and Krabel started their work. Since the towers and their outline were an important part of the ensemble, the architects decided to reconstruct them. They replaced the old water basin structure with a finely detailed steel construction to hold the ensemble's heating plant. The neighboring tower was rebuilt completely. For the new use, office space for a media institute, it was not enough to reconstruct the water basin, but the upper tower part had to be restored as well.



Remnants of cooling tower.

Hall 14 - From Coal Washery to Museum

The largest building and probably largest challenge in rehabilitating Zollverein is Hall 14, the former coal washery. This building differs tremendously in size and also in construction from the other buildings of the ensemble. Due to the complexity of the coal washing and sorting process, the coal washery is equipped with heavy fixtures and machinery. This made another bearing structure necessary, as seen in most of the renovated halls. Reinforced concrete elements were required, alternating with a steel and brick construction.

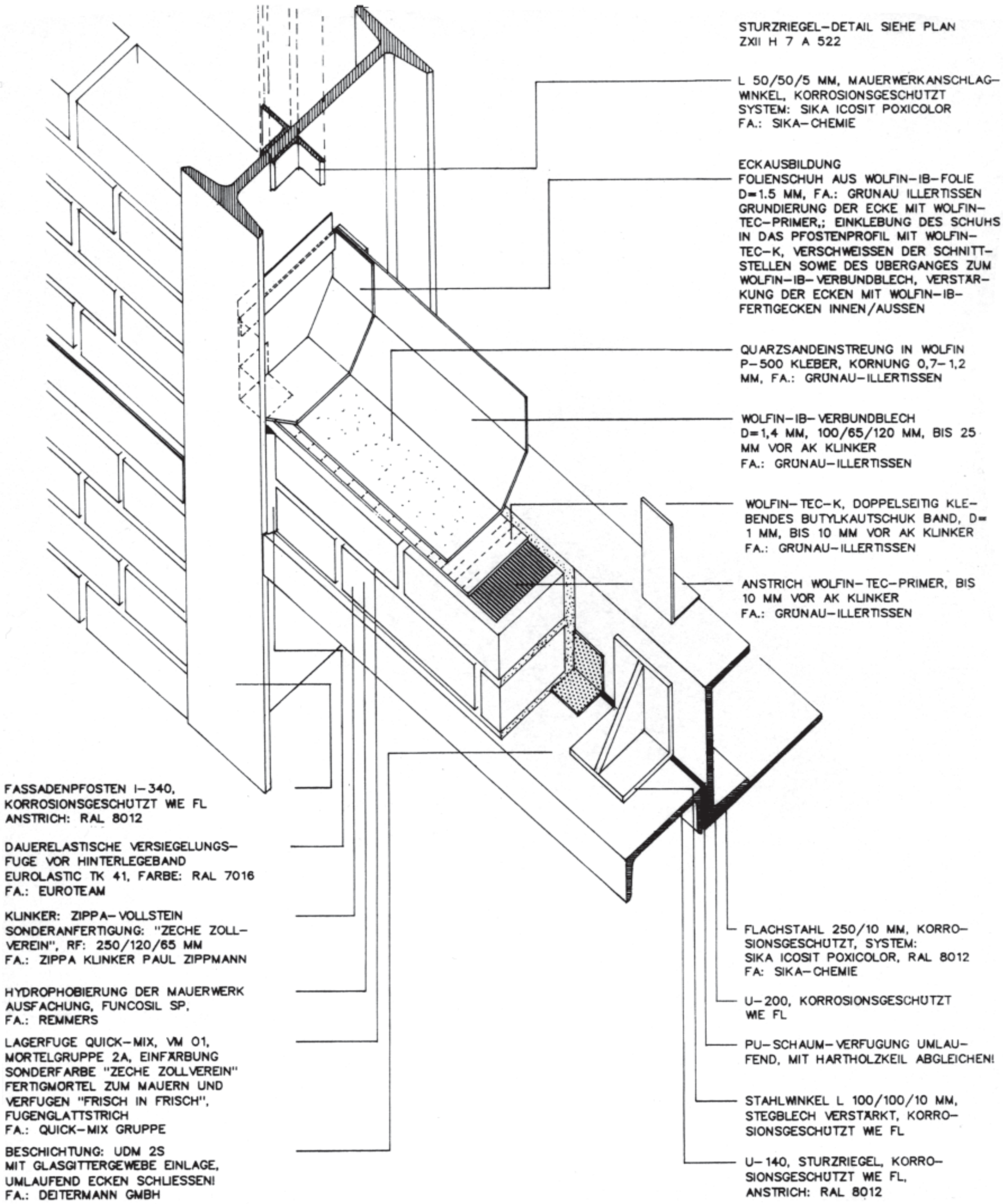
The different character of the coal washery can be seen readily from far. It can also be seen that Hall 14 was probably one of the largest challenges in rehabilitating Zollverein. Its sheer size and accordingly the cost of renovation, its complex inner life and accordingly the difficult task of integrating new uses while preserving historic functions and leaving coal refinement processes visible, combined with the advanced decay of its façade, all contributed to the decision that this building would remain one of the last to be renovated. The work started in 2004. In 2006 an interim condition was achieved and the Entry exhibition invited the public into the building. It drew a large number of visitors who were curious about the exhibition, but probably an even larger number was attracted by the opportunity to see the coal washery in its new guise. In the beginning of 2007, final construction began to change the coal washery into its eventual new use: The Ruhrmuseum, a museum for and about the region, is expected to open in late fall of 2008.

Details of Reconstruction

As described earlier, the bearing structure of most of the Zollverein's buildings consists of steel portal frames to which a curtain wall is attached. This consists of a steel post-and-rail framework with brick panel infill and bands of wire glass. Bricks and bands of flat steel that are not designed to hold the curtain wall's weight are also visible from the outside. As the detail section reveals, an U-shaped beam holds the panels. Since these beams were exposed to intruding rainwater, they corroded heavily, lost their stability and subsequently the entire facade suffers from being exposed to unexpected loads.

To repair this damage, Boell and Krabel decided to fix the decaying construction of the curtain wall while leaving its original components in place. They renovated the corroded beams, added layers of moisture protection, and sandblasted and replaced bricks from the outside. As described earlier, they also inserted an auxiliary corset structure of steel rails from the inside. Mounted between the portal frames, this structure took over the load-bearing function of the curtain wall. The curtain wall retained its original function only near windows and other openings.

Later on, the architects refined their method and started to reconstruct the curtain wall differently: They made a more waterproof construction possible



Improved wall detail with turned U-beam Restoration.

by rotating the inner horizontal beams of the curtain wall. As seen in the detail section, parts of the facade were dismantled, one U-beam was replaced by a C-beam and the existing C-beam was rotated 180 degrees. Thus the brick panels sit squarely on top of the beam and water can no longer penetrate. An additional layer of water protection was added in the form of a metal sheet that deflects any intruding water away from the bricks. Again, the outside appearance of the curtain wall remained the same; however the inner construction was optimized.

This reconstruction detail exemplifies how the long process of renovation and rehabilitation created valuable insights and helped in developing solutions to very site-specific problems. The challenge faced by architects Heinrich Boell and Hans Krabel was to develop very careful renovation strategies that would preserve the unique character of a world heritage monument, and at the same time enable it to become a lively and highly frequented site. This delicate balance was successfully achieved. Zollverein is a worldwide-respected and well-used historic monument of the industrial past. It is probably the most visible and appreciated symbol of the Ruhr area's transformation from a heavily industrialized area to an attractive region of industrial culture.

Notes

All images are courtesy of Architekturbüro Böll, Essen, Germany.

The 20th Century Metal and Glass Curtain Wall

More than any other architectural feature or building technology, curtain walls are seen as synonymous with modern architecture. While considered a quintessential element of the post WWII high rise, the development of the necessary technology took place over decades and is not just limited to the postwar period or a particular geography. Its preservation presents a series of unique challenges both technically and philosophically. Materials, once ubiquitous and hailed as experimental, innovative or the ultimate answer, are no longer available or suitable, The performance or visual characteristics of the replacement materials or alternatives are quite different, glass being an excellent case in point as demonstrated by some of the case studies. On a systems level some of the early examples were quite rudimentary and the technical and performance implications were not yet fully understood. Contemporary experience and analysis and testing techniques allow for many of these issues to be understood and resolved. However, repairing and replacing those early curtain wall systems raises not only questions of technology but also questions of scale and authenticity.

The breath of these fundamental issues is reflected in the papers. Ranging from an overview of curtain wall history and a separate time line showing technology advances chronologically to a discussion of investigation, assessment and repair technologies. Many of these issues are addressed more specifically in the various case studies of projects that include the United Nations Building in New York, the Johnson Wax Building by Frank Lloyd Wright in Racine, Wisconsin to the Zonnestraal sanatorium and the Van Nelle Factory in The Netherlands.

Comparing the Preservation of the 1920s Metal and Glass Curtain Walls of the Sanatorium 'Zonnestraal' (1928-31) and the Van Nelle Factories (1928-31)

Wessel de Jonge

Advanced building technologies that became available in the early 20th century were embraced by the architects of the Modern Movement to respond to functional demands as well as to achieve an abstract imagery. But their acknowledgment of the link between the design, the technical lifespan of a building, and user requirements over time ultimately led to an architecture that is either transitory or adaptable.

Duiker's Sanatorium 'Zonnestraal' of 1931 is a stunning example of the latter reasoning, as it was tailored around a specific functional program with a planned lifespan of only 30 years. The 1930 Van Nelle factory, on the other hand, involved neutrally planned spaces that have allowed for a series of functional changes over the last 75 years. Both buildings have recently been restored by the author and show great differences regarding their suitability for adaptive re-use. This paper explores how in both cases the original architectural concepts lead us to different preservation strategies.

As both buildings feature emblematic and prototypical steel and glass curtain walls of the 1920s, the challenges attached to their preservation will be elaborated. In both buildings, upgrading in terms of building physics was required, but very different solutions have been adopted, retaining the original facades to various extents. Special attention will be given to the key roles of glass types and sealants, and the physical performance of their rehabilitated envelope in relation to climatization issues.

The concept of the curtain wall largely originates in the US and was introduced to the Old World in the early part of the 20th Century. Early European applications concern mostly industrial buildings, where production efficiency benefited from the almost unobstructed entry of daylight and easy ventilation. Starting in the 1910's, avant-garde architects in Europe proposed a similar, rational solution for glazing to other building types.

The Deutscher Werkbund in Germany advocated rational and efficient planning of both workplace and dwelling. The 1914 Werkbund Pavilion in Cologne, designed by Walter Gropius and Adolf Meyer, featured fully glazed facades, that could be regarded as European prototypes of curtain wall technology for non-industrial buildings and which as an exhibition pavilion was influential in promoting new building technologies. Gropius' design for the Fagus Factory in Alfeld-an-der-Leine is more or less contemporary with the pavilion and includes similar elements, and his 1925-1926 design for the new Bauhaus in Dessau featured a fully glazed workshop wing, which formed a subsequent milestone in the development of curtain wall architecture. More examples in other European countries demonstrate that the pragmatic guidelines for industrial buildings, as developed by American engineers, now became conceptual principles for a small group of progressive European architects. By eliminating the load bearing function from the exterior wall, daylight and fresh air was able to enter wherever desired. This became one of the guiding principles for the 'five points' identified by Le Corbusier in his l'Architecture vivante of 1927.

In the Netherlands some modern architects were also eager to take advantage of the great potential of curtain wall constructions. Structural engineer Jan Gerko Wiebenga (1886-1974) was a key figure in introducing this building technology, which would soon allow the architects of the Modern Movement to materialize their conceptual ideals. With architect Van der Vlugt (1894-1936) he designed the remarkably modern new Vocational School (Middelbare Technische & Ambachts School) in Groningen as early as 1922, featuring a load-bearing concrete frame with non-structural partitions and horizontal ribbon windows, placed on a brick spandrel, to allow for future functional adaptability and flexibility.[1] It was still five years before Le Corbusier canonised the free plan with his 'five points for new architecture'[2], providing a theoretical basis for the architectural avant-garde of the Modern Movement.

Transitory or Adaptable?

The architecture of the Modern Movement is strongly rooted in the cultural, social and technological developments of the Industrial Revolution, when the building tradition underwent unprecedented changes. Industrialisation and urbanisation triggered a demand for new building types. The functional programs for buildings became increasingly diverse and specific and, as a result, more short-lived. New materials and construction technologies allowed engineers and architects to fulfil these needs to an ever growing extent.

In the 1910's and 1920s, architects acknowledged a direct link between the design, the technical lifespan of a building and user requirements over time. As the time span for use changed as well, time and temporality ultimately became important issues in architectural theory. Consequently, this led either to an architecture that was temporal or one that could be adapted. The consequences of these ideas when translated into practice produced the specific architecture of the Modern Movement, of which both the Van Nelle Factories in Rotterdam, and Sanatorium 'Zonnestraal' in Hilversum are stunning examples.

Ruled by the principle of utmost functionality, coined 'spiritual economy' by leading Modern Movement architect Jan Duiker[3], a rigorous distinction was made between load bearing structures and infills to allow for maximum functional flexibility. Light and transparent materials in the facade ensured the unhampered access of daylight and fresh air. Related to the idea of different and flexible life spans was the introduction of prefabrication for building components, allowing for the easy replacement of deteriorated parts and future adaptations responding to functional changes. At the same time, these buildings were designed with extreme sensitivity concerning building science.

Sanatorium Zonnestraal after restoration in 2003. (Photo: Sybolt Voeten)

Zonnestraal Sanatorium, Hilversum
(Duiker, Bijvoet and Wiebenga, 1926-1931)

Designed between 1926-1928 by Jan Duiker (1890-1935) and his associates, sanatorium 'Zonnestraal' is probably one of the most clear cut demonstrations of the avant-garde philosophy of the Modern Movement in architecture. Duiker advocated an architecture that would be the result of reason rather than style, and he attributed great importance to the connection between form, function, material, economy and time. Clearly, he regarded buildings as utilities with a limited lifespan by definition and occasionally even as 'throw-aways'. According to some of his writings, he promoted the idea that whenever a building's purpose had to change, the form would loose its right to exist and the building must be either adapted or demolished altogether.

Based on a solid belief in Science and Progress, the sanatorium buildings were established in the conviction that tuberculosis would be exterminated within thirty to fifty years.[4] He managed to subtly balance user requirements and technical lifespan with the limited budget of the client, creating structures of breathtaking beauty and great fragility at the same time. Hence, we are faced with the conservation of structures that were intended to be transitory.

The buildings seem to evoke a striking demonstration of Behne's original definition of 'functionalism' of 1923, as opposed to 'rationalism'[5], organically producing a tailor-made suit. In 'Zonnestraal's' main building each room has particular dimensions, and even the height of the parapet varies for visibility and privacy according to the use of the space concerned. The specificity of this architectural solution went hand in hand with the short functional life expectancy.

Industrial Technology

The extensive research performed since 1983 in preparation to the projects, showed that 'Zonnestraal' had been a testing ground for new and experimental building technologies.[6] While conceptually aimed at industrial mass production and the dry assemblage of prefabricated building parts, most of the work implemented in the main building still involved hand-made prototypes, with all the related problems and failures. Remarkably, Duiker had the opportunity to improve some of the technologies applied in the main building and first pavilion of 1928, when completing the second pavilion three years later.

Also in the materialisation of the sanatorium buildings Duiker demonstrated a remarkably profound understanding of how to balance the technical lifespan with the requirements and the scarce resources of the client. By using cheaper non-galvanised steel windows he limited the technical lifespan of the buildings, though they would surely last for the expected functional lifespan of thirty years. Moreover, as part of their labor therapy, it was the intention to have the patients paint the steelwork regularly, thus reducing maintenance costs.

The buildings feature an extremely light reinforced concrete structural frame, and are almost like a functional program enclosed by a steel, glass and plaster envelope. The main building of 1928 involved a prototypical curtain wall, consisting of individual window units made of 25 mm (one inch) deep steel profiles, mounted against steel posts that ran between the floors. By not allowing any dimensional tolerance in the joint between the individual window units gave rise to immediate problems in controlling the overall dimensions. Also, the shallow profiles caused the 1.50 m (five feet) wide top hung casements to be too unstable and too flexible resulting in early glass breakage.

When the third building, a second pavilion, was finalized in 1931 Duiker avoided these shortcomings by selecting stronger deeper steel sections, a larger measure of dimensional tolerance and introducing side hung and smaller casements. Another example of improvements made were the spandrel panels for the 1931 pavilion, involving the first prefab 'concrete' building parts known to be used in Holland in contrast to the 1928 buildings that still featured a parapet of plastered mesh.

These developments in curtain wall and spandrel constructions make the sanatorium complex a unique witness to the rapid developments in building technology in the second half of the 1920s. In Europe, these were halted by the economic depression and the subsequent outbreak of the Second World War, and did not re-emerge till the start of the building boom of the post-war reconstruction.

Restoration

The restoration of 'Zonnestraal' was the result of a collaboration between Hubert-Jan Henket architects and our office. Our approach for the rehabilitation of the first of the sanatorium buildings has been inspired by Duiker's original design, which did provide us with clear guidelines for the project. In a way, the 'functionalist' principles in which the sanatorium buildings originate, and Duiker's search for new and specific technical solutions and materials, have caused us to attach greater value to the authenticity of the very materials than has been the case at the Van Nelle restoration discussed further below. Also, it has required more craftsmanship than anticipated.

There has been little conservation or restoration of authentic materials except for the concrete structural frame and a few partitions, while the salvaged original parts of one facade were moved to another position and reassembled there: as the original profiles could not accommodate double glazing, the salvaged parts were moved to a corridor zone. Some lost parts have been carefully reconstructed at high cost such as the steel window casements, the sheet glass and some finishes like the linoleum and terrazzo floorings. Some components like window hardware may have been industrially produced in the 1920s but have since been taken out of production and had to be hand crafted for the restoration.

Apart from the small salvaged section, the facades have been built up from new, steel frame window units. As the shallow 25 mm (one inch) deep cross sections of the original casements could not accommodate the increased thickness of insulated glass and the initial stability problems had to be avoided, the new units have been made of slightly heavier 32/37 mm deep sections (1 ¼ inch for fixed lights to 1 ½ inch for vents), similar to the 'improved version' of 40 mm deep (1 5/8 inch) that Duiker used himself in the 1931 pavilion. The facade was redesigned into a series of individual casements, fixed against the vertical posts with a minimal dimensional tolerance of 3 mm (3/16 inch) in between.

Glass

Given the great historic and architectural qualities of the transparent enclosure of the building, it required serious efforts to find types of glass that would be truthful to the perception of the original. Predating the invention of float glass[7], the drawn sheet glass as used for 'Zonnestraal' was slightly warped, producing vertical distortions, which was essential to the vision and reflection qualities of the state-of-the-art curtain wall of 1928.

Carefully reconstructed parts such as the steel window casements, the sheet glass and the linoleum floorings. (Photo: Jannes Linders)

Low-iron colorless sheet glass similar to that of the 1920s could only be found at reasonable cost in the new member states of the European Union and was imported from Lithuania.[8]

Single pane glass was used again in spaces that did not require careful climatization, such as circulation spaces. For the workspaces, single pane glass was not acceptable and a sophisticated solution for insulated glass was designed to meet the required conditions. Recent developments in UV-proof adhesive technology allowed the slightly warped Lithuanian drawn glass to be joined with a colorless float glass inner pane, using a specially produced, neutral gray U-PVC spacer. The 11 mm (7/16 inch) thick double glazing units could be accommodated in the steel sections of the new window units. The increased depth of 32 mm (1 ¼ inch) of the steel window sections allowed for a putty bead of the same size and profile as found in the original single glazed section of the facade.

Van Nelle Factories, Rotterdam
(Brinkman & Van der Vlugt, 1925-1931)

In contrast to 'Zonnestraal', the factories for the Van Nelle company seem to evoke a striking demonstration of Behne's definition of 'rationalism', providing large quantities of flexible space to accommodate functions that were anticipated to vary greatly over time. The a-specifity of the factory halls suggested a long functional lifespan and motivated a long technical life expectancy.

Again, the factory layout is ruled by the doctrine of "spiritual economy", which involved the efficient employment of material properties and structural capacities, of scientific and technological developments, and of human resources, pairing

The Van Nelle Factories after restoration in 2004. (Photo: Fas Keuzenkamp)

social responsibility with functional criteria. The architects adhered to the idea that daylight, fresh air, free space and greenery were preconditions for a healthy existence.

These social aspirations blended well with the commercial considerations of the client - Taylorism and efficiency - as well as with his spiritual inspiration - Theosophy, in which daylight has a particular meaning.

Studies had been performed that concluded that the width of the floor of about 19 m (16 feet and 4 inches) would ensure the incidence of sufficient daylight. This explains the linear lay-out of the floor scheme of the factories proper. The large glass fronts that were created as a consequence were also intended to serve the firm's corporate identity as a modern company.

Facades

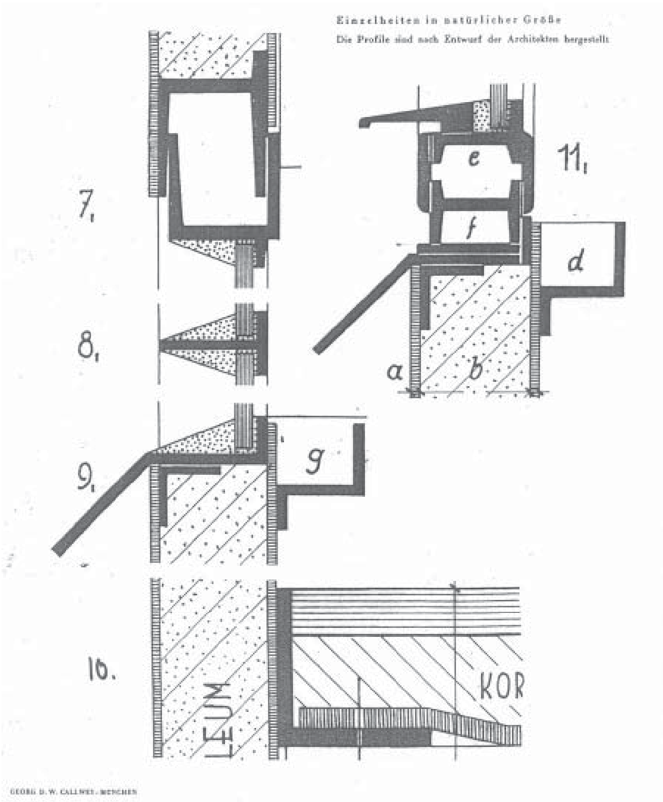
The factory buildings are constructed with a concrete frame of mushroom columns and beamless floor slabs. By placing the columns off the perimeter of the floor slabs, the curtain wall can run smoothly and continuously over the full height of the buildings.

After earlier variations inspired by the 1926 Bauhaus buildings in Dessau and which included parapets of stuccoed brick, eventually the curtain wall design developed into a highly original prototype of modern and efficient facade technology.

Self supportive storey-high facade units of steel span from floor to floor. Between standard steel sections, produced in Holland under license of the British firm Crittall Windows[9], steel sheets have been welded to create a spandrel. The spandrel panels were insulated with impregnated peat. The facade units were first sprayed with molten zinc and finished with aluminium paint.

The proportioning of the facade fronts is entirely based on the standard size of glass panes as they were used in Holland's greenhouses, which were therefore cheap and readily available. American sunshades made of aluminium painted wooden slats controlled solar heat gain. The apparent simplicity of the details demonstrates the idea of immaterialisation, producing a universal aesthetic.

In the late 1980's and early 1990's, the facades of the factory buildings underwent a first refurbishment. Due to the quite exceptional level of maintenance performed until that time, the condition of the original facade elements needed minimal



After earlier variations inspired by the 1926 Bauhaus buildings in Dessau, eventually the curtain wall design developed into a highly original prototype of modern and efficient facade technology.
(From "Der Baumeister", vol. 29, no.4 ,1931.)

repair, involving grit blasting and repainting.

Restoration

In 1998, the 60.000 m2 (c. 646,000 square feet) buildings have been acquired by a property developer to convert them into a business centre for the creative industry. A master plan for the Van Nelle Design Factory was prepared by our office and we also performed the design review on the projects carried out by various other design teams engaged in the restoration of the various buildings.[10]

Again, the design approach of the original architects – however different from that for Zonnestraal – inspired our vision on the revitalisation of the factory buildings. In contrast to the 'craftsmanship' approach for Zonnestraal inspired by the functionalist' principles of the original architects, the rationalist' approach of the Van Nelle architects allowed for a restoration that has been of a more conceptual nature, aimed at the manageability of change rather than the material aspects of the very buildings.

The outside of the buildings has been carefully kept intact by large-scale maintenance and repair of glass breakage with colorless drawn sheet glass imported from the Czech Republic, as still used in Dutch greenhouse construction. Within this authentic envelope an infill has been realised in order to secure proper indoor conditions.

Secondary Glazing

In order to create appropriate conditions for the workspaces the principle of a double facade was proposed by project architects Claessens Erdmann from Amsterdam, introducing secondary glazing on the inside. Before the proposed solution was finally approved, extensive mock up tests were performed to minimize the effects of double reflections.

At the shadow-side, the secondary glazing is located at some distance from the original facade leaving enough space for corridors. At the other side, the sun side, the glazing has been placed between the columns, corresponding with the position of the original sunshades, creating a climate-regulating wall. Solar heat gain is caught in between, as is the noise from the nearby railway. Natural air is supplied through the automated windows in the facade, through the climate-regulating wall and sound insulated inlets in the secondary glazing, to enter the work spaces where a mechanical exhaust system creates a slight vacuum. Like in the past, all ventilation ducts, piping, and data systems are accommodated in the zone between the columns and the facade, and further distributed through the topping on the concrete floors.

The impact of this intervention on the exterior has been carefully considered, even including the effect of the new lighting fixtures. As the original suspended opaque balloon light fixtures had all been lost and would have created glare in

At the shadow-side, the secondary glazing is located at some distance from the original facade leaving enough space for corridors. At the other side, the sun side, the glazing has been placed between the columns, corresponding with the position of the original sunshades, creating a climate-regulating wall. (Photo: Fas Keuzenkamp)

In order to create appropriate workspaces the principle of a double facade was proposed by the project architects. Like in the 1920's, the interiors benefit from daylight and transparency of the buildings. (Photo: Sybolt Voeten)

the monitor screens, a standard fluorescent lighting fixture produced by Zumtobel has been modified so as to recreate the original lighting conditions without compromising their performance in terms of contemporary use, as the potential tenants accepted a general light level of 200 lux. Some salvaged (but not original) opaque balloons, sufficed for the corridors and the staircases.

In order to keep the strong image of the building intact for the benefit of all tenants, design guidelines were prepared dealing with some aspects of the interior fittings and the locations of taller pieces of furniture. However, the attraction of this powerful 'machine' excites enough enthusiasm with the tenants to compensate for these restrictions.

Conclusions

In view of the underlying philosophy and the limited functional lifespan of many Modern Movement buildings, many building materials used in such structures may be short lived. As the authenticity of materials is therefore more often difficult to maintain, a glib argument for ignoring the material aspects of these modern prototypes seems therefore to be at hand. The restoration of 'Zonnestraal' taught us that such an excuse can easily be erroneous, and that the material authenticity of the restored building helps us understand what to us may appear as the anachronisms of the era.

Although the Van Nelle buildings appear as stout and robust, primarily due to their immense scale, in fact also these glass-enclosed volumes are fragile. Like soap-bubbles, they may burst as soon as the balance between content and surface tension is disturbed. The authentic skin of the buildings is characterized by the absence of material rather than the presence of it. And if there is only minimal material, it is almost impossible to change or add anything without disturbing the essence of the existing, authentic materialization. Hence, the strategy of the secondary facade allowed the essential characteristics of the buildings to be respected.

Observing the obvious differences between both projects, we realised how the contrasting visions in the 1920s to respond to short-lived functional programs, as suggested by Behne's definitions, have produced buildings that show great differences regarding their suitability for adaptive re-use. A highly specific, taylor-made 'functionalist' building like 'Zonnestraal' may not be so easily adaptable to functional change and is likely to have a short functional life expectancy, as opposed to such striking examples of 'rationalism' as the Van Nelle Factories in Rotterdam, where the a-specific, flexible space could be relatively easily adapted to a new use as a centre for design studios.

This underlines the necessity to study comprehensively the conceptual background of a building – next to the material aspects – before making decisions as part of the redesigning or restoration process. Even within the Modern Movement, various architectural concepts lead to principle differences between Modern buildings that must again lead to different approaches when planning their restoration.

Notes

1. *These features were adopted by Wiebenga to respond to the limited construction time that was allowed, while the program for the schools was still unclear, thus creating maximum adaptability. See. Jap Sam, E. (ed.): 'The Wiebenga complex. Conversion and Restoration of the Technical Schools in Groningen (1922-1923)', and Molema, J. and P. Bak (ed.): 'Jan Gerko Wiebenga. Apostel van het Nieuwe Bouwen', Dutch text, 010 Publishers, Rotterdam 1987.*
2. *Le Corbusier and Pierre Jeanneret, untitled, in 'L'architecture vivante, (Autumn/Winter 1927), 13-27.*
3. *Duiker, J.: 'Dr. Berlage en de "Nieuwe Zakelijkheid"; in De 8 en Opbouw. 1932, pp.43-51.*
4. *The sanatorium was built for the Amsterdam Diamond Workers Union, and funds were in extremely short supply. Quoted from the minutes of the January 26, 1924 meeting of the building development committee of the 'Zonnestraal' Association (Studiecommissie exploitatie landgoed 'Zonnestraal'), it appears that the depreciation period was set at fifty years. The minutes were in the 'Zonnestraal' historical archives (uncatalogued), which are currently housed in the International Institute for Social History (IISG) in Amsterdam.*
5. *Adolf Behne, Der Moderne Zweckbau (Munich, Drei Masken Verlag, 1926) had already been written in 1923 but could only be published years later, when publications by Gropius, Mendelsohn and others had already sparked a wide debate.*
6. *The research by H.A.J. Henket and W. de Jonge resulted in a report, that has later been summarized and extended with an English summary, in 1990 see Henket, H.A.J. and W. de Jonge: 'Het Nieuwe Bouwen en Restaureren. Het bepalen van de gevolgen van restauratiemogelijkheden', Dutch text with English summary pp. 96-100. Since then, the building history of the individual buildings has been reported in greater detail by our office in various unpublished volumes.*
7. *An absolutely smooth contemporary glass, produced by floating molten glass onto liquid metal. See Jonge, W. de and O. Wedebrunn (ed.): 'Reframing the Moderns. Substitute Windows and*

Glass', DOCOMOMO International Conference Proceedings, preservation technology dossier 3, Delft April 2000 and Wiggington, M.: 'Glass in Architecture', Phaidon Press, London 1996.

8. *For the Van Nelle factories, sheet glass in smaller sizes was found in the Czech Republic. Similar glass is artificially reproduced as 'Bauhaus Glass' by Schott, Germany, though at higher cost. More about glass technology and types in Jonge, W. de and O. Wedebrunn (ed.): 'Reframing the Moderns. Substitute Windows and Glass', DOCOMOMO International Conference Proceedings, preservation technology dossier 3, Delft April 2000 and Wiggington, M.: 'Glass in Architecture', Phaidon Press, London 1996.*
9. *Very similar rolled sections of steel of the 35-37 and 40 mm series are still manufactured in Britain. The 25 mm series is no longer made but, according to various sources, may still be available from some Asian or African countries.*
10. *See Jonge, W. de: 'The Technology of Change. The Van Nelle Factories in Transition', in Back from Utopia, Henket, H.A.J and H. Heynen (ed.), 010 Publishers, Rotterdam 2002. p 46 and Backer, A., D. Camp and M. Dicke (eds.): 'Van Nelle Monument in Progress', De Hef Publishers, Rotterdam 2005, p. 250 .*

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The United Nations Secretariat Curtain Wall History, Current Condition, and Future Restoration[1]

Robert A. Heintges

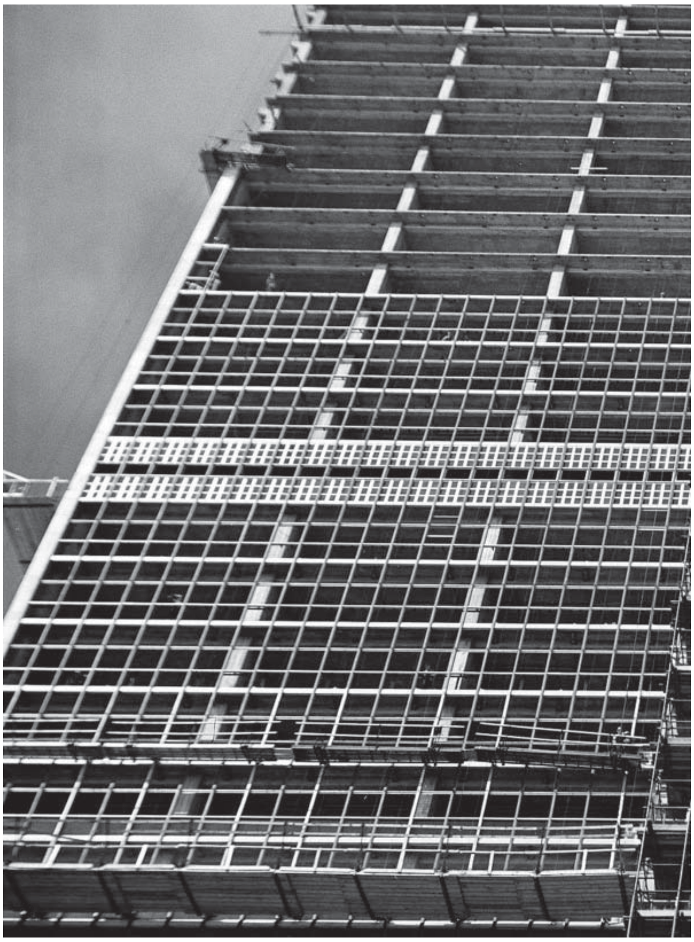
The original United Nations Headquarters campus in New York was completed in 1952. Now, more than 50 years later, a major refurbishment is proposed that will ensure the viability of the landmark complex well into this millennium. An investigation, assessment of conditions, and study of renovation options for the exterior walls were undertaken as part of an overall program for the entire complex. The many different façade types, in various conditions of deterioration, have presented some unique challenges and opportunities. This paper will examine these, focusing in particular on the Secretariat curtain wall. Among the topics that will be addressed are the history of the initial design, the original curtain wall system, and the current condition of the facade. Restoration, repair, and reconstruction options in the context of the institution's current needs and future goals will also be discussed.

Refurbishment of the United Nations Headquarters campus has been proposed in accordance with a Capital Master Plan preliminary phase report that was completed by the UN in 2002. Each of the building components of the complex presents different façade designs and consequent problems. The campus includes the General Assembly, Conference, and Secretariat buildings, completed together in 1952; the Dag Hammarskjöld Library completed in 1961; and the South Annex and North Lawn Extension added in 1979. In the context of a wide range of programmatic and performance requirements, the facades of these buildings present an extraordinary range of preservation opportunities and constraints within one complex. Of these the Secretariat Building,

View of United Nations campus, c. 1952.

arguably the first skyscraper curtain wall of the modern movement in the United States, stands as the most historically significant work and possibly the most enlightening preservation case study of the group.

My firm, R. A. Heintges & Associates, was charged with assessing existing conditions and recommending restoration strategies for the facades and curtain walls of the United Nations complex. Our work on the Secretariat curtain wall has brought into focus the dilemma of purist preservation standards versus contemporary performance expectations, and the realization that a flexible approach to interpreting preservation guidelines, combined with a pragmatism guided by contemporary environmental and global political issues, is essential to the continued viability of early curtain wall buildings. More specifically, an understanding of the concept, mechanics, and function of the Secretariat curtain wall supported the unanticipated conclusion that faithful reconstruction is entirely compatible with the aesthetic ideals and original intent of its designers. The original design of the glass curtain wall was based on the use of standardized, mass-produced, and easily reproducible machine-made parts, which were not unique, precious, or irreplaceable then or today. It was the daring manner in which those parts were used to make a whole—an ordinary



Installation of curtain wall, c. 1949.

window sash repeated over thirty-nine floors—that made the Secretariat curtain wall such an unusual achievement.

This paper will review our investigation, analysis, and proposed recommendations for the Secretariat curtain wall, essentially covering the past, present, and future of the building. I will offer first a brief historical background of the building in the context of the technical, code, and performance requirements of the mid-twentieth-century curtain wall; next, a description of investigation techniques and an evaluation of current conditions in the context of original and contemporary performance requirements; and finally, strategies for preservation of the Secretariat curtain wall in the context of current and projected technologies, performance standards, and the programmatic needs of the United Nations.

Past: Historical Background

Significance

Construction on the Secretariat Building began in 1947, the year that Pietro Belluschi's Equitable Building in Portland, Oregon was completed. The first glass and aluminum-skinned skyscraper in the United States, the Equitable Building is a concrete structure closely clad with aluminum panels and in-filled with aluminum-framed glazing. In contrast, the Secretariat Building, which was completed in 1950, was enclosed with free-hanging glazed curtain walls on its primary east and west elevations. Although Gordon Bunshaft's Lever House, finished a year after the Secretariat Building in 1951, was the first skyscraper entirely clad in a suspended curtain wall, the Secretariat Building retains the distinction of being the first tall building in the United States to be constructed with a curtain wall suspended on the exterior of the building structure, and, in such, it stood as a precedent for subsequent curtain wall skyscrapers. Just after the building was completed, the editors of Architectural Forum suggested in their November 1950 issue the reciprocal significance that the concept of the United Nations itself and the new expression of architectural technology bestowed upon one another:

> Just as the modern Secretariat had supplied a monumental symbol for the UN, so the UN had, in turn, given modern architecture an aura of respectability, an association with worldwide prestige.

Despite its historical significance, however, we have learned that the specific technical features of the Secretariat Building, and particularly its curtain wall, are not well known, perhaps because it came into being as a collaboration by committee, without authorship, and therefore had no parent to nurse it along and ensure its place in history. It is possible that serious problems with the curtain wall immediately upon completion also discouraged publicity. In addition, the Secretariat Building was soon to be overshadowed by the Lever House, the Lake Shore Drive Apartments, the Seagram Building, and many others that did have pride of authorship. As a result, a lot of misinformation regarding the Secretariat Building curtain wall has been published, and indeed a lot is still unknown.

Original Design Intent and the As-Built Design

Originally planned as a forty-five story structure, the Secretariat Building was reduced to thirty-nine floors for economic reasons. The north and south elevations are clad fully in Vermont marble[2], while the major east and west elevations are comprised of glazed curtain walls with windows and spandrels of blue-green tinted glass, and a grid of louvered frames at the mechanical floors (6^{th}, 16^{th}, 28^{th}, 39^{th}) and the parapet level. Column-bay spacing is twenty-eight feet, with seven curtain wall modules of four feet each. Floor to floor heights and mullion spans are typically twelve feet, and are thirteen feet at mechanical floors.

The curtain wall, fabricated and installed by the General Bronze Corporation, is comprised of mullions spanning floor to floor, with framing and glass in-between. Cold-rolled steel channel mullions, supported at each floor slab, are clad with clear and black anodized aluminum extrusions. Details and construction photographs suggest that steel channels and extruded aluminum cladding were pre-assembled into story-height “ladders” prior to installation and then infilled with glass. This construction method prefigures the contemporary factory pre-assembled, or “unitized,” curtain wall.

The original design process, however, soon fell victim to that uniquely American concept of architectural design, affectionately known as “value engineering,” resulting in an as-built façade that fell short of the ideals and aspirations of its two major designers, Wallace K. Harrison and Le Corbusier. Le Corbusier envisioned a scheme that incorporated his beloved brise-soleil, arguing that physical shading devices were the only solution to the solar orientation of the building. Harrison and other members of the United Nations’ international committee of architects were keen to enlist the emerging technology of insulating glass to achieve a taut, all-glass wall without projecting shading devices. Ironically, the building itself has neither brise-soleil nor insulating glass, as both, it appears, were too expensive. This “value engineering” may be another “first” for the Secretariat Building in the evolution of the skyscraper curtain wall.

The building perimeter was conceived as a total climate control system, incorporating individually controlled induction units with two-pipe coils for reheating or cooling at each office. Operable window sashes coupled with “Flexalum”® Venetian blinds and interior individual climate controls were a key aspect of the design, acknowledging the diverse group of delegates from a wide range of climates. Window washing is accomplished in the traditional manner, with access from the interior through an open window. Exterior sills of patterned cast aluminum provided for improved footing, and at each mullion harness attachment buttons welded to steel channels protruded through the aluminum cladding.

In 1947, when design of the Secretariat Building began, there were a number of major manufacturers of aluminum sash windows, all of which offered similar extruded profiles that were almost interchangeable. As the curtain wall design developed, it seems that the process had emboldened and enticed the windows industry with an easy formula: stack conventional window sashes one atop the other to create the uninterrupted surfaces of the modern glass curtain wall. During the three-year period in which the Secretariat Building was under construction, these window manufacturers reinvented themselves into curtain wall manufacturers, duly advertising as such. The United Nations’ architects took enormous risks with this limited technology; in doing so, they essentially invented an industry. Indeed, the most notable attribute of the Secretariat Building's curtain wall with respect to the ideals of the modern movement is the use of standard, mass-produced components. The whole was far greater than the sum of its parts: it was the concept and expanse of the glazed wall that was revolutionary.

Continuous glazing was of course an unfamiliar solution for a skyscraper at the time, and the design team researched the choice of glass diligently. The Board of Design Consultants undertook studies of sun angles and intensity to determine the annual solar load that the orientation of the tower (29° east of north) would incur, and what measures could be taken to minimize solar gain. A four-story visual mock-up of the curtain wall was built on the roof of the Manhattan Building on East 42nd Street to study various façade materials, and, in particular, different types of glass. As mentioned above, Harrison argued for a glass solution using the latest technology, while Le Corbusier insisted on an exterior shading design, his brise-soleil, having recently installed them as a necessary retrofit to his Salvation Army project in Paris. When the architects reached an impasse, Syska & Hennessy, then a young mechanical engineering firm, was asked to study the costs and benefits of four glass types in conjunction with four different shading solutions. Clear and tinted (heat absorbing) monolithic glass, as well as clear and tinted insulating glass, were considered. A proprietary new insulating glass product of the Libbey-Owens-Ford (LOF) Company, Thermopane®, which incorporated two layers of glass with an air space in between, was demonstrated to be cost effective, even at a premium of 50%, in comparison to the high cost of the brises-soleil. For this reason, and because of concerns about ice build-up and maintenance, the brises-soleil were eliminated from consideration.

A number of sources have stated erroneously that Thermopane® was used as the original glass on the Secretariat Building. In fact Thermopane® was also eliminated, not only as a result of "value engineering", but because, we believe, it was too heavy for the hardware of the curtain wall's double-hung sash frame. Final specifications listed two choices of heat-absorbing, tinted, single-pane, polished plate glass: Libbey-Owens-Ford's (LOF) blue-green, and Pittsburgh Plate Glass's (PPG) green (trade name Solex®); both products are still available today, albeit as float, not plate, glass. A record sample in the UN Archives suggests that the final choice was PPG Solex®. The LOF blue-green glass, however, came to be used as the typical replacement vision glass. This is most likely because when both varieties were converted to float glass in the mid-1960's, the LOF float glass, by chance, resembled the original Solex® plate glass more closely than did the later Solex® float glass. At spandrel areas, a heat-absorbing, blue-green, rolled, wired glass was used. The product appears to have been specific to this application, and we believe it was Aklo®, the spandrel glass developed by Corning Glass Works US and made by ASG Industries under license. This spandrel glass has a much richer color saturation than the LOF/PPG vision glass.

Present: Research, Inspection and Analysis

Research

Fortunately, the UN's archives include substantial documentation, especially regarding the Secretariat Building, including the original specifications from the UN Planning Office, dated 1949; as-built pencil-on-vellum record shop drawings prepared by General Bronze, dated 1948 and revised 1949; and subsequent remedial shop drawings for early repairs dated 1951-1953. The archives also include some material samples, construction photographs, and contractor correspondence. The accuracy of the as-built drawings was confirmed during subsequent inspections. Advertisements and manufacturers' catalogs from the period were useful for verifying specific materials used.

Parameters of Inspection

As a first step, we conducted visual inspections of interior and exterior portions of the curtain wall to check for evidence of failure such as water damage, staining, deterioration of finishes, material deformations, broken glass, failed sealant, and overstressed joints. Once suspected problems were identified at the surface, they were confirmed by borescopic inspection, which entailed drilling small repairable holes at the exterior for insertion of the borescope. These initial inspections were done from the interior with access out through open windows. Subsequently, more elaborate inspections were undertaken of the exterior wall from a ground-rigged scaffold. This work involved the temporary removal of components in a manner that would preclude damage and permit re-installation, including removal and replacement of spandrel glass and aluminum framing elements. This also allowed for further borescopic inspection.

In panning any inspection regimen, it is typically necessary to determine a statistically meaningful sampling size and distribution, since it is usually not realistic to inspect every component of an entire wall, especially on a skyscraper. Using the design evaluation and preliminary visual inspection results combined with a statistical probability evaluation, the firm developed a partial inspection program for the Secretariat curtain wall.

Criteria for Evaluation

In order to evaluate any early curtain wall design from its shop drawings, an investigator must have a thorough knowledge of contemporary curtain wall design principles, as well as relevant codes, wind engineering principles, and material science. When one evaluates an early curtain wall design by today's engineering standards, its problems are usually readily apparent, and an efficient inspection regimen can be more easily defined. Of these principles, the most important are listed here and described as follows.

Pressure Equalization: Perhaps the most important design principle is pressure equalization and the concept of the double seal: an outer "weather seal" and an inner "air seal." The pressure in the space between these two seals is equalized to the exterior by controlled openings in the outer seal. This enables any water migration through the outer seal to drain harmlessly to the exterior, since there is no pressure differential across the weather seal, and as a result water cannot be sucked into the building. Early curtain walls, such as that on the Secretariat Building, were not pressure equalized and relied on a single seal for weathertightness. Single seal curtain walls must rely completely on the viability of the sealant itself, since there is a pressure differential from exterior to interior across the seal.

Building Movements and Joint Design: With early single-seal detailing and stick-system design, weather tightness was a function of the ability of joints in the curtain wall to accommodate building movements within the limitations of early sealant materials. In the Secretariat wall, primitive asbestos mastic caulking and glazing putty, and, later, polysulfide sealants, were not able to accommodate the movements imparted by the building structure to the wall, or those due to thermal expansion and contraction.

Corrosion and Dissimilar Metals: Although early designers were more cognizant of corrosion resulting from dissimilar metals than designers today, the all-metal curtain wall presented new challenges, particularly in its combined use of steel and aluminum. In the presence of an electrolyte (water or, even worse, acid rain), metals with dissimilar electromotive potentials essentially become poles of a battery when in contact with each other, resulting in disintegration of the less noble metal. Over fifty years, even a small potential can lead to corrosion. This has been a significant problem with the Secretariat wall due to the limited lifespan of the isolation materials used between dissimilar metals, and to the limitations of the original detailing itself.

Wind and Seismic Loads: Wind and seismic engineering has advanced significantly since 1950. Contemporary analytical and wind tunnel testing methods suggest that wind loads on tall buildings are often greater than those that were originally assumed, and that the highest loads do not necessarily occur at the top of the building as was once thought. It is important, therefore, to consider whether a curtain wall is being subjected to loads greater than those for which it was originally designed. An analysis of wind loading on the Secretariat Building in accordance with the latest edition of ASCE publication No. 7, "Minimum Design Loads for Buildings," indicates that loads by today's calculation methods are approximately one and a half times that recommended in 1950 by the National Bureau of Standards. While the original wall, if it were still sound, would still be viable within the limits of original safety factors, the loss of capability due to corrosion is a significant problem in the context of current design wind loads.

Thermal Performance: Energy code requirements today are considerably more stringent than the requirements of previous decades. While inefficiencies can be easily modeled, and the cost of a poorly insulated wall readily calculated, these are not necessarily a cause of deterioration, except in the case of condensation. Inspection of the Secretariat wall confirmed the conclusion of our thermal analysis that considerable condensation had occurred within the wall, resulting in corrosion of concealed components.

Evaluation of Existing Conditions

Based on the investigation regimen described above, a detailed review of original shop drawings, and subsequent inspections and probes, an assessment of the existing condition of the Secretariat wall was developed and documented as follows.

Vision Glass: Almost immediately after completion, it became apparent that the single pane window glass had significant performance problems. Environmental comfort was problematic due to heat gain and glare, especially at the east elevation. Within several years of completion, a reflective film material manufactured by 3M was applied to the inside of vision glass at the east elevation; a modification which completely altered the original aesthetic of the glass and curtain wall, increasing outward reflectivity from 7.5% to 57.5%. Over time, and through numerous replacements, these film materials have exhibited typical characteristics of aging, such as scratches, bubbling, wrinkling, peeling, and edge separation. Early installation of the film may also have resulted in microscopic scoring of the glass surface near its edges, thus weakening the glass. Because the original annealed glass was not heat treated, the film induced thermal stresses in the glass causing an ongoing breakage problem that lead to a replacement program. Over time, most of the glass has been replaced with various heat-treated versions of the original glass, resulting in further compromises to the original transparency and uniformity. The United Nations has recently installed reflective film on the west elevation as well. In winter months, with or without film, the Secretariat Building's monolithic glass provides only minimal resistance to thermal conductivity in comparison to today's high performance insulating glass, at a U-value of approximately 1.09 vs. 0.30 BTU/(hr•sf•°F).

Spandrel Glass: The original Aklo® blue-green tinted wire glass has been variously replaced with clear glass and non-wire heat-strengthened colored laminated glass. The original color has been approximated using a tinted blue-green PVB interlayer in the laminate, but it lacks the color vibrancy of the Aklo® product. A heavy bead of sealant has replaced the stainless steel spring clips that were originally employed to secure the glass. The concrete masonry knee walls visible behind the spandrel glass were originally painted with black masonry paint. The paint is in varying stages of disintegration, and as a result, the visual effect of the spandrel glass is no longer as originally intended, with the joint pattern of the concrete block now clearly visible through the glass.

Air Infiltration: Because there is no true air seal closure at the interior of the wall, air infiltration through the spandrel and sill areas is significant. We calculated that the air in- and ex-filtration rate is about 0.50 cfm/sqft, or over eight times the standard allowable today (0.06 cfm/sqft). In tall buildings, due to stack pressure effects, infiltration is worse at the lower floors and exfiltration worse at upper floors. This results in varying degrees of discomfort and in considerable inefficiency in heating or cooling the building. Infiltration of humid summer air is also partially responsible for the condensation problems that have contributed to corrosion of steel mullions and anchors.

Water Infiltration: Immediately upon completion, the curtain wall had significant problems with systemic leakage due in part to the single-seal design, and in part to the inability of the joint configuration and sealants to accommodate thermal or building movements. Only a year later, the mullions were retrofitted with black anodized aluminum angles that functioned as sealant joint covers. Mullion splices were also retrofitted with covers to divert water from joints, and weep holes were plugged. These solutions were not permanent, requiring ongoing maintenance and joint resealing. Ironically, these attempts to seal up the wall made matters worse: sealing holes and gaps eliminated any inherent pressure equalization, thus increasing the pressure differential at the remaining joint seals and therefore the potential for leakage once the remedial sealants failed. This remediation also resulted in aesthetic compromises to the wall's original sightlines and appearance.

Aluminum: Alcoa produced the aluminum extrusions with a 6063 alloy, still a common alloy for architectural extrusions today. It was manufactured with a T5 temper, also still standard. Extrusions were clear anodized using Alcoa's polished "Alumilite" process with a film thickness comparable to a Class II, or A31 designation, which today would only be used for interior applications. Face cap extrusions and subsequent repair angles were black anodized. Current standards would dictate a Class I, or A41 finish, with a film thickness almost twice that of the Secretariat Building, especially in the marine environment of the East River waterfront. The specifications called also for all extrusions to receive a coat of DuPont (1234®) lacquer. The newly installed aluminum was undoubtedly very shiny and bright, with the particular specular personality unique to clear anodized aluminum. This intended appearance was quick to fade, however, as the lacquer weathered unevenly and that which remained turned yellow and retained dirt. In addition, the aluminum soon began to oxidize as the thin anodic coating failed. Surface pitting of the clear anodized aluminum removed the shine and increasingly retained atmospheric contaminants as well, thus accelerating surface corrosion that is now so prevalent. The black anodized aluminum coating also failed, with the black color reduced to a chalky gray; over the years, this material has repeatedly been improperly refinished with black paint, and these finishes have failed as well.

Cracked and sealed spandrel glass.

Caulking and Sealants: Original metal-to-metal seals were made with the asbestos mastic caulking available at the time, a material ill suited to the performance requirements of a skyscraper curtain wall. Subsequent repairs involved a range of successively newer sealants, but the limitations of the original joint design, combined with improper oversealing with incompatible products, precluded the viability of both the original and the replacement seals. Furthermore, because architectural sealants attract and hold dirt, the joints would have appeared shortly after installation to be smeared with grime.

Insulation: Insulation of the exterior wall is provided not at the curtain wall, but at the inside surface of the masonry knee wall. The insulation is of little value in this position, since there is no insulated closure between the curtain wall and the top of the knee wall. In this configuration, the interior spandrel environment is thermally contiguous with the exterior, with the net effect that the curtain wall is poorly insulated. The original asbestos insulation has environmental issues, of course, especially where it was used to fill gaps at interior closures subject to differential air pressure.

Thermal and Condensation Performance: Based on the observations above regarding air infiltration, insulation, and glass specifications, the overall energy loss through the wall was estimated at 23.7 billion BTUs annually, 71% greater than what could be achieved with current construction standards. At 2002 energy costs, this amounted to an estimated annual cost premium of approximately $517,000. At current oil prices, this premium is much higher and will most likely continue to increase.

Structural Integrity: Finally, and most importantly, the analysis of the original details suggested the possibility of hidden corrosion problems within the structure of the curtain wall. A full week of inspections from the interior had been completed, however, before the first hint of a larger problem was discovered: several slightly bulging aluminum mullion covers were found, suggesting the expansion that occurs when steel rusts. Borescopic investigation through holes drilled in the mullion confirmed this diagnosis: one steel mullion inspected had less than 30% of its original material. With this degree of corrosion, a mullion would no longer meet the strength requirements of current codes. We also inferred that many mullions without visible bulging were in less advanced states of deterioration, but considered it impractical to drill holes in each of the 5,000 mullions on the building.

Based on the preliminary evidence, the UN agreed to an exterior inspection from a swing stage and to more extensive probes, which included the removal of spandrel glass and the inspection of anchors. In the interest of time and cost, a program of partial inspections was developed on the basis of the statistical probability that, with a confidence level of 99.9%, inspected portions would reveal any potential problems and enable a meaningful extrapolation of the overall condition of the wall. Areas were chosen based on an analysis of wind effects on the surface and on exposure: three hanging scaffold drops on the east elevation (two at corners and one at the field condition) and two corner drops on the less exposed west elevation. These five drops, encompassing 29% of the wall, were deemed representative of the entire wall. Inspections entailed the selective removal of spandrel glass, horizontal extrusions, and flashing.

Remedial aluminum covers and weep hole plugs, c. 1952.

The probe effort revealed that there was significant corrosion of the steel curtain wall support anchors, which we subsequently categorized by three levels of severity, with level three being the most severe. 97% of all the anchors inspected exhibited some form of corrosion, and 54% had significant corrosion identified as level 2 or 3. Analysis of the worst of these suggested that, based on current code wind loads, failure would occur in an extreme wind event. We did determine, however, that actual collapse at any one anchor is not an immediate problem due to the overall contribution of the adjacent curtain wall units and anchors.

Future: Preservation and Remediation Strategies

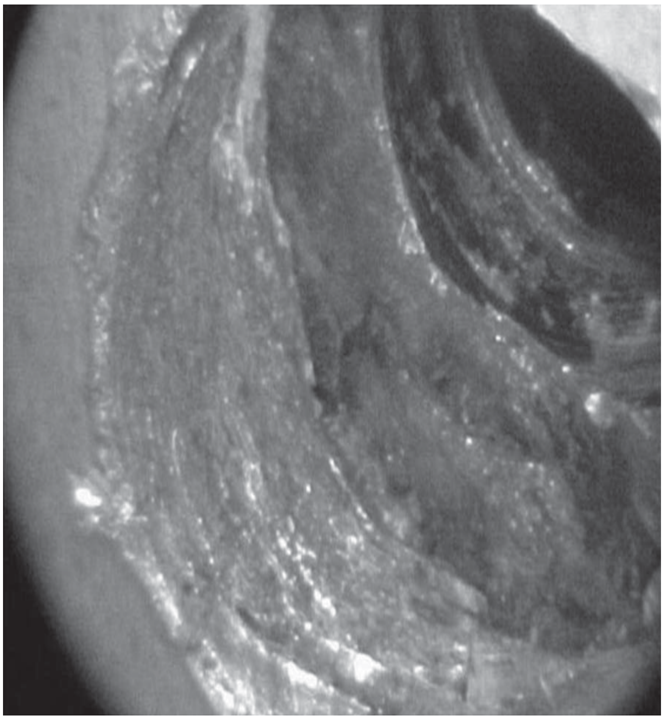
The assessment and evaluation of current conditions suggested that no single strategy for remediation would work for all of the façade enclosures of the United Nations complex. We identified three remediation strategies, and defined them in terms of levels of intervention: reparation, restoration, and faithful reconstruction.

The option to repair constitutes comprehensive inspection and repair work, but with minimal intervention. This would be followed by a program of scheduled inspections and ongoing reactive repair. In the case of the Secretariat Building, repair of the corroded anchors would necessitate destructive removal of a significant percentage of the wall, which precluded this option.

The option to restore constitutes comprehensive system restoration to original condition, to be followed by a program of scheduled inspections and reactive repair. In the case of the Secretariat Building, restoration to original condition would reinitiate all of the original problems of the Secretariat Building, and would entail almost complete replacement due to the fact that anodized aluminum cannot be restored unless painted over. The unique, pre-assembled “ladder” construction of the original wall makes it impossible to remove the aluminum cladding without destroying it.

The option of faithful reconstruction constitutes complete removal of the existing wall and replacement with a new state of the art enclosure, custom designed and fabricated to the original profiles, materials, finishes, and design intent. Replacement with new extruded aluminum, when original alloys and finishes are employed, can replicate the original appearance if new extrusion dies are cut exactly to the original profiles. Faithful reconstruction can provide identical sightlines and exterior profiles with a new curtain wall that conforms to current performance requirements.

Failed Anchor



Borescope view: corroded steel mullion

Selection Criteria for the Remediation Options of the Secretariat Building

Six selection criteria were identified: performance, longevity and long term cost, historic preservation, security, opportunity, and sustainable design. To determine the best remediation option for each of the many facades of the UN complex and for the Secretariat curtain wall, each was evaluated according to these criteria. The various criteria were not always easy to reconcile, and this tension forced the UN and its design team to make some difficult choices, especially in the case of the Secretariat Building. The UN's programmatic and performance requirements, in a new century and unsettled times, guided the selection process. These criteria are defined as follows.

Performance includes energy efficiency, structural soundness, fire resistance, air and water tightness, safety, occupant comfort, and code conformance. The condition assessment and evaluation of the original details suggest that none of the performance requirements for remediation can be met by the original Secretariat Building design, even if restored to original condition.

Longevity and Long Term Cost concerns the life span of original and replacement systems, components, materials and finishes, as well as life-cycle costs and fiduciary responsibility. The United Nations had mandated that renovation extend the life of the complex by at least 25 and preferably 50 years. Operating and maintenance costs for the wall in its current state have become prohibitively expensive, and new building codes as well as internal UN mandates specified that the energy efficiency of the wall be brought to the level of good-practice standards as a minimum. The three remediation options (reparation, restoration, and faithful reconstruction) were analyzed in terms of current capital cost versus future maintenance cost. Only the reconstruction option guarantees the viability of the Secretariat curtain wall beyond 25 years.

Historic Preservation ordinarily entails the retention and restoration of original materials, matching original colors, profiles, transparencies, and general aesthetic. None of the remediation options, however, can duplicate the original appearance without using replacement materials.

Security includes ballistic and blast resistance. Requirements for blast resistance would be very difficult to address in either the repair or restoration options without significant compromise to the appearance of the curtain wall. By contrast, the reconstruction option can accommodate detailing strategies that will satisfy the requirements without visibly altering the original design intent.

Opportunity involves the degree of disruption to occupants and building function in relationship to schedule, construction time, and coordination with other related construction. The Capital Master Plan refurbishment of the entire Secretariat Building presents a once-in-fifty-year opportunity for major work to be done on the curtain wall that would otherwise be prohibitively expensive and too disruptive to the occupants of the building. Faithful reconstruction would be the solution with the greatest longevity, and, as a result, the least disruption in the long term.

Sustainable Design includes resource conservation, operating efficiency, human health and well being, and innovative design practice. The United Nations has committed itself to the principles of sustainable design in undertaking the Capital Master Plan. For the curtain wall, only the option of faithful reconstruction can ensure optimal sustainable design.

System Description for Faithful Reconstruction

The Secretariat Building may be the first example for which complete reconstruction of an important early curtain wall of a modern skyscraper has been seriously proposed in the context of state of the art performance standards. The conditions assessment and evaluation were undertaken initially with the premise that repair and restoration were the only options. As explained, this premise became increasingly unrealistic as the investigation proceeded, and it became apparent that a new wall would have to be considered.

The concept of faithful reconstruction was outlined and recommended in the Preliminary Phase Report of the Capital Master Plan. The proposed replacement curtain wall would be a fully unitized and pressure-equalized assembly of steel-reinforced extruded aluminum profiles duplicating the exterior shapes, profiles, and interior sightlines of the original curtain wall as completed in 1950; i.e. prior to the repairs and later changes. The new system would incorporate vision and spandrel glass to match the original specifications, with a super-insulated aluminum shadow box at spandrels replicating the original black painted CMU knee wall. It would also have none of the exposed sealants that now attract dirt and contribute to the overall depressed appearance of the wall. Operable windows and new perimeter mechanical equipment with individual controls would retain the character and comfort of the original as well. The replacement curtain wall would conform to all current codes and standards as a minimum, and would provide the benefits of a state-of-the-art high performance sustainable design. Ironically, that “original” appearance is something few design and preservation professionals working today have seen, and in fact may have only existed for a few months. The Secretariat curtain wall we see today bears little resemblance to that of the original, and has not for decades.

Aluminum: The bright metallic quality of the curtain wall’s original aluminum framing became dull in appearance after only a few years, as was discussed above. All new extruded aluminum shapes would be finished with pretreatments and a Class I clear anodic finish that will not only match the original color and gloss, but will also provide more durable protection. Face extrusions that were originally black anodized will be finished with a high performance fluoropolymer coating that is baked onto the extrusions; this will preclude the inevitable chalking of a black anodized finish. All extrusions will be thermally broken to enhance thermal performance and preclude harmful condensation.

Glass: The consistent transparency of the original glass curtain wall has in the decades since its construction been reduced to a hodgepodge of varying colors and degrees of reflection due to various mismatched replacement glasses and films. All glass would be restored as nearly as possible to its original appearance. Vision glazing of blue-green tinted insulating glass incorporating a high performance, hybrid low-e coating, and blue-green tinted spandrel glass would be custom designed and manufactured to match the color and transparency of the original glazing. New glass would also provide the necessary performance to meet current energy code and comfort requirements, and would also reduce the glare and heat gain that necessitated the retrofitting of reflective film materials beginning in the early 1950s.

Conclusion

The major premise of the faithful reconstruction design option for the Secretariat curtain wall is that it must be indistinguishable in its visible profile and detail from the original. The use of standardized, mass-produced, machine-made parts on the original curtain wall suggests that faithful reconstruction, with components similarly produced, is the most appropriate option. We believe this option will prove to be the best way to respect and restore the original character of the Secretariat Building, and will secure its importance in the history of the skyscraper curtain wall by ensuring the continued viability of the building it encloses.

The restoration of the United Nations Secretariat Building is a unique project with an unprecedented preservation opportunity. The faithful reconstruction solution would provide a new life for the Secretariat curtain wall, and would perhaps become a model preservation strategy for other important curtain wall buildings: a solution hopefully worthy of the original intent.

In a sense, this reconstruction would be putting right what did not quite come off in the original. The replacement would be both a restoration of Harrison's all glass ideal and an ironic vindication of Le Corbusier's concerns that grew out of his experience with the Salvation Army building. I would propose that this confrontation of philosophies in the design of the Secretariat curtain wall—faith in materials vs. design principle—represents an important turning point in the modern movement, from tectonics to technology, and from Europe to America. After the completion of the Secretariat Building, curtain wall design in the U.S. would increasingly put its faith in the emerging technologies of new materials, particularly reflective glass and, later, silicone. This dependence on product innovation would dominate skyscraper curtain wall design in the U.S. for decades to come but would ultimately leave it lagging in the design innovation that continued to progress steadily in Europe during that time. Regardless of whether one favors one or the other side of the argument, the marking of that turning point is perhaps the major point of historical significance of the Secretariat curtain wall.[3]

Notes

1. *This paper was originally presented in September 2004. It is reproduced here with minor grammatical and no substantial changes, excepting all footnotes, which were added in January 2008.*
2. *This paper considers the remediation and renovation of the Secretariat Building curtain wall. Extensive research was also conducted on the granite-clad north and south facades; those findings, however, are a topic for another paper.*
3. *As of this publication, the renovation is proceeding in accordance with the conclusions and recommendations described in the paper, with the addition of enhanced performance requirements for energy efficiency and security.*
4. *All historic photographs are courtesy of the United Nations Photo Archives and the illustrations of current conditions were provided by R.A. Heintges and Associates.*

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Some Notes on the Conception, Implementation, and Future of the Curtain Wall

Elwin C. Robison

The modern glass and metal curtain wall is the result of many years of experiment, evolution, and aesthetic refinement. Over the course of the 20th century it became the dominant construction type for all but low rise structures. Lighter in weight, smaller in section, faster in construction, and able to be prefabricated, the glass and metal curtain wall brought with it tremendous economic advantages. At the same time architectural aesthetics created a design climate that favored the curtain wall. The convergence of these economic and aesthetic factors explains the dominance of the curtain wall in modern construction.

Introduction

The development of the metal and glass curtain wall depended upon three elements:

1. A realization that the functions of structural support and enclosure did not have to be contained in a single building system–in particular in tall buildings where loads dramatically increase, there is considerable economy in separating these two functions.
2. The development of manufacturing systems for materials that can efficiently support and enclose space.
3. The development of structural analysis systems that can model gravity and wind loads on skeletal framing arrangements.

Modern Antecedents

London's Crystal Palace of 1851 was one of the most prominent buildings of the 19th century to clearly separate the functions of structural support and enclosure. Designed by Joseph Paxton, a landscape gardener, and assisted by Fox Henderson & Co., the Crystal Palace was a triumph of technology and organization. Its unusual design came about because the board of governors for the British exhibition had failed to implement a design for the exhibition building. Their procrastination jeopardized the entire exhibition because there would not be sufficient time to construct a conventional brick and mortar structure. The combination of Joseph Paxton's social contacts through his railroad entrepreneurial activities, his experience building large greenhouses, a chance ride in a railway carriage with the engineer Robert Stephenson, and persistent lobbying of the royals and the public led to Paxton's greenhouse design being multiplied bay after bay to create a 1,851 feet long hall that was a grand success.[1]

The Crystal Palace marks the first time that standardization and prefabrication were used on such a large scale. These are two critical elements of the modern curtain wall. Cast iron columns supported 24 feet long cast iron girders, and 48 and 72 feet long wrought iron, cast iron, and wood composite girders to create a true self-supporting structural skeleton. At the peak of construction 310 cast iron columns were fixed in a week. Paxton reported seeing three columns and two connecting beams erected in 16 minutes.[2] Wall infill panels of glass near the entrances, and more commonly wood to provide display space,[3] were absolutely non-load bearing and could be switched out and replaced at will.

Although the structural skeleton was truly self-supporting, it survived only through a few fortunate circumstances. Public objections to cutting down 300 year old oak trees in Hyde Park led to the introduction of a transverse barrel vault in the center of the building[4] which acted like an expansion joint. In the best modern curtain wall form, it was prefabricated and lifted into place. In warm weather columns were pushed by expansion of the iron skeleton about 2 inches out of plumb[5]. One wonders what would have happened in the absence of the central barrel vault to absorb the movement.[6]

Paxton's design for the Crystal Palace took into account condensation on the glass, something which most curtain wall designers didn't take into account until well after World War II. For Paxton, the problem was condensate dripping on the Victorian dresses of his wealthy clients. Paxton developed a wooden beam/gutter that supported a ridge and furrow glass roof (not a folded plate system as has been erroneously suggested by some). Into the side of the gutter/beam Paxton cut drip channels that conducted water back to the hollow cast iron column that doubled as a rain downspout.

Paxton's Crystal Palace also confronted another problem of some contemporary curtain wall buildings–solar heating. It was good fortune that Paxton's design was built in London, one of the cooler and cloudy of the European capitals. Had the design been built in Rome or Madrid one wonders whether it would have received the wide acclaim it continues to garner. Other than opening windows and vents, and hanging white muslin to cut the direct sunlight on patrons, there was little to be done to counteract the effects of solar heating.

By the time of the Paris Exhibition of 1889, designers were rationally dealing with structure, lateral loads, and window wall systems. Designed by Dutert and Contamin, the Galerie des Machines is one of the great exhibition buildings of all time. Designed as a series of three-hinged arches, it improved on designs for train sheds that required long spans and lofty interiors to dissipate fumes from locomotives.

Of interest in this context is the design of the window wall on the ends of the exhibition hall. Trussed stiffeners support the glass wall from the ground to the large three hinged arch above. Clearly this is a rational design to counteract horizontal wind loads on a glass wall with a large sail area. This building is not the result of an adaptation of traditional building practices, but rather is a carefully engineered response to environmental forces.

It is probable that no provision was made in the design to deal with corrosion. Short-lived exhibition buildings are rather forgiving in that sense, and one assumes that combinations of cast iron, wrought iron, and perhaps some early steel were used to hold the glass lites in place.

Similar needs were found in early department stores, such as Victor Horta's L'Innovation department store in Brussels (1901). Set in the voids between the riveted steel framework elements are large panes of glass, needed to introduce light into the retail areas. Together with a skylight and open light court in the interior, this glass facade supplemented the relatively crude artificial lighting devices in use at the time.

The Curtain Wall and the Skyscraper

The first curtain walls on tall buildings were of masonry. As engineers and architects developed increasingly independent steel frames and masonry wall systems, they solved many of the design and analysis problems that would eventually be used in metal and glass curtain wall design.

The curtain wall is a necessary development for the tall skyscraper. That necessity is best illustrated by the Monadnock Building of 1888-91. Commissioned by the Brooks Brothers of Boston, they were mistrustful of the new iron columns inserted into exterior masonry walls because of the potential for corrosion. Seeking to protect their investment, they required the designers, Burnham and Root, to use load bearing masonry walls.

The design which results from the ideas of Root and the demands of the Brooks is one of the most elegant office buildings in North American of any age. However, the accumulation of floor loads plus the wind loading on the building resulted in a wall thickness of six feet two inches at the ground. Since the highest rent per square foot at this time was generated by ground floor shops with sidewalk display windows, the rents on a four to five feet swath around the perimeter were uncollectible due to their occupation by masonry. Clearly, 16 stories is close to the limit for a conventional load bearing structure.

William LeBaron Jenney was the first architect to take a significant step towards the curtain wall skyscraper. His First and Second Leiter Buildings were clear attempts to minimize the wall area and maximize the windows of these multistory warehouses. But it is the Home Insurance Building where Jenney first substituted iron for masonry in an effort to maximize the window area of the building.

The Home Insurance Building of Chicago (1883-85), often called the first skyscraper, was neither the tallest nor the best engineered building of its day. It is not a curtain wall building, and its design details did not provide structural continuity between perimeter and interior structure. However, it does introduce an iron skeleton into the perimeter wall as a way of opening up more wall area for windows, and represents a critical step in the eventual development of the modern skyscraper.

This nine-story office building (later extended to eleven stories) has a perimeter wall that begins as solid granite masonry for the first two stories. Much stronger than brick, the granite was able to support higher compressive stresses. However, at the point where the granite changed to brick, Jenney would have had to make smaller window openings in order to provide sufficient brick area to support the loads. In an effort to keep the windows as large as practical, Jenney substituted mortar filled cast iron columns for the brick in the piers between the windows. Since iron has an allowable compressive stress two orders of magnitude greater than brick, more weight can be supported on a smaller area. In this sense Jenney was thinking much like the master mason of the Ste. Chapelle in Paris where Jenney studied architecture and engineering–namely to reduce the supporting structure to its minimum in order to maximize the window area.

The Home Insurance Building has been well analyzed as to its structural details and the support of the brick masonry[7]. In summary, the brick surrounding the cast iron column is self-supporting, with only the brick above the windows being carried by cast iron pans and transferred to the iron skeleton (which of course is then transferred back to the granite walls of the lower two stories). A contemporary of Jenney's, Leroy Buffington, tried to patent his concept of a curtain wall building developed at approximately the same time as Jenny's Home Insurance Building. The patent documents show that Buffington's idea was far better thought out and creates much more rational load paths. However, architects had nothing to gain in recognizing Buffington's innovation, and much to lose in the way of paying royalties to a patent holder. With no big power brokers to support him, Buffington's suit was easily dismissed, and Jenney has remained as the "Father of the Skyscraper."

The innovation of using iron to support loads brought about interesting hybrids in early skyscrapers. The Society for Savings building by Burham and Root in Cleveland, Ohio of 1890 uses self-supporting masonry walls with iron columns set inside the masonry wall.[8] These columns do not form a self-supporting frame, but rather are tied to the masonry for lateral stability. In essence there is an iron skeleton but no curtain wall.

The first skyscraper to consider the iron skeleton as a independent frame was the Old Colony Building in Chicago (1894). The engineer, Corydon Purdy, stacked up bridge portals to stiffen the building without totally blocking off interior spaces. Even so, he rationally assumed that 30% of the wind loads would be resisted by the partitions.[9] It was not until the publication of the cantilever method by Fleming in 1908 that an easily applied, reliable method of calculating independent steel frames for skyscrapers was available to designers.[10] This calculation method was a necessary condition for the emergence of the glass curtain wall on skyscrapers (and not just on low-rise factories or schools). However, it would be another 45 years before such dreams would be realized.

Aesthetics of the Modern Movement

While American architects and engineers were pushing buildings higher and higher above the city streets, European architects were changing the aesthetic rules that would govern the architectural expression of those skyscrapers. Ironically, one of their primary inspirations was the flat-roofed factory buildings and concrete silos photographed by Eric Mendelson and later published in a doctored and air-brushed form in Le Corbusier's avant-garde periodical L'Esprit Nouveau.[11]

Also influential was Adolf Loos' racist manifesto entitled "Ornament is Crime." Loos compared architectural ornament to a tattooed Papuan, calling both the ornament and the Papuan "degenerate." He also indulged himself is some rather Freudian sexual imagery that has a disturbingly violent undertone. Despite these subtexts in his argument, or perhaps expressly because of them, Loos' essay was enormously influential.

In concert with his architectural ideas were the changing cultural forms espoused by the Futurists, and the promise of machine production touted by the Deutsche Werkbund and others. These ideas, manifestos, and projects resulted in architectural forms devoid of ornamentation, a separation between load bearing members and the enclosing envelope, and the increasing use of large areas of glass.

Some of the earliest examples of architectural forms that responded to this idea were industrial buildings. Already devoid of ornament, industrial buildings shared a need for light with retail and exhibition buildings. Even after the development of the tungsten filament bulb in 1906 by the Siemens Company, getting adequate light to the worker's level was a constant concern. Therefore the curtain wall had a natural building type for developing concepts and topologies.

Peter Behren's Turbinfabrik of 1908-09 has a monumental curtain wall underneath the gable that follows the polygonal upper chord truss of the building. Flanked by brick piers with streamlined recesses, it was the embodiment of the future. It was also practical. Electricity was relatively expensive, and the literature of the day is full of advertisements for white paint that reflects light off of walls reducing the need for artificial lighting in the work place.

Walter Gropius and Adolf Meyer took this basic curtain wall concept from the Turbinfabrik and gave it a classical yet asymmetrical twist when they took over the construction of the Faguswerk shoe last factory (1911). Working within the limits of a foundation system already constructed, they took the American factory concept filled with machinery from Brooklyn, and molded it into a statement of modernity.[12] The curtain wall, projecting from the surface of the brick wall like that of the Turbinfabrik, introduced good light in to the work spaces. The stair towers in the corner were especially important, as Gropius and Meyer let the reinforced concrete stair slabs and landings cantilever out from central piers, graphically demonstrating the complete independence between the curtain wall and the load bearing elements. This idea was further developed in the Model Factory built for the Deutsche Werkbund exhibition in Cologne in 1914. However, with the assassination of Archduke Ferdinand in Sarajevo that same year, Germany plunged into a war that would hobble its development until the end of the Marshall Plan.

With a crippled economy, German architects turned to visionary projects or government sponsored projects instead of the commercial sector or industry. Gropius himself is most remembered for two projects involving the curtain wall. One is the Chicago Tribune competition entry of 1922. It envisions a glass curtain wall skyscraper with an asymmetrical tower and projecting slabs at discrete points giving a sense of movement and speed that gives form to the earlier dreams of the Futurists. The other was his Bauhaus school in Dessau of 1926. Built as an industrial building housing the art and craft school designed to serve the needs of industry, it features a curtain-walled studio block connected by corridors and bridges to the dormitory and classroom buildings.

More important to the history of the curtain wall was Ludwig Mies van der Rohe's interest in the aesthetics of glass. His visionary projects of 1919 and 1920 where he investigated what form a glass skyscraper could become remain as astoundingly prophetic architectural visions. Germany between the world wars, struggling under the heavy reparations demanded by the Treaty of Versailles, did not possess the ability to realize these visions. Hence these two projects depend upon the deceit of photography for their impact. The Freidrichstraβe project is a photomontage showing the relationship between a crystalline glass tower and the context of pre-WWII Berlin. His second glass tower model was photographed in a garden surrounded by shrubbery with small models of context buildings below. He did not confine his interest in the curtain wall to skyscrapers. An early remodeling job in Dessau sets the stage for some of the worst architectural acts committed in the modern world by encasing an older building in a faceless glass and metal curtain wall. Perhaps it is fitting that Mies should reveal both the future greatness and future banality of the curtain wall in a single career. Eventually, threats by the Nazi regime drove Mies to the United States and he neatly transferred his aesthetic vision to North America.

Although not involved directly in skyscraper design, Le Corbusier's writings and residential designs continue to have a lasting effect on architecture. His 1929 Villa Savoye in Poissy became perhaps the most important built work of the first half of the 20th century with his declaration that a house is a "machine for living in."[13] Planar stucco walls, large sliding glass walls, and ribbon windows, which expressly communicate the fact that all enclosing walls are curtain walls, started an architectural revolution. This is despite the fact that the family abandoned the structure by 1938 because it was uninhabitable due to leaks and subsequent mold infestations.[14] As we will see, Lever House owes a tremendous debt to this structure, leaks and all.

Le Corbusier's first attempt at a monumental curtain wall was a spectacular mistake. In his Cité de la Refuge built for the Salvation Army, he envisioned something akin to a Trombe wall that would heat the building in winter and provide cooling convective currents in summer. Finished in 1933, the building was uninhabitable in the summer months due to the solar heating of the south-facing curtain wall and cold in winter when clouds obscured the sun. It was not until 1952 that the building was climatized and colorful metal brise-soleil installed outside the curtain wall to shade it. Unlike his other uninhabitable building, this one was fixable, but is not nearly as famous today.

The Post World War II Skyscraper

In 1945 the world was faced with an incredible pent up demand for building, the likes of which may never be seen again. In the United States, very few major civilian projects had been built from the stock market crash of 1929 to the war's end in 1945 (Rockefeller Center in New York being a notable exception). By the time the American economy had shifted from a wartime economy back to a consumer-driven economy, almost 20 years had elapsed.

The first glass skyscraper erected was not built by Mies van der Rohe, but rather by the firm that was soon to become synonymous with corporate architectural design, Skidmore, Owings & Merrill. Gordon Bunshaft, the chief designer of the New York office, had seen much of Europe during the war and of course knew the writings and manifestos of the influential European architects. His Lever House of 1951-52 was the result of many years of thinking about the skyscraper as he built airfields and military installations during the war.

The Lever Brothers Soap Company was looking for a building to match their corporate image– clean, modern, with a hint of hygiene. The glass skyscraper was just the ticket. The development of tinted glass, the decision to seal the building and rely totally on air conditioning and power ventilation, and the Lever Brothers CEO who was trained as an architect, were all necessary ingredients in its creation.

The aesthetics of the Lever House were dominated by the architectural concepts of Le Corbusier. The building is raised on pilotis, or columns, the ribbon windows are taken to the extreme of eliminating the architectural expression of a mass wall, the interior plan was free to develop independently of the structural frame, and there was a roof terrace placed on the lower building volume. If Corbusier's Villa Savoye ever were to be transformed into a skyscraper, the Lever House is it.

Of course Bunshaft had to deal with New York City setback laws, too. The glass slab is really a 25% tower without the stairstep building envelope that was permitted by law and characterizes the majority of its contemporaries on Park Avenue. Some serendipitous events augmented the impact of the building. When the decision was made late in the design process to turn the tower slab 90 degrees and to fully display its form, the design team had to confront the existence of a subway tunnel underneath the street. The 9'-8" cantilever that so dramatically expresses the curtain wall actually is needed to miss the subway underground. Of course it would have been possible to make the cantilever with an subterranean grade beam, but the decision to fully expose the cantilever above ground has much to do with the influence of the building on post war construction. The building would not have the same impact were the curtain wall to be brought straight down to the ground with no cantilever.

Bunshaft chose to articulate the curtain wall as an extremely thin plane. The stainless steel curtain wall caps have a delicate recess at the corner implying about a 2" plane. This is somewhat deceptive as the actual wall thickness is far greater. New York City codes required a masonry wall, and there is a masonry wall behind the dark glass spandrels of the building. Clearly, aesthetics and technology were ahead of the building code officials. Of course, condensation and galvanic corrosion were ahead of the technology. Carbon steel framing of small tees and channels which held the glass in place was sheltered by the stainless steel caps, but the combination of an inadequate number of weeps, water infiltration that occurs in the absence of rubber gasketing, and condensation eventually necessitated the facade replacement/restoration recently completed. Rolled steel members were replaced by aluminum extrusions hidden behind the caps. Although many stainless steel caps were in good condition, the new caps could not accurately match the finish on the originals and so all were replaced. A machine-produced object should reflect its genesis, and so the counter intuitive decision was made to throw away original material in favor of recreating the original aesthetic. The two-piece spandrels were replaced by a single sheet of glass with a "fake" mullion in front, a compromise between reducing the number of potential leakage points and retaining the original aesthetic.

It is interesting to compare the Lever House designed by the New York office of SOM with the Inland Steel Building designed by Walter Netsch of the Chicago office. Similar in scale, the Inland Steel Building has a more muscular articulation. Instead of masking the structure behind thin planes, the underlying frame is clearly expressed through stainless steel clad projections. The Inland Steel Building has not garnered the attention of the Lever House. However its servant/served space concept with the building's utility core moved to the rear of the building lot has a clarity of logic that the Lever House does not possess. On the other hand, it is not the homage to Le Corbusier that Lever House is, and it is not "all glass" like Lever House. Perhaps a thin, planar slab could not be built in Chicago where the expression of the underlying steel frame was such an honest, organic tradition.

Bunshaft's Pepsi-Cola building of 1959-60 is perhaps the ultimate expression of the Corbusian ideal brought to Manhattan. Raised above the street level on concrete columns, serenely composed with large expanses of glass and brushed aluminum, it captures the aesthetic of the machine for living in (or in this case, working in) better than anything designed by Le Corbusier. Advances in glass manufacture, curtain wall detailing, and a deft aesthetic eye distinguish this jewel from most of its neighbors.

But just catty-corner from Lever House sits another fundamentally important curtain wall skyscraper, the Seagram Building. Designed by Mies van der Rohe, who had envisioned the total glass skyscraper back in prewar Germany, it does not seek a glass aesthetic. Rather, Mies used the new bronze tinted glass just made available to create a bronze monolith that evokes the visceral power of an obelisk. The result of the Seagram Company's need for a corporate symbol in Manhattan and Phyllis Lambert's leadership of the selection committee, the Seagram Building is remembered as much for its urban planning as it is for its elegant curtain wall.

The initial genius of the Seagram Building was the extravagant voiding of an open plaza on what was at the time the most expensive real estate in the world. This granite paved plaza served as the perfect foil for the bronze obelisk above. Rising directly from the surface plane, the curtain wall of the Seagram Building alternates bronze spandrel panels and bronze tinted glass. Even the signature wide flange sections used to stiffen the curtain wall and articulate the vertical plane were specially rolled in bronze. A special motorized blind system prevents the unsightly chaos of random blinds by forcing them into one of three positions: retracted, deployed, and half deployed. Clip angles welded to the steel frame provide the attachment points for the bronze curtain wall.

Mies' obelisk is not as simple as it first appears. It, too, had to confront the New York City setback laws, and it is also a 25% tower. In order to provide sufficient floor space a lower addition was appended to the rear of the building, unseen from the plaza. But this has not dimmed the clarity of vision that Mies brought to the design.

These two New York buildings sitting nearly across the street from each other provided the inspiration for the next generation of corporate architects. So much so, that Tom Wolfe in the 1980's pinned the blame for the banal glass skyscraper on German worker housing in the witty if inaccurate From Bauhaus to Our House.[15] The success of Mies' open plaza spawned a whole host of imitations, some by Mies himself, that had disastrous consequences for American cities. Windswept and sterile plazas just don't attract people, no matter how good they look in foamcore models, and no matter how clever the curtain wall design.

Following the adage, "Talent imitates, genius copies," it is fascinating to follow the career of the architect of record for the Seagram Building, Phillip Johnson. Mies was not granted a license to practice architecture in New York because apparently he didn't finish high school. Accordingly, Phillip Johnson, a strong supporter of Mies, became the licensed architect for the project. Ironically, Johnson himself was reprimanded for practicing without a license and only had completed registration after multiple attempts.[16] Johnson managed to use the association with Mies as a springboard that would lead to domination of skyscraper design in the 1970s and 1980's. The glass curtain wall of his IDS Building in Minneapolis brilliantly captures the spirit of Mies's early glass skyscraper projects, and his Pennzoil Place development takes the theme of the Seagram Building and breathes new life into the form. However, his later buildings used the freedom of expression of the curtain wall as more of a cartoon than as an expression of an architectonic idea. Johnson's fame soared as a result, but architecture was left with many looking back fondly at the old "banal" glass box days.

The John Hancock Building remains as one of the most interesting curtain walls of the 20th century. Designed in direct response to the Prudential Building about ½ mile away, the John

Hancock Life Insurance Company blackmailed the City of Boston into granting permission to build directly on Copley Square, throwing the square in shadow for much of the day. There was no way the board of the John Hancock Insurance Company was going to continue to meet looking up at the board room of the Prudential Insurance Company just a quarter mile to the west.

Originally designed as a cylinder with a facet cut out of the perimeter, financial analysis of the project demanded an increase in floor area and a decrease in cost. What role this cost cutting had on the eventual history of the building is unknown, but with a reduced site area and greater floor area, the final design was not as much a corporate symbol as it was a speculative investment.

The building itself is a fine later modern tower. Sheathed in a mirror surface glass, it traces a slender parallelogram in plan, with a rabbet taken out of the short end which emphasizes its slenderness. However, the disastrous decision to build right on Copley Square and immediately adjacent to Henry Hobson Richardson's Trinity Cathedral was pigheadedly defended both by Henry Cobb, the chief designer, and the American Institute of Architects. Construction in the soupy Back Bay Boston fill resulted in millions in dollars of damage to the adjacent Trinity Church. Dewatering of the excavation caused subsidence in the church, and resulted in a seven figure lawsuit. The Copley Square Plaza Hotel to the west suffered the same fate, but the building was eventually purchased by John Hancock as a less expensive way of settling lawsuits. Defending the decision to build adjacent to Richardson's masterpiece, Cobb stated, "The tower's uniformly gridded and reflective surface, stripped of all elements that might suggest a third dimension, mutes the obtrusiveness of its enormous bulk, and defers in all respects to the rich sculptural qualities of its much smaller neighbor."[17] Despite the erudite language of the statement, one cannot hide a skyscraper no matter how cleverly designed the curtain wall. Despite the siting and technical disaster of the building, it received not only an AIA award in the year it was built, but received a 25 year Gold Medal as well. Buildings don't disappear by cladding them in mirror surfaces. Nearly 30 years following construction, it is still a disappointment to see Trinity Cathedral cast in shadow.

Whatever the demerits of the siting, the building itself is sublime: a combination of the beautiful and the terrifying. The curtain wall represents an aggressive leap forward in curtain wall design. Up to this time, curtain walls had a glass window covering the occupied space only, with a separate spandrel covering the mechanical and structural space between floors. However, with the John Hancock Building the glass stretched 11 ½ feet to reach floor to floor. In addition, a new silver coating on a traditional lead gasket system was developed by the Libbey-Owens-Ford company. This new curtain wall resulted in a prismatic form that emphasized the clean lines of the parallelepiped mass. The rabbet cut into the short side of the skewed building elegantly emphasizes the slenderness of the mass.

During construction some of these 4-1/2 by 11-1/2 feet, 500 lbs. pieces of glass broke and rained down on the construction site, but this is hardly an unusual occurrence during construction. However on 20 January of 1973 a storm with 75 mph winds broke 16 lites and damaged 49 more.[18] By June of that same year 2,400 lites were removed and replaced with plywood. For a thermopane glass system rated for 35-40 psf, this was an unforeseen event at best.

It has been reported that just before failure, the panels reflected light differently, enabling crews to remove the glass before it became a 500 lb guillotine. Soon there were spotters with binoculars in radio contact with crews in the building who would remove the glass panel and replace it with plywood. Finally, the Boston Fire Marshall shut down the building due to the quantity of flammable plywood on the facade, forcing the company to find new space to rent, move out, and initiate the inevitable lawsuits.

After the first preliminary investigation structural stiffening of the frame was undertaken in the spring of 1975. This came as no surprise to many, as excessive movement and/or torsional twisting was suspected by many as a contributing cause of the failure. However, to everyone's surprise, the stiffening took place in the longitudinal direction, not the transverse. The company stated that these repairs were to add "satisfactory performance over the long term." Since the code-mandated wind velocity threshold in Boston at the time of construction was only 80 mph, many have speculated that this extremely low figure for a coastal city was unwisely used in the frame design. Others have speculated that only the transverse direction was calculated for wind forces, leaving the longitudinal axis only designed by rule of thumb or rough approximation.

After the stiffening of the steel frame, replacement glass was installed in the building. Instead of an insulated thermopane system, a single pane float system rated for 220 psf was installed. Apparently John Hancock wanted something that was absolutely not going to fail. Switching from a double to a single pane system required a $300,000 upgrade to the HVAC system, and increased future energy consumption.

In 1990 the legal action involving the curtain wall failure was settled with the consultant, Simpson Gumpertz & Heger Inc. testifying that despite the flaws in the structural system, the cause of the curtain wall failure was the bond between the lead gasket and the glass. Although the system had been used successfully for many years with smaller pieces of glass, the very large size of the John Hancock tower glazing set up forces that overwhelmed the system. As the lead gasket pulled away from the glass, it brought pieces of the glass with it, leaving weakened areas on the glass that set up cracking and failure.

Many lessons can be learned from the John Hancock tower: respect for urban spaces and institutions, the danger of ego, and the advantage in designing to the correct specifications. However, in our context, it should be pointed out that a metal and glass curtain wall has limitations. One cannot just draw something on a piece of paper and assume that current technology can make it work.

The Future of the Curtain Wall

What is the future of curtain wall construction likely to bring? Several buildings illustrate potential scenarios for the future. All examples admittedly are extremes, but hopefully they communicate the point.

First is the Wexner Center designed by Peter Eisenman from 1983-89. It is a complex building that represents a series of "dislocations" (Eisenman's term) to confront the occupant. It is a museum with generous amounts of glass (including roofs) introducing light into galleries. These glass planes run up the vertical wall and then wrap around the roof plane creating an almost Pyranesian interior as they interact with the steel tube construction that angles into the ground on the east facade. The difficulty is that this curtain wall and skylight roof do not provide the protection of gallery artifacts that most museums require. Once leaks developed in the roof "curtain wall" few entities wanted their artifacts to be displayed in a space that had no sunlight protection and leaked. A decade following its completion the Ohio State University issued an RFP to rehabilitate the glass systems in the building, with an expected cost about one third of the original construction bill. [19]

Second is the Lloyd's of London building by Richard Rogers (1979-84). It is an inside-out building, with the curtain wall on the inside and the structure and mechanical elements on the outside. There is no doubt that this structure creates an exciting and dynamic form. The homage to the Crystal Palace, the glazed barrel vault, looks more like the cylinder head on a racing engine as the ducts that feed into the conditioned spaces look more like header pipes. Elevator cabins travel up and down, exposed on the outside surface of the wall. In a twist of irony this monument to conservative capitalism is the closest embodiment of the Constructivist experiments of the early Soviet Union, such as the early Pravda projects by the Vesnin and Melnikov. It is unclear how many climatic zones could sustain a building on this type–common sense dictates that accumulations of freezing vapor emanating from air gaps would interfere with elevator equipment in cold climates. From a heat gain perspective it probably outperforms the typical glass box, but it would be fascinating to know what the maintenance costs are on a structure of this type, relative to more conventional office buildings.

Third is the Peter B. Lewis building at Case Western Reserve University by Frank Gehry. A continuation of the design idea that met such acclaim in Bilbao, Spain at the Guggenheim Museum, this structure tries out the titanium clad medium in a slightly different climate. It is a visually exiting building both inside and out, but it became even more exciting the winter of 2004 as accumulated snow started sliding off the roof to the sidewalk below. The university quickly fenced off the sidewalk adjacent to the building, and there are plans to plant shrubbery to occupy a snow landing zone. Not so fortunate has been Gehry's experience at MIT, where snow and ice from the Stata Center's warped surfaces cascade on emergency exits, and mold grows on the building envelope. [20]

These examples from three different designers suggest that there likely will not be new materials used as curtain walls in the future (note that I don't necessarily call titanium a new material–it is similar enough to stainless steel sheets in terms of detailing and forming that I view it as a new texture). Instead, existing materials or variants of them may be asked to perform in ways that they have not been asked to do in the past. If designers focus on the poetic meaning of their forms and just cover junctions with sealant, then we are likely to have some interesting stories to tell in the future.

What is the future of the curtain wall that one ought to see? Since the infrastructure continuing to be built in western countries continues to suck up embarrassingly large percentages of world energy resources, it would be novel for the glass and metal curtain wall to try to change that trend. How can designers keep the glass and metal curtain wall inexpensive, thin, and lightweight, yet allow it to respond to climatic conditions in a way that reduces energy usage? Photovoltaic cells may some day be incorporated into wall systems to power the equipment needed to cool down the building as the sun heats it up. More technologically feasible today, liquid crystal elements might reflect away heat on warm days and become transparent on cool days to allow the sun to warm the interior. Such changeability might even become part of the building's aesthetic if a designer were clever enough to work with the medium.

These comments and critiques do not imply that the curtain wall is dead, or that it is a thing of the past. On the contrary, the glass and metal curtain wall is a building form that has many years of life in it. However, as world politics and economics redraw boundaries and assumptions rapidly in the current world, the curtain wall will have to be equally nimble if it is to retain its dominance in the construction of tomorrow.

Notes

1. *John McKean, Crystal Palace: Joseph Paxton and Charles Fox (London: Phaidon Press, 1994), pp. 19-21.*
2. *McKean, p. 25.*
3. *Tom F. Peters, "Some structural problems encountered in the building of the Crystal Palace of 1851," in Robert Thorne, ed., Structural Iron and Steel, 1850-1900 (Aldershot:Ashgate,2000), p. 28.Peters estimates that only 45% of the outer skin is of glass, whereas the roof was approximately 90% glazed.*
4. *A transept was originally proposed by Henderson for reasons of stability, but later Charles Barry, the architect of the new Houses of Parliament, insisted that a barrel vault be added for aesthetic reasons. See McKean, pp. 19-20.*
5. *Peters, p. 7. Peters quotes Robert Mallet's eyewitness account from The Record of the International Exhibition, 1862 (Glasgow/ Edinburgh/London: William Mackenzie, [1862]), p. 60.*
6. *Note that oak wedges were used to tighten the cast iron girders against the cast iron column flanges, perhaps anticipating such thermal movements.*
7. *Roula Mouroundellis Geraniotis, and Gerald R. Larson, "Toward a better understanding of the evolution of the iron skeleton frame in Chicago," Journal of the Society of Architectural Historians v. 46 (Mar. 1987) p. 39-48.*
8. *Elwin C. Robison, "The Society for Savings Building in Cleveland and the Development of Skyscraper Frames," published as chapter 23 in Architecture: Design Implementation (Association of Collegiate Schools of Architecture Press, 1991) pp. 126-28.*
9. *Elwin C. Robison, "Early Skyscrapers and Engineering Calculation Methods," published as chapter 23 of On Architecture: The City and Technology (Butterworth, March 1991)pp.114-6.*
10. *Robison, Early Skyscrapers....op cit.*
11. *Reyner Banham, A Concrete Atlantis: U.S. Industrial Building and European Modern Architecture (Cambridge: MIT University Press, 1986), see especially Chapter 3.*
12. *Helmut Weber, Walter Gropius und das Faguswerk (Munich: G. D. W. Callwey ,1961).*
13. *Le Corbusier [pseu.], trans. by Frederick Etchells, Towards a New Architecture (London : J. Rodker, 1931), p. xxx.*
14. *Kevin D. Murphy, "The Villa Savoye and the modernist historic monument," Journal of the Society of Architectural Historians, v. 61 no1 (Mar. 2002) p. 68-89.*
15. *Tom Wolfe, From Bauhaus to our house (New York: Farrar Straus Giroux, 1981).*
16. *See Franz Schulze, Philip Johnson: Life and Work (New York : A.A. Knopf, 1994).*
17. *Robert Campbell, "Evaluation: Boston's John Hancock Tower in context." AIA Journal, v. 69 (Dec. 1980), p. 22.*
18. *William Marlin, "Some reflections on the John Hancock tower," Architectural Record, v. 161 (Jun 1977) p. 125.*
19. *Robin Pogrebin, "Extreme Makeover," New York Times 18 Sep 2005.*
20. *Shelly Murphy, "MIT sues Gehry, citing leaks in the $300m complex," The Boston Globe, 6 Nov 2007.*

The History of the 20th Century Metal and Glass Curtain Wall and Evolution of Curtain wall Standardization and Performance Testing

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This paper will focus on the history of the 20th century metal and glass curtain wall, beginning with a review of how world events, natural disasters and shifts in both politics and culture have combined through the years to influence the growth and direction of that industry. In addition to exploring the confluence of people and events during and after the Industrial Revolution that would prove critical to the birth of the contemporary aluminum and glass curtain wall industry, we will also explore the evolution of window and curtain wall standardization and performance testing from its inception in 1960 to today. Changes in language and scope within each test standard for air, water and structural performance will be explored, together with changes in the use and interpretation of those standards through the years and the factors that continue to influence their use and interpretation today.

1. Industrial Revolution

1.1 "Curtain Wall" as a Design Aesthetic

The curtain wall concept began in its most basic form with the functional greenhouse, moved through the unitized application (at least in its aesthetic) at the Crystal Palace in 1851, and found its "true" application as the cladding for the skyscraper, developed by William Jenney at the end of the 19th century, which freed the building skin from its traditional load-bearing role. Though the concept was in place, the widespread application of the streamlined glass curtain wall as we now know was hampered by the aesthetic of the day, which searched for the solid and massive appearance of traditional stone masonry, the lack of modern construction materials such as large sheets of glass and high performance sealants, and the building codes at that time which were focused (some say biased) towards traditional masonry construction and stipulated the materials and methods to be used in construction, rather than relying on a performance-based specification. Though there were several notable exceptions, such as the Fagus Shoe Factory in Germany (1913) and the Hallidie Building in California (1918), it would take another 40 to 50 years until the aluminum curtain wall would "conquer" masonry as the façade material of choice for commercial architecture.

1.2 Birth of the Glazed Aluminum Curtain wall Industry

In the decades following the Civil War, the United States emerged as an industrial giant. Old industries expanded and many new ones, including petroleum refining, steel manufacturing, and electrical power, emerged. Railroads expanded significantly, bringing even remote parts of the country into a national market economy. During the mid 1800s through the early 1900s, innovations, world events and natural disasters combine to create the industries and technology necessary to give birth to the 20th century metal and glass curtain wall.

- During the late 1800's, C.M. Hall (principal founder of Alcoa), works to improve the aluminum smelting process, and subsequently develops alloys, both of which reduce the price of an aluminum ingot from $4.86 per pound in 1888 to 0.78 per pound in 1893, making it a viable material for widespread application.[1]

- The Chicago World's Columbian Exposition of 1893 is arguably the single most significant event in the history of architecture in the U.S and, somewhat surprisingly, also a place where the fathers of the modern metal and glass curtain wall (Francis John Plym and Libbey) would gather, one searching for inspiration (Plym), the other for validation (Libbey), both would go on to play critical roles in the development of the modern metal and glass curtain wall. Francis John Plym (principal founder of Kawneer), reportedly inspired by the design, technology and innovation on display at this exposition, begins pursuing higher education and is admitted to the College of Engineering at the University of Illinois. And Edward Drummond Libbey, reportedly facing financial ruin, invests all of his remaining capital in an exhibit of his glass products at the Chicago World's Columbian Exposition. The effort is successful, thereby allowing Libbey to finance (later) the Owens Bottle Company – an introduction that would eventually lead to the establishment of Libbey-Owens-Ford Company (LOF), one of the largest flat-glass manufacturers in the world today.

- Hurricane Camille (1900) stuns Galveston, Texas with a level of wind-borne destruction never before seen in the U.S. The significance of coastal design and construction is "exposed", perhaps for the first time.

- The devastation of the 1906 San Francisco earthquake created an urgent need for new buildings and storefronts. This need was met in part by Plym, who, two years earlier, had begun work on a resilient metal framing system for glass storefronts and display cases that would allow for large expanses of unobstructed, storefront glazing - a response to the limitations of wood frames, which were vulnerable to moisture-related expansion, contraction, rot, and similar decay that caused large panes of plate glass to crack. In 1906 Mr. Plym is granted three patents for his new "Kawneer" storefront system "pertaining to the production of a small, unobtrusive, and durable Sash-bar and the portion of construction surrounding and supporting the window glass."[2] During this period Kawneer also develops the roller-die process which is a forerunner to extrusion process currently in use today.

- In 1912, E.D. Libbey and Michael Owens, after securing the patents of I.W. Colburn for a "sheet-glass drawing machine" (1902), invent the world's first successful flat-drawn window glass machine, thereby making flat-drawn glass a commercially viable product for the first time. This invention would result in the formation of the Libbey-Owens Sheet Glass Company.

- In 1921, Willis Haviland Carrier patented the centrifugal refrigeration machine. The 'centrifugal chiller' was the first practical method of air conditioning large spaces. The use of "comfort cooling" through air conditioning made the curtain wall, which was now structurally and conceptually possible, livable for the building occupants.

- The Bauhaus is forced to close in Nazi Germany in 1933, forcing many notable teachers from that school to relocate to the United States. Many of these masters of the modern movement would be influential in promoting the use of the curtain wall in architectural design.

During this nascent period of curtain wall development, the growing industry began to discuss standards and form organizations to monitor and research the emergent products. In 1936 the Ferrous Metal Window Institute (NFMWI) is formed and in 1938 The National Association of Architectural Metal Manufacturers (NAAMM) is founded in Chicago to act as a trade association representing manufacturers of metal products (both ferrous and non-ferrous) used in commercial and industrial building construction. Though these organizations were in place, much of this early work did not make its way to the architects, designers, or to the job sites.

2. The World at War

Although World War I was arguably the first world conflict that lead to a global focus of manufacturing and industry toward a common goal, it was the dawning of World War II and its aftermath that lead to the most significant and rapid development of industry and technology instrumental in the growth of metal and glass curtain wall.

The invention of the airplane and subsequent growth of the aircraft industry, particularly during World War II, becomes the catalyst for the explosive growth of the aluminum manufacturing industry in the United States. The demand for aircraft during World War II led to a demand for production increases that made the aluminum extrusion process more economically viable, and led to inventions such as the aluminum “sandwich” panel, silicone, acrylics, and epoxies that form the basis of today’s metal and glass curtain wall industry. The end of the war provided a huge supply of aluminum, which was now available for non war-related applications. Several architects, including Pietro Belluschi, anticipated this surplus and designed buildings clad in aluminum to take advantage of the opportunity. The first result of Belluschi’s prescience was the Equitable Savings and Loan Building in Portland, Oregon. “This trim, compact office building originally 12 stories high and later 13, set styles for hundreds that came after. It was the first to be sheathed in aluminum, the first to employ double-glazed window panels, and the first to be completely sealed and fully air-conditioned” (from Sylvia Hart Wright, Sourcebook of Contemporary North American Architecture, “Postwar to Postmodern”).

As the tide began to turn during World War II, Kawneer formally introduced its storefront product line to a jury consisting of Mies van der Rohe and William Lescaze, among others, in 1943, thereby signaling a shift in emphasis for the metal and glass fenestration industry from the war effort back to architecture, the modern movement, and the International Style.

World War II also brought with it the development of the War Standards Procedure, a process intended to accelerate the development and approval of new and revised standards necessary to increase industrial efficiency for war production. This, of course, became the catalyst for the continued growth of national standards in the U.S. and, more specifically, the development of the American National Standards Institute (ANSI) that we see today.

In addition, several innovations in the curtain wall industry developed during the end of the 1940s.

- In 1946 C.H. Johansson of Norway writes:

  > “It is clearly unwise to allow walls, whether of rick or porous cement, to be exposed to heavy rain. They absorb water like a blotting paper and it would therefore be a great step forward if an outer, water-repelling screen could be fitted to brick walls…. This screen could be applied so that water vapour coming from within is automatically removed by ventilation of the space between wall and screen.”

  This quote was also considered by some to signal the birth of the modern “rainscreen” wall principle as a viable approach for commercial design and construction.

- In 1948 Kawneer introduces the first extruded aluminum profiles for door systems, signaling a shift in the industry away from roller dies, a process also pioneered by Francis Plym and Kawneer. In 1956 Kawneer introduces the first unitized curtain wall system, a process utilizing factory pre-assembled wall sections for one and two-story buildings. And Kawneer introduces the concept of the snap-in aluminum-glazing bead with its “Narrow Line” framing system, which included the use of “roll-on”, vinyl glazing gaskets.

- In 1952 Alistair Pilkington conceived the idea of forming a ribbon of glass by floating the melted raw materials at high temperature over a bath of molten tin. It took seven years to develop the process. Pilkington set out to replace the twin grinding and polishing process for making plate glass. In the event, the float glass process superseded not only that process, but also the sheet glass process for making ordinary windows. It was to become the universal process for the manufacture of high quality flat glass.

- In 1954 A.A. Sakhnovsky assumes responsibility for an “obscure window test facility” at the South Campus of the University of Miami (Florida) which is later identified by NAAMM (TM-1-68T) as the Housing Research Laboratory at the University of Miami - a major contributor to the science of curtain wall testing.

Thus, by the mid to late 1900s, all of the ingredients necessary to the construction of the modern aluminum curtain wall were in place: the concepts were developed and had begun to be applied, aluminum was readily available and the extrusion process was refined, high quality flat glass was affordable and available, and insulating glass units are being developed, silicones, acrylics, and epoxies had been developed, polysulfide sealant for glass and glazing applications was introduced into the construction industry in the early 1950’s (principally as a means to seal insulating glass units at the spacer bar-to-glass interface), and glazing gaskets were invented by the General Motors Corporation. Now the challenge became how to properly combine these ingredients to provide a weather-tight, durable façade.

3. Early Standardization and Performance Testing

Once the curtain wall was accepted and began to be implemented throughout the American and European cityscape, the industry grew quickly. Sensing a new and profitable outlet, many of the window manufacturers of the day attempted to become curtain wall manufacturers by applying the same methodology of window construction just on a larger scale, or by joining smaller window units together to form a larger whole. Needless to say, this method was not particularly successful. But even in the case of the “engineered” curtain wall systems on high profile projects such as the U.N. Secretariat building in New York City (1950) leaks were noted on the building, reportedly due in part to a failure of the glazing putty, less than a year after the construction was complete. It is interesting to note that the specifications for this project did not require field testing of the curtain wall system.

3.1 An Industry Organizes

Fortunately, concurrent with the new boom in curtain wall usage, it became clear that this was a complex system that would require comprehensive design and analysis, and the industry responded with the development of diagnostic and performance testing.

In 1945, the Aluminum Window Manufacturer’s Association (AWMA) is formed and shortly thereafter, the Institute for Building Research, Pennsylvania State University, begins offering “static pressure tests” for windows, with a 16’X16’ maximum test specimen size, as well as “thermal cycling” tests of the same size test specimen (and combination of both thermal cycling and static tests on same test specimen). Cycling ranged from -60F to +120F; with a maximum surface temp of +150F, unique among labs available at that time for this type of testing.

And during the 1960s the industry moved to standardize the curtain wall industry in earnest:

- In 1960 NAAMM publishes the first “Metal Curtain Wall Specifications Manual”, which includes sections titled “Metal Curtain Wall Design Principles” and the “Metal Curtain Wall Specifications Manual”.

- In 1962 the Architectural Aluminum Manufacturer’s Association (AAMA) is formed in Chicago. AAMA is a trade association for manufacturers of aluminum products used in the construction industry. During this year, the first window is certified by AAMA.

  AAMA establishes the first independent, third party verification program for windows. The program is later certified by ANSI and continues to this day.

- 1965-ASTM Committee E06 on Performance of Buildings first publishes E283-65T, “Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors”, the first apparent use of a static air pressure differential to assess window and curtain wall performance (in this case, net air infiltration) by a recognized, independent testing and standards agency.

- 1966-NAAMM first publishes its “Entrance Manual”…

  ASA reorganizes and renames itself the United States of America Standards Institute (USASI), predecessor to ANSI.

- 1967-ASTM Committee E06 first publishes E330-67T, “Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference”, an adaptation of static air pressure differential as defined in E283 to assess the structural performance (maximum deflection under simulated positive and negative wind pressures) of glazed metal windows and curtain walls.

  ASTM Committee E06 first publishes E331-67T, “Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference”, the first apparent use of static air pressure differential to assess water penetration resistance of glazed metal windows and curtain wall under simulated positive wind pressures.

4. 1968- A Watershed Year

1968 was significant in the evolution of curtain wall standardization and, more importantly, performance testing. It was the culmination of all of the preliminary discussions and incidental testing that had been in development in a non-standardized and/or academic way since curtain wall construction began.

4.1 NAAMM TM-1-68T

NAAMM updates and re-publishes its “Metal Curtain Wall Specifications Manual” (originally published in 1960), which includes a section titled “Methods of Test for Metal Curtain Walls” (TM-1-68T). This test method is characterized by NAAMM as an interim standard intended to “serve the immediate needs of the industry” until ASTM Committee E06 finishes its on-going expansion of ASTM E-283, 330 and 331 to include metal and glass curtain walls. NAAMM further acknowledges that “it may be some time before the revised ASTM Test Methods are finalized and published [and that] these revised [ASTM] methods, when published, will contain provisions similar to some of those specified in this Standard. In that case, parts of this Standard will likely be withdrawn and the applicable ASTM methods will be referenced instead”.

Despite the previous statement from NAAMM, it is interesting to note that the ASTM “static series” of tests (E283, E330, E331) were, according to our review of ASTM records, already published and available for use at the time this document was developed by NAAMM. Regardless, this appears to be the earliest documented evidence of significant cooperation/collaboration between ASTM and AAMA in the development of window and curtain wall performance test standards. In reviewing both the ASTM “static series” of tests published during this time and NAAMM TM-1-68T, the similarity in both format and language between the two documents suggests close cooperation between NAAMM and ASTM during this time period.

NAAMM TM-1-68T included general information about performance testing of metal curtain walls and their:

- Resistance to Air Infiltration
- Resistance to Water Penetration
- Structural Performance Under Uniform Loading

Two general test methods were included in the standard:

- The Static Method: "In which the test specimen is sealed into one side of a large air chamber or box, and is subjected to static air pressure, either by blowing air into, or exhausting air from, the chamber".

- The Dynamic Method: "In which the test specimen is subjected to a blast from a wind generator, such as an aircraft engine or propeller".

Because structural deformations in the test specimen could not be accurately measured under dynamic loading, air infiltration testing was limited to the "static method". In contrast, it was determined that water penetration resistance tests "could be performed using either the static or dynamic method". However, it was also generally agreed that, although the dynamic method "… is far more dramatic and impressive… [and] more closely represent[s] the impact of unpredictable and suddenly shifting wind gusts and wind-blown water…", the static method offered "more accurate control of a given set of test conditions" that could be considered a more "severe" test in that it included:

- A first stage requiring the continuous application of water "… to the outdoor face of the specimen at the rate of five (5) gallons per hour for each square foot of test specimen… at the same time a differential static [air] pressure of four (4) pounds per square foot [is] applied against this face…" for a period of not less than fifteen (15) minutes.

- While maintaining the water flow, a second stage requiring an increase in the static air pressure differential to 20% of the "full specified design load" for the building, for a period of not less than fifteen (15) minutes.

Several basic tenets of curtain wall design and performance testing established by this standard have survived largely unchanged to this day. It also interesting to note the language in this standard very candidly describes the limitations of laboratory performance testing as a reliable indicator of actual performance in the field, and foreshadows the development of field air and water penetration test standards during construction by including the following language:

> "A second check on resistance to water penetration during actual construction in the field may often be advisable and in fact highly desirable where practicable. A recommended standard method for conducting such field checks may soon be made available."

These field tests, the first of which was published in 1969 by NAAMM as FC-1-69, "Field Check of Metal Curtain Walls for Water Leakage", is the precursor to AAMA 501.2, a calibrated spray "nozzle" test that remains in use today, largely as a diagnostic tool to diagnose and repair uncontrolled rainwater penetration in a variety of glazed aluminum fenestration systems and sealed exterior wall construction joints.

During this time AAMA establishes a "Curtain Wall Division" and NAAMM members involved in the manufacture of metal curtain wall systems transfer their membership to the Curtain Wall Division of AAMA, expanding their membership to include companies involved in the manufacture of non-ferrous metal windows, storefront and entrance systems. This group is then renamed the Architectural Window, Curtain Wall and Storefront Division of AAMA.

The "obscure window test facility" at the University of Miami (Florida) is deemed "unrelated to the academic mission of the University…"[3] and, therefore, sold to A. A. Sakhnovsky. A. A. Sakhnovsky establishes the Construction Research Laboratory (CRL) in Miami, Florida.

ASTM revises and re-publishes E283,

"Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors" and re-publishes E331, "Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference".

5. 1970's & 80's-AAMA and Field Testing Come of Age

The 1970's saw the growing consolidation of the fenestration industry under AAMA, beginning in 1973 with the merger of their Curtain Wall and Storefront and Entrance Divisions and subsequent re-publication (in 1975) of the "Metal Curtain Wall Specifications Manual" originally published by NAAMM in 1960 and 1968. Today, this consolidation is even more evident with the recent addition of the vinyl window and door industry to AAMA, as well as the on-going negotiations with the Window and Door Manufacturer's Association (WDMA) to join AAMA.

"Aluminum Curtain Walls", which included the following: In 1971 AAMA begins publishing a series titled "Aluminum Curtain Walls", which included the following: "The Rain Screen Principle and Pressure-Equalized Wall Design," *Design Details of Three Recent Buildings* (Vol. 2, February 1971) and "Lockstrip Gaskets in Architectural Applications AAMA's New Contract Addendum: An End to Inequities" *Design Details of Two Recent Buildings* (Vol 4, December 1971).

It is interesting to note that, with the issue of publication No. 2 (1971), the pressure-equalized rainscreen principle appears to be more formally accepted in the United States, reportedly following discussions between its author and "a number of Canadian researchers." This document listed the following "critical features" of a rainscreen wall system:

- An exterior rain barrier containing "protected" openings, which permit the passage of air, but not water, and which have a minimum dimension of at least 6mm to prevent blockage caused by heavy rain.
- A confined air space in which the air pressure is essentially the same as the external air pressure.
- Insulation fixed to the outer face of the inner leaf and not the reverse face of the cladding panels.
- An interior barrier which limits the passage of air and water vapour, and which is capable of withstanding all incident window pressures (positive and negative).

It is also interesting to note that, with the issue of publication No. 4 in this series (1971), AAMA appears to begin tackling legal issues on behalf of its membership. Specifically, the introduction in this issue of the AAMA Standard Addendum to Curtain Wall Construction Contract Documents may signal the first formal reaction of the curtain wall industry to perceived inequities in general contracting practices. Based on our review of the document, this appears to be in response to concerns associated with "…unreasonable retainage; denial of lien rights; excessive and unreasonable guarantees; and delayed payment for project-specific engineering, tooling and fabrication costs."

And in 1973 The Canadian National Research Council (CNRC), principally through the work of J. K. Latta, re-advocates the use of the pressure-equalized rainscreen wall system to resist uncontrolled building envelope rainwater penetration, as well as to control condensation, citing the following advantages of an insulated, drained, pressure-equalized rainscreen wall system:

- The cladding assembly does not rely on the use of gaskets or sealants, which usually require periodic inspection and maintenance if performance problems are to be avoided.
- The problems of tolerance and fit and cyclic thermal movements in the cladding assembly become less critical that with fully-sealed walls.
- The inner leaf, which forms the air barrier, is protected from the effects of heavy wetting. As a result, minor imperfections in the air barrier become less critical since they are not subjected

to the combined effects of heavy wetting and wind-induced air-pressure differentials.

- The outer leaf acts as a solar screen, so that thermal expansion and contraction of the inner structural element is reduced.
- Joint seals and other materials on the indoor side of the cavity (presumably the "inner leaf") are protected from the potentially deleterious effects of ultra-violet radiation.
- A layer of vapour-permeable thermal insulation can be applied to the outer face of the inner leaf, where it need not be bridged by structural elements such as floor slabs and columns. If located there, the layer acts as an insulating shield, which maintains the structural element at a relatively stable temperature.
- Water vapour permeating through the inner leaf into the air space can be carried away by an air current entering at the base of the cladding, leaving (exiting) at the top. This back-ventilation also facilitates the evaporation of any condensation, which may have formed within the cold outer layers of insulation on the inner leaf. By allowing the building to "breathe", the moisture of construction stored within the wall is also allowed to escape to the exterior.

This and related research appears to foreshadow the prescriptive approach later adapted by the Division of Building Sciences in Alberta, Canada (as well as other provinces), which appears to require design professionals to adapt a pressure-equalized, compartmentalized, rainscreen wall system that includes a layer of vapor-permeable insulation located outboard of the inner leaf of the wall assembly.

In 1975 ASTM first publishes E547, "Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential", the first apparent use of a cycled static air pressure to simulate the effects of short-term, gusting wind and wind-driven rain rather than the continuous, uniform static air pressure difference embodied in ASTM E331 (laboratory test for water penetration resistance under uniform load) and, later, E1105 (field test for water penetration resistance under uniform load).

And in 1979 AAMA publishes its first "Aluminum Curtain Wall Design Guide Manual", which is intended to summarize and update the first nine (9) volumes of their "Aluminum Curtain Wall" series in a single document. In this document, AAMA indicates that the Aluminum Curtain Wall series will continue, and will be further supplemented from time to time by Technical Information Reports (TIR's) addressing subjects "…of major interest to architects and the industry."

7. 1990's-Andrew, Terrorism and the Rising Cost of Litigation

The 1990's, which bore witness to the first attack on the World Trade Center complex in 1993, also saw the landfall of Hurricane Andrew along the south Florida coastline in 1992. The impact of this storm on building codes, performance test standards, and the manufacture of glazed window, curtain wall, and door products in the United States cannot be underestimated, and remains a watershed moment for the U.S. design, construction and insurance industries. In an interview published on-line by Florida Focus, Mr. Robert "Bob" Sheets, director of the U.S. National Hurricane Center in Miami at the time Hurricane Andrew hit, offered the following summation: "Structurally, the houses were there [where they needed to be]. The failure points were windows and doors… so we said: 'Protect those windows and doors'".

Florida Focus went on to report that, ten months after Hurricane Andrew, Miami-Dade County strengthened its building code with regard to wind loads on buildings and structures and, perhaps more significantly for the glazing industry, its stance with regard to the impact of large and small wind-borne debris on buildings and structures. Because it was determined (presumably, in part, by the insurance industry) that loss-reduction related to damage caused by flying tree limbs and/or smaller debris driven by hurricane-force winds can, in the words of Mr. Sheets, "… range between 25% and 33%", code requirements for glazed exterior windows and curtain wall systems were also strengthened as a result of this storm. This gave rise to a new series of laboratory tests developed by ASTM and AAMA for large and small missile-impact testing of glazed fenestration products.

In addition to natural disaster, we would be remiss if we ignored the growing influence of design and construction-related litigation on the development, use, interpretation, and refinement of curtain wall performance test standards for water penetration resistance during this decade. This is particularly true in the area of moisture-related construction claims for uncontrolled rainwater penetration through the exterior walls of buildings and structures. In a paper published by Mark Bomberg in 1993, uncontrolled rainwater penetration and moisture ingress were cited as two of the most common threats to the structural integrity and performance of the building envelope, representing up to 80% of all construction-related claims in the United States at that time. For the metal and glass curtain wall industry, the impact of this trend may be evidenced, in part, by the addition in 1993 of the following definition for "water penetration" during field testing in accordance with ASTM E1105:

> Water Penetration: Penetration of water beyond the vertical plane intersecting the innermost projection of the test specimen, not including interior trim and hardware, under the specified conditions of air pressure difference across the specimen.

Similarly, AAMA offered its own definition of "water leakage" with its publication, in 1994, of AAMA 501-94, "Methods of Test for Exterior Walls". However, in contrast with the ASTM definition added to E1105 in 1993, the definition offered by AAMA read:

> Water leakage is defined as any uncontrolled water that appears on any normally exposed interior surfaces, that is not contained or drained back to the exterior, or that can cause damage to adjacent materials or finishes. Water contained within drained flashings, gutters, and sills is not considered water leakage. The collection of up to one-half ounce of water (15 ml) in a 15 minute test period on top of an interior stop or stool integral with the system shall not be considered water leakage.

In comparing these two definitions, it is interesting to note that both ASTM and AAMA appear to abandon one of the basic tenets spelled out in NAAMM TM-1-68, the source-document from which all current laboratory and field air and water penetration tests were drawn, which stated:

> The test specifications provided in this Standard establish only the method to be used in testing; they are not intended to define the required standards of performance. It is the responsibility of the architect to establish these performance standards in his own specifications for the all…

It is also interesting to note that, while ASTM appears to focus its efforts on what water penetration "is", AAMA appears to be more concerned with what water leakage "is not". This subtle shift in language is not necessarily surprising given the growth and acceptance of these field test standards during the 1990's as a means by which the installed performance of metal and glass window and curtain wall systems could be fairly evaluated in new construction. Though subject to some debate, the distinctions offered by AAMA can be fairly characterized as more precise and necessary to address the inherent inequities that exist between performance levels that can be achieved in a testing laboratory versus those that can be reasonably achieved in the field, a concept first embodied in NAAMM TM-1-68:

> It must be recognized, too, that even the most conscientious testing cannot accurately predict how the wall will function in actual use. There are obvious limitations…on the extent to which laboratory testing can guarantee performance in the field. Because of the unpredictable human factors affecting installation work and the wide variation in site conditions…

8. A New Century

Today, the definition of water penetration remains unchanged in the current version of ASTM E1105. However, with the recent publication of AAMA 502-02 and 503-03, it is also interesting to note that AAMA has revised and, more significantly, re-structured its definition of water penetration. To wit, AAMA 503-03 (curtain wall) now defines water penetration as:

> … no uncontrolled water shall pass the innermost surface of the specimen, as defined by the face of the vertical or sloped surface of the innermost framing member, or shall enter the wall cavity during the water penetration resistance tests.

AAMA further defines water leakage as:

> … acceptable, controlled water leakage is defined as any water that is contained in an area with provisions to drain back to the exterior, or the collection of up to 1/2-ounce of water in the 15 minute test period on top of an interior horizontal frame surface that does not spill onto adjacent finishes or materials.

Similarly, AAMA 502-02 (windows) includes the following definition:

> Water penetration shall be defined as penetration of water beyond a plane parallel to the glazing (the vertical plane) intersecting the innermost projection of the test specimen, not including interior trim and hardware under the specified conditions of air pressure difference across the specimen. Any such water penetration shall constitute failure of the water penetration resistance test. It shall also constitute failure if water penetrates through the perimeter frame of the test specimen. Water contained within drained flashing, gutters, and sills shall not be considered failure.

Although both appear, at first glance, to represent a shift back to what water penetration "is", rather than what it "is not", it is important to note that the provision in AAMA 501-94 allowing for "… the collection of up to 1/2 ounce of water in the 15 minute test period on top of an interior horizontal frame surface" is retained largely unchanged in AAMA 503-03 (curtain wall), save for the stipulation that water "does not spill onto adjacent finishes or materials." However, unlike AAMA 501.94, the definition of allowable, or "controlled", water penetration in AAMA 503-03 has been separated from the definition of "uncontrolled" water penetration and recast as a separate paragraph. Setting aside the various arguments that have been made in support of this language, the concept of any standing water on an exposed, interior curtain wall frame surface during an actual rain event is one that our experience suggests is subject to frequent debate. As such, it is an allowance in the definition that can be excluded by the architect from his/her own definition of water leakage in the contract documents for a given building or structure.

Curiously enough, it should also be noted that all of these definitions for water penetration can be inadvertently included in the same specification section. Because ASTM E-1105 is included, by reference, in both AAMA 502-02 and AAMA 503-03, a built-in conflict within the contract documents with regard to the intended definition of water penetration can exist. Unless otherwise clarified by the architect, this conflict can result in significant confusion in the field.

It is also interesting to note that, with this standard, AAMA introduces the "2/3" rule for field testing of water penetration resistance, which states: "Water penetration resistance tests shall be conducted at a static air pressure equal to 2/3 (0.667) of the test pressure specified for the applicable product designation in ANSI/AAMA/NWWDA 101.I.S.2. This change, which is intended to reflect a reduction in product performance in the field versus in the laboratory, has had the practical effect of allowing selected window products to be tested at a static air pressure differential that is less than the calculated value derived using ASCE 7. Misinterpretation of the "2/3 rule" has also resulted in field testing at a static air pressure differential that is less than design intent of the architect who, unfortunately, is often largely unaware of the subtle nuances in the language contained in each test standard and their appropriate interpretation and enforcement in the field.

9. Conclusion

Although world events, natural disasters and shifts in both politics and culture continue to influence the growth and direction of the curtain wall industry, it is perhaps most interesting to note the growing influence of design and construction litigation on the direction of both the curtain wall industry and the interpretation of performance standards and testing. Ongoing changes in both the language and scope of test standards for air and water penetration resistance, together with changes in the use and interpretation of those standards over the past 20 years, suggest that this trend is likely to continue. An example of the impact of this trend can be seen in a Memorandum Opinion issued by a Federal District Court in the Mid-Atlantic region of the United States, in which the court held that:

- The subcontractor's argument that "… the windows leaked because [the general contractor] performed an improper and 'more stringent' test (a "chamber test") on the windows, rather than 'a hose test as required by the specifications'" is not persuasive, in part because the subcontractor acknowledged in their own correspondence that "… several deficiencies have been observed… [in] the existing installation… [that] are direct contributing factors to the [failure of] field water [penetration] testing…".
- A change by the Owner to a more stringent series of field tests (as alluded to above, a shift from the AAMA 501.2 "nozzle" test specified to a series of ASTM E-1105 "chamber" tests) does not constitute a "…constructive change to the Subcontract" under the terms of contract for construction (American Institute of Architects Document A201, General Conditions), which states, in pertinent part: If the Owner determines that "portions of the Work require additional testing, inspection or approval… the [Owner] will… instruct the Contractor to make arrangements for such additional testing, inspection or approval."
- The subcontractor's third party complaint against the curtain wall manufacturer for their "… failure to properly design the… windows" is not persuasive, in part because the subcontractor: a) acknowledged in their own correspondence and subsequent testimony that "…[a]ll the deficiencies are items that are not installed as per [the curtain wall manufacturer's] installation and assembly instructions', and; b) the curtain wall manufacturer's warranty states that the manufacturer "… shall not be liable… for negligence in the manufacture, design, or installation of the products" (emphasis added by the Court).

The first two findings listed above are significant in that they appear to embrace the concept of field testing as a diagnostic tool to evaluate the quality of the installation, rather than simply as a "pass/fail" hurdle to be cleared by the subcontractor during initial installation. This interpretation emphasizes, and appears to give considerable weight to, proper installation and workmanship. As these can be considered harbingers of long-term durability and performance, this interpretation is encouraging in that it appears to be consistent with the spirit and intent of the field test standards and, perhaps more importantly, in the best long-term interests of the owner/end-user and all parties involved in the project.

The third ruling is significant in that it appears to give considerable weight to the liability protection contained in the warranty language developed by the curtain wall manufacturer on this project for the use and installation of their products and systems. Although owners and developers may be aware that a curtain wall manufacturer cannot reasonably be held liable for the misapplication or misuse of their products in a given design or installation, they may not be fully aware that the manufacturer can be indemnified against their own negligence in the manufacture, design and, by extension, performance of those products in the field. Given that many of these products are, in fact, advertised (and, therefore, selected and specified) as pre-engineered curtain wall systems with laboratory-certified performance ratings for air and water penetration resistance (rather than simply a "kit of parts"), the opinion of the court with regard to this claim is important to note, and further underscores the critical need for properly specified field air and water penetration resistance testing on every project to verify the installed performance of window, curtain wall, storefront, and sloped glazing systems.

Notes

1. *www.alcoa.com/The Alcoa Story/Page 3*
2. *www.kawneer.com/History of Kawneer/Overview/1906*
3. *www6.miami.edu/campaign/donors/donors_dp_sakhnovsky.html*

Concrete Restoration of Modern Buildings

The development and use of concrete during the modern and postwar eras was pronounced as a building material that gave form to the most well known buildings of the 20th Century. Examination of the use of concrete, including its manufacture and application techniques are essential to understanding a variety of approaches to material conservation and their preservation as presented in this section.

In the Concrete Restoration of Modern Buildings, authors present their unique case studies and identify general approaches to the conservation of both cast-in-place and precast concrete structures. Identification of concrete building technologies, signs of concrete deterioration and their repair are addressed. Each of the authors, Pyburn, Seitz, and Ruggieri set out to cover a range of topics through projects and research from the U.S.A, France and Italy. Clearly, these authors not only establish the significance of global iconic structures but demonstrate how unique manufacturing and fabrication give form to modern design of the 20th Century. Each author explores challenging areas of concrete conservation that are associated with concrete fabrication and which can require specialized finishing techniques if these buildings are to be maintained successfully. For example, author Pyburn discusses issues related to these challenges through an in depth discussion on concrete manufacture of three mid-century architectural precasting systems which include Precast Building Systems Inc. (PBSI), the Mo-Sai Associates, and Schokbeton. The author Seitz goes on to explore the use of concrete fabrication on a massive scale in the rebuilding of the city of Le Havre on the north coast of France which was entirely reconstructed after WWII. Here, Seitz sets the stage for how architects like Auguste Perret along with a consortium team of architects planned and implemented new urban planning principles and used concrete technology to rebuild and shape visions for a modern city built starting in 1960. Author Ruggieri provides a similar background in his analysis on the work of Pier Luigi Nervi's work which includes a few examples of an analysis on decay mechanisms in case study analysis of Pier Luigi Nervi's Exposition Palace in Torino (1950), the Sports Palace in Rome (1956) and the Flaminio Stadium in Rome (1957). Here Ruggieri introduces an extensive background on the use of reinforced concrete and the ferro-cemento on the ribbed vaults. He points out how Nervi's use of prefabrication and pre-tensioning led to the concept of the load bearing structure which went far beyond the traditional articulation for building structures.

The Role of Precast Concrete Technology in Post War Building Construction

Jack Pyburn

This paper focuses on the origins and characteristics of three mid-century architectural precast concrete production systems. It will illustrate how differences in production objectives, characteristics of production and production techniques influenced the resulting precast product. An understanding of architectural precast production can aid in the appreciation of the significance of buildings and building systems as well as the identification of appropriate approaches to treatment and conservation.

The three significant mid-century architectural precasting systems discussed below present very different approaches and qualities and include Precast Building Systems Inc. (PBSI), the Mo-Sai Institute and Schokbeton. PBSI is an example of many independent local and regional architectural precasters exploring the potential of concrete for a variety of uses in the second and third quarters of the twentieth century. The Mo-Sai process was an evolution of casting techniques developed by the sculptor, James Earley, with a priority on the use of exposed aggregate. Mo-Sai became the first casting process to be transported beyond the East Coast to other regions of the United States. Schokbeton, a Dutch precasting system, focused on production techniques, processes and equipment that could deliver consistent quality precast concrete. Schokbeton produced precast concrete throughout Europe and the United States, and in parts of Canada, Africa, the Middle East, Australia and Japan. Each of these systems sought to achieve sufficient consistency in precast finish and color to successfully market their product as architectural quality, that is a finish product.

Each of the three systems was initially developed to achieve specific and differing goals. The characteristics of the concrete mixes, approach to casting, mold construction and finishing techniques used by each producer highlight the significant differences that can be found in mid-century architectural precast products.

There were a number of factors that supported the development of viable architectural precast concrete technology at mid-century. They included greater control of the casting and curing process and thus better and more consistent quality of concrete, rising labor costs and the potential of precasting to reduce labor requirements in concrete construction, shortages of steel after World War II, built up demand for housing and commerce and the availability of competitively priced raw materials contained in concrete.

In the pioneering days of architectural precasting, the first half of the 20th century, the precasters were exploring the potential of concrete with a wide variety of functional and aesthetic goals. These goals influenced the concepts of production and the characteristics of the equipment they used. When affordable housing was the focus of the precaster, efficiency of production trumped the quality of the exterior finish. When the quality of the exterior finish was the primary precasting objective, a production process was designed from the outside of the mold, the exposed face, inward. When overall performance of the precast unit was the primary objective, a high standard was sought for each aspect of production: mix design and mixing, mold design and construction, casting, and finishing.

Until the 1950's, precast concrete fabricators typically served a specific locale or region due to a variety of factors. The understanding of concrete's characteristics and performance was still evolving. Precasters continued to have difficulty producing acceptable results, particularly in finish. Transportation for large heavy objects was limited. Materials were local commodities. The architectural precasting process was complex requiring higher skilled labor rather than transient labor typically found at construction job sites. Producing quality architectural precast concrete required a stable and skilled work force.

Comparison of Three Approaches to Mid-Century Architectural PreCast Concrete Production

Three architectural precasting companies are examined here that illustrate the variety of production approaches used and breadth of product created at mid-century.

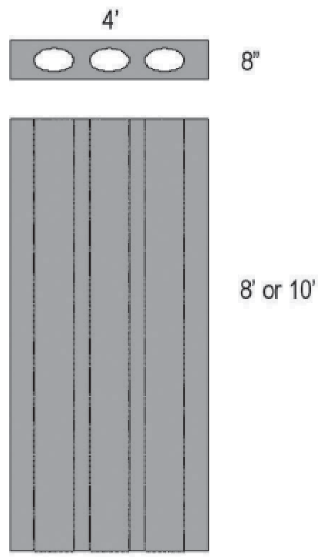
Precast Building Section, Inc.

Precast Building Section, Inc. evolved from the interest of a prominent New York architect and housing reform activist, Grosvenor Atterbury, in producing affordable housing using concrete. In 1907, with the support of the Russell Sage Foundation, Atterbury began studying the efficiencies of concrete precasting. Specifically, he was interested in producing the largest and most efficient sections that could be precast to achieve the affordable housing goals of both Atterbury and the Sage Foundation. Atterbury worked with the Carnegie Steel Company to adapt their steel making equipment and materials handling processes for concrete precasting.

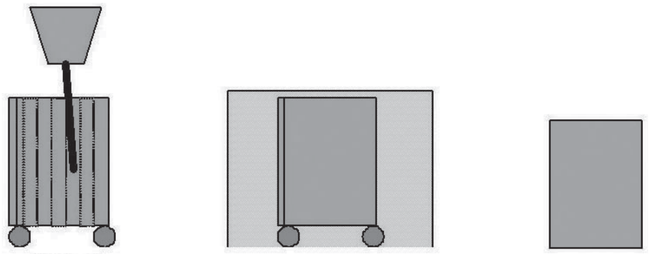
In 1909, Atterbury and Fredrick Law Olmstead, Jr. teamed up to design a pioneering commuter suburb with the financial support of the Russell Sage Foundation. The Forest Hills development was an experiment in producing a quality, affordable and planned living environment. One of Atterbury's objectives was to test the use of concrete to meet those objectives. In 1910, Atterbury constructed a precast concrete plant at Forest Hills Gardens. There, standard size house components were produced in steel molds. Components were cast, transported and erected to produce the walls, floors and trim for the Arts and Crafts style housing. Exterior walls were built with slabs one story tall, about six feet wide and eleven inches thick using steel forms.[1]

Forest Hills Gardens succeeded in becoming a quality suburban retreat from the density and intensity of New York City but in the end the Forest Hills development did not meet the objectives of affordability. The fact that the application of the Atterbury system used at Forest Hills was not replicated elsewhere suggests at least one reason for higher costs in the Forest Hills development was the inefficiency of the system. Such an outcome could be expected for first generation experiments in both suburban development and architectural precasting.

Atterbury did not give up on concrete's ability to respond to the demand for affordable housing. In 1950, again with the financial support of the Sage Foundation, the first permanent precast concrete plant based on Atterbury's casting concepts was constructed under the name Precast Building Section, Inc. A *New York Times* article described his plant as "a modern factory with giant overhead cranes to carry the massive units out of the pouring pits and into steam rooms." The plant was producing wall panels ten feet high by four feet eight inches wide and eight inches thick with hollow cores for insulation. The panels were not structural and contained no reinforcing steel. The steam rooms were intended to accelerate the curing process.[2]



Basic PBSI Panel



The PBSI casting concepts and techniques made durable concrete with a consistent finish difficult to achieve. The plant consisted of mixers and eight to ten steel forms with stainless steel cores equally spaced along the centerline of the form that could be infused with steam to aid in controlling the curing process and thus improving the quality of the precast panels. The cores were tapered to allow them to be removed from the casting. There was one and one half inches to two inches of concrete thickness at the cores. The un-reinforced panels were cast using lightweight (Wight Lite) aggregate. The forms were positioned vertically for casting. Concrete was placed using devices called “tremie tubes,” steel tubes that transported the concrete from the hopper overhead to all parts of the vertical steel mold. Molds were transported from casting pits to steam rooms via small rail cars. The steam room was used to keep the concrete moist during curing.

The first wall panels produced in PBSI’s New Hyde Park, Long Island plant were used to enclose the ground floor of the “tall fire-poof buildings” of the Queensview cooperative housing project in Astoria being constructed by Rheinstein Construction Company. They have since been removed and replaced due to the deterioration of the concrete.[3]

Atterbury’s system ultimately failed despite years of experimentation and significant investment. It is very difficult to achieve uniform placement in narrow and tall molds standing upright. Higher water content was required by the PBSI methods to achieve uniform concrete placement in the lower reaches of the vertical forms. The higher water content reduced the strength of the concrete in the castings and increased shrinkage and cracking, both undesirable outcomes. The lack of reinforcement eliminated one of the primary qualities of concrete, structure. By the late 1950’s the Atterbury system of precasting was completely abandoned. PBSI continued to operate until the mid-1970’s by adapting the failed Atterbury to more conventional casting methods. A notable building produced during this adaptation to more common methods of precasting was the First Presbyterian Church in Stamford, Connecticut designed by Wallace Harrison.

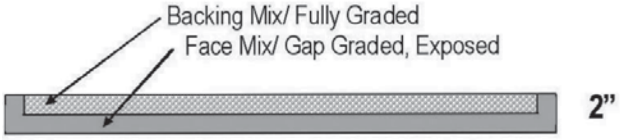
Mo-Sai Associates

At about the same time as Grosvenor Atterbury became interested in concrete for affordable housing, James Earley, a sculptor in Roslyn, Virginia, and later his son John with Basil Taylor, Jame’s trusted and knowledgeable assistant, explored concrete’s potential as an artistic medium. The focus of experimentation that became known as the “Earley Process” was with the exposure of aggregate on the surface of precast concrete. The Earley’s wanted their product to be more closely associated with cut stone than concrete. Therefore, concrete played a supporting role in their process. The Early Studio, as the business was known, developed elaborate techniques for using exotic aggregates and rendering designs in exposed aggregate precast concrete components that referenced, if not approached, the visual quality of mosaics. To achieve the mosaic effect, manipulation of the aggregate grading was required.[4]

In I938, the Earley Studio in association with a New Haven, Connecticut cast stone manufacturer, Dextone, produced a significant precasting project, the David W. Taylor Model Testing Basin (135,000 s.f.) for the United States Navy at Carderock, Maryland. Based on the relationship that developed between Earley and Dextone and the resulting precasting knowledge transferred to Dextone from Earley, Dextone organized the first nationally based group of precasters in the United States under the name Mo-Sai Associates in 1940. This group used the "Earley Process" of precast concrete production under a licensing arrangement with Dextone and Earley Studios. Mo-Sai was a derivation of Earley's "mosaic." The seven charter members were from the East Coast, Wisconsin and Utah. The association was founded for the exchange of technical information and joint marketing activities. Territories were defined and competition rules established.

The standard Mo-Sai product was a two-inch thick reinforced (with 4"x 4"x 3/32" welded wire) flat panel presenting exposed aggregate of various types, patterns and degrees of exposure. Panels were cast horizontally. The standard panels varied in size from 20 to 200 square feet. They were cast in two pours. The outer most pour was about one inch with aggregate not exceeding 5/8". The second pour was fully graded common gray concrete. Molds were typically made of wood and lined with Masonite, an assembly developed prior to 1940 by John Earley. A retarder was applied to the mold to slow the curing process on the surface concrete of the casting. When the casting was removed from the mold the yet fully cured surface concrete was removed by hand labor A significant amount of hand finishing by skilled and disciplined workers was required to achieve the desired exposed aggregate finish.

Mo-Sai Associates produced high quality work including the first high rise building clad in architectural precast concrete, the Hilton Hotel in Denver, Colorado by I.M. Pei. They also produced work for other major architectural firms like SOM, Vincent Kling, Minoru Yamasaki, John Portman, Emory Roth & Sons, Paul Rudolph and Marcel Breuer among others. They included Paul Rudolph's Blue Cross Blue Shield Building in Massachusetts and Peachtree Center in Atlanta by John Portman.



Typical Mo-Sai Wall Panel

The Mo-Sai approach to architectural precasting produced the best quality in the United States in the 1940's and remained competitive in the building industry until the late 1970's. The Mo-Sai group was disbanded by the mid-1980's due to the risk and complexity associated with architectural precasting, the changes in building economics, the advent of new competitive building assemblies and products, the changing structure of ownership of building materials and production systems and the lack of foresight and motivation to grow technologically and geographically.

Schokbeton

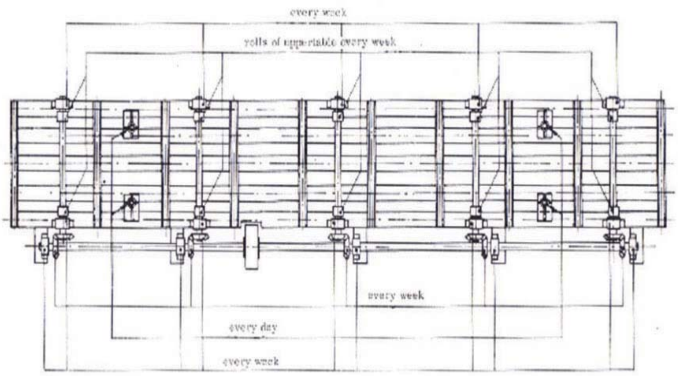
Schokbeton arrived in the United States from the Netherlands in 1960. The Schokbeton process and custom equipment was patented in Holland in 1932. The focus of the Schokbeton process was to produce fully consolidated concrete of optimal strength and consistent finish. A group of young engineering graduates from Brooklyn Polytechnic, led by Donald Rothenhaus, obtained the first license under the name of Eastern Schokbeton and established a plant in Boundbrook, New Jersey.

Schokbeton was distinctly different from the two precasting processes described above. Schokbeton focused on capturing the optimal results from concrete's three primary qualities, structure, plasticity and finish. Schokbeton undertook considerable research, testing and engineering in developing its process and production equipment. Schokbeton did not have a standard product like PBSI and Mo-Sai.

At least four aspects of the Schokbeton process distinguish it from its competitors of the time.

Schokbeton used a shock table (Schokbeton in English means "shocked concrete") approximately thirty-two feet long and eight feet wide that raised and dropped the mold filled with concrete one quarter of an inch two hundred and fifty times a minute. The frequency and distance of drop was empirically determined to facilitate consolidation of the concrete without undesirable segregation of its component materials. Molds had to be reinforced to withstand the force of the shock table.

Mold making was an art. Eastern Schokbeton's lead mold maker, Pete Miller, was a Master Scottish patternmaker prior to immigrating to the United States in 1960. The skill and craftsmanship in Schokbeton's mold making was a direct link between old world craftsmanship and modern mechanized building production. Schokbeton used a number of materials in mold construction depending on the characteristics of the desired casting including steel, wood and fiberglass.



Shock Table Diagram

Schokbeton's approach to precasting started with designing the concrete mix most appropriate to the desired casting while achieving the three primary qualities of concrete. Its mixing philosophy was to have a fully graded mix thus maximizing the stone, the strongest component, and minimizing the cement, the binder, and water, the catalyst. In addition, Schokbeton used a German manufactured mixing system designed for the glass industry that included a vertical rotating vat with counter rotating paddles. This equipment produced an exceptionally uniform mixture of concrete.

Schokbeton produced the precasting for the first "total precast" building in the United States, the 1960 Police Headquarters in Philadelphia, Pennsylvania by Geddes Brecker Qualls and Cunningham. In the United States they also produced precast building components for Minoru Yamasaki, Marcel Breuer, Philip Johnson, Edward Durell Stone, SOM, Geddes Brecker Qualls and Cunningham, John Johansen, Vincent Kling and the Grad Partnership to mention a few.

Conclusions

While the quality and characteristics of the component materials are important, the characteristics of architectural precast concrete are substantially derived from the methods and process that produced it. The three approaches to architectural precasting presented above illustrate the diverse objectives for architectural precast concrete. They illustrate the corresponding diverse concepts for, approaches to, and methods of production. A knowledge and understanding of both can contribute significantly to the quality of judgment applied to the conservation of architectural precast

Police Headquarters in Philadelphia, Pennsylvania by Geddes Brecker Qualls and Cunningham.

concrete. The three mid century precasting systems discussed above produced very diverse products. Their diversity is an illustration of the fragmentation in the mid century precasting industry and suggests that the approach to the conservation of mid century concrete should respect the individual characteristics of each building.

Notes

1. *Susan L. Klaus, A Modern Arcadia, Fredrick Law Olmstead, Jr. and the Plan for Forest Hills Gardens, (Amherst & Boston: University of Massachusetts Press & Library of American Landscape History, 2002), 77.*
2. *M. S. Shepard, "Pre-Cast Blocks Used in Housing," New York Times, 12 October 1950.*
3. *Robert Rheinstein. Telephone interview by Jack Pyburn, AIA, 31 May 2004, Atlanta, Georgia*
4. *Fredrick W. Cron, The Man Who Made Concrete Beautiful, A Biography of John Joseph Early (Fort Collins, Colorado: Centennial Publications, 1977)*
5. *All Illustrations are by the author.*

Postwar Building in France: Le Havre

Frederic Seitz

This paper is about the city of Le Havre, whose buildings were entirely destroyed during World War II and rebuilt by Auguste Perret, a famous French architect and specialist in concrete during the 1950s and 1960s. It will present an analysis of the work of Auguste Perret, and explain the principles of reconstruction of the city of Le Havre from a town planning and technical point of view. It will also examine the cultural center built a couple of years later by Oscar Niemeyer and the one that Jean Nouvel did was inaugurated in July 2008. This paper will be extended to technical and social thoughts, as well as considerations about the preservation and the conservation of this city, its buildings and their materials, including this fundamental question: Do French politicians and architects consider this matter from a conservative or dynamic point of view? In other terms, do they consider this matter with the vision of a "dead" historical city, or with a vision of a city in which contemporary inhabitants live?

Le Havre, located on the North West coast of France, in the district of Seine-Maritime, is a city of nearly 200,000 people. Its harbor is the most important in France and the sixth most important in Europe; and the cities main activities consist of the shipyards, in relation to the building of high technology ships; the automobile industry, an important industrial unit was created by Renault in 1963; and metallurgy. Recently, a university of sciences and technology has also been established.

The contemporary urban and architectural character of Le Havre is the consequence of World War II. From 1940 to 1944, Le Havre was successively bombed by both the German and British armies, due to its strategic location. The most devastating destructions happened on September 5th and 6th, 1944, when 1,000 tons of bombs were dropped on the city center; breaking the harbor area to pieces, leaving 300 ships destroyed, along with more than 10,000 buildings; killing 5,000 people, mostly civilians, and leaving 80,000 people without any shelter.

As a consequence, the French government decided to rebuild the city and, after some hesitations about the choice of an architect, Auguste Perret was selected for the reconstruction; in spite of the hostility of the mayor and most of the population of Le Havre who wanted the city to be rebuilt as it was before the war. He brought together about 20 architects for the constitution of what he called *L'Atelier pour la reconstruction du Havre*. His urban, architectural and technical drawings were representative of the Modern Movement and of the classical principles that he admired. The Museum constructed by Guy Lagneau, completed in 1961, an iron footbridge raised by Guillaume Gillet in the 1970s, the *Maison de la Culture* erected by Oscar Niemeyer between 1978 and 1982, and the recent planning of the seaboard by Alexandre Chemetov are all examples of the prolongation of Auguste Perret's masterpiece.

View from the Bassin du Commerce, looking West past the Volcan (front, by Oscar Niemeyer) towards the Eglise Saint Joseph. (Photo: Cristiana Peña)

New Urban Principles

The new city planned by Auguste Perret -based on a new allocation of its territory- was arranged in a system of axes, regular figures and symmetrical partitions. The center of the new city is constituted around the old *Bassin du Commerce*- which was created in 1787 and put into service in 1820. Along this basin, all the boulevards and streets run parallel to one another to form 102 square blocks. A second area, whose urban design was determined by the configuration of the coast, surrounds this central one. It includes 29 blocks with the *Perrey* zone, or seafront, on the south and the area adjacent to the *Bassin du Roi*. By the side of this area, a "wall" of buildings is constructed as a protection of the city against the wind. A third area called *Saint-Francois* contains 12 blocks. Its planning is very different from the two others and is more like the one that could be found in the ancient city.

The design of the city includes a very specific urban arrangement: the triangle whose straight sides are constituted by the Avenue Foch, the Boulevard Francois I, and the Rue de Paris and whose three points are the Town Hall Plaza, the Ocean Gate and the South seafront.

The Town Hall plaza -280 meters long and 250 meters wide- built from 1947 to 1953, symbolizes a connection between the old city –the Boulevard de Strasbourg- and the new city- the Avenue Foch and the Rue de Paris. Opposite to the Town Hall -whose tower is a main symbol- are the famous apartment buildings called *Immeubles sans affectation individuelle* (ISAI).

The Avenue Foch is a second monumental urban composition: 700 meters long, 80 meters wide. Along this avenue are located apartment buildings and a park called Saint-Roch. At the end of it is the legendary Ocean Gate, designed by the architects as a wide-open space. Through this gate, people would have admired transatlantic boats ... if they had not been replaced by transatlantic flights.

View of an apartment house along Boulevard Francoise 1er. (Photo: Cristiana Peña)

The Boulevard Francois I joins the Ocean Gate to the South seafront. Along this boulevard, public housing units and important public buildings -like schools, a polyclinic or Saint-Joseph church- are located.

The Rue de Paris was an important line of traffic in the old city, joining the center to the harbor and along which many shops were located. In the new planning, the Rue de Paris is different from the other main avenues of the city: its width is smaller, only 18 meters, and its architecture is different, with buildings being erected with porches and porticos. This new planning drastically changed the center of the city of Le Havre and made this city one of the most modern in Europe.

An Original Architecture and an Innovative Building System

The unity and the harmony of the new city are reinforced by Auguste Perret's architectural choices, where every building is constructed with concrete, which is the only material the architect ever used in his works. This material -whose laitance is removed from the surface to make the color of the aggregate visible -brings out the aesthetic appearance of his buildings.

The structural system of these buildings, is a quite simple framework made with columns in concrete supporting floors in concrete. Modules of the facades, closed or opened, were then positioned inside this skeleton. The roofs of the buildings are terrace-roofs, which include cornices along the outside walls acting as a protection against the rain. In this type of buildings, the framework -always regularly divided in symmetrical, well-balanced lines- is the support of an original architectural expression.

An important distinction is made between these frameworks and the components of the facades, whose only function is to protect the interior and its inhabitants from the outside. Perret's constructions are like a huge technological game, which allow the creation of apartment buildings as well as large public masterpieces. This technological game, thanks to his simplicity, makes the principles of standardization and industrialization usable, which is very important from an economic point of view, but which is quite unusual in French processes of construction.

A World Urban and Architectural Heritage

At first, the inhabitants of Le Havre, who were very upset by the destruction of their city did not like Auguste Perret's architecture. Until recently, the anniversary of the Liberation of France is often associated by Le Havre inhabitants with this destruction, who were nostalgic for the old buildings they used to live in, in spite of their age and often unhealthy and sanitary conditions. However, in response to the actions of the mayors of Le Havre and due to the activities of French architectural and historical movements, people gradually changed their mind and started respecting the city and its modern urban, architectural and technical types, being grateful for the good quality of the buildings, the easy flow of the traffic, the facilities of the utilities, etc. Le Havre gradually appeared the way it really is: a modern city in which the way of life may be pleasant, considering its residences, public buildings, commercial and business activities.

The city center rebuilt by Auguste Perret is also interesting from another point of view: today, its urban and architectural characteristics are quite untouched and are not altered by anarchic or chaotic processes of demolition and construction. However, although Auguste Perret's masterpieces have been preserved, other modern buildings have been lost including Auguste Normand's shipbuilding facility, built in 1951 by the architect Francois Vitale- and which was replaced by the Residence of France-Georges Candilis being the architect- or the extension built along the Town Hall by the architect Pierre Colboc, between 1985 and 1987. However, these examples are not entirely disastrous, as they do not really spoil the cohesion of the Modern Movement town.

The importance of Auguste Perret's architecture has slowly emerged: in 1965, Saint-Joseph church was added to the list of the French Historical Monuments; and between 1991 and 1999, a general survey of the heritage of the city was made. In 1995, the council of Le Havre decided, in accordance with the state administrations and private owners, to set up an original approach of the conservation of this heritage: a zone called *Zone de protection du patrimoine architectural et paysager* (ZPPAUP) was created, inside which precise rules guide and control the processes of the restoration of existing buildings and of the construction of new ones. The renovation of Saint-Joseph church started last year.

To promote the preservation of the city, DOCOMOMO France became involved in activities starting in 1995, when the council desired Le Havre to be written on the UNESCO World Heritage List. Professor Joseph Abram, a member of DOCOMOMO France, was appointed as an expert for this matter. In September 1996, the case of Le Havre was related in a conference in Bratislava, Slovakia. For the 7th International Conference of DOCOMOMO International in Paris, in September of 2002, DOCOMOMO France and the French Institute of Architecture choose Le Havre for a study trip. In

January 2003, DOCOMOMO France, represented by its president Fabienne Chevallier, and the council of the city of Le Havre began discussions about a scientific partnership concerning the constitution of an index of the 32 most remarkable buildings of the city, the valorization of theses buildings and the organization of an international conference in Le Havre in 2005.

All these actions will not only be an opportunity to increase the value of both the urban planning and the architecture of the Modern Movement; they will be also a chance of inventing a new approach to our contemporary heritage including historical, architectural, political, economical and social points of view.

Pier Luigi Nervi's Work: Technological Values, Typical Degradations and Conservation Criteria

Nicola Ruggieri, Gennaro Tampone

The buildings designed by Pier Luigi Nervi are characterized by their architectural and structural identity; in everyone of them one can recognize, in addition to the achievement of innovative aesthetic expression, the presence of technological invention, the search for the most suitable production process, minimization of cost and speed of construction of execution.

These buildings, in Italy and elsewhere, are in excellent condition from a structural point of view, a sure sign of the correctness of the intuitions and calculations of their performance made by the designer. Nonetheless, they are found to be highly vulnerable to chemical attacks where they cause a widespread decay on the surface of the members which are exposed to moisture and pollution.

A few examples of the decay which affects the most important buildings erected in Italy are presented here; with the simplest analytic method of decay assessment then indicated.

The reasons of the mentioned decay are to be individuated in the thinness of the member sections and in some factors which are typical of the period, mainly the poor quality of the building materials available at the time, the little consideration for the porosity of the concrete, some inaccuracy in the execution of the works, in addition to lack of maintenance.

A general conservation and restoration work is therefore necessary. Undoubtedly Nervi's buildings carry historical and formal values; but we must recognize that they also carry, organized in a singular combination with the first ones, fundamental technological qualities. They demand therefore a special approach, more comprehensive than usual, in the planning of the conservation work. Specifically, the removal of original surfaces and the replacement of parts with new elements should not be allowed; the decayed concrete and the corroded steel elements should be conserved and repaired in situ: we wonder whether suitable analysis instruments, products, techniques, industrial organizations and, more important, skilled technicians are available yet to achieve these new frontiers of architectural conservation.

Introduction

Pier Luigi Nervi (1891 – 1979), a structural engineer, who has been defined as the "Architect", started his practice in the late Twenties and continued until the early Seventies. This long, fruitful period included the development of his structural concepts and the study and testing of structurally pre-cast concrete. At the same time, he designed several buildings, from the first realizations of Stadio Berta in Florence (1929-1932) and the Hangar in Orvieto (1935), to the following constructions of the '40s and '50's: Exposition Palace in Turin, the Small Sport Palace in Rome, the Pirelli Skyscraper in Milan, to the American projects of St. Mary's Cathedral in San Francisco and the Cultural and Convention Centre in Norfolk, Virginia.

Nervi's practice is characterized by a constant search for innovative structures; he patented a large number of structural inventions which he immediately punctually applied and experimented with in his buildings. The research carried out by Pier Luigi Nervi on ferro-cemento (cemento ad armatura equiretinata), or reinforced concrete on the ribbed vaults, its prefabrication and pre-tensioning led to a concept of the load bearing structure which goes far beyond the traditional applications. In a building, of the different constituting elements such as structural members and curtain walls, i.e. bearing elements and supported parts, to reach, by means of the process, a global organization is formed where every element plays a role in supplying, even in different proportions, resistance, stiffness, obstacle to deformation; everything is planned in order to ensure the general efficiency and stability of the whole structure.

Nervi's approach to the building process was comprehensive, where his extraordinary accomplishments are achieved by mastering all the factors which affect the building process, namely the experimenting with new structural configurations, the planning and the realization of specific constructions, the production of structural elements, the logical economical progression of the building activity and the planning of the provisional works, the aesthetic aspects, and the economics of the construction.

The Planning and Realization of Specific Constructions

The 1940's and 50's were characterized by a fruitful period for Pier Luigi Nervi's works and at the same time the inventions of shapes and procedures were numerous. The six hangars for Orbetello aeronautics (1940), unfortunately demolished by the second world war bombardments, mark the beginning of plans in which the use of prefabricated elements become more and more important for a perfect and successful construction and for limiting the cost of construction.

The following examples are emblematic examples in the evolution of Nervi's work:

E*xposition Palace, Main hall, TORINO, 1950*

The building is formed by a rectangular hall 94,3x75 m. long completed by a semicircular apse with a 60 m diameter, covered by a 40 m diameter dome. The hall's covering is formed by a single thin vault of wavy prefabricated ferro-cemento elements. This kind of prefabricated element is a Nervi invention, called "Procedimento costruttivo per la realizzazione di strutture cementizie ondulate o curve con o senza tensione preventiva" n° 445781, 1949.

The invention consists in the use of thin prefabricated elements from 2 to 3 m long of ferrocemento, with the cross section shaped as a semi-wave (in some versions with square corners); steel bars come out of the body of the elements in order to create an effective transverse connection between the individual pieces.

To avoid instability of the long, thin elements during the transfer and when in situ, triangular, therefore rigid, meshes of braces prefabricated in the same way, are added to the elements; in some versions these are further complemented with a series of cleverly designed undulated transverse diaphragms which have the same function as bracing. The triangular bracings and the diaphragms serve a dual purpose, i.e. as stiffening members during the transfer to the site, and when in situ they become part of horizontal rings – like parallels of the globe - which are connected with the radial elements - half-meridians - of the waves. By means of temporary supports, the elements are put close to the adjacent ones in order to form a succession of waves to define a covering having the chosen shape; they are later connected by ribs in reinforced concrete, put at the bottom and at the top of the waves along the radial direction, and poured in place.

The key height is 18,4 m and the illumination is provided by the pre-fabricated elements' opening. The semi-dome which covers the apse is also obtained by pre-fabricated elements; the latter with a rumble shape are put near to each other and after placing of the necessary steel rebars they are connected by a further pouring of concrete. The structural system is composed of a series of pillars lined up, one for every 7,5 m, inclined in order to favour the stability and resist the downward thrust; each pillar formed by the connection of 3 fan-shaped members through which the vault joints the pillars. The horizontal forces are absorbed by the perimeter floor with a 10 m span; from this they are transferred to a resistant framework placed in the walls between the hall and the apse. The perimeter floor is formed by beams cast in situ, hollow flat tiles and upper slab reinforced in both ways. The foundations are characterized, in a longitudinal direction, by big plinths of approximately 12 m, on which the ribbed arches rest; simultaneously plinths of a smaller size absorb the tensions of the floor.

Small Sport Palace, ROMA, 1956-57

The building is circular in plan and is made up by a bowl dome formed by 1620 reinforced concrete prefabricated elements with a rumble shape. The dome is 60 m in diameter with a highest point of 21 m. The covering elements are Nervi's patent "Procedimento per la realizzazione di superfici resistenti piane o curve costituite da reticolati di nervature in cemento armato completato o meno da solette di collegamento tra le nervature", n° 465636, 1951. The first application of this pre-fabrication system is represented by the hangar in Orvieto, built in 1935. It consists of pre-fabricated elements 2,5 cm thick, which are placed in the final position and later connected by ribs of reinforced concrete cast in the voids purposely left between the same elements. In this way a network of members is created which is oriented in two main directions and is kept in their position by the pre-fabricated elements, creating a kind of weave of knitted tissue. The reinforcement is formed by steel bars of 6 mm, placed in both directions, and by a double layer of wire mesh: the slab is reinforced with steel bars of 5 mm arranged throughout the parallels and the meridians, while the upper ring is reinforced by extra steel bars of 16 and 24 mm. The steel bars that come out are intended to ensure the structure's continuity.

View of Nervi's concrete Y-shaped trestles, Sport Palace, Rome. (Photo: Sarah Rinehart)

The dome, calculated as a shell, is supported by a ring of 36 trestles with a Y shape, that absorb the weight of the dome and convey the forces to the foundation; the latter is formed by a pre-compressed reinforced concrete ring of 81,5 m in diameter with a 2,5 m thickness .The prefabricated covering elements are assembled by means of a metallic scaffolding with a crane situated in the middle of the construction.

Sport Palace, ROMA, 1958-60

The Sport Palace was built on the little hill which delimitates to the west the main axle of the area intended to be the place for the 1942 Universal Exposition. The design of the area, with all the streets and paths that surround it and the big artificial lake, were planned by the Italian architect Marcello Piacentini.

The ground floor of the construction has two levels of tiers. The main structural problem of the construction was the necessity to cover the circular space of almost 100 m in diameter without intermediate pillars. The solution was to put a dome as a covering; however, this involved the question of how to balance the prominent horizontal forces at their impost floor. Given the presence of a very good foundation soil, the most natural and economical solution seemed to be that of bringing, via suitable structures, the actions of the dome directly to the ground. The dome is formed by a wavy structure completed at the upper level by a slab with only 9 cm thickness. The waves are formed by prefabricated elements of the same type of the ones in the Expositions Palace. In this way a system of ribs, connected together by the final slab, is formed by creating a highly resistant structural system. The system achieved is iperstatic. The corrugated dome can be interpreted as a membrane or as a series of

View of interior ribbing. (Photo: Francis Jonckheere)

ribbed arches. The intradoxal surface of the waves is covered by an absorbent material suitable for noise abatement, while wide openings are placed in the walls for the air exhaust of the conditioning system.

Flaminio Stadium, ROMA, 1957-59

The stadium structure is formed by frames cast in situ, which are connected by secondary ribs and by the structures which form the tiers. These are formed by two distinct elements in reinforced concrete and the system was patented by Pier Luigi Nervi in 1957: “Sistema di costruzione di gradinate di cemento armato ad elementi prefabbricati per stadi o tribune per spettacoli, e relativi elementi prefabbricati” Patent n°564484. Each step or tier is formed by two distinct elements of which one has the bearing function as well as to convey the raining water while the other, which is supported by the previous, forms the stair tread and the seats. The bearing elements have a “U” section where they rest directly on the main structure, and are connected to each other with steel bars left protruding at the end of each element.

The penthouse of the covered tribune is formed by two separate structural elements. One cast in situ rests on external frames and on an inclined post, formed by iron tubes filled with high performance concrete; the other is made up by curved prefabricated elements of ferro-cemento, that jut out 14,54 m.

The foundations are plinths in reinforced concrete and rest on piles ranging in diameter from 33,5 to 50 cm .The project broke ground started in 1957 with the laying of the building foundation and the erection of the structural frame, where the pre-fabricated elements of tiers were placed on the frames after the setting of the concrete. After the two curves were erected and their prefabricated elements placed, work on the penthouse on the west tribune started.

Typical Degradations

According to research developed by the authors about the state of conservation of Pier Luigi Nervi works in Italy[1], his architecture, with the exception of some unique cases like the transformation of the Stadium of Florence (the most serious) or the penthouse of Piazza Italia in Milan, have aged in exemplary condition. In particular the structures have passed, after approximately half century, the test of the time and the use. They are in fact completely free from structural failures. However they are affected by some degradations of the materials with which they were constructed, in particular the concrete and the reinforcement.

The causes of this vulnerable state to the chemical attacks are various. Frequently Nervi designed his prefabricated elements with the reinforcement steel bars too close to the concrete surface, and his innovative structures make use of ferro-cemento as a structural material. The ferro-cemento, for which Nervi patented in 1943, consisted of several layers of steel wire mesh (thickness less than a millimeter and openings of about one centimeter); this skeleton is later covered by concrete of a plastic consistency, with modest mechanical properties, and of modest protection from environmental aggressiveness; the thin covering of the steel bars is not sufficient to constitute a barrier to the penetration of water and aggressive chemical agents. Besides inaccuracies in the mixing and pouring of the reinforced concrete, such as the inadequate shape and size distribution of the aggregate, an excessive presence in the concrete mix of tiny air bubbles, were rather common in this period. Besides in some cases the aggregate has been found to have impurities that restricts the bonding of concrete (i.e. Sport Palace in Rome). In addition to these inefficiencies there is the surrounding environment of Nervi's structures; cities with pollution and in particular CO2 emissions, considerably increased in the last decades. All these factors were not considered during the planning and are the causes of the decay in several of his constructions.

The observed chemical corrosion phenomena are still incipient today but they can shortly increase and switch to structural failures. The most important works in Italy are affected by the carbonization of the concrete, which is caused by the CO2 penetrating to the inside of the thin (sometimes too thin) concrete layers that cover the metallic elements lowering of the values of the Ph, and provoking a loss of passivity of the steel and the consequent initiation of the corrosion.

This can be found in the "Sport Palace" in Rome, the "Labor Palace" in Turin, the "Skyscraper Pirelli" in Milan and the frames and the bleachers of the "Flaminio Stadium" in Rome. In particular, in this last case, the degradation of the insubstantial concrete and the corrosion of the reinforcement is so high that the reliability level of the whole structure is considerably lowered.

Another example is represented in the "Flaminio Stadium", in Rome, by the trenches that houses the pipe installations, under the bleachers. In this case the corrosion of the steel reinforcement is caused by sulphates coming from the evaporation emitting from the drains. These chemical compounds react with the steel and lead to the corrosion of the surfaces with cracks in the reinforcement and, in the long run, lead to breaks of the overstressed steel.

The above mentioned effects have been detected and studied by means of on site investigations in similar cases of degradation and experimental research carried out in the field and in laboratory. In particular, tests have been made with the Ph phenolphthalein detector, to verify the possible loss of alkalinity of the concrete caused by the carbonization: such substance, in fact, changes colour from the red to the neutral in an acid ambient.

Conservation Criteria

The monument and in general a work of art, at whatever time period it belongs, is not a perennial archetype that is insensitive to the passage of time; on the contrary it represents an open work like every "living organism" that follows biological laws, changing its formal components and materials, endowing itself with strong affective and didactic connotations that reflect the conditions of man.

The monument lives, it deteriorates and dies; it undergoes incessant changes that enrich the work with new elements of "wisdom" and teaching. It has a monumental character that is not abstract but tangible; linked to historic values that appear like events that have been marked with degradations, losses and transformation of such a document; therefore, independent from our culture, sensibility or other preferences, linking the status of the work of art to the precise moment in history where it explains itself in its overall forms, its materials and unique components that we must conserve because they are authentic even if deteriorated.

No doubt then that the modern architecture considered to be of significance is to be integrally conserved in all their parts. The work of the contemporary masters to us is clearly characterized by aesthetic connotations and by historical and technological values unequivocally linked to a precise culture and time period.

The approach to the conservation of Nervi's works, even if they are expressions of contemporary architecture, must be similar and of equal rigor to that held towards the great monuments of antiquity, owing to their exceptional quality, the testimony they offer of the particular ideation method, the contribution to the development of the architecture and of the building technology that they represent.

The identity, in the specific case, between architecture and structural system does not lead, in regards to conservation, at least in the theoretical level, to the rise of problems of distinction between these two essential members; rather it supplies the tangible demonstration of the necessity to also conserve the supporting mechanism of the monuments and to do it in the same rigorous way as the architectural elements and decoration.

Therefore there is not the danger that involves other buildings in which the structure is differentiated from the other constructive elements, also for its concept, paternity, execution etc. is concerned. In the discussed cases the structure often is not the object of careful conservation, particularly if it is not visible: so, unfortunately, in many cases the load bearing structure is deeply modified or replaced, in part or entirely, that means altered or destroyed.

However, problems of this kind would arise, even for Nervi's structures, in the operative activity of the general restoration. The most peculiar characters such as the structural and technological innovation, the productive and economic process control and others, case by case, are the values to preserve. It is not possible, in any case, to remove the original material: which means, in fact, to destroy a conspicuous part of the authenticity of the building. However, exceptions can be made.

On an operating level the considerations clearly involve that the practices commonly adopted for buildings, including the important ones, when structural members of reinforced concrete are affected with the degradation of the material, resulting in the elimination of the decayed parts and in their replacement with the application of prosthesis (for ex., with the technique of the béton plaqué), can obviously not be applied to Nervi's works.

Consolidation treatments of decayed structural materials must instead be preferred to the substitutive and imitative practices; for the metallic materials, a method that could certainly lead to interesting results, after the necessary experimental investigations and adaptations, is the use of converters of the products of the corrosion. Other suggestions come from the modern employment of the pneumatic structures which could be used as permanent external supports.

Conclusions

The restoration interventions to be planned on Nervi's works, owing to the above cited qualities, could offer excellent examples of structural conservation, if properly planned and executed and if repair would be promoted instead of the present practice of replacement, modification and destruction. The technical solutions, that can be defined only by means of a scientific research, will be of great help for all the works of modern architecture which deserve proper conservation.

Notes

1. *The research has been carried out on 15 works of Nervi in Italy (Stadio comunale "Berta", 1929-32, Firenze; Piscina per l'Accademia navale, Livorno,1947-49; Manifattura tabacchi; Bologna 1949-52; Palazzo per esposizioni salone C, Torino, 1949-50; Palazzo per Esposizioni salone principale, Torino, 1950; Pensilina emiciclo piazza Italia, Milano 1952; Deposito tranviario, Torino, 1952-54; Palazzetto dello sport, Roma 1956-57; Flaminio Stadium, Roma, 1957-59; Viadotto olimpico corso Francia, Roma 1958-60; Sport Palace, Roma, 1958-60; Centro Pirelli, Milano, 1956-60; Palazzo del lavoro, Torino, 1959-60; Copertura a pianta ellittica del salone delle feste, Chianciano, 1962; Sala delle udienze pontificie, Città del Vaticano, 1964-71; The research included the constructive, structural and formal aspects and the aspects related to the yards and material analyses. The research analyzed therefore the environment that characterizes the works of Pier Luigi Nervi and possible improper use and alterations and concluded by the state of conservation through laboratory and in situ tests.*

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Stone and Technology in the Modern Movement

Stone fabrication and building with stone changed significantly after World War II. The papers included in this section present stone cladding and its inherent role in architectural design. Postwar buildings with monumental stone clad facings and jointing patterns together accentuate effects of stone textures and veining. Throughout these case studies, general approaches to the diagnosis and repair of stone cladding structures are presented. The authors —Wedebrunn, Jokinen, Gelk et al., Poretti et al., and Gras—describe challenging approaches and conservation solutions from numerous parts of the world including Finland, Sweden, Denmark, France, Italy, and Mexico.

The authors establish the significant role that stone cladding has played in postwar building structures with a unified common theme that includes a thorough investigation of deteriorative conditions of stone cladding; in particular, distress due to weathering that occurs over time. As an introduction, author Wedebrunn provides an overview of the philosophical underpinnings, offering a poetic interpretation of the evolution of stone cladding through an ocular historical perspective and appreciation of natural building stones. The first case study in Scandinavia begins with the renowned case study of Finlandia Hall. Here, author Jokinen discusses the development and available research data which is available due to the investigation and evaluation of the physical material properties behind thin marble cladding. As Finlandia Hall is protected by law, renovation and recladding of the concert hall using the same original Carrara marble is required. Thin marble cladding is further discussed by authors Gelk et al., as illustrated by numerous postwar building examples throughout central Europe. Here, the authors provide an overview of types of deterioration and repair methods including discussion of a series of cladding and anchor systems that are used to stabilize and maintain building structures. Authors Poretti et al. were able to bring the focus of the session toward the state of conservation in the stone cladding case studies of the Post Office building and the Palazzo della Civilite Italiana in Rome. The authors examine issues on how and why it is important to retain and conserve as much of the original building fabric as possible. An array of repair techniques is presented including replacement of Roman travertine as part of a larger restoration program. The final paper of this session travels across the Atlantic to Mexico City, where author Noelle Gras discusses the legacy of Juan O'Gorman, who utilized indigenous stones to create gigantic mural facades at the Central Library of Ciudad Universitaria. As a bold representation of Mexican cultural history, O'Gorman's work within the context and evolution of organic architecture is documented, including in-situ repair work to retain the original mural fabric of this modern icon.

Experiencing Stone, Structure and Cladding

Ola Wedebrunn

It is hard, heavy, unyielding, motionless within the shape of its boundaries: yet the individual's experience of stone might be soft, light and obedient.

Impressions of volume, surface, pattern, colour, and light reflection enrich the effect of materials. Touch and see the stones - as when you hear the echoing of stone slabs as you walk in a narrow alley; stone might even appear tasty. Thus from varied experience we learn to appreciate stone as having different characteristics: granite, sandstone, marble.

Through the experience of character we even discover the meaning of the material. The meaning of stone might be monumental and solemn. In this respect stone and modernity seem to be a contradiction: stone as an age-old material and modernity as contemporary constructions looking toward the future. Nevertheless, when experiencing the stone of modern buildings there is no doubt that the interaction of immediate sensations of stone and technology make sense, and so stone is an important material in Modern Movement architecture.

Structure and Cladding. Model and Garment

Modern concrete and steel construction challenges the classical understanding of horizontal load-carrying wall constructions of stone laid upon stone. Mainly we could say that reinforced concrete has changed our perception of gravity and space in constructions. As structure becomes continuous, it rests in its own centre of gravity independent of any foundation. Thus the cladding of a structure even increases its independence of gravity. As the cover doesn't need to be part of the structural system of the building, its dimensions can be minimal. Instead of taking weight, stones as cladding have to deliver weight to the structure, like a dress or a cloak swept around a model. Changing from an integrated part of the structure into an independent cladding, the facade becomes the dress of the building. Like thread in the fabric of a dress, the geometry of tiles and joints makes the cladding'. By combining with new technology stone cladding, like a new fabric, becomes a modern building material.

As the structure of gravity is different from the structure of cladding, cladding is a construction in itself. Tiles and joints are the elements in the fabric of the cladding just as cloth is in a garment. Thus the cladding is not necessarily dependent on the same effects as the structure of gravity.

The Meaning of Stone

Meaning is often related to the idea of the origin of stone, and considered as the inherent properties to be performed as the character of the material. When it comes to stone, the origins go back to many sources, geographical and historical as well as physical.

Every stone in itself might be considered a testimony of production and time: a granite is volcanic in origin, limestone is a sediment of the ocean. Thus the way in which stone is conceived will affect its character in terms of the direction and density of sedimentary horizontal layers, for example, or more homogeneous layers with no direction.

As a fragment of the rock, stone is a holistic fragment of our planet in its geography, history and physical mechanics. In the nineteenth - century, the testimony discovered through stone led to a battle about geological history between the scholars who believed the origin of stone and the earth was melting lava - Vulcanists - and those who believed the geological origin was to be found in the sediments of the sea - Neptunists. No matter which side you choose, stone remains a testimony to mechanics and represents a metamorphosis of organic as well as mineral origin. Whether cosmic or geologic, history of mankind and human history proceeds and may even turn the conception of time itself around. Where history and time cease, stone signifies continuity of myth and science; no wonder stone has become significant for monumentality. Egyptian architecture is considered the epitome of stone construction, and we believe classical architecture is the transformation of wood into a monumental stone construction. A similar experience is possible even in modern building: for example the wooden Lenin Mausoleum in Moscow was eventually rebuilt as a red granite construction.

Alvar Aalto used the marble of Carrara for the cladding of Finlandia Hall in Helsinki,1967-71, and together with Jaques Barüel for the Museum of Art in Aalborg in Denmark 1958-72 as a sign and symbol of classical beauty and virtue. He also used it in parts of two buildings at the University of Technology in Espoo 1946-64, the library and the Department of Architecture, in both cases using marble as a reference to a classical humanist tradition. However at the University of Jyvaskyla, built in 1951-71, Aalto has used granite of a very light colour in combination with red brick for the meeting room of the university board, a building that seems archaically stylized.

Very often the choice of stone is motivated by economic factors. Thus the Danish Prime Minister Thorvald Stauning explicitly asked for several official buildings in the 1930s to be clad with marble from Greenland. Danish chalk stone became an important material for cladding on many buildings from the thirties in Denmark. It was a suitable home-grown alternative to travertine, bright and durable, not without a certain dignity and pride.

Marble cladding at the Museum of Art in Aalborg in Denmark. (Photo: Ola Wederbrunn)

Surface and Colour

Touching stone with your hand tells you about the treatment of the surface - and there are considerable differences. A stone split directly from the rock is rough; often it even reveals an individual identity characterized by a confident expression. As the mason encounters the stone, working with surface and volume, the stone changes in appearance. Split, pointed, chiselled, honed or polished, the work reveals a range of experiences, silent and unwritten. Persistent work with the stone becomes a dialogue with the material. Experiencing stone through the hands, with tools, instruments, machines, cuts, strokes, and with the mind establishes an outline of production and begins a continuous tale of light, texture and weathering.

In their 1931 book The International Style, architectural historian Henry Russell-Hitchcock and architect Philip Johnson describe their preferred surface as “a continuous even covering”, believing that a rough surface would blunt the perception of the volume of a building and be likely to suggest mass. Although their ideal is a surface covering all of the building, they recognize stone slabs as a surfacing material: “As in the architecture of the past, the finest materials for wall surfacing are stones, granites and marbles. Unless they are large in area, however, the separate units are likely to appear like the faces of blocks of masonry, suggesting weight and mass.”

Even Le Corbusier embraces stone as a material of modern buildings, not least by stressing contrasts in materials, as in the masonry of split rocks contrasted with smooth plaster surfaces in the Mme Mandrot house in Toulon. In the Swiss Pavilion in Paris, Le Corbusier refines the diversity of scale in contrast by using split rocks as wall covering for the lower wing, and rectangular tiles of smooth cut sand stone to cover the higher main building. Finally, rocks distributed around the grounds seem to emphasize the transition from blocks of natural rock to the smooth machine-cut slabs of the same stone used as cladding material of the main building. Thus the scale of varying treatment of the stone becomes an important expression of surface and volume.

The change from craft to industrialized machine work could be explained technically, in terms of stereometry, as suppressing ornamentation and volumetric sculpturing of stone. Instead, the character of colour and the treatment of surface become the aesthetic expression of the material. Hence for those educated at the Bauhaus school in Weimar and Dessau, where the ability to experience, analyze, and synthesis material qualities were primary skills to be learned, the experience of matter in terms of contrast and scale was of central importance. Inspiration was found in natural science and sensations of contrast of oriental philosophy, as it was thought at Bauhaus to be related to the technology of modern production rather than to traditional craft.[1]

Stones of Venice

Venetian architecture has a long tradition of beautiful stone claddings, from oriental and Byzantine inspiration to the Romanesque work of the Lombardo family. In the book The Stones of Venice the 19th-century English artist John Ruskin, an admirer of Venetian architecture, argues in favour of the virtue of traditional works of stone. Ruskin's view of stone masonry, opposed to modern technology, rejected extensive use of iron and cement. Still, the way he depicted stone in drawings, words and watercolours reveals an experienced sensitivity that is modern in character. His appreciation of Venetian stone thus indicates a valuable experience in stone structure as well as cladding. The Stones of Venice remain an inspiration.

Like the acoustics of the Viennese waltz of the orchestras of elegant cafés are reflected in St. Marco's stone-clad facade, the pioneers of modern Austrian architecture seem to have been influenced by the stones of Venice'. The Austrian architect Adolf Loos, as the son of a stone-mason, grew up in close contact with the wordless experiences of materials and craftsmanship. Venice was not only the Mediterranean resort closest to Austria, it was actually part of that country from the Napoleonic wars until 1866. Loos discovered the modern pleasures of Venice during a summer holiday at the Lido in 1913. Even without written sources it was certainly possible for the inspiration of Venice's stones to be reflected in Loos' work and in modern stone buildings.

Vienna and Barcelona

Like Ruskin, Loos appreciates material for what it is. It is as if the experience of material enables him to free matter from ornament and conventional meaning. When it comes to symbolic value however he returns to tradition, using classical Doric columns. At Looshaus on Michaelerplatz in Vienna, built in 1910, monolithic load-bearing stone columns of green Cipollino marble from Euboa are erected with the lines in the marble raised vertically. Often stone cladding is used as a conscious choice in Loos interiors, precisely for its colour and texture as a lining material. Materials such as stone and wood enter the space to dress the structure of architecture. When it comes to stone in modern buildings, the Barcelona pavilion by Mies van der Rohe must unquestionably be seen as the most central in importance. The Italian architect Benedetto Gravagnuolo puts the pavilion in the tradition of Loos, as a silent minimal experience of architecture, as the expression of matter. It shows a vast podium covered by travertine, walls of onyx from Algeria, green marble from Belgium, dark green marble from the Greek island of Timos, smoke coloured and opalescent glass, chrome columns, red velvet curtains and white leather seats. The Barcelona pavilion must be considered a true Modern

Movement masterpiece of stone and space.[2]

Prinzip der Bekleidung: Pattern and Structure

In the article called Principles of Cladding, Adolf Loos writes: “Ein jedes Material hat seine eigene Formensprache, und kein Material kann die Formen eines Anderen Materials für Sich in Anspruch nehmen.”[3] He attributes the principles of cladding to Gottfried Semper,[4] but goes further to define “Das Gesetz der Bekleidung”: “Die Möglichkeit, das bekleidete Material mit der Bekleidung verwechseln zu können, soll auf alle falle ausgeschlossen sein.”[5]

Seen in relation to the principles of cladding, this means that as long as the cladding is not mistaken for the structure there is no deceit in cladding the structure. The principle might also be expressed as Henry-Russell Hitchcock and Philip Johnson’s recommendation to “use plates so that their true character of sheathing is evident” and large areas of stone slabs to express surface. Hitchcock and Johnson stress the importance of not confusing the expression of stone cladding with load-bearing constructions by using small-sized stones suggesting mass and weight. Thus when it comes to experiencing stone in modern buildings, it is worth considering what Loos, Hitchcock and Johnson, for example, have written.

The size of the tiles and also the geometry of the cladding distribution are important for the experience of the facade. There are many different ways to arrange cladding. The geometry and size of the tiles and the pattern of the bond are important expressions of the facade.

Vertical rectangular tiles distributed with continuing horizontal joints, horizontally laid rectangles and continuous vertical joints, or square tiles where horizontal as well as vertical joints are continuous could all be regarded as expressing volume rather than mass, emphasizing cladding as a cover of the supporting construction.

A study of historical references and theories can assist understanding, especially when references to single buildings are available. But still nothing can replace the experience of standing before the building itself.

Notes

1. *Ideas of contrast where central to the philosophy of the teaching of Bauhaus Master Johannes Itten and later in the teaching of Lazlo Moholy Nagy*
2. *Gravagnuolo Benedetto, Adolf Loos, London 1995*
3. *Translated: Every material has its own idiom, and no material can claim the shape of another material*
4. *As early as the 19th century the German architect Gottfried Semper described cloth as the origin of architecture and weaving as the origin of technology*
5. *Translated: The possibility to confuse the cladded material with the cladding must by all means be avoided*

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Renovation of the Marble Cladding of Finlandia Hall

Martii Jokinen

The restoration of the marble facade of Finlandia Hall is a case study of replacement as well as part of an international research project to develop knowledge of the physical and chemical reactions of marble as a facade cladding material.

Finlandia Hall. (Photo: Chris Walton)

Finlandia Hall

Finlandia Hall was built between 1967 and 1971. The congress wing was added between 1973- 1975. Alvar Aalto's idea to use white marble as a symbol for humanism and Mediterranean culture was seen for the first time at Jyvaskyla University in 1955, where the upper part of the faculty dining hall was covered in marble. Similar to this is the Technical University of Helsinki 1964 designed by Aalto; where the southern facade of the architectural department was clad in Carrara marble, while the elevations of other departments were constructed in red brick

Legal Protection for Finlandia Hall

1990. The city of Helsinki approved the use of both Tolga White and Bethel White for the renovation of marble facades. Later on Mount Airy was also accepted to the approved list. All of these are granites. None of these selections were subsequently accepted by the National Board of Antiquities (NBA).

1992. The Association of Finnish Architects (SAFA) together with the Museum of Architecture and the Society of Architects proposed landmark designation for Finlandia Hall. This was a second attempt, after an earlier one had been rejected in 1991 by the provincial government. On May 6, 1993, the building was designated a landmark by the Finnish Government; where the first section of the designation report states that in the facades of the building the appearance corresponding, the originality of material, colors and design must be preserved. The National Board of Antiquities, which was responsible for preparing this order had written clearly that only the use of marble is possible. This was alleviated later along in the process by the provincial government in changing the words and inserting instead of marble "corresponding, the originality...".

Many problems arose from the decision to insert the words "corresponding the originality". The city of Helsinki continued to search for light-colored hard stones and finally they had a new proposal, stone from China which was light in color but had a reddish hue. The pressure to abandon marble was immense, where during the last years the subject was written up weekly in newspapers and discussed on television in a very negative tone where only a minority understood why to use of marble. On June 2, 1997 after many long and heated discussions and meetings the city of Helsinki finally made a decision to use Carrara marble.

Original Marble Cladding

The maximum size of the original panels was 140 cm (4'- 7"), the thickness was 3 cm (1

3/8”). Each panel was fixed by four pins, two on each vertical side connected to the next panels side by side. Pins were installed one quarter from the edges of panels. Because the panels were staggered vertically, one panel was connected to the sides of four panels, which made it very difficult to change panels out in the middle of façade.

Problems with the original marble facade:

- the deterioration of marble, surface deterioration, cracking and safety problems
- the overall appearance
- the bowing of panels
- too rigid fixing system not allowing the panels to move according the temperature
- the lack of ventilation
- poor insulation

Plan of Renovation

The City of Helsinki asked for the permission from the NBA to reduce the size of plates. After studying the original drawings we estimated that a reduction of the size would be possible with a maximum amount of 20%. After the NBA wrote this statement we realized that Alvar Aalto had already done this reduction. The city of Helsinki had our opinion paper and still they wanted to reduce the size of existing panels 20% more. This was studied carefully by architects and accepted with the understanding that this marble facade was in effect only temporary and would have to be renovated again at some point in the future. It would contribute to the study and add new knowledge about marble useful for the next renovation and ultimately result in a solution with a longer service life.

Demands for new marble facade:

- the (flexural) strength of marble should be more than 9 Mpa/mm2
- the appearance of marble should resemble the original, even the veins rising diagonally from the left
- the fixing system should be flexible and allow movements and changes in the panels easily
- the ventilation gap
- better insulation

Assumptions concerning the properties of marble:

- the strength correlates with bending
- the stronger the marble the less bending
- the color correlates with the strength
- the darker marble the stronger, contradicting our aim for white marble

Implementation

In 1997 Helsinki chose a contractor who turned out later to be quite inexperienced, while their Italian partner was proved to be unreliable. The visual appearance of marble was so poor and color so dark that half of it had to be rejected on site in Finland. This caused problems and schedule delays and finally the work was stopped in the fall of 1997 and the contractor was terminated. Insulation material in some parts had been changed and only a few slabs had been installed on the eastern wall of the concert hall tower the building was left as it was to wait for next spring.

Next time Helsinki was very careful in the selection of both the contractor and the Italian stone producer. We traveled in summer of 1998 to Carrara to look at two companies, their stone samples and preferences. Both marble producers were asked to produce full scale mock-ups for the wall of Finlandia Hall. The choice was clear. The primary reason was the appearance, but also the company’s attitude and capacity. Savema was selected, which turned out to be a very good decision. They kept their promises, quality of marble was good and they were on schedule. After accepting the mock-ups we signed each slab and the other one was sent to Finland as a reference.

In order to secure the desired quality of the marble and the installation a specific control system was created and every piece of marble got a reference number indicating the place it was taken from. This number was written on blocks at the quarry and on slabs at the processing plant

On the building site a map was created where each slab had this code and if that piece of marble did not meet the specifications according laboratory tests this slab as well as all others originating from the same block were rejected and changed. The amount of marble used in Finlandia Hall was 7.000 m2 (75,000 square feet), which is c. 80 blocks.

The completion was celebrated in May 1999. In the fall of 2001 after realizing that panels are bending again newspapers started to write articles about who is responsible for making the same mistake once again.

Mara Project

The Public Works Department of the City of Helsinki with support from the European Union (Raphael program) had earlier launched a research project titled “Developing long-term durability of marble facades” also known as the MARA-project. It took two years and ended in 2001.

Helsinki was responsible for managing the project. Other participants were in Finland; The National Board of Antiquities, Stonecon Oy, Technical Research Centre of Finland (VTT) and Helsinki University of Technology; in Italy: Parma University, Internazionale Marmi e Macchine (IMM), Henraux S.p.A and Savema S.p.A in Portugal Cevalor. A number of other companies producing marble also took part in the project.

The main goal of the project was to find out the reasons for the characteristic behavior of marble panels in outdoor uses. This information in turn can be used in finding better solutions for building a more durable marble facade or in restoring the existing facades and monuments comprising the European cultural heritage.

One of the other goals was to create an active network between European stone companies, experts and research institutes and a blueprint for on-going development work between them. The project contributes also to transform technologies developed outside Europe that are dealing with research and use of marble. The research concentrated only on Italian marbles quarried in the Carrara, Massa and Lucca areas. The behavior of marble is strongly defined by its microstructure. Three different structures were chosen to represent the qualities: one homoblastic texture, one xenoblastic texture and two intermediate ones.

Xenoblastic structure is characterized by the interlacing of irregular grains that are closely fitted to each other along the wavy contours. Homoblastic structure is characterized by regular-shaped grains with straight or gently curving boundaries. In general xenoblastic marbles present greater flexural strength, smaller water absorption, a smaller coefficient of thermal expansion and contraction and a higher modulus of elasticity than the homoblastic marbles. The Carrara marble used in this renovation fell somewhere in the middle showing both xenoblastic and homoblastic features.

Field Tests

The behavior of marble structures consisting of thin stone panels was followed in actual circumstances in the facade above the roof terrace of Finlandia Hall. Studied matters were the impact of marble panel thickness, stone panel size and initial stone strength on the durability of marble and coating structure. Also the bowing and changes in color were measured. Different types of marble-coated structures were selected for the research as well as different qualities of Carrara Bianco. Three granites were added for comparison.

Each sample covers about 10 m2 (about 107 square feet) of the research wall, the total area of which is 140m2 (about 1,500 square feet). The actual weather conditions i.e. humidity, temperature and the composition of the air by the wall were followed very closely. One of the most important factors was the cycle of freezing and thawing.

Research Program

The main objective for the MARA research was to develop more durable solutions for facade cladding of white Carrara marble (Carrara Bianco) in order to achieve a longer service-life. Practical research was focused primarily on the durability properties of marbles.

In order to achieve the main objective the MARA-project was subdivided into the following secondary objectives and tasks:

- main causes for marble deterioration in facade claddings
- main influencing factors and the failure mechanism
- method for testing the suitability of a given marble
- technical specifications for the maintenance of a marble facade

Finlandia Hall was used as the main reference object. Previous experience obtained from Finlandia Hall as well as the ongoing tests at the actual facade provided a valuable contribution to the research activities.

Three types of light-colored granites were included in the research. During the long preparation period for the recent renovation, all of these granites have been submitted to obtain a permission to be used in the Finlandia Hall facades. Panel sizes were according to the architectural design, panel thicknesses were 30, 40 and 50 mm. Surfaces were honed like in Finlandia Hall at 600, which gives Carrara Bianco smoothly shining appearance. Finishing was different for each side (front side 600 / back side diamond-sawn) and the same (both sides 600).

	A	D	E	K
microstructural characterization	homo/ xenoblastic	homoblastic	xenoblastic	homo/ xenoblastic
appearance	white veined	white veined clear contours	white slightly veined	light grey slightly veined
strength	medium or high	low	high	high
porosity	low	low	low	low
typical uses	all purpose	mainly interior	all purpose	all purpose
earlier experiences about suitability	considered to be one of the best qualities in the region	known to have durability problems when used outdoors	known to be durable	known to be durable
rough geographic location	Carrara	Carrara	Lucca	Massa

Table I. Basic properties of Carrara Bianco marbles A, D, E and K used in MARA research project. A (“Lorano Pradetto”) was used in Finlandia Hall in the most recent renovation.

Conclusions of the MARA project

The main reason for degradation of Carrara white marble in cold climates is due essentially to the anisotropic thermal expansion of the constituent calcite granules. It is the not the result of the acidity of air or rain. A temperature increase of a few degrees' temperature is sufficient to produce a significant, self- equilibrating state of the various stresses inside the material because the thermal anisotropy directions of the various granules are randomly oriented in marbles. Moreover, a leading parameter in the material characterization should be represented by the micro-structural mosaic texture of the constituent grains. Marbles formed by round-shape grains with gently curved boundaries (homoblastic textures) should show poorer properties than those formed by grains with wiggly contours (xenoblastic textures) because of the greater degree of intergranular connection of the later with respect to the former.

Before this research the estimated number of freeze thaw-cycles was about 20 in a year, but in reality it is more like 60 to 70. The number of freeze thaw cycles is probably a little lower on the inner surface of the marble slab than on the outer surface. The difference was about 10%. As this causes more strain on the outer surface than on the inner, this could be one of the factors contributing to the bowing of the slabs. Daily variations were bigger on the southern walls than the northern ones. Very low temperatures (-20˚ C degrees or more) seem to be more damaging, even without frost effect. But also temperatures from +30 degrees to +50˚ C degrees are causing permanent changes in the microstructure of some marbles. These kinds of temperatures can easily exist in Nordic climate.

The strain caused by freezing and thawing may have had a further accelerating effect on the deterioration process after it has started and enough cracks have been formed. The very first cycles can have the most significant influence. The numbers of the cycles does not have any major impact after the first five. After that the deterioration process slows down and the properties of marble will stay more or less the same. But in order to predict the behavior of marble for any extended period, a longer time for monitoring the marble properties would also be required. Temperature cycling also has a strong effect both on the porosity and capillary water absorption coefficient.

This study indicates that the greatest reduction of the marble quality due to the thermal cycling is directed to marble E (from Lucca) with the best original quality. So the thermal cycling seems to equalize the differences in pore characteristics between the marble types.

According to the measurements the renovated walls of Finlandia Hall have already begun to deteriorate. The decrease in strength of the marble slabs after installation is 20-30%. Panels installed first in the autumn of 1998 are bowed more than those installed in the spring of the following year. The reason for this must be the very cold winter in Finland during 1998-99.

Marbles behave differently because the microscopic arrangement of the crystals. Any marble is composed for more than 99% of pure calcite, whereas the other accessory components have practically no influence on the mechanical properties. Due to the higher imbrications granular decohesion is certainly more favored in homoblastic than in xenoblastic marbles. Therefore this study suggests that the grain texture may be a major qualifying characteristic for selecting marbles able to endure over the years.

Building Physical Design Principles

The following physical principles should be applied to the design of a natural stone cladding:

- stone cladding should be jointed by sealants to prevent rain penetration to allow for small movements and deformations of structural elements without risking internal stresses

- water or water vapor in the wall structure should be able to escape through a ventilation cavity behind the stone cladding, proper functioning of the ventilation gap is to be made possible through sufficiently sized openings allowing air movement in both directions
- connections between panels should be flexible to allow deformations due to thermal stress
- internal stresses, due to fixings and deformations between structural elements, should be eliminated by proper design of the fixings
- protective coatings can be considered necessary as protection against environmental impurities

Structural Design Principles

As a conclusion, the following structural principals are recommended to be applied for a natural stone cladding:

- panels are attached individually to the structural frame of the building using load bearing and restraint anchors of stainless steel or aluminum
- anchors are placed in the joints between stone panels and fixed to the edges of the stone panels with stainless steel pins
- load bearing anchors, placed in the lower part of each panel, carry the weight of the stone panels and part of wind forces
- restraining anchors, placed in the upper part of each panel, secure the panels laterally and take only wind forces

Is Carrara Marble Still Possible?

Marble seems to be prone to bend when it is used as thin panels in facades. It is possible to choose xenoblastic marble which is bowing less than the others. The MARA-project also shows that it is possible to find white marble of better quality than used previously or today. However, the main problem – bending - remains. The city of Helsinki will continue the research of marble cladding alone after the MARA-project, because there are so many unanswered questions. It is possible to create a new kind of solution; some of them have even been in service for years.

In Karjaa, west from Helsinki there is an office building about the same age as Finlandia Hall. Its facades are made of Carrara marble. There is no problem with bowing at all, because the structure is composite: marble is only 1 cm thin together backed by 3 centimeter (1 ⅜ “) of concrete. Because concrete in use will shrink when drying the marble slab is pre-bowed by sandblasting its back until an amount of ‘counter-bowing’ of 4 mm (3/16”) is reached. So when the concrete is drying the slab will be straightened.

In the middle of Helsinki in Iso Roobertinkatu 21 there is an office building with a Carrara marble cladding. It was finished 1966 and the slabs are still straight. There is some bowing but it is barely visible. The size of the slabs is similar to the slabs of Finlandia Hall, even thickness is the same at 30 mm (1 ¼ “). The facade is towards the south and thus exposed to sun and rain. Why is this possible?

What about the Change of Stone and Color of Finlandia Hall?

It is not quite clear whose idea it was to use marble in Finlandia Hall. Alvar Aalto favored it and for him it was an important link with Mediterranean culture which he wanted to introduce into Finland. But the assistant of Aalto, architect Jaakko Kontio tells when planning the church in Seinajoki (1955-1960) that Alvar Aalto wanted to make both the church and bell tower of black granite. But it was too expensive and Aalto chose the cheapest way, white lime washed red brick. He says also that Aalto suggested the black granite in the beginning for Finlandia Hall, but the mayor of city preferred white. In this respect black granite could be considered a solution even though it would take considerable courage to use it.

To change a color only a little bit while trying to imitate the original Carrara marble facade is doomed to fail. Finlandia Hall shall lose its main character. If a change of stone is selected the difference between the original cladding and the new one will be so markedly different and clear that it is not anymore designed by Aalto. However, preserving the cultural heritage of Alvar Aalto for coming generations is our responsibility. When the marble has to be changed in the future the costs will not be not so high because the fixing and the insulation which was a large part of the expense of the last renovation can be reused.

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Deterioration of Thin Marble Cladding - Observations from the Inspections of Buildings with Marble Cladding in Europe

Bent Grelk, Björn Schouenborg

All over the world, the long-term deformation and loss of strength of some marble claddings have led to major concerns about its safe and durable use. A comprehensive study was undertaken by a project team named TEAM (TEsting and Assessment of Marble) that represents a consortium of nine European countries and comprises sixteen partners (see www.sp.se/building/team). The project has a budget of approximately $ 5 million USD and was partly funded by the European Commission under the contract no. G5RD-CT-2000-00233. Within the TEAM project, detailed inspections of facades combined with comprehensive laboratory testing were used to develop a hypothesis for the observed deterioration and subsequently the development of a test method for discriminating between suitable and non-suitable marble for cladding purposes. This paper discusses some of the results from the inspection of marble clad buildings.

Introduction

Aim of Work

Numerous buildings with marble cladding facades have been the subject of investigations over the last couple of years. The reason is that the marble cladding on some occasions has deteriorated. When exposed to weathering, some claddings are known to bow, expand and for the marble to lose its strength.

This paper presents observations made from inspections of buildings all over Europe in an attempt to assess the extent of the problem, and to establish the mechanisms responsible for the bowing of marble cladding. In order to do so, the general geographical distribution of recorded cases of marble bowing is established. Subsequently, the marble clad facades on the selected buildings are systematically investigated taking into consideration the degree of deterioration, the (micro) climate, the types of marble and their specific properties. The aim was to demonstrate that the performance of marble used for cladding may vary quite substantially, even though they appear to be of the same quality and marble type, came from the same area, and are exposed to the same climatic conditions. It is emphasized that the technical quality (durability) of the marble can be established via laboratory tests. The investigation was part of the TEAM project.

Background Information

Natural stone has been used for façade applications for centuries. Originally, the stone was rather thick, when used as load bearing construction elements, and the durability was apparently good. Scientific research on properties of marble began in the late 19th century. In the years following, because of changes in fabrication and construction technologies, the thickness of natural façade stones decreased from over 40 inches to typically 1½ – 3 inches. Even though most marble claddings perform satisfactorily durability problems have begun to appear at an increasing rate after some 50 years of using thin cladding. Well-known buildings such as the Amoco Building in Chicago, SCOR tower in Paris and the Finlandia Hall in Helsinki have had their marble cladding replaced after less than 30 years at a cost of many millions of dollars. The deterioration results in a very conspicuous change in the appearance of the panels, they bow, warp or dish.

Most cases of bowing involve marble from the Carrara area, simply because it is the most widespread and used marble type. It is, however, vital to emphasize that many building façades with

Marble deterioration on a monument in Montmartre cemetery, Paris. (Photo: Brent Gelk)

Carrara marble perform well, and furthermore that marble from other areas all over the world also exhibits similar durability issues.

The bowing of marble is not only restricted to buildings, but gravestones of marble are also known to bow as is seen in e.g. Montmartre Cemetery. At present time, most of the recorded cases are from Europe or North America, most likely because of the much more widespread use of thin marble claddings is in those parts of the world. However, individual incidents have been recorded in India (Grabmal des Humayun, Bouineau & Perrier 1995) and Cuba (Cemetery at Havana, Kessler 1919).

Despite more than 100 years of research and being a worldwide problem, the solution to the problems with bowing marble has not yet been found. Numerous methods have been employed to investigate possible factors responsible for deterioration of marble. However, no systematic investigation based upon inspections of building facades with marble cladding have been carried out before now.

The TEAM project

In response to the growing concerns related to both the economic and safety implications of the observed durability problems, the TEAM (TEsting and Assessment of Marble) project was set up in March 2000 with funding from the European Union. The objectives of the project are to find the mechanisms of bowing of façade claddings, the expansion of marble and the related loss of strength. The project also focuses on field monitoring, evaluation and inspection guidelines for façade cladding (NT BUILD 500), which includes risk assessment and service life predictions. Laboratory tests have been developed for this purpose (NT BUILD 499). They are to be refined within the TEAM project and proposed to the European Standardization of natural Stone; CEN TC 246.

The TEAM project is interdisciplinary and its 16 partners from 9 countries, include research institutions, consultants, industry and building owners, all committed to the project. The first result of the project is the state-of-the-art report on “Deterioration Mechanism Hypotheses” (TEAM 2000), which compiles more than 200 papers from the last 100 years. Even though no conclusive explanation on the bowing marble was found, two parameters were agreed on: temperature variations and moisture, in combination. The project has developed from this point, and other key factors like the internal microstructure of marble has now been recognized.[1] Further research pointed out that laboratory testing for bowing, expansion and flexural strength is a very good method to establish the durability of a given marble.[2] Successive in-situ measurements and inspections of field exposure sites and of building façades have contributed to the knowledge on the bowing mechanisms in relation to environmental conditions and construction specific parameters.[3] This paper deals mostly with results obtained in relation to the latter work.

Building Inspections, Geography and Climate

By 2004, TEAM partners had documented more than 200 buildings around Europe and about 50 of these were reported to have displayed bowing. The recordings are wide-spread all over the continent (Fig 2), and they are for practical reasons particularly concentrated in northern Germany, Denmark, Finland and Sweden. However, there are also plenty of examples from the rest of Europe including Slovenia, Switzerland, Austria, France, UK, Belgium, Italy, Spain and Poland. So far no relationship has been established between any particular climatic condition and the long-term bowing and expansion of marble. Cases of bowing have been recorded in the most different climates, from Italy in the south to northern Scandinavia. A daily temperature variation and a source of moisture are however common to all locations.

Several examples of bowing marble are seen outside Europe. In number of recorded cases North America comes second to Europe, most likely due to an increased focus on the bowing marble cladding. Single recordings from India (Grabmal des Humayun, Bouineay & Perrier 1995) and Cuba (Cemetery at Havana, Kessler 1919) indicate that the bowing is a global phenomenon.

Examples of marble deformation

A wide range of buildings were visited where their condition was recorded along with details of the type of stone used, the panel dimensions, the fixing system, insulation and the local environment. One of the first signs of deformation of marble claddings is usually seen

National Bank of Denmark, Copenhagen. (Photo: Brent Gelk)

as bowing. However, the most important physical change observed in marble is the loss of flexural strength, where the recorded strength loss of marble on buildings was between 10 and 85% of its initial strength.[4] In addition to the bowing and loss of strength, permanent expansions of the marble were also evident. This is often associated with movement of the panels and result in spalling of the stone around the fixing points, and ultimately falling of stones.

An example of bowing marble is seen at the National Bank in Copenhagen, Denmark, built in 1965-1978. The building was designed by the Danish architect Arne Jacobsen and has an exterior cladding of Norwegian marble. The marble type, which is a contact-metamorphosed calcitic-silica limestone with remnants of fossil corals, is, because of its beauty, very often used as façade cladding on buildings. However, after approximately 30 years of use the panels on the lower part of this building show medium deformation in the order of 10-15 mm, the most bowed panels being on the southbound façade.

Serious bowing is observed on La Grand Arche de la Defence in Paris, France from 1989. The building, which was designed by another Danish architect Johan Otto Von Spreckelsen, is


La Grand Arche de La Defence, Paris. (Photo: Brent Gelk)

covered with the white Carrara marble from Italy. After only 15 years of exposure, the panels show high degree of deformation. The most severe panels are bowed 20-30 mm out of their original plane, and a total replacement of the cladding is expected in the foreseeable future.

Other examples of buildings with deformed façade cladding from the Carrara quarries are the SCOR Tower in Paris, France, which had its marble panels replaced by granite in 2002-2003, and the IBM Tower in Brussels, Belgium, which recently had its marble cladding replaced by aluminum panels. A quite puzzling bowing behavior was observed on the Finlandia Hall in Helsinki, Finland: the original panels on the façade bowed in a concave fashion and were replaced by the same type of marble, which after a few months started to bow convexly. No explanation for the mode of bowing has yet been established.

In the city of Malmö, Sweden, one office building is also covered by Italian marble. Even though the building is only 20 years old the cladding exhibits severe deterioration. Numerous failures at anchor points, broken stones and stones falling down have been observed. It has not been possible for us to measure the bowing of the stones on this building, but via visual inspection from the ground, the degree of bowing is estimated to be very high.

Other types of marble have also exhibited deformation problems. The façade of a hospital in Lünen, Germany is currently being renovated because of very strong bowing (20-50 mm). A Portuguese marble covers the building. Part of the University in Göttingen, the Juridicum, has exterior cladding of an Austrian marble, which is also deformed in the magnitude of 20-30 mm.

Examples of buildings with non-deformed marble cladding

It is crucial to state that the above-described examples of bowing are not typical for marble cladding. In most cases there is actually no or only minor deformation observed (less than one quarter of the buildings inspected by TEAM exhibited a notable marble deformation). Carrara marble is often considered sensitive to weathering; however, it is vital to emphasize that many building façades with Carrara marble perform very well.

A very illustrative example is seen in the city of Malmö located in the southern parts of Sweden. Here, the City Hall is located next to the above-described office building. It is also covered with the Italian marble Bianco Carrara and is, furthermore, almost the same age (25 years). However, the marble panels of the City Hall are still in good shape, no bowing or degradations of the panels is recorded and the flexural strength is reduced by only 10%, which is normal for other durable stone types like granite. Note also that the surface of the City Hall is still glossy from the original polished finishing.

The City Hall of Borås, Sweden, which is approximately 39 years old, also has a façade cladding of Carrara marble, and no deformation has been detected. Another example of a durable facade with Carrara marble is a Bank in Brussels, Belgium.

The City Hall of Aarhus, Denmark has

Detail of deteriorated marble on a hotel, Helsinki.
(Photo: Björn Schouenborg)

an exterior façade of the Norwegian marble from Porsgrunn – a similar type causing some problems at the Danish National Bank in Copenhagen. The building is from 1934, but no serious deformation has been observed on the facade of this building. The marble façade of Lyngby City Hall, Denmark is also in a very good condition despite being from 1941. The facade is clad with a calcitic marble type from Marmorilik, Greenland.

Microstructure and testing of Marble

The experience of the TEAM project is that most marble types are known not to deform. Marbles that, to the eye, look exactly the same and come from the same area have been observed to exhibit quite differently degrees of bowing, when exposed to the same environment. On the other hand, very different marble types are observed to perform in the same way, and both calcitic and dolomitic marble types are known to bow in some cases, while not bowing in other cases in the same environment. Thus there is no clear indication as to the effect of appearance, area of origin and mineralogy by the deformation of the bowing of the marble.

The TEAM project has found the microstructure of marbles to be a very indicative parameter for their bowing behavior. The marble, which tends to bow and deform, displays a so called granoblastic structure, which is characterized by the single polygonal grains of calcite to be of regular shape with straight boundaries. Marbles with a xenoblastic structure have interlobate grain shapes and irregular boundaries, and seem to be quite resistant to deformation.

Whereas the microstructure can give only an indication of the durability of the marble, TEAM partners have developed test methods for bowing and permanent expansion potentials. A very good correlation is established between the bowing problems observed on buildings and the laboratory bow tests. All stone types, which have been observed or reported to bow on the facade were also found to bow in the laboratory. Stone types, which did not bow in the laboratory, have not been observed or reported to bow on any facade.

Conclusion

Bowing and non-bowing marble cladding is known to occur all over the world. No climate seems to be typical of the conditions that result in long-term bowing and expansion, whereas daily temperature variations and moisture are responsible for the degradation. The various bowing behaviors of different marbles are due to a different microstructure, which can be determined by testing.

The main conclusion of this work is therefore, that very different marble types safely can be used on exterior facades, if tests for bowing potential and loss of strength give an approved result. It is anticipated that the test methods developed by TEAM will become European standards in the future for all marble and limestone claddings.

Notes

1. *See Alnæs et al 2004*
2. *See Grelk et al. 2004*
3. *For field exposure sites see Malaga et al. 2004, for building façades Yates et al. 2004.*
4. *See Yates et al. (2004)*

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Conservation of Stone Facing in Modern Italian Architecture

Sergio Poretti, Rinaldo Capomolla, Tullia Iori, Stefania Mornati and Rosalia Vittorini

This paper illustrates recent conservation and refurbishment operations on the stone facings of two important twentieth century Italian architectural monuments: the Rome Post Office Building by Adalberto Libera (1933–1935) and the Palazzo della Civiltà Italiana in Rome by Giovanni Guerrini, Ernesto Lapadula, Mario Romano (1938–1943). In both cases, the project began with a meticulous investigation of the buildings' architectural and construction features and the peculiarities of the stone facing. In the case of the Post Office Building, the front portico facing reveals a strong degree of deterioration. The construction system employed to erect this building is emblematic of the experimental trend of the early 1930s in Italy: thin stone facings on mixed reinforced concrete and masonry structures. The restoration operation was conducted to salvage the original architectural features whilst also finding new solutions for the original technical defects that caused the deterioration. The Palazzo della Civiltà Italiana is likewise emblematic and its marriage of heavy travertine facing with a reinforced concrete structure is typical of the cultural, economic and political environment of the autarchic period. The operation, currently underway, to restore and employ the building (after years of neglect) required a careful evaluation of the stone facing deterioration causes and an ad hoc conservative restoration project for the facing.

The report focuses on how, in these two cases, the historical reconstruction of the original building solutions and the diagnosis of the causes of deterioration led to the definition of the restoration project solutions.

Introduction

The complete marble facing of Italian public works epitomizes the influence on Modern Italian architecture of the peculiar cultural and economic environment in Italy between the two world wars. Protectionist policies of the fascist regime, intended to support the Italian marble industry and offset by the drastic decrease in exports by encouraging internal consumption dictating the use of marble in public buildings. The regime had political motives as well; stone facing resembles ashlar construction and conjures an image of solidity, permanence, and monumentality. Because of these factors, marble facing is a pervasive element of the building grammar of Modern Italian architecture – and a key focus of conservation efforts.[1]

Use of marble facing was experimental from both an architectural and a technical perspective. In fact, the experimental nature of this style often resulted in the deterioration of the facing that buildings of this period suffered immediately after their erection.

Maintenance and restoration of stone facing raises various questions. For example, which tools should be employed to implement consolidation? And, is it correct to indiscriminately adopt the technique – presently the most widely used in Italy – of securing stone slabs to walls by means of adhesive anchors and external spackling? Rather than discuss solutions to these problems abstractly, we will look at two recent restoration experiences.

These case studies involve two monumental buildings erected in Rome: Adalberto Libera's Post Office Building erected between 1933 and 1936; and the Palazzo della Civilità Italiana, designed by Giovanni Guerrini, Ernesto Lapadula and Mario Romano, with construction begun in 1938 for the Universal Fair of 1942 (which never occurred because of the war).

All analyses and operations, in both cases, were implemented by the "Architettura e Costruzione" Group of the University of Rome Tor Vergata. This group, coordinated by Sergio Poretti, includes Rinaldo Capomolla, Tullia Iori, Stefania

Post Office building on via Marmorata by Adalberto Liberia and Mario De Renzi. (Photo: Sergio Poretti, 1990)

Palazzo della Civilta Italiana in Rome by Giovanni Guerrini, Ernesto Lapadula, Mario Romano. (Photo: Sergio Poretti)

Mornati and Rosalia Vittorini.

Both buildings underwent extensive analysis commissioned by the present proprietors (Poste spa and Eur spa) in view of the restoration operations, and in both cases, the analysis was followed by a conservation project. Restoration operations were completed on the Post Office Building and are still underway on the Palazzo della Civiltà.

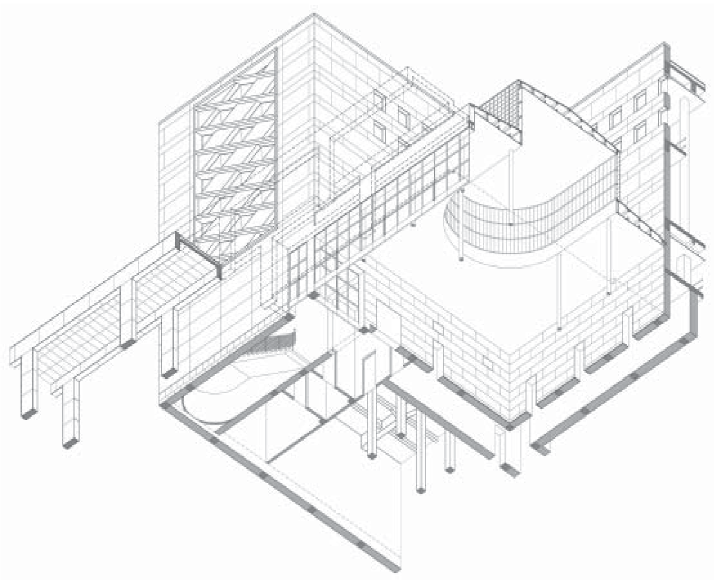
Post Office Building on via Marmorata

The Palazzo delle Poste is faced entirely in travertine.[2] Violet porphyry from Predazzo was used to face the portico to make it stand out materially and chromatically from the main nucleus. The facing consists of thin slabs (three to four centimeters thick at most), applied directly to the mixed-style construction of reinforced concrete and traditional masonry. This is an unusual method that had not yet been experimented with at length at the beginning of the thirties. The slabs were affixed to the main nucleus of the building by traditional building techniques. Every slab rested on the one beneath it and was joined to the wall by hooks made of reinforcing rods of galvanized iron.

The solution adopted for the portico was far more innovative. There, the thin slabs were joined to the reinforced concrete structure by means of invisible cramps and eyelets. Facing of the pillars was executed by resting the slabs one above the other and using galvanized iron reinforcing-rod hooks, previously inserted into the structure, to prevent the slabs from falling over. Eight hooks suspend the much smaller horizontal slabs from the beams and floor system intrados. The eyelets were necessary to affix the vertical facing to the architrave, which had no resting point. Metal spikes (inserted into conical lodgings half the width of the slab) were mounted on the slabs to allow them to be joined to the main structure.

Soon after the building was completed, the portico slabs began to detach. The few fixed anchoring points proved insufficient for the large dimension of these slabs (2.15 meters long and 1 meter wide), which were also rather hazardously shaped to reduce the discontinuity in cuts. Diverse thermal dilations between the structure (which had no joints) and the porphyry facing led to stress that could not be absorbed by the metal reinforcing rods.

Adalberto Libera, summoned in 1943 by the Technical Office of the Italian Postal System, began to study solutions to this problem. Focused on reducing the facing slab dimensions, his sketches depict facings with the slabs reduced by



Post Office Building: Axonometric drawing (Drawing: T. Iori)

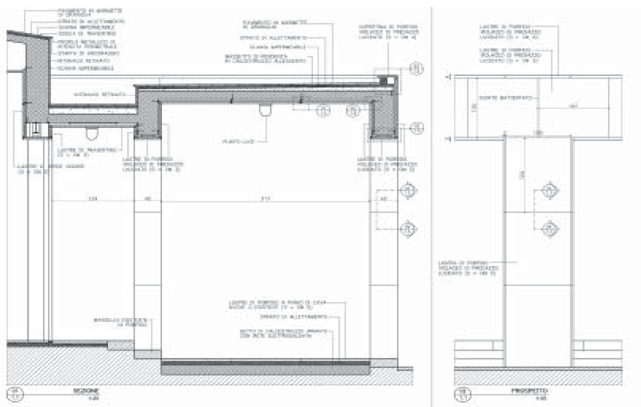
a half, a fourth and even an eighth of the original dimension.

At the end of the Sixties, the entire portico facing was removed as a safety precaution, and between 1966 and 1971 the structure was consolidated and refaced with travertine from Tivoli, thereby eliminating the chromatic and material contrast that had been envisaged by Libera. The surface of the portico intrados was faced with azure glass tesserae.

Finally, in 1997 the Postal Service decided to implement extensive conservation maintenance on the facing. The stone slabs of the main nucleus were consolidated by using stainless steel adhesive anchors, and perforations were sealed with a mixture of putty and travertine powder. An experimental procedure that had been proposed to conceal the adhesive steel anchors — employing the stone wedge that had been removed to insert the adhesive anchors — was not accepted by the building management. Most important, however, violet porphyry was still available, and the portico was returned to its original appearance.

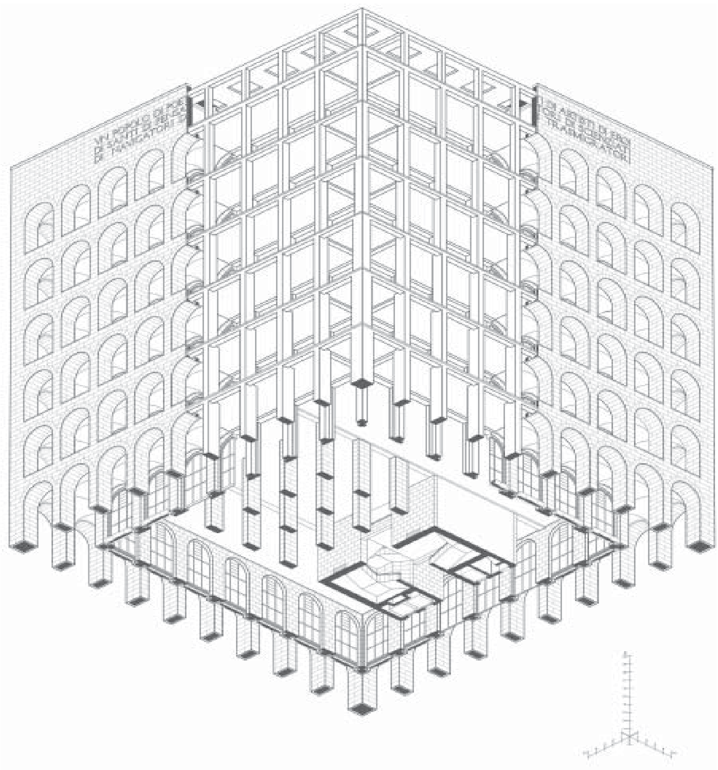
Nonetheless, the construction technique had to be updated. The slabs were to be affixed only to the structure and not joined to each other in order to permit free thermal expansion. This was implemented by adopting a stainless steel framework that joined every individual slab to the pillars and beams with double expansion anchors. In this way, every slab was held in place independently of the others and was slightly distanced from the structure itself.

Although modern techniques would have permitted the original large slab design to be erected efficiently and safely, it was hard to overcome the client's opposition. It remembered the damage that had originally been caused by that type of solution. In the end, a solution that had once been suggested by Libera himself (in his 1943 sketches) was adopted: The dimension of the slabs on the main façade was halved and standardized to four centimeters in width.[3]



Post Office Building: Conservation Project. (Poretti 2005)

During the executive works phase, a few variations had to be implemented in the project on account of the modest machinery that the contracted construction company possessed. (This issue is rather lengthy and cannot be addressed at this time.)



Palazzo della Civiltà Italiana: Axonometric drawing. (Poretti, 2005)

The Palazzo della Civiltà Italiana

The use of inadequately supported thin slabs caused problems in many of the buildings erected during the first half of the Thirties (including Giuseppe Terragni's Casa del Fascio in Como).[4] Italian technicians quickly identified the reason for the slab detachment – the main cause was the difference in thermal dilation between the marble and the reinforced concrete structure – and devised more efficient techniques such as the one that was brilliantly employed in the Palazzo Montecatini in Milan.

By 1938, when construction began on the Palazzo della Civiltà Italiana, the situation in Italy had changed dramatically. The autarchic economy and the new architectural strategy of the fascist regime had brought stone facing of walls back into fashion. However, the slabs lost their initial character as a slender skin applied to the main structure and became thick and massive, thinning as they reached higher. In short, the facing had become an autonomous and self-supporting external shell.

The Palazzo della Civiltà Italiana has an elementary configuration.[5] It is a gigantic cube perforated by 216 round arches, repeated identically on all four facades, nine per floor on all six floors. The stability of the building is based on its reinforced concrete framework. The framework, however, is complemented by traditional brick masonry on the inside and the external travertine facing. The inner masonry "filling" varied greatly in width (from 3 to 97 centimeters) depending on the progressive reduction of the pillar width in relation to the building height.

During construction, the brick "filling" was raised together, step-by-step, with the travertine slabs, often creating a single heterogeneous but indistinguishable unit. The slabs were adjoined to the brick masonry by means of steel rods. Floor by floor, this elaborate brick and stone structure acquired its own static autonomy, absorbing the load of the travertine ashlars on the archivolt (usually about 15 to 20 centimeters wide), as it was built not only to imitate the arches but also to conserve its static drive. The 17-cm-thick frames that upheld the arches were not completely self-supporting, but were also anchored to the pillars and the floor system above by iron and steel rods.

The complex interactions between the facing and the main supporting structure and the loss in efficiency of the joining cramps have led to the present state of deterioration. This does not, however, present any generalized slab detachment as occurred in the buildings faced with thin slabs. In this case, the deterioration entails local ruptures and loosening of individual elements (mainly the corner slabs due to the load pressure).

Thus, the proposed project presents many analogies with the typical restoration of stone facings in ancient buildings. The restoration aims to secure the detached slabs with anchoring methods similar to the original ones (but made with more resistant materials); integrate the missing slabs (removed years ago to examine the facing and the underlying structure); substitute the newer facing slabs (which usually have a different color and superficial finish); remove all spackle, putty sealing, cramps, and pins added in previous consolidation operations; and spackle and clean the entire surface. In particular, great attention has been paid to perfectly sealing the joints in order to prevent – as far as possible – water leaking behind the facing, which poses the greatest threat to the pins securing the slabs.[6]

Conclusions

Returning to the question of what solution to adopt in a facing conservation operation, we can draw two conclusions.

The first is that the solution can in no way be determined in a laboratory, but must be defined, case by case, in relation to the building characteristics and the historical reconstruction that details the original project phases, the construction yard work and the elements that caused the process of deterioration. The very history of the architectural work will suggest the procedures to be implemented.

The second conclusion is that the solution does not follow automatically from an investigation, but instead must be perfected while in progress. Even if the objective is to restore a building element by respecting the original solution, or to carry out regular maintenance and conservation operations, all procedures must be developed through a highly detailed, graphical project.

Notes

1. *See Sergio Poretti, "Marble Sheeting in Modern Architecture", in Stone in Modern Buildings. Principles of Cladding (Roma: Ograro, 2003) 14-18.*
2. *See Sergio Poretti, Progetti e costruzione dei palazzi delle poste a Roma 1933–1935 (Roma: Edilstampa, 1990).*
3. *See Sergio Poretti et al, Il restauro delle Poste di Libera (Roma: Gangemi, 2005).*
4. *See Sergio Poretti, La Casa del fascio di Como (Roma: Carocci, 1998).*
5. *See Sergio Poretti, "Identità e futuro di un monumento", in Il Palazzo della Civiltà Italiana. Architettura e costruzione del Colosseo Quadrato, eds. Maristella Casciato and Sergio Poretti (Milano: Federico Motta, 2002) 11-35.*
6. *Sergio Poretti, "Il Palazzo della Civiltà Italiana: storia e riuso di un monumento moderno", MdiR monumentidiroma 1-2 (2004): 81-88.*

The Restoration of Juan O'Gorman's Central Library of University City, National Autonomous University of Mexico

By Louise Noelle Gras

Juan O´Gorman, was an architect, painter, and author of the celebrated Library of the Ciudad Universitaria in Mexico City. Here the artist designed both, the building and the murals that cover all the exterior walls; these murals were made with a new technique of stone mosaics, discovered in conjunction with Diego Rivera. Their conservation and restoration has called upon professionals in this field as well as scientists from the Institute of Geology of the National University, to act upon the problems of protecting the minerals, as well as to find new pieces when needed.

Juan O'Gorman (1905–1982) is perhaps one of the most controversial figures of contemporary Mexican architecture for having promulgated a series of extremist propositions that he later denied, raising questions and polemics.[1] As a student, he was one of José Villagrán García's first disciples, from whom he received lessons on functionalism; thereafter, his affiliation to the Communist Party and his study of Le Corbusier's postulates intensified his positions in both theory and practice.

Among his first dwellings of an austerity bordering on poverty and inspired by the "Esprit Nouveau," is Diego Rivera and Frida Kahlo's house-studio (1929–1930). Around the same time, O'Gorman also built more than twenty public schools in which he sought to modify the educational system by optimizing and typifying the design through adopting modular classrooms and abandoning the traditional cloister scheme.[2]

O'Gorman's contribution to the Modern Movement is evident in the works he built during seven short years of professional practice, from 1929 to 1935. He eventually abandoned his practice for different reasons, some ideological, to dedicate himself to painting. During fifteen years he poured himself into mural painting, with works like "The Conquest of Air by Man" (1938), and "History of Michoacán" (1941), and easel painting, producing an important series of portraits. He was accustomed to investigate in depth the subject matter to be shaped in his murals in order to achieve results of great accuracy and detail, summarizing important subjects in a clear manner and in a small space.

He later returned to the field of architecture with a series of new propositions, first as Diego Rivera's advisor in the construction of Anahuacalli, the Diego Rivera Museum in Mexico City (1945). Indeed, during the construction process, Rivera was concerned about the poor aesthetic aspect of the concrete slabs in the spandrels, for which it "occurred to them to devise a [unique] procedure of great importance… over the wood mold we put

Juan O'Gorman, Gustavo Saavedra and Juan Martinez de Velaczo, Murals, Central Library, University City, UNAM, 1952. South Facade. (Photo: Louise Noelle Gras) a layer of pedacería [pebbles] of grey stone… (to) do the usual straining… (resulting) [in] a mosaic without any drawing. Later the master demolished the said slabs to make others with concrete that would have mosaics with drawings…”[3] Thus, the first natural stone mosaics were born. It is with an adaptation of this technique that the internationally famous library of Ciudad Universitaria (1950-1952), Universidad Nacional Autónoma de México (National Autonomous University of Mexico), was realized; a simple rational structure totally covered with stone mosaics; it is not until the realization of his own house, San Jerónimo (1953-1956), that O’Gorman achieves a totally innovative expression in this field of plastic integration.[4] In this latter case it is an organic and oneiric design (regrettably destroyed) where he takes advantage of a series of natural caves to insert a dwelling that is covered with a profusion of mosaics in relief stone; here evident are a number of influences, like the organic architecture of Frank Lloyd Wright, Max Cetto’s interest in El Pedregal (“stony ground”), Carlos Lazo and the “Civilized Caves,” Diego Rivera’s sculptural mosaics, and O’Gorman’s own easel paintings of fantastical content.

Going back to the Central Library of Ciudad Universitaria, we must note that in the architectural field the building shares credit with Gustavo Saavedra and Juan Martínez de Velazco, although the mural “Historic Representation of the Culture” is solely O’Gorman’s.[5] We must also note that this is perhaps the best known piece of architectural work beyond national frontiers, and in a certain way has become a symbol of contemporary Mexico. It is a building of rectangular plan, with two basements, a ground floor of double height where the main reading room and the mezzanine are located; the body or the repository spaces, practically windowless, is eleven stories high at 43 meters (169 feet) long, 16 meters (63 feet) wide, and 27 meters (106 feet) high, which translates to the largest surface in the world covered with this technique of stone mosaics (approximately 4,000 square meters (15,748 square feet), including a volcanic stone base with reliefs of prehispanic motifs).

From a technical standpoint, the restoration project of the murals implied a multidisciplinary effort, both from the university and outside, in the period between 1989 and 1994 leading up to the restoration work that began in April 1995 and concluded in July 1996. I attempt to document here in brief the development of this effort, manifested through the multiple job meetings, fieldwork, investigation and laboratory work. It is worth noting that the investigation work was the responsibility of the Head Office of Heritage (Dirección General de Patrimonio), UNAM, to achieve an integral diagnostic of the work and to develop a methodology for the restoration project with the Mexican Foundation for World Monuments. (Fundación Mexicana para los Monumentos de Mundo, A.C.), which in July 1994 withdrew from the work. From this point on, the following entities also collaborated in the shared effort: Head Office of Heritage, the Head Office of Works and General Services, the National School of Plastic Arts, the School of Chemistry, the Institute of Anthropologic Research, the Institute of Geography, and the postgraduate program of the School of Architecture.

Among the principal technical studies performed were petrographic analysis (October

Juan O’Gorman, Gustavo Saavedra and Juan Martinez, Murals. West facade. (Photo: Louise Noelle Gras)

Juan O'Gorman, Detail of mural, North facade.
(Photo: Louise Noelle Gras)

1990), environmental conditions (November 1990), petrographic study (June 1991), characterization of glass (July 1991), determination of apparent density and porosity (May 1991), and probable composition of rainwater in Mexico City (June 1992). A precise diagnostic was then elaborated for the restoration project taking first into consideration the construction system employed, as some of the more than 4,000 panels measuring one square meter (3 square feet) each, were exhibiting diverse deformations.

It is worth paying close attention to the original work method to comprehend the complexity of its elaboration as compared to the later restoration work. In the process of fabricating the mural, more than 4,000 cubic feet (113 cubic meters) of natural rocks were employed (except for creating the blue color, which was achieved in glass) and strained in clay molds to avoid the possible deformations of the wood mold; here it is important to reiterate that the painting work of O'Gorman is characterized by a great precision in drawing, for that in this case the artist did a rigorous drawing of full size and tried to avoid a lack of correspondence in the lines and colors of the panel joints. The procedure consisted in carefully accommodating the stone pieces in the mold, applying first a thin layer of non-fluid cement to set them in; then a ferrous bar framework was placed over this, and finally, the pointing was done whereby some bars were left exposed in order to tie into the architectural structure that was prepared to receive each panel.

For O'Gorman it was fundamental the utilization of materials that, according to him, do not get affected through time, for which he thought that a stone mosaic was as durable as possible. As far as the care in the selection of the materials is concerned, the muralist himself tells us:

> "It is certain that in order to make mosaics it was necessary to obtain stones of all the possible colors. For this I traveled through the entire Mexican Republic, after having consulted the case with a mining engineer who was a friend of my father, who indicated [to] me the places where I could find stones of different colors. I visited many mines and quarries to pick up samples of each kind, making a collection of approximately 150 stones of different colors to select the best possible coloration… Finally, I selected ten colors with which [I] could make mosaics[:] one of Venetian red, a sienna yellow, two pinks of different quality, one of almost salmon color and another one close to violet, one of violaceous gray, the dark gray of the stony ground, obsidian black, and chalcedony white… It was also possible to employ white marble, two tones of green, one light and one dark… For the blue, I employed colored glass in pieces and then grinding them [as] if it was stone."[6]

Nevertheless, after 40 years, the decay of the stone mosaics was significant due to, among other factors, problems caused by the construction system and the weathering of the rock materials, as well as significant losses in the surface. Visible damage was triggered by the natural weathering of the diverse types of stone provoked, above all, by the acid rain and the expansion-contraction cycles resulting from temperature variations, as well as the deformation of some of the plaques due to placement and anchoring problems. After a careful study of these problems, the restoration proceeded and lasted 15 months.

The work consisted of: 1) Air pressure cleaning and washing with natural vegetable detergents (chichi herb); 2) Consolidation, taking into consideration the rainy season periods, humidity, and sunny periods (Wacker OH consolidant); 3) Water-repellent application (Wacker 290 L spray, dissolved in ammonia); 4) Replacement of lost fragments, having located the original quarries used; 5) sealing of the inter-planar joints to avoid water infiltration (with gray urethane sealant that is invisible); and 6) Fastening and adapting the panels with expansion joints for greater movement. Scaffolding was done with swing-stages in order not to touch the walls.

The process, performed with great care, was successful but it is very important to continue the conservation of this singular architectural and muralist work. Ten years after the conservation process, preventive maintenance continues with the aim of protecting one of the principal possessions of the heritage of the National Autonomous University of Mexico.

This paper was translated from its original version in Spanish by Olivia Klose.

Notes

1. *See Ida Rodriguez, Prampolini, Juan O'Gorman, arquitecto y pintor (Mexico: UNAM, 1982) and O'Gorman (Mexico: Bital, 1999).*
2. *It is also important to note the decisive role that Juan O'Gorman played in the creation of the Graduate School of Engineers and Architects of the IPN, with which he made clear his anti-academic stance, reducing architecture to technical engineering problems;*
   O'Gorman made this position clear in the famous "Talks on Architecture," organized by the College of Architects, where, in the company of Juan Legarreta and Alvaro Aburto, he proclaimed himself in favor of rationalism and against the artistic.
3. *Juan O'Gorman, "Autobiografía" in Antonio Luna Arroyo, Juan O'Gorman (Mexico: Cuadernos Populares, 1973): 142.*
4. *Louise Noelle, "La integración plástica: confluencia, superposición o nostalgia," (In) Disciplinas: Estética e historia del arte en el cruce de los discursos (Mexico: UNAM, 1999).*
5. *For more information on the symbolic content of the mural see Luis Roberto Torres Escalona's Representación histórica de la cultura: mural de Juan O'Gorman en la Biblioteca Central (Mexico: UNAM, 2003); Torres Escalona also graciously provided me with the report of the restoration.*
6. *Juan O'Gorman, Op. Cit. 143.*

Chroma:
Color and Conservation in Modern Buildings

Color has always been an important element of architecture but has generally received little or no attention whether in the design studio or the classrooms of architectural schools. This was the case in the beginning of the 20th Century and in many ways has not changed today. Where color is applied it is often seen as almost as an afterthought or as an explanatory device rather than an artistic element. Over centuries color studies and color notation systems have been developed including work from Goethe to Munsell. Contrary to the opinion of the general public color was and is an important and key element in modern architecture. This point is frequently misunderstood not in the least because so many of the early publications of seminal modern buildings were in black and white and by photographers of considerable fame. This suggested a level of abstraction and 'coolness' that was hardly present in reality as some of the case studies discussed here will demonstrate.

The papers included are addressing several distinct areas, notation systems, color investigations on modern architecture and perceptual aspects of color. With regards to color notation systems the Natural Colour System (NCS) used predominantly in Scandinavia and Europe is the continuation of a long list of systems developed over the last two centuries. It forms an interesting – by some a much preferred – contrast to the Munsell and Pantone systems, which are more commonly known and used in the US. The importance of color and its impact on key modern buildings will be clearly apparent from the discussions of the investigative work conducted on buildings and structures by Luis Barragan in Mexico and William Lescaze in New York City as well as Alvar Aalto's library in Viipuri, Russia, Jan Duiker's Zonnestraal sanatorium in Hilversum, The Netherlands and Luis Barragan's work in Mexico. The appropriate color investigative and analysis techniques, well established in the conservation of earlier buildings, are applied to these modern structures to determine their original palette and appearance. The results were often remarkable and unexpected and were by no means as monochromatic as expected by so many from modern architecture. Color and art in modern architecture or interior is not just without controversy today but also in the past. The murals painted by Le Corbusier for Eileen Gray's house are an example in point. One of the final presentations titled Dimensional Color at the conference was on the perceptual aspects of color by Lois Swirnoff and which can be found in her eponymous book and in many ways building on the work of Josef Albers.

The NCS (Natural Color System) and its Use in Recording Historic and Contemporary Architecture

Harald Arnkil

This paper discusses the challenging relationship between architecture and color. With a comparison between two color classification systems, the American Munsell system and the Swedish Natural Color system (NCS), the author discusses their role in architecture and building conservation.

Accurate color designation is of central importance in architectural design, building conservation, and restoration, yet, architecture poses many challenges for color identification that are not present in other environments or art forms. First there is the problem of scale: how to translate a color chip of a few square centimeters into an exterior wall surface covering perhaps thousands of square meters. Or backwards: what would be the equivalent of the same vast wall area in terms of a concise color designation, visual or otherwise?

Fortunately, the equipment and methods available to architects and building conservators have greatly improved in the last 25 or 30 years. These include photomechanical measuring equipment such as portable color meters and spectrophotometers and standardized color systems such as Munsell and the NCS. Before the development of universal color standards, colored drawings, sometimes accompanied by painted color samples or paint manufacturer's codes, served as the record of a building's color design. Here, of course, the problem is that the pigments used for the painting may fade, or the acid in the paper may interact with the pigments and discolor or even destroy the paper entirely.

Photography has made the recording of large and complicated environments extremely fast and simple in comparison to the earlier methods of freehand illustration. However, the artist's eye is often far more accurate in recording environmental colors than even the best color photography. This is largely due to the problem of ambient light. The problem lies in the fact that, for determining the colors of objects, our color vision system is entirely dependent on the composition of wavelengths of light bouncing from surfaces and reaching our eyes. Neither the camera nor the eye has an inherent method for separating the color of the light from the color of the surface.

The human visual system has evolved to extract characteristic, permanent, non-changing features from the world, which, as far as our senses are concerned, is in a state of constant change and flux.[1] While colors and other surface qualities of objects belong to the permanent and characteristic features of the world that are essential to our understanding of our surroundings, to a large extent lighting belongs to the nonpermanent features of objects and environments. In order to make sense of the world, the eye and brain possess a perceptual mechanism called color constancy. With this mechanism they are able to carry out an instant assessment of most normal situations to determine real color of a surface in any given ambient light. This "calculation" is so efficient and rapid that we are totally unaware of its working (and thus largely unaware of the problems involved).

Modern photographic equipment can in a crude way perform parts of this calculation. It can provide, for example, automatic adjustment of color temperature or white balance. But it is not able to imitate all the features of human color constancy. In short, photography is an invaluable aid in recording the overall appearance, shape and character of an environment, but it will never fully replace other methods in accurately recording the true or "local" colors of individual surfaces and details.

A visual artist can render the colors of an interior or exterior in two basic ways: 1) as an impression of the surface colors (reflectances) plus the ambient light; or 2) as a rendering of the surface colors or reflectances irrespective of the character of the ambient light. The Swedish color researcher Karin Fridell Anter has termed the true or local colors of environments inherent colors.[2] Fridell Anter defines inherent color as: “A) the color that the object would have if it were observed under the standardized viewing conditions that are prerequisite for the NCS color samples to coincide with their specifications” and “B) the color that one imagines as belonging to a surface or material, irrespective of the prevailing light and viewing conditions; it can be operationally determined, e.g., through comparison with a standardized color sample.”

When designating colors for a new building or recording them for posterity from an old one, the most crucial color information, apart from material and chemical features, is the inherent color of its surfaces. In addition to the problem of lighting, the extraction of this information can be challenging for a variety of other reasons posing different problems to different methods. These problems include:

1. variable surface textures;
2. gloss - matte finish;
3. opaqueness - translucence;
4. variegated colors (as in stone, wood, etc.);
5. metallic, iridescent or pearlescent colors;
6. weathering and aging; and
7. simultaneous contrast of colors.

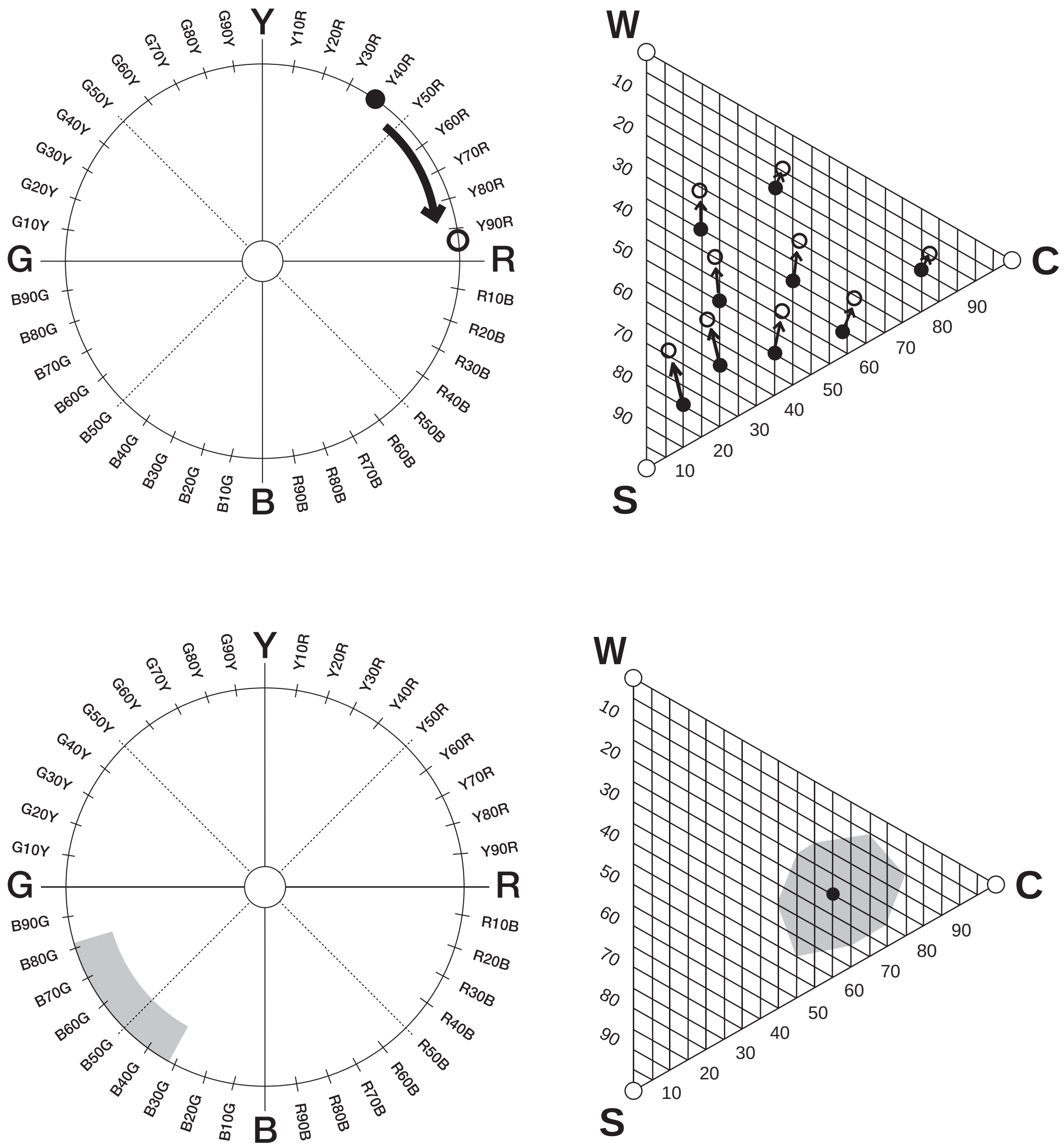
The most accurate record of a surface’s color, and one that will include all possible qualia of the surface, is of course an actual material sample. It is, however, often impractical or even impossible to extract and store physical samples of buildings. Difficulty of access to surfaces such as high ceilings poses other problems to color measurement methods.

The primary requirements of color measurement or designation equipment are accuracy, durability, universality, and ease of use (e.g., portability). Available tools include: A) color charts, such as paint manufacturers’ charts or charts used for the printing process (e.g., Pantone); B) spectrophotometers and RGB color meters that measure the composition of light reflected from surfaces; C) color systems and standards aimed at specifying colors in scientific terms and presenting visual samples of surface colors as standardized color chips or atlases.

The most useful methods to designate and record colors in architecture are standardized color systems that are neutral in respect to materials, processes, and media. Few color systems fulfill the requirements of a such a standard. In order to do this, their color samples must pass rigorous tests of durability, accuracy and light-fastness. In addition, a useful color standard should be practical and have a logical structure, i.e., it should follow the structure and function of the human visual system.

Spectrophotometers, although far more accurate than any method based on visual samples, provide information in the form of series of numbers that are abstract and often inappropriate for determining the visual appearance of spatial colors and surfaces. They are irreplaceable, however, for highly accurate measurements of color difference, whiteness-yellowness and tolerance in many industrial applications. Spectrophotometric data, of course, can be converted into Munsell or NCS notations, but this data indicates nothing about ambient light and texture. Color meters also have difficulties in translating such qualities as gloss and transparency.

Sometimes architects and designers use color charts or color collections that are designed for uses other than the specification of environmental and architectural color. A typical example is color charts for the printing process. It should be noted that the saturation of some of their hues far exceeds the gamut of all architectural surface materials and paint media. Another – and more serious – problem is the relative inaccuracy and non-lightfastness of printed color charts. Left in daylight, a Pantone chart, for example, will start to fade within weeks because of the chemical instability of the printing inks.



The NCS (Natural Color System) and its use in recording historic and contemporary architecture

Munsell or NCS?

Two of the most commonly used color systems in architectural and environmental design and research are the American Munsell system and the Swedish Natural Color System (NCS). Both systems fulfill the above-mentioned requirements of a color standard, and both systems also have a visual basis. In other words, they aim to identify and classify colors according to principles of human color vision rather than pigment chemistry or physics of light. The Munsell system is the oldest color classification system still in use. Its first version was published by the American artist, teacher and color researcher Albert Henry Munsell in 1905, but the system has undergone many revisions since then.

Munsell differs from the NCS and most other color systems in one fundamental respect: it is based on five primary colors, Principle Hues, whereas most other systems are based on either three or, as is the case with NCS, four primary or unique hues. Five primaries allowed Munsell to build a decimal system of color notation, but the inclusion of Purple as a primary hue contradicts all other systems as well as modern color vision research. As the Nobel scientist David Hubel has said, “The artificial results of mixing paints is doubtless what has led to the idea of “primary colors” such as red, yellow, and blue. If any special set of colors deserves to be called primary, it is the set of red, blue, yellow, and green.”[3]

There is a strong agreement among color scientists today that the human color vision system operates at the cortical level on a system of color opponency: redness versus greenness and yellowness versus blueness. The theory for this mechanism was formulated back in the 1880’s by Ewald Hering, and it has been confirmed by subsequent psychophysical tests as well as modern clinical neurobiology.

One of the earliest applications of this theory was Wilhelm Ostwald’s color system, which was published the same year as Munsell’s and was extremely popular in Europe in the 1920s and 1930s. Ostwald’s system fell into disuse after the Second World War, but some of its principles live on in the NCS system. Ostwald, who was a Nobel-prize scientist in physics and chemistry, based his color system on the latest scientific knowledge on human vision. Thus he embraced not only Hering’s modern ideas of four unique hues (opponent colors), but also the three parameters of whiteness, blackness, and chromaticness that psychophysically define the tint and shade of any given color. This idea is based on a scientific law by the famous psychophysicist Gustav Fechner (1801-87). It states that in any given color the percentages of visual whiteness, blackness, and chromaticness will always add up to 100. This classic law is also a cornerstone of the NCS system.

The Munsell system’s idiosyncratic five primary hue foundation presents no problem in most color designation tasks. (Today, Munsell, like the NCS, is rigorously calibrated according to CIE measurements and standards.) It is only in some of the more demanding design and research tasks that NCS may have an edge on Munsell. This is due to the fact that the visual presentation of the NCS is totally symmetrical in all hue areas (another echo of the Ostwald system). The system constitutes a perfect double cone with nuances of hues described in charts in the shape of equilateral triangles. This may run counter to psychophysical truth about the shape and limits of the gamut of human color vision, but it is wholly in accordance with our knowledge and intuition of how we make color judgments.

Thus the Munsell color system, with its asymmetrical color solid, is perhaps a truer representation of the gamut of human color vision, but the NCS is better at describing the mechanism or psychophysics of how we experience color. Due to its 360º symmetry, the NCS system allows for any given color to be graphically marked in a diagram that is the same for all hues and lightness. This is a great advantage when plotting such things as color difference, color tolerances, effects of fading, yellowing, weathering etc. This may be one reason why the NCS is becoming ever more popular in many areas of visual color research.

One of the principal aims of the developers of the NCS was to create a color notation that could be used without measuring devices, charts or translation tables. This led to the development of a precise color code that is easily decipherable by anybody after a few hours of practice. The notation "NCS S 1050-Y90R" breaks down as follows: S refers to Second Edition (of NCS); the first four digits refer to the nuance (tint or shade) of the color. Of these the first two (10) refer to blackness, the second two (50) to chromaticness. Y90R refers to the hue as defined by the four unique hues Yellow, Red, Blue and Green. Thus, the above notation translates as a hue of red with 90 percent redness and 10 percent yellowness. The nuance of this hue contains 10 percent blackness and 50 percent chromaticness of the said yellowish red. The residual percentage of whiteness in the color can easily be calculated (if needed) according the Fechner's law, in this case as 100 - (10 + 50) = 40. These percentages are easily plotted on the NCS circle and triangle, allowing a graphic description of various color changes, comparisons and groupings. It is important, though, to keep in mind that these percentages do not represent percentages of pigments or colorants in paint mixtures.

Three Examples of Using the NCS in Building Conservation

The Finnish architects Mikko Bonsdorff and Kati Winterhalter of Okulus Architects Oy have relied on the NCS system for analysis and design of colors in several demanding conservation and renovation projects. The Franzénia building of the University of Helsinki, designed by Väinö Vähäkallio, represents an interesting transitional style between Nordic classicism and functionalism. It was designed in 1931 with interior color designs by the artist Antti Salmenlinna. The building interior was renovated in 2002-03 and the colors were restored close to the original design. Conservation methods including removal of paint layers and microscopic analysis of pigments were complemented by use of the NCS for visual analysis of color appearance and for designating the final color restoration design. The interior contained rich and elegant art-deco-type colors, including black, Pompeian red, silver, and pale greenish-grey.

The second building, also by Väinö Vähäkallio, is a purebred representative of Finnish functionalism. The State Liquor Monopoly (Oy Alkoholiliike Ab) headquarters, factory and warehouses at Salmisaari, Helsinki, were built just before the Second World War in 1938-39. When the Liquor Monopoly moved to new premises, the building came under extensive renovation and restoration under the supervision of the National Board of Antiquities. The building was thoroughly renovated in 2002-03 and reopened in 2004 as the Helsinki District Court of Law. The original color design was by Eino Kauria, but the interiors had been repainted and renovated in such a way that little of the original remained intact.

The WeeGee Building (originally the printing works of the publishing house Weilin+Göös) in Tapiola, Espoo, was designed in 1962-67 by one of Finland's most renowned postwar constructivist architects, Aarno Ruusuvuori. A model of this building is in MOMA, New York. Its most notable feature is the unique suspended roof structure that allows for huge open spaces without intervening structural walls on the top floor. This building reopened in 2006 after extensive renovation and remodeling to designs by Airas Arkkitehdit Ky. It now houses the Espoo City Museum, the Espoo Museum of Modern Art (EMMA), the Helinä Rautavaara Ethnographic Museum, the Finnish Toy Museum, the Finnish Museum of Horology, Art Gallery Aarni, the Computer Arts Centre CARTES, the Espoo School of Art, and the Juvenalia Music School, as well as the South Tapiola Upper Secondary School. The building has 23,000 square meters of floor space, nearly half of which is occupied by EMMA.

The original color design was by Jaakko Somersalo (1st stage, 1962-64) and Juhana Blomstedt (2nd stage, 1966-67), both notable artists in their own right. For the renovation, research and documentation of the building's history and colors were carried out by Mikko Bonsdorff of Okulus Oy Architects. As with so many of Aarno Ruusuvuori's works, the predominant color was gray due to extensive use of unpainted concrete; more strident colors appeared on such details as steel railings, metal doors and window frames. It was considered important, in this as well as the other two projects, to carefully record and preserve for posterity the colors of the exterior and interiors before the extensive transformation of the building. For this purpose the NCS system has proven to be a reliable and accurate tool.

Notes

1. *Zeki, S. (1999), Inner Vision – An Exploration of Art and the Brain, Oxford University Press, Oxford, UK*
2. *Fridell Anter, K. Fridell Anter, K. (2000). What Colour is the Red House? – Perceived colour of painted facades, doctoral thesis, Royal Institute of Technology (KTH), Stockholm, Sverige*
3. *Hubel, D. (2006), Eye, Brain and Vision:http//hubel.med.harvard.edu//index.html*

The Public Spaces of Luis Barragán: Losses and Recovery

Louise Noelle Gras

This paper is related to the exterior spaces created by the renowned architect, Luis Barragán. It is fair to say that the protection of public places poses a higher degree of difficulty, and some of his creations have been destroyed or modified; also some of the fountains had in their design the use of materials non suited for the outdoors, like wood and certain colors. Thus, the presentation will offer the analysis of some recent restorations, and the technical problems that had to be solved in relation to these components

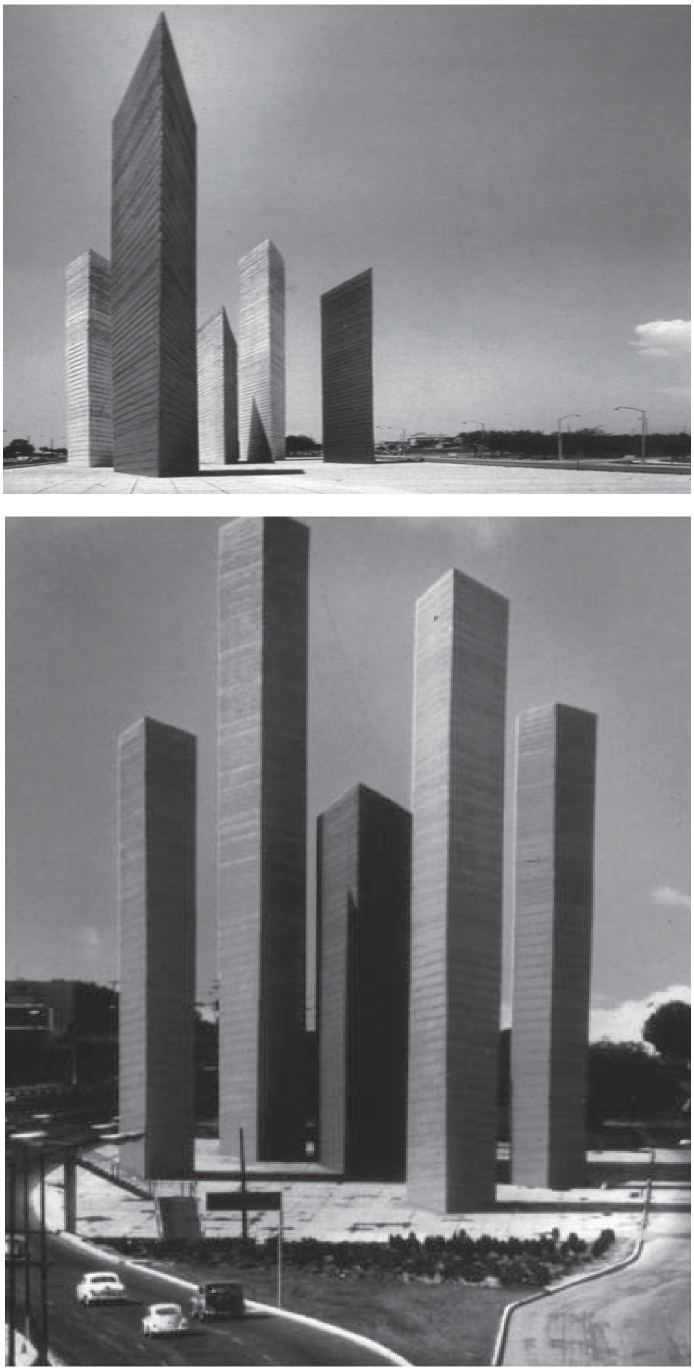
The figure of Luis Barragan (1902-1988)[1] has gained almost mythical status in the world of international architecture in recent years, despite the scarcity of works realized by the architect during the later part of his life. His first projects, completed in his native Guadalajara, are imbued with experiences arising from the local architecture as well as a Mediterranean spirit. Later, after his second trip to Europe during which he encountered the work of Le Corbusier, he established a practice in Mexico City where he launched a series of buildings in the International Style. It is only after 1949, with his own house,[2] that an architectonic style emerged that Barragan himself called "emotional," where impressions from childhood and his trips to Europe melded with the influences of teachers and friends such as Ferdinand Bac, Jesus Reyes Ferreira, Mathias Goeritz, and Frederick Kiesler. These influences were already apparent in his garden designs.

Much can be said regarding this aspect of Barragan's work, from mysticism to the rescue of Mexican identity. Its enormous richness fostered a new language of architectural expression. Its spiritual characteristics – the search for national roots in the vernacular, the affirmation of emotions, the persecution of the mystic and ascetic, the exaltation of beauty and integration with nature – are translated through massive constructions of thick walls with small openings, use of local materials with textures and colors found within the range of popular taste, modulation of light, expressive use of water, and emphasis on gardens.

Barragan's work in the field of urbanism and landscape architecture – parks, plazas, and entrance ways, for example – although in many cases now victims of neglect and abandonment, are excellent lessons in civility and love of nature. He endowed his public spaces with generous dimensions and demonstrated that man can opt for beauty outside of the security of his habitat and have as an ultimate end the satisfaction of his spiritual needs.[3]

The birth of Jardines del Pedregal de San Angel (roughly translated to "Rocky Gardens") in 1945 marked a milestone in Barragan's professional development while at the same time signaling a new urban concept in Mexico. It is worth remembering the impressive photos taken by Armando Salas Portugal of the original terrain, to which Barragan responded with sinuous paths that adapted themselves to the

Luis Barragán, Principal entrance to the Rocky Gardens subdivision in San Ángel, 1945-1950. Original state. (Photo: Juan Guzmán)



Luis Barragán and Mathias Goeritz, Satellite Towers, 1957.
a) Original state; b) Period when the towers were painted different colors of orange. (Photo: Armando Salas Portugal)

landforms. He created an enormous, individualized compound, enclosing the new suburb with tall walls of volcanic rock and emphasizing the protective nature of these walls with clearly marked entry points. These portals allowed Barragan to realize his first urban works, where fountains and gates, along with rocks and vegetation, welcomed the visitor. Most of these works have practically disappeared.[4]

Barragan's landscapes with wide impact included those contained within the Jardín Muestra[5] (roughly translated to "Exhibit Garden"), which was designed around a wide pond that threw into relief a particular rocky formation. In this same terrain was also his Fountain of the Ducks, from which point begins a trajectory on a path of red earth that allowed appreciation of the site's unification with the local flora. With the same premise, Barragan realized two public parks as well as Cigar Plaza, whose structural frame had to contain a deposit of water. Today these spaces are victims of neglect or disfiguration.

His notable urban art included the Towers of Satellite City, realized in collaboration with Mathias Goeritz in 1957. Here, sculptural volumes conserve their monumentality and meaning despite changes of street patterns and visual contamination in the area. The five towers, in their austerity, invoke the tonal and volumetric simplicity of pioneer works of modern architecture while at the same time expressing their own emotive qualities. Except for a certain period when they were painted in red and ochre colors with the consent of Barragan himself,[6] the original color, recaptured in the 1990s, carried the three primary colors – blue, yellow, and red – in addition to white.

Here it is appropriate to examine color and its presence in the works of this singular creator. The first examples of modern architecture practically excluded the use of color. Only certain artists, such as Joseph Albers and Piet Mondrian, had studied and established the importance of the use of primary colors, with applications in architecture through the Bauhaus and Neoplasticism. The existence of painter Joseph Albers' Interaction of Colors in Barragan's library was no accident; Barragan developed a long friendship with Albers, and Albers gave Barragan one of his paintings[7] in which the understanding of color was more than just intuitive.

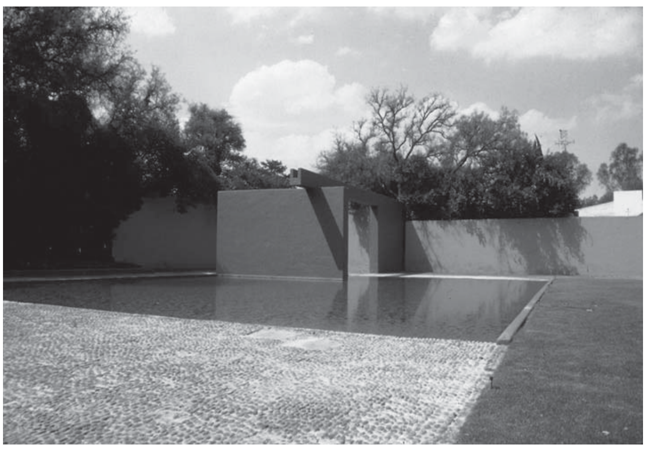
It is also necessary to highlight Barragan's relationship with Jesus Reyes Ferreira,[8] antiquarian and self-taught painter from Guadalajara, who on diverse occasions collaborated with Barragan as advisor and mentor. This relationship reinforced in Barragan his affinity for local elements and encouraged him to experiment with different textures and an increasingly broad and vibrant palette to accentuate architectural planes and volumes. This helps to explain Barragan's approach to certain tonalities of popular extraction; the emotive quality, present in the constructions of his last works, partially originates from the novel application of colors that offer a regional sensibility, coupled with the audacity of the results.

Finally, it is important to point out that, as an architect, Barragan paid as much attention to finishes as he did to choosing colors. From his first works in Guadalajara, he always attended with care to the layer of gesso or plaster that covered his walls as well as to the careful application of lime-based paint (and later, commercial paints). In order to decide with confidence on the color to apply to a certain wall, Barragan[9] had the wall painted in its entirety instead of merely applying test patches, and in many instances changed the color numerous times before arriving at a final decision.[10] This, in addition to the natural variations in color resulting from soiling and rain, makes it very difficult to determine the original color through stratigraphic study.

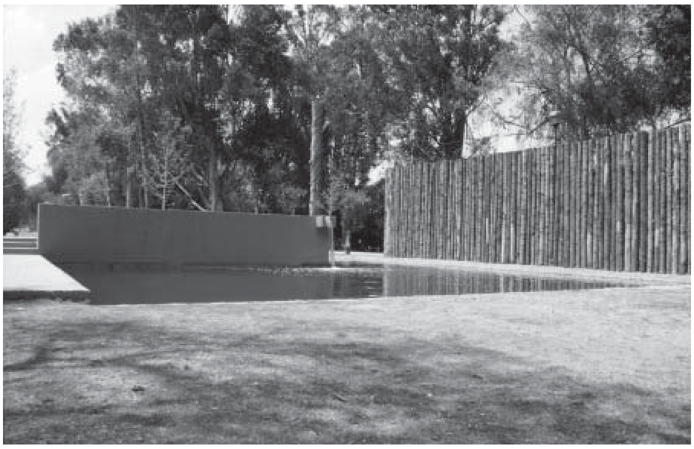
Returning to the theme of urbanism, Luis Barragan employed the same scheme he used for Jardines de Pedregal in other master plans for new subdivisions, although to lesser effect. Jardines del Bosque (Forest Gardens) in Guadalajara was developed in 1955. Its identity was based on the abundant eucalyptus forests, with Mathias Goeritz's sculpture "Yellow Bird" marking the entrance. More well-known within the realm of urban art is Las Arboledas, realized between 1958 and 1961 and later adjoining Barragan's Los Clubes (1964). At Las Arboledas, Barragan conserved the aged eucalyptus trees that bordered the entry to the old hacienda Echegaray, marking the fountains El Campanario and El Bebedero, which function as watering holes. At Los Clubes, Barragan created the famous Fuente de Los Amantes (The Lovers' Fountain).[11] These plazas and bodies of water served as rest stops for horses and riders within a subdivision that projected the equestrian life through nostalgia for the Mexican countryside and the dreaminess that creates solitude.

During the restoration of The Lovers' Fountain in 1996, the Residents' Association of Los Clubes made a series of decisions regarding the deteriorated state of the fountain, including the decision to restore the water feeding mechanism; the color and texture chosen, however leave much to be desired. The two wooden troughs, sometimes interpreted as the "lovers," were never replaced and were eventually lost because their perishable material. In the case of El Bebedero, the problem was simpler because a mechanical pump was not needed and there were no wooden elements involved. Also, the white color of the background wall, while an easy victim to graffiti, offered no complications for selecting the new paint color.

In the fountain and plaza of El Campanario (the Belltower), which was almost demolished, a more thorough restoration was possible thanks to the generous intervention in 1992 of the Residents' Association of Las Arboledas and the Technological



Luis Barragán, Lovers' Fountain, The Clubs, 1964. (Photo: Louise Noelle Gras)



Luis Barragán, Bell Tower Fountain, The Arbors, 1958-61. (Photo: Louise Noelle Gras)

Institute of Monterrey, Campus State of Mexico, with the support of the Directorate of Architecture and Conservation of Goods and Property of the National Institute of Fine Arts. The site was studied with care, and a series of historic photographs assisted development of a comprehensive reconstruction and restoration plan[12]. Challenges included the tree trunks, practically disintegrated after 40 years, and application of the orange paint to the structure. Replacement wood options for the trunks were selected through an analysis of the remains of the originals; the replacement paint color was selected by consensus of original inhabitants from swatches applied to the structure. The final result is favorable, making it possible once again to appreciate this important example of landscape architecture. With it, our descendants will be able to experience the public spaces created by Luis Barragan.

This paper was translated from its original version in Spanish by Olivia Klose.

Notes

1. *Much has been written about Barragan, of which we cover only select titles here, including: Barragán: Obra Completa. Madrid: Tanais Ediciones, 1995; Noelle, Louise. Luis Barragán: Búsqueda y Creatividad. Mexico: UNAM, 1996; Riggen Martinez, Antonio. Luis Barragan: Mexico's Modern Master, 1902-1988. New York: Monacelli Press, 1996; Zanco, Federica, Ed. Luis Barragan: the Quiet Revolution. Milan: Skira, 2001.*
2. *Barragan's house received UNESCO World Heritage status in July of 2004.*
3. *In this sense Barragan wrote down his ideas in this respect in the speech he delivered upon receiving the Pritzker Prize for architecture: "Nature, as beautiful as it is, is not a garden if it has not been domesticated by the hand of man, in order to create for himself a personal world that serves him as a refuge against the aggression of the outside world. The creation and enjoyment of gardens accustoms people to beauty… gardens should be poetic, mysterious, bewitched, serene and happy… a fountain brings us peace, happiness and gentle sensuality. Fountains are happy and serene. When we can also qualify them as bewitched, they are perfect."*
4. *In the entrance to the alley of fountains we also encounter a sculpture by Mathias Goeritz.*
5. *This garden, property of Jose Topete, associate developer of the subdivision, unfortunately lost its integrity through various subdivisions and the construction of a residence, today located in alley of Waterfall 435.*
6. *Essentially, this is how it appears in the catalogue photos of Emilio Ambaz, The Architecture of Luis Barragan (New York: Museum of Modern Art, 1976).*
7. *See the thank you letter to Joseph Albers in Riggen, Antonio. Luis Barragán: Escritos y Conversaciones. El Escorial: El Croquis Editorial, 2000*
8. *Jesus "Chucho" Reyes Ferreira, 1882-1977;*

see de Kassner, Lily S. Jesus Reyes Ferreira: Su Universo Pictórico. Mexico: UNAM, 1978.

9. *It is known that the craftsman that performed this type of work in Barragan's period of maturity was called the "maestro pianito," whom Barragan's always trusted.*
10. *On the theme of this type of application and materials, like paint analyses to determine original colors, see Mora, Paolo, et al. Conservation of Wall Paintings. London: Butterworth-ICCROM, 1984.*
11. *In the realm of urban art, it is worth mentioning that for Las Arboledas, Barragan also realized the Red Wall that emphasizes the entrance to the subdivision, just like the secondary entrance, the Yellow Wall in the Birds' Park, and the fountain in the Rotary of Sports.*
12. *On the theme of photography as an instrument of information and study, see Noelle, Louise, "La fotografía como auxiliar en las técnicas de investigación e restauración," Investigación y Docencia. Mexico: UNAM, 1999.*

Mural Painting vs. Architecture: Le Corbusier vs. Eileen Gray

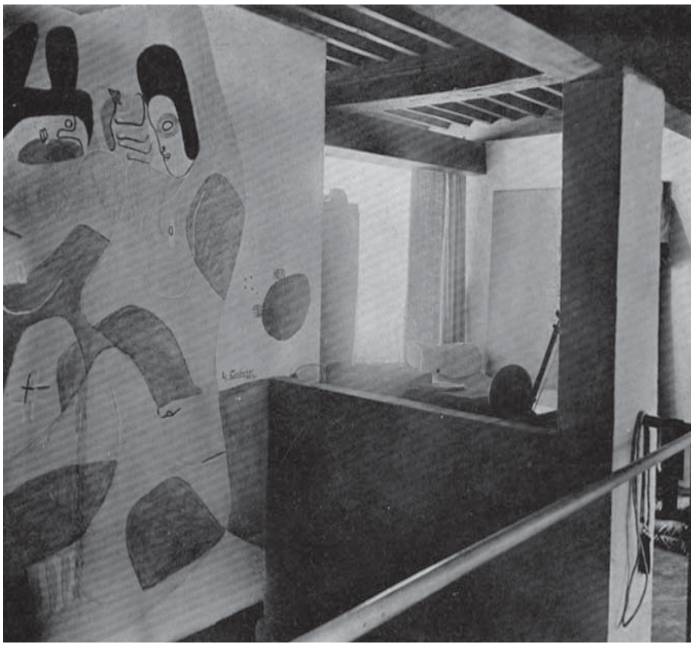
Caroline Constant

The murals that Le Corbusier painted in 1938-39 on the walls of the villa E.1027, designed by Eileen Gray and Jean Badovici, have prompted much controversy. Although Gray despised these murals, Badovici not only sanctioned their production but also admired them. This paper examines the history of Le Corbusier's approach to mural painting, which began in response to a mural that Fernand Léger painted on a courtyard wall of Badovici's house in Vézelay (on which Gray also collaborated) and evolved through numerous discussions with the French painter. Le Corbusier's murals were not only crucial to the preservation of E.1027, but also central to debates about its restoration, a lengthy process that is currently underway.

Le Corbusier, his wife Yvonne, and Jean Badovici in front of mural at entry to E.1027, c.1940 - Artists Rights Society (ARS), New York/ADAGP, Paris, FLC

Between 1938 and 1939 Le Corbusier painted a series of murals on the walls of E.1027, a vacation house overlooking the Mediterranean in Roquebrune-Cap Martin that Irish designer Eileen Gray designed for and with her lover, architect Jean Badovici, in 1926–1929.[1] Although Badovici sanctioned Le Corbusier's pictorial interventions, Gray strenuously objected to these murals, which violated her constructive integration of architecture and furnishings. By this time, however, she was no longer living with Badovici in the Roquebrune villa, but in Tempe à Pailla, the house that she designed for herself outside the nearby village of Castellar. In light of Badovici's role in encouraging Le Corbusier's pictorial interventions in E.1027, as well as subsequent deflection of critical attention from the villa's architecture to its murals and debates over their outcome during its impending restoration, Le Corbusier's attitude toward mural painting and his efforts to control the villa's fate following Badovici's death in 1956 merit re-examination.[2]

In 1935 Le Corbusier painted his first mural in the living room of Badovici's house in Vézelay, inspired by the mural that Fernand Léger's painted in the adjoining courtyard the previous year (Figures 2-3). With financial assistance from Gray, Badovici had purchased five derelict houses in the Burgundian hill town, intending to form an artists' colony. In renovating these structures he sought to advance contemporary architectural principles, subsequently describing his Vézelay houses, along with that at Roquebrune, as "inscribed in the promotional cycle of the avant-garde era."[3] Badovici's own house, a pair of structures renovated according to Gray's plan drawings, incorporates formal devices borrowed directly from Le Corbusier's Maison Citrohan of 1922: a double height living room overlooked by a mezzanine, accessed by narrow ship's stairs and lined with pipe railings. Gray apparently sanctioned attribution of this design to Badovici, perhaps because of all the projects on which the two collaborated, it displays the most explicit use of Corbusian spatial principles.[4]



Le Corbusier mural, Badovici House, Vézelay, 1935 (L'Architecture d'Aujourd'hui 7, no. 3 (1937) 75)

Fernand Léger mural, Badovici House, Vézelay, 1934 (L'Architecture d'Aujourd'hui 7, no. 3 (1937) 77)

To the rear of the house Gray and Badovici opened the ground floor to a raised courtyard only five meters deep, reached by a narrow stair that ascended from the kitchen. As the shallow depth of the garden court and the extreme height of its rear wall reinforced the dwelling's limited volume and obstructed any potential views, Badovici invited Léger to paint a mural on the courtyard wall in 1934. In an essay in Cahiers d'Art, prose poet Jean Follain remarked on the result:

> I met Léger in Vézelay, at the house of the architect Badovici, who asked him to come paint a wall, a wall without life, which blocked all views and closed off a small courtyard. Léger came and he destroyed the wall, pulverizing it under a burst of red color, and, in the play of tonal values, several simple and graceful objects remained in place, expressing all the power of their magical volume, their belonging to the universe and, at the same time, their magnificent isolation.[5]

Although rarely mentioned in accounts of Léger's career, this was his only true mural painting.

Léger had used the term "mural" to designate the pair of easel paintings displayed in Le Corbusier's Pavillon de l'Esprit Nouveau (1925), perhaps because they resulted from his interest in the relationship between architecture and painting. This interest stemmed from Léger's early architectural apprenticeship, and it evolved in discussions with Le Corbusier during the 1920s and 1930s. The idea of creating wall paintings was also inspired by the neon advertising billboards that Léger saw on Broadway during his first trip to New York in 1931,[6] as well as the W.P.A. Federal Arts Project murals carried out under the supervision of Burgoyne Diller, whom Léger encountered during that same visit. Although the Badovici mural was a private commission, Léger's experiences in New York enabled him to envision mural painting as a means by which modern art could be made accessible to a wider public.

Inspired by Léger's example, Le Corbusier painted his first mural on an upper surface of

Badovici's Vézelay living room. Like the narrow double-height volume in which it is situated, Le Corbusier's mural imparts a modern spirit to the Burgundian structure, with its traditional beamed ceilings and stone fireplace. This dialogue between old and new is echoed in the mural's subject matter, which Jean Badovici deemed a contemporary altarpiece - "the new 'Holy Family'" - replete with the masculine props of a pipe, matches, tobacco, and a liter bottle.[7] The objets types that Badovici describes are not evident in photographic reproductions of the mural, the present whereabouts of which is unknown;[8] moreover, such subject matter is more characteristic of Le Corbusier's early purist paintings, while the Vézelay mural exemplifies his predilection during the 1930s for exploring the sculptural potential of natural forms. Badovici's interpretation is also curious because the mural appears to depict a pair of voluptuous women, consistent with Le Corbusier's almost obsessive interest in the female figure in his contemporaneous drawings and paintings.[9]

On the basis of this pair of pictorial interventions, Badovici claimed that he, Léger and Le Corbusier rediscovered the great pictorial tradition of spatial painting, as "assembled before the courtyard wall … an idea occurred to us all: THAT OF THE DESTRUCTION OF WALLS BY PAINTING, crowning, above all, the architecture to come."[10] The statement opposes Gray's position on painting and architecture expressed in one of several dialogues with her that Badovici published in his name alone: "Painting must not … oppose itself to the construction, but on the contrary it must emphasize its character, accentuate its rhythms."[11] Badovici's eagerness to comply with Corbusian polemics may have led him to ignore any incongruities between this pictorial dissolution of the wall and Gray's more constructive integration of architecture and the decorative arts, an idea she developed more explicitly in the design of E.1027.

Le Corbusier's intervention in Vézelay was consistent with Léger's early pronouncements on easel painting ("To me 'the opposite of a wall' is a picture, with its verve and movement"), yet it also countered the Swiss architect's theoretical approach of the 1920s.[12] After experimenting with the use of color in the interiors of his Ozenfant Studio (1923) and Maison La Roche (1924), Le Corbusier continued to argue for the conceptual clarity of white walls:

> The fresco seems to me to be antithetical to the present. We like our walls to be white and empty, open and pure. Naked. Yes … Architectural power via the eloquence of walls that develop spatial sequences unfolding successively in vivid light. White, which gives rise to clear thinking, stands in vivid contrast to the tonic power of color.[13]

Le Corbusier subsequently distinguished between polychromy, with its potential for modifying spatial effects, and mural decoration, which he viewed as antithetical to architecture: "I admit the mural not to enhance a wall but, on the contrary, as a means to violently destroy the wall, to remove it from all sense of stability, of weight, etc."[14] By 1938, however, in the introduction to an album of Le Corbusier's sculpture, paintings, drawings and architecture, Badovici could declare: "Fresco and mural painting are the order of the day."[15] Of paramount influence on this conceptual shift was the figure of Léger.

Inspired by both the de Stijl exhibition at Léonce Rosenberg's Galerie de l'Effort Moderne in Paris (1923) and subsequent conversations with Le Corbusier, Léger had begun during the mid-1920's to seek a more harmonious integration of painting and architecture, in which mural painting could contribute to a modern spatial conception by challenging the flatness of the wall plane. Le Corbusier admired Léger's paintings for their potential contribution to architecture: "It is a new art. And that art existed previously, when painting was close to architecture - masterly and magnificent display of colored and moving forces on the surface of the wall. … This painting is the sister of architecture. That is its contribution. But it remains, profoundly, painting."[16] During the 1920s the autonomy of the arts remained an important principle for Le Corbusier, for whom painting remained a discrete activity, providing both a means of detachment from and a source of inspiration for his architecture.[17]

After completing his Vézelay mural, Léger articulated two distinct means by which mural painting could contribute to an architectural milieu:

> The mural artist is concerned with bringing to life dead surfaces by the application of colour. But first he must study the play of volumes and the sculptures (if any) decorating the building. If the play of volumes is architecturally important the colours must be kept in a low key and not break down the play of the wall. … But if on the other hand volumes play no important part, then colour can have it all its own way and can create a sense of space where none existed before; it can in other words let in light and air.[18]

He described the situation in Vézelay as an example of the second category:

> Recently one of my friends, an architect, asked me to tackle quite a novel problem. At his house in the country, which faces north, the courtyard at the back was enclosed by a wall on which the sun never shone, so that there was no hope of ever growing any flowers or shrubs in front of it. He asked me to come with colour and destroy it. … By applying pure colours in dynamic opposition, sometimes with the aid of modeling, sometimes by a purely flat application, I found that I had given it a true dynamic value, that one no longer had the feeling of a static vertical surface on one plane only. The wall had become mobile, luminous. Its appearance changed with the variation in light, as would that of flowers or shrubs. It had brought joy; the sad monotony of the wall was gone.[19]

For Léger, as for Badovici, the Vézelay mural played a constructive role in the courtyard's spatial elaboration.

Under Léger's influence, Le Corbusier soon began experimenting with the potential for mural painting to transcend the confines of a restricted volume by imparting spatial ambiguity to the wall, a position he endorsed in a lecture delivered to the Réunion Volta in Rome in October 1938, while his Roquebrune murals were underway.[20] In contrasting the spatial effects of mural painting to those of architecture, however, he overlooked the potential symbiosis afforded by Léger's concept of murals in a "low key" that conform to the volumetric qualities of the architecture. Le Corbusier subsequently rationalized this shift in his approach to mural painting by recourse to historic precedents:

> For fifteen years (from 1918 to 1933) I distanced myself from mural painting, full of suspicion and objections aroused by the equivocations that were proposed to us. The search for modern architecture was on, modern painting was underway, the correct and magnificent route opened by cubism. Unintelligent comments put to the painter by the architect: 'I want you to preserve my wall!' and by the painter to the architect: 'I will not disturb your wall!' At first the motive was cowardly: I am doing it but, in doing it, I am doing nothing. The principle that a wall tumbles or breaks down, escaping its confines, as soon as it is filled with lines and colors, was itself false, as is proven to anyone who thinks about it. An entire range of distortions, up to collapse or disintegration is available, from the Egyptian mastaba to Tiepolo.[21]

In this implicit defense of his E.1027 murals, Le Corbusier was drawing upon Léger's rationale for a contemporary approach to wall painting, as he explained in a lecture in Zurich in 1933:

> … painters are put into this world in order to destroy dead surfaces, to make them livable, to spare us from overly extreme architectural positions. Why is what was possible during the eighth and twelfth centuries not possible today?[22]

Nevertheless, Léger continued to endorse more moderate means to address the issue:

> "an agreement among the wall - the architect - the painter."[23] Indeed, he found the Roquebrune murals too intrusive, as he subsequently commented to Le Corbusier, "don't you think that you have gone too far with color for an interior?"[24]

As with the Vézelay murals, Badovici not only sanctioned, but encouraged Le Corbusier's pictorial interventions at E.1027. His eagerness to comply with Corbusian polemics may have led Badovici to ignore any incongruities between this pictorial dissolution of the wall and Gray's more constructive integration of architecture and decorative arts, wherein wall and window, furniture and carpets, contribute equally to a complete, but flexible, spatial milieu that combines sensuality with practicality.[25] However contrary to Gray's architectural intentions, these murals brought Badovici considerable pleasure, as he recounted to Le Corbusier after surveying the damage they sustained under the Italian bombardment during World War II: "Your frescoes more luminous and beautiful than ever. Intact. The contented always have little need to express their joys too vocally…."[26]

After the armistice Le Corbusier's obsession with obtaining complete photographic documentation of the Roquebrune murals prompted a protracted correspondence with Badovici, who provided only the few closely cropped images that Le Corbusier published in a special issue of L'Architecture d'Aujourd'hui (1948) devoted to his work. In anticipation of this impending publication, Le Corbusier urgently requested further photos of the murals, both in isolation and in their architectural contexts.[27]

While Gray may have considered Le Corbusier's pictorial interventions at E.1027 "an act of vandalism,"[28] she deemed his published remarks about the murals' role in the architecture a more problematic provocation:

> The walls chosen to receive nine large paintings were the most colorless and insignificant. In this way the beautiful walls have remained and the indifferent ones have become very interesting…. This villa that I animated with my paintings was very beautiful, white on the interior, and it could have managed without my talents. One must recognize above all that the proprietor and I had witnessed the nourishment and development of a spatial phenomenon - as, little by little, the paintings emerged under the brush. An immense transformation. A spiritual value introduced throughout.

Apparently aware of the controversy his paintings aroused, Le Corbusier concluded:

> It is not for me to decide whether this value is, here, pleasing or the contrary. When one opens one's doors to an artist, one gives him speech. When he speaks, one listens. … Hence the great risk one runs in having his walls painted.[29]

In a letter that Gray encouraged him to write, Badovici issued a sharp rebuttal to Le Corbusier's published comments:

> What a narrow prison you have built for me over a number of years, particularly this year through your vanity. On the contrary, my attitude toward you has been nothing but joyful and full of happy trust - seven volumes of the heroic era of L'Architecture Vivante. My hut [baraque] served [you] as a testing ground by sacrificing the profound direction of an attitude that formally banished painting. As purely functional architecture, that was its strength for such a long time: 1925.[30] And you have denied its absolute character with such harshness in your writings, disseminating them through your world-wide authority. You lack any generosity toward me. A correction from you seems necessary; if not, I will be forced to do it myself, thus to reestablish the original spirit of the house by the sea.[31]

This unexpected barrage only increased Le Corbusier's anxiety that Badovici carry out the photography "before eliminating the murals," and he retorted with a personal attack of his own: "Perhaps I misunderstand the underlying sense of your thoughts, as, even though you have lived in Paris for thirty years, you have not yet been able to make others comprehend your writing."[32] This last comment reveals not only the viciousness of Le Corbusier's attack, but also his apparent blindness to the thrust of Gray's architectural thoughts, conveyed clearly and eloquently in her numerous dialogues with Badovici. Estranged from his mentor by this bitter exchange, Badovici died intestate in 1956, leaving the villa's fate uncertain.[33]

Badovici's death only augmented Le

Corbusier's proprietary interest in E.1027. His interference took architectural form the following year with the construction of a hostel he designed directly overlooking the villa on the property of Thomas Rebutato, who in 1950 had ceded Le Corbusier the land on which to build his own cabanon. Elevated on pilotis, Le Corbusier's intrusive two-story hostel not only destroys the visual isolation of E.1027 but also operates, together with his cabanon and work hut, to situate Badovici's villa within a Corbusian frame.[34]

Between 1958 and 1960 Le Corbusier actively sought "to find a solution for the purchase of the Badovici house" by soliciting potential buyers from Switzerland, explaining to Willy Boesiger (editor of his Oeuvres Complètes): "some have thought of making a museum out of the house."[35] Le Corbusier's primary concern was for the murals and their preservation rather than the fate of the house itself. In 1960 he contacted Madame Marie-Louise Schelbert in Zurich, sending her photographs of E.1027, and she purchased the villa that summer.[36] Le Corbusier took an active interest in preserving both the house and its contents; he not only sought and received Madame Schelbert's permission to restore certain of his paintings in December 1961, but also prevented her from destroying Gray's furnishings.[37] In 1964 Jean Petit suggested that Le Corbusier seek the assistance of Culture Minister André Malraux in preserving the E.1027 murals, arguing "Madame Schelbert is well, but the house could change hands."[38] Here the archival correspondence ends. After Le Corbusier died of a heart attack on 27 August 1965 in the sea in front of E.1027, the local municipality designated the Roquebrune/Cap Martin footpath that provides access to Le Corbusier's cabanon as well as the villa "Promenade Le Corbusier."

Although both E.1027 and its contents were included on the national supplementary inventory of historic monuments in October 1975, Petit's advice was prophetic. Subsequently called "La Maison Blanche," E.1027 has sadly deteriorated, having been left upon Madame Schelbert's death in 1982 to her Swiss physician, Peter Kaegi, who first removed Gray's furniture to Switzerland and then sold it.[39] In August 1996 Kaegi was murdered at the house by his gardener, leaving the villa's future again in doubt. In June 1998 vagrants living on the property vandalized what remained, breaking all the windows and shattering an entry partition that Le Corbusier had urged Badovici to remove. This act of vandalism finally spurred official efforts to save E.1027, which was reclassified a full "Monument Historique" in November 1998, enabling the community of Roquebrune-Cap Martin to purchase the property and begin efforts toward its restoration. Ironically the murals, which Le Corbusier took pains to maintain during his lifetime, are the villa's best preserved aspect; without them, the house would undoubtedly have suffered a worse fate.

The restoration process has been delayed, however, by debates about the status of the murals themselves. Advocates on Gray's behalf insist they should be removed, thus restoring E.1027 to its "original" condition, while those on Le Corbusier's side argue that, as unique reflections of his painting career and significant aspects of the villa's history, they should be preserved. A compromise between these disparate approaches has tentatively been reached: the murals are to be maintained, but concealed behind mobile panels, facilitating alternative, but decidedly a-historical experiences for visitors to the renovated villa. In its restored state, E.1027 will visually manifest the difficulties of preservation efforts that seek to reduce a living work of architecture to a particular moment in time – an issue that is not unique to this particular building or to its historic circumstances.

All translations are by the author, unless indicated otherwise.

Notes

1. *The name Gray gave the villa, "E.1027," is a cipher for the designers' intertwined initials [E – J – B – G], reflecting the collaborative nature of the undertaking.*
2. *Stanislaus von Moos, "Le Corbusier as Painter," Oppositions 19/20 (1980) 88-105; Beatriz Colomina, "War on Architecture," Assemblage 20 (1993) 28-29. Colomina has subsequently published numerous variations on this essay.*
3. *Badovici letter to M. Poirier, secretary of the Union des Artistes Modernes, 1 September 1955; cited by Brigitte Loye, Eileen Gray 1879-1976: Architecture Design (Paris: Analeph/J.P. Viguier, 1984) 86.*
4. *For attribution of the Vézelay houses to Badovici see Le Corbusier, La Ville Radieuse (Paris: Vincent, Fréal, 1933) 53-55; "Jean Badovici" [memorial tribute], L'Architecture d'Aujourd'hui 27, no. 67-68 (July/August 1956) IX.*
5. *Jean Follain, "Fernand Léger," Cahiers d'Art 15, no 1-2 (1940) 22. The mural was carried out to Léger's design by Raoul Simon, a painter residing in Vézelay who subsequently executed murals for Le Corbusier in both the Pavillon des Temps Nouveaux (1937) and the Pavillon Suisse (1948). Personal communication Raoul Simon, Vézelay, June 1995.*
6. *Fernand Léger, "New York vu par Fernand Léger," Cahiers d'Art 6, no. 9/10 (1931) 438.*
7. *Jean Badovici, "Peinture Murale ou Peinture Spatiale," L'Architecture d'Aujourd'hui 7, no. 3 (1937) 78.*
8. *In 1961 Madeleine Goisot arranged for Le Corbusier's and Léger's murals to be removed to linen backings in order to preserve them. When museum officials took no interest in this effort, it was funded by a genealogist in the boulevard St. Germain, M. Coutot, who loaned Le Corbusier's mural to relatives in Paris and, owing to its great size (388 x 440cm), consigned Léger's mural to the Musée National d'Art Moderne, where it was exhibited several times before its removal in 1989 to the Centre Georges Pompidou. See Ruth Ann Krueger Meyer, "Fernand Léger's Mural Paintings 1922-55" (Ph.D. Diss., University of Minnesota, 1980) 220; Madeleine Goisot, "Sur l'origine des fresques de la maison Badovici," Les Amis de Vézelay 30 (Summer 1991) 23.*
9. *Because Le Corbusier's interest in lesbian subjects is evident in many sketches and paintings of this period, his adoption of this theme in the Vézelay and E.1027 murals should not necessarily be interpreted as a commentary on Gray's bisexuality.*
10. *Badovici, "Peinture Murale ou Peinture Spatiale" (1937) 75 [emphasis in original]. Léger made a similar argument in Fernand Léger, "Revival of Mural Art," The Listener 18, no. 450 (25 August 1937) 403, 409. Le Corbusier published his Vézelay mural in New World of Space (New York: Reynal and Hitchcock and Boston: Institute of Contemporary Art, 1948) 73; "Unité," L'Architecture d'Aujourd'hui 19 (1948, numéro hors série) 49; My Work (London: The Architectural Press, 1960) 247.*
    The Vézelay murals by Léger and Le Corbusier inspired further wall decorations from Badovici's visitors, several of which are still intact. During World War II Jean Follain wrote on a salon wall: "L'oiseau qui chantait dans la cour du chapitre se tut;" surrealist poet and anti-war activist Paul Éluard inscribed a bedroom wall: "La confiance est dans la poitrine à l'hauteur où l'aube de leur seins se lève," and nearby he wrote: "Vézelay, chair ancienne, chair enfantine, corps d'oubli;" Pierre Guéguen wrote on the inner salon wall: "Poutre de nit, le crin noir de ses nids." Goisot, "Sur l'origine des fresques" (1991) 21-23.
11. *Jean Badovici [and Eileen Gray], La Maison d'Aujourd'hui (Paris: Éditions Albert Morancé, 1925) 18. Badovici also used dialogue form in: Intérieurs de Süe et Mare (1924); "Harmonies" Intérieurs de Ruhlmann (1924); Intérieurs Français (1925); "La Maison d'Aujourd'hui," Cahiers d'Art 1, no. 1 (January 1926) 12-13; "Architecture Utilitaire," L'Architecture Vivante (1926) 17-24. He cited Gray as coauthor in "De L'Eclecticisme au Doute," L'Architecture Vivante (Winter 1929) 17-21. All were published in Paris by Albert Morancé.*
12. *Fernand Léger, "Pensées," Valori Plastici (Rome: February/March 1919), cited by Christopher Green, "Painting for the Corbusian Home: Fernand Léger's Architectural Paintings, 1924-26," Studio International 190, no. 977 (September/October*

1975) 105; Fernand Léger, "Correspondance," Bulletin de l'Effort Moderne no. 4 (April 1924) 11.

13. Le Corbusier, "Notes à la Suite," Cahiers d'Art 1, no. 3 (1926) 51, 52.
14. Le Corbusier letter to Vladimir Nekrassov, 20 December 1932, cited in Le Corbusier. Le passé à réaction poétique (Paris: Caisse nationale des Monuments historiques et des Sites/Ministère de la Culture et de la Communication, 1988) 74-75. Le Corbusier initially elaborated this idea in a text entitled "Polychromie architecturale" for a brochure of color harmonies that he put together for a firm of wall paper manufacturers, Salubra SA of Basle, in 1931; Fondation Le Corbusier B1 (18); cited by Christopher Green, "The Architect as Artist," in Le Corbusier Architect of the Century (London: Arts Council of Great Britain, 1987) 123.
15. Jean Badovici, "Avant-Propos," Le Corbusier: Œuvres Plastique, Peintures et Dessins, Architecture (Paris: Albert Morancé, [1938]) 7.
16. Le Corbusier, "L'architecture et Fernand Léger," in Fernand Léger, Selection V (Anvers: February 1929) 23, 24; republished in response to Christian Zervos's query, "Fernand Léger est-il Cubiste?, Cahiers d'Art 8, no. 3-4 (1933) 124. Le Corbusier first published his interview with Léger, which forms part of this essay, in "Salon d'Automne," L'Esprit Nouveau 19 (December 1923) n.p.
17. Le Corbusier voiced this distinction between architecture and painting in his letter to Amédée Ozenfant concerning the hanging of Cubist and Purist paintings in the house he designed for Raoul La Roche in Auteuil (1923): "I am absolutely adamant that certain parts of the house/gallery should remain completely free from paintings, so that a double effect can be created between pure architecture on one side, and pictorial art on the other." Le Corbusier letter to Amédée Ozenfant, FLC P 5-1 (208), cited by Jacques Sbriglio, Le Corbusier: Les Villas La Roche-Jeanneret, trans. Sarah Parsons (Paris: Fondation Le Corbusier and Basel, Boston and Berlin: Birkhäuser, 1997) 100.
18. Fernand Léger, "Revival of Mural Art," The Listener 18, no. 450 (25 August 1937) 403.
19. Ibid. 409.
20. Le Corbusier, "Peinture, sculpture et architecture rationaliste" (1938) in Françoise de Franclieu, ed., Le Corbusier Savina: dessins et sculptures (Paris: Fondation Le Corbusier and Philippe Sers, 1984) 18.
21. Le Corbusier, "Unité" (1948) 53.
22. Fernand Léger, "The Wall, the Architect, the Painter (unpublished lecture, 1933), Functions of Painting, trans. Alexandra Anderson (New York: The Viking Press, 1965) 96.
23. Ibid., 97.
24. Le Corbusier Sketchbooks, 1957-1964 (Cambridge, MIT Press and New York: Architectural History Foundation, 1982) 4, no. 778.
25. See Caroline Constant, "E.1027: the non-heroic modernism of Eileen Gray," Journal of the Society of Architectural Historians 53, no. 3 (1994): 265-79; "A Non-Heroic Modernism: E.1027," Eileen Gray (New York and London: Phaidon Press Ltd., 2000), 93-125.
26. Jean Badovici letter to Le Corbusier, 2 July 1941 (FLC E1-5-53).
27. Le Corbusier letter to Jean Badovici, 23 March 1948, private collection; Le Corbusier letters to Badovici: 5 September 1949 (FLC E1-5-84); 10 September 1949 (including sketches of preferred views, FLC E1-5-85); 1 January 1950 (FLC E1-5-99). Le Corbusier published images of the E.1027 murals in several books and periodicals: Le Corbusier, "The murals of Le Corbusier," Le Corbusier, Œuvre Complète 1938-46 (Zurich: Les Editions d'Architecture, 1946) 158-161; Le Corbusier, Œuvre Plastique. Peintures et Dessins. Architecture (Paris: Albert Morancé. 1938) 25; "Unité" (1948) figs. 55, 58, 59, 61 (45-50); New World of Space (New York: Reynal and Hitchcock, 1948), 18, 90, 99-102; "Graffiti at Cap-Martin," My Work (London: The Architectural Press, 1960) 212.
28. See Peter Adam, "Eileen Gray and Le Corbusier," 9H no. 8 (1989) 150-53.
29. Le Corbusier, "Unité" (1948) 53-55. Le Corbusier's remarks in his Œuvre Complète 1938-46 were more insulting: "They [the murals] are not painted on the best walls of the villa. On the contrary they burst out from dull, sad walls 'where nothing is happening.' The result: Meaningful paintings on indifferent walls and all the fine white walls are preserved." Le Corbusier, "The murals of Le Corbusier," Œuvre

Complète 1938-46 (Zurich: Artemis, 1946) 158.

30. *Badovici had a propensity for adjusting dates to promote the avant-garde status of his work; he dated the facade drawing for his Vézelay house 1924, three years before he purchased the property. See M. Blumenthal, "Jean Badovici 1893-1956," Technique et Architecture 16, no. 4 (1956) 24.*
31. *Jean Badovici letter to Le Corbusier, 30 December 1949; originally FLC E1-592, but no longer catalogued with Badovici correspondance.*
32. *Le Corbusier letter to Jean Badovici, 1 January 1950 (FLC E1-5-99).*
33. *According to French law, the bulk of one's property could only be left to next of kin; thus Gray could not have inherited the villa unless Badovici was without kin. Accordingly, upon his death legal rights to the villa automatically went to his sister. As a Romanian citizen, she could not inherit property, and proceeds from the sale of Badovici's possessions reverted to the Romanian state.*
34. *Although Le Corbusier supplied design drawings for the hostel, it lacks the tectonic assurance associated with his work of the time and was apparently built by Thomas Rebutato without the architect's supervision. See Bruno Chiambretto, Le Corbusier à Cap Martin (Marseille: Parenthèses, 1987) 67. Le Corbusier later claimed that his hostel design took half an hour. Le Corbusier, The Modulor II (Cambridge, MA: Harvard University Press, 1980) 239.*
35. *Le Corbusier letter to Willy Boesiger (Zurich), 7 August 1958 (FLC E1-5-119).*
36. *Peter Adam relates that when E.1027 was auctioned in Menton, Le Corbusier intervened, thus enabling Madame Schelbert to purchase the villa and preventing it from falling into the hands of the highest bidder, Aristotle Onassis. Peter Adam, Eileen Gray Architect/Designer (New York: Harry N. Abrams, 1987) 359.*
37. *Le Corbusier initially modified the Roquebrune murals in about 1949; in August 1961 he began planning to restore them to their initial form, while suppressing some of the original color. See Le Corbusier Sketchbooks 4 (1982), nos. 776-778 and his letter to Madame Schelbert, December 1961, seeking permission to carry out the restoration (FLC).*
38. *Jean Petit memorandum to Le Corbusier, 28 June 1964 (FLC E1-5-161). As Minister of State in charge of Cultural Affairs (1959–1969), André Malraux engaged Le Corbusier to build his Maison des Jeunes et de la Culture in Firminy (1961-1965) and delivered Le Corbusier's funerary oration.*
39. *There were numerous efforts to thwart these acts of vandalism: Madame Schelbert's family pursued legal means to block the change of ownership, but their lawsuit was unsuccessful; when Kaegi sought to sell the furniture, a pair of Swiss architects found a potential buyer for both the villa and its contents and arranged a meeting with the owner, but Kaegi was unwilling to discuss the matter. Personal communication, Christian Müller, Frankfurt-am-Main, October 1996. When the Centre Georges Pompidou arranged to buy the furniture, it was with the understanding that Kaegi would use the proceeds to restore the villa, but he made no effort to do so. Personal communication, Marie-Laure Jousset, Curator of modern design, Centre Georges Pompidou, June 1995.*

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Nicola Ruggieri, Ph.D (Pier *Luigi Nervi's Work: Technological Values, Typical Degradations and Conservation Criteria)* previously taught at the Accademia delle Arti del Disegno in Florence and is currently practicing architecture in the south of Italy.

Björn Schouenborg *(Deterioration of Thin Marble Cladding - Observations from the Inspections of Buildings with Marble Cladding in Europe)* is Manager of CBIs and SPs Rock Material Centre (SP Technical Research Institute of Sweden). CBI is a company, in the SP group, with approximately 60 employees covering a wide range of activities such as testing, research, damage investigations and other consultant assignments for the industry. Mr Schouenborg has a PhD in Mineralogy & Petrology and has been in charge of all research activities concerning bedrock materials and related products at SP since 1990. He has been transferred to the new daughter company CBI in 2008. Mr. Dr Schouenborg was the coordinator of the EU project TEAM (Testing and Assessment of Marble and Limestone, and has now a leading position in the EU-project I-STONE

Frederic Seitz, Ph.D (Pos*twar Building, e Havre, France)* is an architect and a specialist of the history of contemporary architecture. He is a professor at the Universite Technologique de Compiegne and at the Ecole Speciale d'Architecture in Paris. He is also the vice president of DOCOMOMO France. He has been working for several years about the status of technology in French buildings and architecture. He is also the author of many books and articles about the Modern Movement in France and Europe between the two World Wars and after World War II.

Rosalia Vittorini *(Conservation of Stone Facing in Modern Italian Architecture)* is an architect and Associate Professor of Technical Architecture at Tor Vergata University of Rome. Her research activity focuses on building techniques in Italian architecture in the XX century.

Gennaro Tampone *(Pier Luigi Nervi's Work: Technological Values, Typical Degradations and Conservation Criteria)* holds degrees in Civil Engineering (1961, University of Bari) and in Architecture (1969, University of Florence). He is a member of ICOMOS, ISCARSAH (Committee for Historic Structures, ICOMOS), of UNI (Ente Nazionale Unificazione) and a member and Secretary General of Wood International Committee (ICOMOS). He is a full academician of the Accademia delle Arti del Disegno, Florence; President of Collegio degli Ingegneri della Toscana and Lecturer in the University of Florence on Architectural Conservation. Tampones research focuses on Ancient Building Techniques, Methodology for Strengthening the Structures of Monumental Buildings, and the Pre-historic Architecture, Conservation of Timber Structures. He has published 140 papers and several books.

Professor Tennaro Tampone has received three invention patents.

Ola Wederbrunn, Ph.D *(Experiencing Stone, Structure and Cladding)* is an architect MAA, Ph. D, associate professor at the Royal Danish Academy of Fine Arts in Copenhagen, and curator for exhibitions on architecture and art. Ola Wedebrunn has published several books and articles about Modern Movement architecture, material and technology. He is a member of ICOMOS 20th Century heritage International Specialist Committee, the DOCOMOMO International Executive Committee and holds the chair of DOCOMOMO Specialist Committee on Technology.

Conference Program

September 30 - October 2, 2004
at Baruch College
East 25th Street & Lexington Avenue
New York, NY

THURSDAY, SEPTEMBER 30

7:30am-5:00pm	Registration Baruch College, Newman Atrium
7:30am-8:30am	Continental Breakfast, Vendors
7:30am-8:30am	DOCOMOMO US- Scheduled Committee Breakfast Meeting
8:30am-10:00am	DOCOMOMO International and DOCOMOMO US Introduction and Welcome Theodore Prudon, President, DOCOMOMO US
10:00am-10:30am	Break
10:30am-11:45am	Introduction to Technology Seminar Program Kyle Normandin, Chair of the Technology Seminars
11:45am-12:45am	Lunch
12:45am-1:45pm	Evolution of Concrete Technology in Postwar Building, Le Havre, France Frederic Seitz, Ph.D. Universite de Tenologique de Compiegne and Ecole Speciale d'Architecture, France
1:45pm-2:45pm	Break
2:05pm-3:05pm	Preservation Guidelines for Contemporary Architecture at the University of Chicago, IL Harry Hunderman, FAIA and David Patterson, AIA, Wiss, Janney, Elstner Associates, Inc., USA
3:05pm-4:05pm	The Restoration of Brancusi's 'Endless Column," and Sur rounding Settings, Targu-Jiu, Romania John Stubbs, Director of Field Programs World Monuments Fund,USA Mihai Radu, Principal, Lauster & Radu Architects, USA Richard Pieper, Principal, Jan Hird Pokorny Architects, USA
4:15pm-5:00pm	Panel Discussion and Closing Remarks
5:30pm-7:30pm	DOCOMOMO US Technology Seminar Opening Cocktail Reception Institute of International Education, 809 United Nations Plaza The Kaufman Center (Aalvar Aalto Rooms) 809 United Nations Plaza (e. 45th St. and First Avenue) Welcome and Program Introduction, Theodore Prudon Announcement of Book publication entitled, Alvar Alto Library in Vyborg, Presented by Maria Kairimo Screening of Documentary Film, "What's the Time in Vyborg?", by Liisa Roberts

FRIDAY, OCTOBER 1

7:30am-5:00pm	Technical Seminar Registration

7:30am-8:30am	DOCOMOMO International Scientific Committee-Technology (ISC-T) Meeting
8:30am-9:30am	Parallel Sessions
	An Overview of Curtain Wall Development Elwin C. Robison, Ph.D, School of Architecture and Design, Kent State University, USA
	History and Development of Concrete Technology in the United States Susan McDonals, NSW Heritage Office Parramatta, Australia
	History and Use of Dimension Stone Cladding Mike Scheffler, P.E., Senior Consultant Wiss, Janney, Elstner Associates, Inc., USA
	Color Survey of Modern Architecture Theodore Prudon, DOCOMOMO US, USA
9:30am-9:45am	Break
9:45am-10:45pm	Parallel Sessions
	Glass Facade Assessment Thomas A. Schwartz, P.E., Principal, Building Technology, Simpson, Gumphertz & Heger, USA
	Investigative of Concrete Buildings, Paul Gaudette, P.E., Consultant, Wiss, Janney, Elstner Associates, Inc., USA
	History and Use of Dimension Stone Cladding in Postwar Building Kate Burns Ottavino, A. Ottavino Corporation, USA
	The National Color System and its Use in Recording Historical and Contemporary Architecture Harald, Arnkil, Faculty of General Studies, University of Industrial Arts, Finland
10:45am-11:00am	Break
11:00am-12:00pm	Parallel Sessions
	Restorations of the Sanatorium 'Zonnestraal" (1928) and the Van Nelle Factories (1929-31) Compared: Hands-On Experience Results on 1920's Metal and Glass Curtain Wall Preservation Wessel de Jonge, DOCOMOMO International, The Netherlands
	Concrete Repair Materials for 20th Century Postwar Concrete Myles A. Murray, P.E., CEO, Restruction Corp., USA
	Modern Stone: Subtle Surface and Ambiguity of Rock Ola Wederbrunn, Ph.D, DOCOMOMO International, Denmark
	Silent Witness: Architectural Paint Research of the Viipuri Library and the Zonnestraal Sanatorium Complex Mariel Polman, RDMZ/ Polman Kleur & Architectuur, The Netherlands
12:00pm-1:00pm	Lunch

1:15pm-2:15pm	Parallel Sessions The United Nations Complex and the Secretariat Curtain Wall Robert Heintges, AIA, R A Heintges & Associates, USA Concrete Conservation Techniques of the Unites d'habitations by Le Corbusier in Reze and in Briey, France and the Restoration of the Maison du Bresil in the Cite Universitaire Internationale, Pars France Bernard Bechard, DOCOMOMO France, Restoration of Marble Clad ding at Finlandia Hall Martii Jokinen, National Board of Antiquities, Finland The Use of Color by Architect William Lescaze. Uncovering a Modern Color Palette at the Edward A. Norman House in New York City, 1940-1941 Joan Berkowitz, Principal Jablonski Berkowitz Conservation, Inc., USA
2:15pm-2:30pm	Break
2:30pm-3:30pm	Parallel Sessions Conservation of Weathering Steel (Corten) Buildings Carolyn L. Searles, P.E. Principal, Building Technology Simpson Gumpertz & Heger Inc., USA The Pier Luigi Nervi's Work: technological Values, Typical Degradations, Conservation Criteria Nicoli Ruggiero, Ph. D, Architectura Conservator, Italy Thin Skinned: Conservation and Stabilization Challenges in the Architecture of Edward Durrell Stone Jeff Koerber, AIA and Mike Scheffler, P.E., Wiss Janney, Elstner Associates, Inc., USA Dimensional Color Lori Swirnoff, Feltman Chair, The Cooper Union Art School, USA
3:30pm-3:45pm	Break
3:45pm-4:45pm	Parallel Sessions Forensic Analysis of Frank Lloyd Wright's Johnson Wax Re search Tower Edmund P. Meade, P.E. and Michael J. Auren, P.E., Robert Silman Associates, P.C., USA The Role of Precast Concrete Panel Technology in Postwar Building Construction Jack Pyburn, AIA, DOCOMOMO US/Georgia, USA Investigation and Study of the Llenroc at the Empire State Plaza in Albany, New York Mike Petermann, RA, Consultant Wiss Janney, Elstner Associates, Inc., USA Investigation and Analysis of Works of Luis Barragan Louise Noelle Gras, Universidad Nacional Autonomia, Mexico (UNAM), Mexico
5:30pm-7:00pm	Reception for Architecture and Revolution in Cuba,

1959-1969
Storefront for Art and Architecture
97 Kenmare Street
(Kenmare and Lafayette)
Architecture and Revolution introduces a body of work virtually unknown outside of Cuba. The exhibit will feature images documenting over 50 architectural projects built by the Cuban government be tween 1959 and 1969, which will be grouped by categories that reflect social initiatives adopted by the Cuban government following the revolution

SATURDAY, OCTOBER 2

8:30am-5:00pm	Registration
9:30am-10:30am	Parallel Sessions La Maison Prouve, Nancy, France Agnes Caillau, Architect de Batiments de France, France Deteriorative Concrete and Conservation Techniques for Shell Structures Invited Speaker Juan O'Gorman and the Use of Stone and Technology Louise Noelle Gras, Universidad Nacional Autonomia Mexico (UNAM), Mexico Perception of Color Invited Speaker
10:30am-10:45am	Break
10:45am-11:45am	Parallel Sessions Lever House in New York City and the Air Force Chapel in Colorado: The Restoration of Two Modern Landmarks Using Today's Technology Carl Galiotto, FAIA, Partner, Skidmore, Owings, Merrill (SOM), USA Matching Concrete Repairs Keith Niles and Paul Goudeter, Chicago, USA
10:45am-11:45am	Conservation of Stone Cladding in Italian Modern Architecture: Post Office Building by Adalberto Libera and Palazzo della Civilta Italiana at E42 Sergio Poretti, Ph.D, Engineer and Rinaldo Capomolla, Ph.D, Engineer Technical Architecture a Tor Vergata University of Rome, Italy Case Study Analysis on Le Corbusier Murals Caroline Constant, University of Michigan, USA
11:45am-1:115pm	Lunch on your own
1:15pm-2:15pm	Parallel Sessions Part I: ASTM and AAMA Diagnostics for Window and Curtain Wall Testing: Field and Laboratory Testing Techniques Dennis K. Johnson, P.E. Consultant, Raths, Raths & Johnson, Inc., USA Matching and Finishing Concrete Repairs Techniques Keith Niles, Chicago, USA Deterioration of Thin Marble Cladding- Observations from the Inspections of Buildings with Marble Claddings in Europe Bent Grelk, Ramboll Group,

	Denmark Jan Anders Brundin, Jan Anders, Consulting AB, Sweden, and Bjorn Schouenborg, SP Swedish National Testing and Research Institute, Sweden
2:15pm-2:30pm	Break
2:30pm-3:30pm	Parallel Sessions
	Part II: Case Studies for Protection of Modern Curtain Wall Systems Tony Cinnamon, Senior Associates, Wiss Janney, Elstner Associates, Inc., USA
	Part I: Laboratory Testing and Analysis of Historic Concrete L. Brad Shotwell, School of Structural Geology, Tectonics and Petrology, Kent State University, USA
	Comparative Analysis of Patch Repair Compounds for Repair of Stone Masonry Inge de Witte, Ph.D, FTB Restoration, Belgium
3:30pm-3:45pm	Break
3:45pm-4:45pm	Parallel Sessions
	Case Study Analysis of Current Restoration Projects in New York City (Invited Panel Speakers)
	Part II: Historic Concrete: Hands-On Petrographic Examination Studies L. Brad Shotwell, School of Structural Geology, Tectonics and Petrology, Kent State University, USA
	The Performance of White Carrara Marble on the External Claddings: Products Systems and Researches in Progress Marcantonio Ragone, Manager, IMM Carrara Spa, Italy
	Case Study Analysis of Current Restoration Projects in New York City (Invited Panel Speakers)
4:45pm-5:30p,	Closing Plenary Session to include Closing Panel Discussion, Questions and Technical Session Closing
Evening	On Your Own

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