

FACADES OF MODERNIZED BUILDINGS – DIFFERENT STRATEGIES, DIFFERENT EFFECTS – CASE STUDIES OF SELECTED PUBLIC UTILITY BUILDINGS

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Abstract

After certain time of buildings performance, the modernization of their facades is both a necessity and an opportunity for improving their quality, not only in terms of the external shell but also in many functional aspects. The scope of the paper is the discussion of different strategies of facades modernization, starting with popular thermal insulation of the external walls, through the exchange of glass curtain walls, new double-skin facades, to intelligent facades combined with the Building Management System, and facades equipped with photovoltaic systems that change the skin of buildings into energy generators.

Streszczenie

Po pewnym okresie użytkowania modernizacja elewacji jest koniecznością, a zarazem okazją do podniesienia jakości nie tylko samej powłoki zewnętrznej, ale także wielu aspektów funkcjonowania całego budynku. Artykuł prezentuje różne strategie podejścia do procesu modernizacji fasad, od popularnego docieplania ścian zewnętrznych, poprzez wymianę szklanych ścian osłonowych, dobudowywanie podwójnych powłok, po fasady inteligentne, sprzężone z systemem BMS oraz elewacje wyposażone w systemy fotowoltaiczne, zamieniające skórę budynku w generator energii.

Keywords: Modernization; Thermal insulation; Replacement of facades; Second skin; Intelligent facade; Photovoltaic modules.

1. INTRODUCTION

In its life cycle every building faces the need of change, the reasons of which are usually: poor technical quality, transfer of ownership or planned new functions. Together with the modernization of the entire building, facades are also subject of alterations. However, there are different strategies of the approach towards transformations of the exterior walls resulting from different functions, the range of construction works and financial outlays at the investor's disposal. Therefore, there are different outcomes of such changes.

The approach towards the modernization of facades depends on the type of building under reconstruction. Modern buildings with closed walls and window openings are treated in a manner different from buildings with glazed facades or, first and foremost, from histor-

ical buildings, in which the facades are often the only element that is worth preserving.

In the course of reconstruction works various dependencies appear between design strategies and the benefits for the interior environment of buildings, their surroundings and, last but not least, for their users.

2. THERMAL INSULATION OF THE EXTERNAL WALLS AND REPLACEMENT OF WINDOWS AND DOORS

Nowadays the modernization of facades is often associated with thermal insulation of buildings. The range of renovation works usually involves external thermal insulation composite systems, such as lining the external walls with Styrofoam plates, plastering, painting in accordance with the architectural design, or replace-



Figure 1.
Faculty of Social Sciences building, University of Silesia in Katowice (photo J. Tymkiewicz)



Figure 2.
Department of Physics building, University of Silesia in Katowice (photo J. Tymkiewicz)



Figure 3.
Management and Social Sciences College building in Tychy (photo J. Tymkiewicz)

ment of windows and doors. There are many examples of such procedures in Poland, in old university buildings (Fig. 1-3). Under such circumstances, the interiors of office buildings often receive new equipment including mechanical ventilation or air conditioning.

The above mentioned measures are important in view of the introduction, as of January 1st 2009, of the European Parliament and Council of Europe's Directive concerning the energy quality of buildings, according to which up to the end of 2018 public authorities may own or lease only such buildings that provide very good energy characteristics [16].

The advantages of the thermal modernization of facades include, first and foremost, the improvement of the thermal insulation of the external walls and better aesthetics of the building. However, this may involve a certain problem. For example, *M. Włodarczyk* is very critical of the thermal modernization of the facade of the Pedagogical Academy in Krakow, in the outcome of which, unique designs of the window walls partitions devised by architect *W. Zaucha* at the turn of the 1960s/1970s were replaced by common window frames: "completely destroying the previous beauty of this building. Beauty understood in an empathic and artistic manner" [15].

After thermal modernization, the internal environment conditions in buildings may be worsened, due to excessive tightness of the external partitions.

In the course of thermal modernization works the range of changes in the external image of the building may go beyond "pure" thermal insulation of its walls. Sometimes jutting out risalits, bay windows, canopies above the entrance are added, or bigger glazed surfaces introduced, together with elements of visual information.

3. REPLACEMENT OF GLASS FACADES

In case of buildings with glazed facades, design architects are faced with a difficult decision – should the modernization respect the original composition of the building, its partitions and structure, or should it be given a completely new, modern look? An example of renovation, involving the replacement of the glazed facade and complete change of its partitions, is “Biprohut” office and conference building in Gliwice, erected at the turn of the 1960s/1970s. The original window partitions, clearly separated by protruding “brise soleil”, had been displaced by half a module on the successive floors (design architect *R. Moszant*, 1965-1973). According to the administrator of the building, the rotating timber windows were very draughty.

In 2007-2009 the building was subjected to modernization works (design architect *C. Knebloch*) and received a new “skin” in the form of glazed facades, aluminium structure, with two types of glazing – transparent and opaque. In the strip below the windows spandrels were used, thanks to which the facade seems completely glazed (Fig. 4-6). The renewal of the facade was intended to improve the micro-climate of the interiors (air conditioning was planned to be installed), energy-efficiency and aesthetics of the building, as well as to endow it and its owners with a new, modern look.

How does the discussed building perform in practice? In 2009 and 2010 interviews were made with the administrator (the research team was supervised by *J. Tymkiewicz* and included: *B. Krok*, *K. Mastej*, *A. Nowak*, *M. Rydzy*, *N. Rozenbajger* and *D. Purchała*, *D. Lempa*, *P. Nowak*), but the sort time of the functioning of the building with its new facades was insuf-



Figure 4.
Replacement of glass facades – “Biprohut” building in Gliwice (photo J. Tymkiewicz)



Figure 5.
The front facade after renovation – “Biprohut” building in Gliwice (photo J. Tymkiewicz)



Figure 6.
The back facade of “Biprohut” building in Gliwice (photo J. Tymkiewicz)

ficient to enable the assessment of its energy-efficiency. Also, there was no opportunity to conduct appropriate measurements.

As far as the microclimate is concerned, one of the problems that occurs in “Biprohut” building is the overheating of the rooms behind the glazed facades in the warm season – despite the use of special type of glass. In the autumn of 2010 the rooms had no air-conditioning yet and the users could still open the windows, which will be impossible after the installation of air-conditioning (there will be special keys to prevent this).

The protection against the sun is provided by blinds that may be individually adjusted, thanks to which the building facade creates the impression of change and liveliness, although it may seem a bit “messy” – due to various position of the white blinds. Furthermore, completely unfolded blinds eliminate the visual contact with the external environment. On the other hand, the noise reaching the building from the streets around was reduced.

The new window bay highlights the flat facade and makes it look more dynamic; moreover, it serves some specific function – it enlarges the floor area (total: 70 m²). In addition, a recreation zone was created at the top floor of the building.

The design of the new facade had to consider the safety issues, as it is possible to open the windows. The glazed surface has the windows that open out from the bottom. In the inclined part of the bay window (4⁰), customized tilt windows were installed, opening inside from the top. Such solution protects the users from falling out of the window.

The facade needs to be washed twice a year. Thanks to specially installed rails, the washing may be commissioned to specialized mountain-climbing companies.

4. THE SECOND SKIN – GLASS SCREENS

Haus der Presse in Dresden (designed by *W. Hänsch* and *H. Löschau* in the 1960s) is an example of the renovation focused on quality improvement in its many aspects, and not limited to better insulation of the walls and nice-looking facade. The key to the success of the renovation project and the final decision concerning the modernization method were the preceding studies, analyses and simulations. Accordingly, the optimal solution was accepted in a conscious way. In 2001-2003 the complex of the buildings nowadays housing Publisher Sächsische Zeitung was renovated in accordance with the design made by

Cornelsen+Selinger Architekten BDA) (you can see the photographs of this buildings on the website <http://www.swiat-szkla.pl/content/view/1707/lang,pl/>) [1], [18].

The renovation process was analysed in detail by *M. Brzezicki* [1]. According to the author, in the course of using the building, problems typical for the 1960s constructions were revealed: poor thermal insulation of the external partitions, and consequently, excessive energy consumption and thermal discomfort felt by the users. Furthermore, there were several obstacles to modernization changes, including: insufficient height of the floors (about 3 meters gross), making it impossible to install suspended ceilings and channel air-conditioning, not to mention a very small reserve for the load bearing capacity of the building and the necessity of conducting detailed static analyses before the commencement of any renovation works [1].

It was demonstrated at the research stage that, instead of improving the condition of the building, standard procedures such as: thermal insulation of the walls and replacement of the windows may actually make it worse, because warm air accumulated inside the building could not be transferred outside, due to its sealed external shells. It was estimated that the energy balance would be less favourable. On the bases of computer simulations, the design architects tested other solutions. It turned out that the best outcome would be achieved by the installation of climate convectors – elements of a decentralized air-conditioning system [1].

Accordingly, such solution was chosen for implementation. However, its introduction involved the intervention into the structure and construction of the external walls. Under such circumstances, the design architects made a decision of a simultaneous solution of several different problems. One of the factors influencing such decision was the fact that the users of the building, while assuming a sitting position, were not able to look through the windows, as the window sills line was too high (120 cm from the floor). Thus, complex measures were applied: the window sills and ledges level was lowered down to about 80 cm, the ferro-concrete strip below the sills was removed and replaced by thin-wall prefabricates, making it possible to install climate convectors in the created channel. Also, bigger windows were put in and the second skin made of screen printed glass sheets added at the distance of 20 cm, thus differentiating the degree of glass transparency. In the inter-facade space, blinds were placed. In this way, inter-

esting light and shade effects were achieved, magnified by the effect of depth [1].

Haus der Presse in Dresden is one of the many examples of modernization schemes based on the use of the glass skin. Glass screens may also be added to the existing facades in different systems. For instance, SUVA Insurance Building in Basel (Switzerland), modernized in 1988-1993 in accordance with Herzog & de Meuron office's design, offered another structural solution. The new facade with post and beam structure has three horizontal strips of windows on each floor. Each of the glazed strips functions differently and fulfils different tasks:

- The upper strip consists of automatically controlled windows containing prism panels made of plastic and improving the natural lighting conditions;
- The middle strip is made of transparent glass windows that can be manually opened for ventilation purposes;
- The lower strip consists of screen printed window panes that provide energy-efficiency in the sub-window sill part covered by stone.

In the winter season the closed windows in the lower strip serve as a buffer space reducing heat losses. In the summer season, thanks to the opened windows, the sub-window part is prevented from overheating [8].

Glass screens added to existing facades may generate some functional problems. For example, Telus – William Farrell Building in Vancouver, Canada, erected in 1940 as a ferro-concrete structure, was subjected to renovation in 2001 in accordance with Busby&Associates Architects' design. The building was equipped with an additional external shell mounted at the distance of about 1 m from the external walls surface. In the original facade, the windows that could open vertically were not replaced, but the brick lining layer was removed. The glass wall with aluminium profiles has transparent panes and screen printed glass panes reducing sunrays penetration. Its windows open to the outside and are controlled by actuators. The inter-shell space is not divided, which in conjunction with the possibility of opening the windows to enable the ventilation of rooms, leads to the penetration of noises and smells through the rooms. The absence of the partition in the inter-facade space poses threats of smoke and flames propagation in case of fire. Another problem is the land ownership. Due to the addition of the external shell at a certain distance from the original facade, the building is no

longer contained within the boundaries of its proprietorship plot [8], [7].

5. MOVABLE GLASS PANELS – THE INTELLIGENT FACADE

Another interesting model example of modernization in accordance with the energy-efficiency principles is the “Berlaymont” – the headquarters of the European Commission in Brussels. The building was to serve as a benchmark and a comparative model for studies on “the quality of the internal environment, safety of use, minimization of energy consumption and functionality, at the concurrent rational consumption of energy supplied to the building” [10].

In 2004 the Project of devising energy certificates for the building was initiated, in accordance with the procedures and standards binding in European Union states. The project participants were: Austria, Holland, Luxemburg, Germany, Poland, Portugal [17].

The Project was to mark an important stage of implementing Directive 2002/91/EC of the European Parliament and the Council of Europe dated December 16th 2002 and concerning the energy quality of buildings [17].

The building, erected in 1960-69 (the design architects: *L. De Vestel, J. Gilson, and J. and A. Polak*), was given the form of a cruciform with four wings and fourteen above-ground floors. The renovation and modernization architectural design (authors: *P. Lallemand, S. Beckers and W. Van Campenhout* 1995-2004) assumed shielding the building facade with a double-glazed wall. The external shell consists of movable laminated screen printed glass panels. The panels are divided into autonomous units and are automatically controlled by the BMS, which, thanks to the coupling with the meteorological station, determines their position, depending on the prevailing weather conditions. Moreover, an integrated system of managing the lighting of the building was installed with sensors placed in the rooms, coupled with the system of adjusting the position of the panels in the external building facade to achieve the required lighting intensity on the surface of the workstations – 500lx [10] (Fig. 7-9).



Figure 7.
The headquarters of the European Commission in Brussels after modernization (photo K. Mastej)



Figure 8.
Facade of Berlaymont building in Brussels (photo K. Mastej)



Figure 9.
Details in the facade of Berlaymont building, Brussels (photo K. Mastej)

6. PHOTOVOLTAIC MODULES

The already mentioned European Parliament and Council of Europe's Directive also assumes that, starting with 2018, the demand for energy will have to be substantially covered by renewable sources that generate energy at site or in the nearest vicinity [16]. One of the possible solutions are photovoltaic modules that may be applied in renovated facades. For example, the USA Embassy building in Genève, which is 20 years old, had its facade and roof transformed in 2005 into a specific solar power plant [12]. A Polish example of modernized facades with the use of PV modules is the building of the Faculty of Environmental Engineering, Warsaw University of Technology, which has the photovoltaic modules installed on its facade and on the roof [12] (Fig. 10, 11).

Thanks to recent and most advanced technologies, it is possible to replace old linings with solar modules that have double functions: serving as external skins and generating energy.



Figure 10.
The facade of the Environmental Engineering Faculty building, Warsaw University of Technology (photo J. Tymkiewicz)



Figure 11.
PV modules installed on facade – Environmental Engineering Faculty building in Warsaw (photo J. Tymkiewicz)

From the economic point of view, such activity is justified, as some of the facade materials are more expensive than the modules themselves. Certainly, the solar panels that constitute the only layer of the facade must comply with all the conditions set forth for the external partitions, including: thermal insulation, durability, air-tightness and mechanical resistance. In view of the thermal insulation and the necessity of cooling the heating up modules, two-skin solutions are applied, in which the inter-facade space between the internal glass skin and the external modules enables the air flow that removes the heat from the modules [13].

There are also transparent modules that facilitate the access of natural light to the interiors. They transfer not more than 30% of the sunlight and absorb a part of the light spectrum. Hence, the use of such modules in public utility buildings is common (communication

routes, staircase, etc.). In the design of transparent modules, an attempt is always made at concealing the system of their mounting and the associated electrical connections [13].

7. A NEW BUILDING IN ITS OLD SKIN – A HISTORICAL SHELL

Reconstruction projects often concern post-industrial buildings with well-preserved brick facades, ornamented with few or abundant architectural details, the interiors of which were once open-space but have nowadays been given new partitions. The facades of modernized buildings may function as independent skins, inserted into empty but aesthetically attractive shells and strengthening the old walls. In the city of Madrid such renewal was designed by *Herzog and de Meuron*, leaving only the brick walls of the old 19th century power plant, whereas the interiors were destined for the function of the arts centre – a site of exhibitions, concerts, seminars and community meetings. Thanks to the huge pillars of the building, it was possible to devoid the external walls of their original stone foundations and to achieve the effect of an optic detachment of the building from the ground surface. Also, an additional cubic structure was built above [5].

Likewise, in Poland, in the course of the revitalization of post-industrial sites and facilities, numerous projects have been implemented involving the use of old building facades endowed with new functions (Fig. 12, 13).



Figure 12.
The revitalised building of the old granary house in Gliwice – presently housing the lofts designed by Medusa Group (photo J. Tymkiewicz)



Figure 13.
Preparation works for further revitalization – empty “shells” of Gliwice Steel-Works facilities (photo J. Tymkiewicz)

Such manner of altering the functions of buildings poses some serious problems, which for instance came up in the case of I. Poznański’s factory facilities in Łódź, transformed into “Manufacture” Centre. Originally, the facilities served industrial functions, with fairly constant internal air parameters during the 24 hours. In the early 1990s the facilities were not heated and started to deteriorate year by year [4]. The unprotected elements of the buildings were exposed to the destructive impact of the external environment, including rainwater. The technical condition of the facade “made of dark red brick with highlighted lesenes joined with the frieze and brick cornices” was seriously threatened [3]. The new functions embedded in the old structures evoked changes in the internal and external “environmental context” of the renovated complex. As far as the external space is concerned, the intervention in the urban system led to changes in the local climate, involving the natural lighting, shade, and air flow around the buildings [4]. To secure the durability of the historical factory walls and to prevent their destruction caused by the internal and external environments, simulation analyses were conducted focused on the assessment of the impact of various modernization methods on the condition of the external walls. One of such methods is discussed in detail in D. Heim and S. Krawczyński’s paper, where the authors presented the analysis of the physical and construction problems occurring in post-industrial facilities on the basis of the case study of “Manufaktura” in Łódź, which was the biggest European brown-fields revitalization project and a specific “study field” (Fig. 14-15) [4].



Figure 14.
Post-industrial facilities in Łódź, designed by H. Majewski in the late 19th century (photo J. Tymkiewicz)



Figure 15.
“Manufaktura” shopping mall, leisure and business centre (the modernization design – 2003, implementation – 2006 – Sud Architectes and arch. A. Mrowiec – conceptual design), (photo J. Tymkiewicz)

In case of historical walls, the selection of a renovation method is by no means easy. Currently, brick walls with the thickness of three single bricks (about 80 cm) do not comply with the binding regulations concerning thermal protection, but popular thermal modernization schemes are very difficult, or even impossible to be performed. The facades with historical details that are listed and that fall under the protection of national heritage, are not subjected to thermal insulation of their external walls; whereas, brick, which is held in such esteem by interior design architects does not enable internal thermal insulation of the buildings [4].

The author of this paper had the opportunity of verifying the performance of post-industrial facilities that nowadays serve new functions in the course of

visiting the post-mining complex in Gliwice. The visit included the round and local inspection of the buildings, interview with the administrator and surveys of the users. From the aesthetic point of view, the buildings are on a very high level. The revitalization project has brought the site of the liquidated coal mine back to life. The problems involved in the old walls were effectively solved and new functions really well-planned [2], [14]. However, one of the problems that has not been properly addressed is the micro-climate of the office facilities arranged in the old Machine House (designed by *G. and E. Zillmann* in the early 20th century) (Photographs 16, 18). The implemented concept of “a building inside the building” (Photograph 17), i.e. an independently glazed structure inserted into the single-space interiors of the old facility (foredesigns for the adjustment of the post-mining buildings to serve new functions: ArKuS design and consultation office, the construction project: Mexem, 2004/2005). The combination of various issues – starting with the assumed ventilation concept, through the ensuing decision about the modules of the glazed internal partition that cannot be opened, up to the so called “human factor”, have all resulted in the users’ complaints about excess heat in the building and their total incomprehension of the fact that the simplest solution, involving opening the windows and airing the overheated interiors, is impossible.



Figure 16.
The old Machine House at the site of the previous coal mine in Gliwice – the back facade (photo J. Tymkiewicz)



Figure 17.
The entrance facade of Machine House building, Gliwice (photo J. Tymkiewicz)



Figure 18.
Interior of Machine House, currently functioning as an office building (photo J. Tymkiewicz)

8. CONCLUSIONS

If it is assumed that a building is regarded as a set of successive layers with different durability, facades are the least long-lasting elements in comparison with the whole building structure, yet, more durable than installations, partitions and interior fixtures and fittings. The life span of modern facades is about thirty years [6]. After that time technically and aesthetically worn external skins should be replaced. In case of glass facades, the guarantee period is usually ten years, but their durability (understood as stability of the parameters) is estimated for about fifty years.

The modernization of facades is an opportunity for the improvement of the quality of the skin of the building, which, in turn, exerts an impact on many other functional aspects important to the performance of the building and the comfort of its users.

Currently, one of the most popular solutions applied in buildings constructed after World War Two is the thermal insulation of the walls, replacement of windows and doors, resulting in better insulation of the external partitions and improved aesthetics. However, in practice, the design assumptions do not always work. Instead of savings, tightly sealed buildings may generate additional costs incurred due to air-conditioning. The insertion of big glazed surfaces in the course of the renovation works contributes to overheating the rooms in the spring and summer seasons, and underheating in the winter season. In each case, sun protection of the glazed surfaces must constitute an integral element of the facade design. It often happens that the applied type of sunlight protection cuts off the access of natural light, once the blinds or shutters are pulled down, enforcing the turning on of artificial light during the day and increasing the costs of electric energy consumption.

Nowadays, the external skin of buildings is often a glass facade, the technical quality of which depends on a combination of different factors, starting with the design concept and the selection of adequate construction schemes, choice of materials and joints, through the consideration of their strength parameters, to workmanship and proper maintenance (for example: appropriate washing of the glass facades). Glass curtain walls are replaceable for those with better parameters. In view of the aesthetics of the 1960s-1970s modernist architecture still unappreciated by investors, and, unfortunately, architects, some special respect should be shown. The buildings constructed in this period are becoming more valuable with the passage of time, as far as their architectural layers are

concerned, yet, unfortunately, due to poor technical quality, many buildings worthy preservation lose the qualities of their perpetual modernism in favor of ad-hoc thermal insulation solutions and temporary fashion fads. According to the Internet forums, the inhabitants of cities like renovated buildings much more than their previous dilapidated forms. However, specialists in the history of architecture spot certain problems. The discussed renovation of the facade of "Biprohut" office building in Gliwice has been categorized as: "negative acceptance" attitude [9].

One of the most modern solutions are double-skin facades. According to U. Knaack, the initial euphoria accompanying this solution, the rupture over the technical and aesthetic possibilities involved, in time gave way to a more pragmatic approach. Nowadays not every single modern building must have double-skin facades. They are mostly used at sites where they are necessary, to prevent the impact of street noise, or the wind load. Such applications are justified and economically feasible [6].

The future shall probably belong to buildings with the facades that facilitate the recovery of energy from renewable sources. Photovoltaic cells, initially placed onto the facade structure, are now replacing facade materials. Such integration of the photovoltaic systems with the building structures is labeled: Building Integrated Photovoltaics (BIPV) [13].

Currently, the provision of adequate quality of a modernized building compels the cooperation of architects and specialists of various engineering disciplines, including constructors, structural physicists, air-conditioning and ventilation experts. The structure of the building should be designed in such manner that the layer of the highest durability does not intrude into the replacement of less durable elements. Skeleton structures are given preference, as, equipped with curtain walls in modular systems, they facilitate a relatively easy and clean fragmentary disassembly after years of usage, without the need of excluding the building from usability performance [11]. The main objective should be complex quality improvement in all its aspects, supported by previous studies that enable the most optimal and conscious choice of modernization methods. Modern technology and available research tools in the form of computer simulations make it possible to forecast the consequences of the adopted design modernization solutions.

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