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TECHNOLOGIES OF CONSTRUCTING WARSAW'S GREEN ELEVATIONS IN THE CONTEXT OF GLOBAL AND POLISH REALIZATIONS

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ABSTRACT

Green elevations are one of the elements of modern and technologically advanced pro-ecological architecture. As a result of this phenomenon, greenery has become a material modifying the character of the architectural object, constituting a new quality element in the urban landscape of Polish cities. The development of technical possibilities of shaping vegetation systems allowed for various applications of greenery in architecture also in more difficult climate conditions, such as a cold, dry winter and a hot, dry summer like those found in Poland. The use of greenery on the facade has many positive aspects, which are obtained as a result of the synergy of nature, technology and art.

Key words: green elevations, vertical gardens, Warsaw, construction technology, architecture

INTRODUCTION

Shaping green walls is an important element of designing pro-ecological architecture. In order to realize the idea of sustainable development, it is particularly important to select appropriate technologies, so that the free development of plants in given climatic conditions is possible. Only then the green facades will be able to perform their functions. Vertical gardens are of interest to architects because of the possibilities of shaping attractive urban spaces with a unique character. The development of modern technology has made it possible to introduce greenery into the intensely built-up urban fabric and improve the quality of life in the city. Integration of vegetation with architectural solutions through green infrastructure is an important element of the urban system and its interdependence (Grochulska-Salak, Zielonko-Jung & Zinowiec-Cieplik, 2018). The possibility of classifying contemporary facade solutions using greenery as a material shaping the architectural expression of the object allows to indicate the trends in their development, in terms of technical and construction possibilities, urban planning and aesthetic or ecological values.

INFLUENCE OF GREENERY ON ARCHITECTURAL OBJECTS, URBAN SPACE AND ENVIRONMENT

Green elevations are multifunctional elements of particular value both for the architectural design as well as urban spaces or the environment. Green elevations can be defined as elements or technologies that allow to apply greenery on vertical surfaces and which have an impact on the view of the elevations and superimposed sections. There are basic aspects in which green elevations play an important role: technical-energetic, ecological, aesthetic, or urban planning, landscape and psychological.

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Among the basic technical aspects, it is worth noting that the use of greenery on the facade helps to protect the facade against atmospheric factors (precipitation, wind, temperature, pollution), thus contributing to the increase of energy gains in winter, reducing the loss of energy needed to cool the building in summer (savings of 15–30% per year) (Związek Szkółkarzy Polskich, 2017). Moreover, they allow to obtain smaller changes of air humidity in the nearest environment and allow to reduce the daily amplitude of the wall temperature (Związek Szkółkarzy Polskich, 2017). Green elevations do not adversely affect the materials used, and even similarly as in the case of green roofs, they may constitute a protective barrier for the building's successive layers and may increase the possible lifetime of elevation and insulation materials. On the basis of research carried out at the Building Research Institute, it has been shown that vascular adhesions, which are biologically active, are inert to building materials and only at significant magnification are visible microcubes of slurry in the adhesions' contact layer with plaster (Związek Szkółkarzy Polskich, 2017). Moreover, it was shown that, in many cases, the adhesion of the product to the plaster filler was better on walls overgrown with climbers, which may suggest a beneficial, protective effect of this form of greenery on the facade (Związek Szkółkarzy Polskich, 2017). Green walls are also an important acoustic barrier, especially in massive technologies. In addition, climbing plants growing in the ground near the foundations of the building may become attached to the drying area around the foundations (Związek Szkółkarzy Polskich, 2017).

Among the ecological aspects, it should be emphasized that green facades, as one of the elements of greenery in the city, affect the reduction of the phenomenon of heat islands in urban areas. Moreover, they allow to stop and absorb air pollution, including smog. Vegetation also contributes to improving air quality by producing oxygen and absorbing carbon dioxide (Dover, 2015). Green facades and roofs also enable rainwater retention in highly urbanized areas, where it is hindered by too much accumulation of hardened surfaces. Green facades also have a positive impact on the biodiversity of fauna and flora in the urban environment, as they are a convenient place for insects and birds to live (Dover, 2015).

Additionally, vegetation improves the aesthetics and shapes as well as the specificity of the place. The greenery used on the elevation, with some assumptions, can be considered as an ornament (Tymkiewicz, 2012b), shaping the expression of the elevation. Not without significance is also the dynamic, time-changing character of the facade obtained in this way.

Moreover, it is desirable to create landscape and scenic connections within the humanization of space, in which the greenery used both inside and outside the buildings plays a significant role. Not without significance is also the context related to biophilia, in which greenery plays a significant role in shaping human mental and physical health. The ideas of biophilic design (Kellert & Calabrese, 2015) and Shirin Yoku unanimously prove the significant influence of greenery on human living space by reducing stress and stimulating spiritual balance. The traditional Japanese art of *immersion in greenery* requires large green areas, such as forests, where one can benefit from a unique microclimate, rich in essential oils and silence. Introducing green urban spaces can often be difficult in highly urbanized areas where the cost of the land is high and the investors use every allowed area for development. However, it seems reasonable to have constellations in various world cities, where the basic assumption is to allow the inhabitants to access greenery in a form conceived within a 5-minute walk from the place of residence and a maximum of 15 min for larger green areas (squares, parks). In this context, the possibilities of introducing greenery on the facade play an important role.

In order to optimize profits associated with the use of green facades, it becomes important to choose the right technology. The consequences of a wrong choice of system solutions may significantly adversely affect the technical properties of materials used to build external walls (mechanical damage, moisture) and cause other complications. The proper selection and arrangement of plants are also important, taking into account such elements and parameters as appropriate sunlight, protection against excessive wind, thickness and quality of the substrate, irrigation methods used, as well as resistance and strength, especially to difficult climatic conditions of vegetation.

APPLIED GREEN ELEVATION TECHNOLOGIES IN THE CONTEXT OF GLOBAL, POLISH AND WARSAW SOLUTIONS

Technical development has a very instinctive influence on green elevation solutions. Over the years, a variety of technologies and measures for implementing greenery have emerged in architectural objects. One of the most basic methods is the arrangement of terrace greenery in facade solutions and architectural objects. This type of application does not involve a significant increase in costs in the case of low vegetation placed in mobile pots. The impact on technical solutions is visible in the case of choosing plants of considerable weight or choosing fixed pots, integrated into the structure of the building. The benefits of using a terrace system include visual contact with greenery or low construction and maintenance costs. Projects of this type are aimed at significant exposure of greenery in architecture, as an essential element in its shaping, but this effect is also possible in objects that are not newly designed. For this research, examples from Europe were chosen for the analysis, as most of them clearly present possibilities of using greenery on vertical surfaces. The exception is one example of a building in Japan because of its innovative and unprecedented design approach.

The solutions for terraced gardens can be seen in the Elephant & Castle Eco-Tower in London by architects Ooi Tee Lee, Loh Hock Jin, Ong Eng Huat, or the Caag Tower in London by project K. Yeang, R. Fathan, K. Chung. The Acros Fukuoka office building in Fukuoka City, Japan, designed by Emilio Ambasz & Associates, is also an example of this trend. This example was chosen because of its importance and innovative way of thinking. The main idea of the project was to leave a maximum large area of the park and accumulate all necessary public functions (museum, exhibitions, conferences, etc.) and offices in one 14-storey building. The southern elevation of the building was shaped in cascade. This form of the building made it possible to introduce a green facade and a green roof. Individual terraces are connected with each other by stairs. The public climbing garden created in this way has an area of 1 ha and complements the remaining area of Tenjin Central Park (Belogolovsky, 2020). As a result, in addition to the numerous vegetation introduced, the facility also has significant water retention and uses rainwater to water the terrace garden. Moreover, thanks to the green elements used, the energy demand was reduced. This object is a special example of combining architecture and nature.

In Warsaw, an object that deserves attention in this respect is the extension of the Rialto Hotel, i.e. the Nobu Hotel by architects from the Medusa group in 2020 (Fig. 1). Thanks to the use of terrace systems,

Fig. 1. The Nobu Hotel in Warsaw with terrace greenery on the facade (photo by A. Nowak)

the facility stands out in the space of Koszykowa and Wilcza Street, where there is not much vegetation. The object, among other things, thanks to the use of an unusual, alternate terrace system of vegetation, is a new element in the urban space, which certainly gives this place a new identity. Another object, which also uses vegetation in the terrace space, is the revitalization of the Warsaw Zodiac Pavilion of Architecture. The existing pavilion was demolished, and in its place, the architects from the Kalata Architekci studio designed a similar one in the form and style of the object. On the first floor, there is a conference room, which is connected to an outdoor terrace with vegetation in containers. The introduction of vegetation has a positive impact on the reception of the object located in a concrete, urban space.

A significantly simplified terrace system reduced to cantilever facade pots fixed to the structure of the object was realized in the building of a multi-storey parking lot on the premises of the Kielce Trade Fairs Chodor-Projekt project. At the early stage of the object's use, the vegetation requires a larger pattern in order to achieve the architectural effect of the project.

Also, one of the basic possibilities of introducing greenery into the urban space in the form of green elevations is the use of climbing plants, which do not require supports or racks, and which have the ability to attach to various facade materials (Trzaskowska, 2010). This type of vegetation does not have high soil requirements and, with a significant biologically active area, it needs a small soil area necessary for development.

This feature is particularly noticeable in cities such as Amsterdam, where despite heavily built-up streets, greenery can be found in many urban spaces on facades. More and more often, vineyards and glycines are used for this purpose, which are extremely attractive during the flowering season. There are also cases where the greenery is in harmony with the architecture, as in the case of the Müller Villa in Prague designed by Adolf Loos (Fig. 2).

In Poland, you can observe many objects that are overgrown with vegetation, often as a result of accidental plantings, which significantly grow and cover up less attractive facade elements. However, it happens that such applications of climbers on the elevation perfectly blend in with the surroundings, creating the continuity of the architectural and natural landscape, as in the case of Wawel Castle.

A more controlled effect can be achieved by using rope and scaffolding elements intended for the construction of a climbing plant. The shaping trains on the principle of grates with appropriately shaped

Fig. 2. The climbers on the facade of buildings in Amsterdam and on the example of the Müller Villa in Prague designed by Adolf Loos (photo by A. Nowak)

divisions depending on the species of plants, and can be an integral part of the facade or a free-standing element. The costs of introducing such elements are small and they do not require difficult and complicated building solutions. The accepted solution of green elements should be, however, an integral part of the architectural design. Systems of cable elements, treads and pergolas can form an integral part of the facade or function as a self-supporting element, which can be introduced at any time during both the design and use phase. Examples of such solutions can be the Sihl City Green Wall in Zurich designed by architect Theo Hotz, or the parking building of the US Census Bureau HQ in Maryland by the Samplearchitekture studio. The introduction of greenery on simple and very regular elevations has a positive impact on the reception of the building.

An example of such a solution can be the Cristal Park office building in Warsaw, designed by the JEMS Architekci studio in 2009. On the western and eastern elevation, metal frames with steel ropes were installed, which serve as supports for creepers, similar to training systems. Vertical elements were attached to concrete cornices, balancing horizontal lines in the elevation. Functional details create a characteristic wall drawing. By using greenery as an element shaping the aesthetic expression, a specific character of the object, changing in time, was given. Appropriate selection of plant species also made it possible to provide protection against heating of facades overgrown with vegetation in summer, with simultaneous exposure to sunlight in winter. The *plant layer* of the elevation was distanced from the curtain wall, which allowed for its exposure also from the inside of the object, creating a structure of viewing links with the landscape and paying attention to utility aspects.

Among the objects where the training system was applied, one can also mention the University of Warsaw Library designed by the Marek Budzyński architectural studio. The elements constituting the supporting structures for the creepers were placed both inside and outside the building in 1999 (Fig. 3). The greenery has been treated as a characteristic element of this object, thus fitting into the specificity of Powiśle. In the library building, various technologies were used to introduce vegetation, from the green roof to the facades.

The pergola system has also been equipped in the case of the Center's Commodity Houses, which have been located on the side of the Wiecha Passage since 2007. The elevation was divided into sections, in which metal nets were attached to the metal support structure (grid), acting as supports for climbing plants.

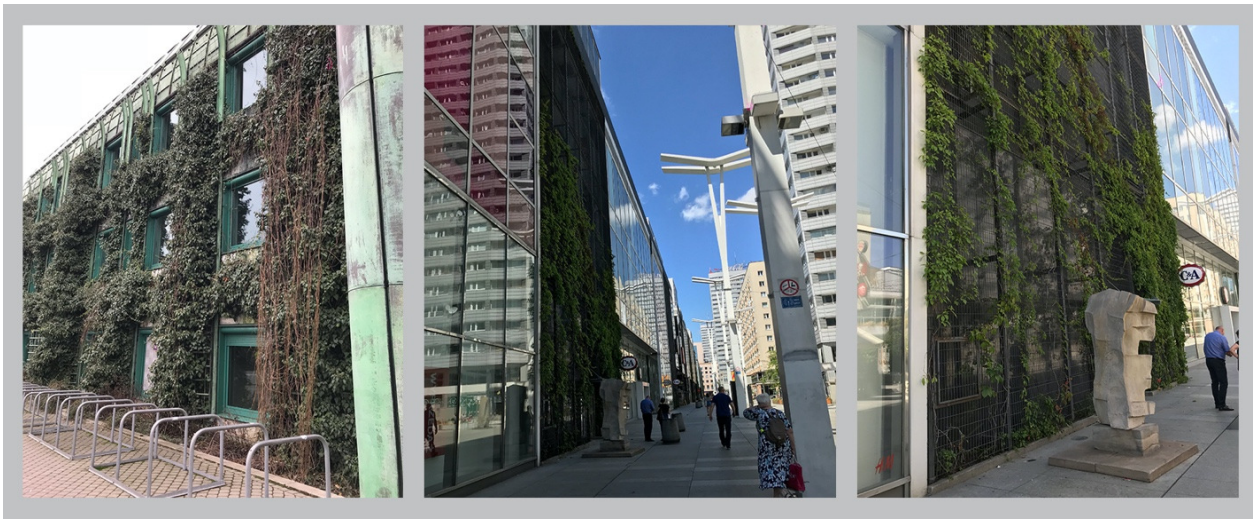

Fig. 3. Climbing support systems on the facade of the University of Warsaw Library designed by architect Marek Budzyński and Center's Commodity Houses from the side of Wiecha Passage (photo by A. Nowak)

In the design of green elevations, technological and material solutions are more and more often sought after to shape surface greenery systems, the so-called vertical gardens. Surface greenery systems can be designed in the technology of vertical hydroponic gardens, using a lightweight substrate, a gabion construction with a heavy substrate, a curtain wall, or a self-supporting gabion system (De Garrido, 2011). Systems that are not self-supporting require attachment to facade structures, using an air gap for better ventilation. For vertical hydroponic garden technology, and using elements with a lightweight substrate, a scaffold substructure is required. For solutions using gabion systems, steel structures with coffers are used, anchored to the structural elements of the outer wall of the building. Green curtain walls are designed in mullion and transom technology, with the possibility of using lattice structures made of steel flat bars. This allows to create a technical space between the vegetation layer and the building wall (Barnaś, 2011). Often, however, when implemented in colder climates, hydroponic techniques do not work, and it is necessary to introduce technologies specifically designed for the region and use appropriately selected vegetation, highly resistant to harsh conditions, and with lower soil requirements. As a result, different climate zones produce a variety of green walls through vegetation.

The pioneer of hydroponic vertical garden solutions is botanist Patrick Blanc. A particularly interesting example of his work is the green wall of the building on Caixa Forum Square in Madrid. It is an important element of the concept of shaping public space as a juxtaposition of two expressive facades. The project by the architects Herzog and de Meuron, carried out in collaboration with the botanist, emphasized the importance of shaping the facade as an element creating urban space, especially public space (Tymkiewicz, 2012a).

The specific character of the building, which also affects the senses (sight, smell, touch), was obtained when the technology of vertical hydroponic gardens was applied in the Quai Branly Museum in Paris, designed by J. Nouvel. The green wall was also created as a result of a collaboration with botanist P. Blanc. Thanks to this technology, it was possible to shape superficial greenery, which made the building fit into the urban landscape in a specific way. Unfavorable wind conditions from the north side adversely affect the vegetation located on the facade. The greenery on the facade from the east has favorable conditions for development (Nowak, 2014).

The technologies proposed by P. Blanc of the gardens were used, among others, on the facade of the parking lot at Place Pie – Mur Végétal in Avignon, France. In this way, the aesthetic appearance of the facade of the parking facility was also obtained; the variable depending on the season and its negative impact on the environment was limited. A similar project is the Suhl Parking Garage facade in California, designed by Seasons Natural Engineering in collaboration with Edwards Lifesciences. Such solutions are particularly important in the context of minimizing smog and absorbing carbon dioxide in highly urbanized areas.

It is also worth underlining that not all the projects of *living walls* are successful, as in the case of Paradise Park in London, which encourages a prudent analysis of the conducted investments in the context of the idea of sustainable development (Architektura Murator, 2014) and minimizing the risk of its failure already in the design phase.

This threat is also associated with the introduction of hydroponic green elevations to the Polish climate. This is particularly true of the search for technologies adapted to the more difficult climate conditions. This type of technology was designed as a result of research conducted at the Wrocław University of Life Sciences and was used in the implementation of the green elevation of the Wrocław City Hall building. This project is also important due to the fact that greenery in the city, including as an element of architectural objects, is an important aspect in the development programs of cities, and the discussed elevation is an element promoting the establishment of public gardens through special pilot programs. The elevation was made using panels of corten and perennial perennials.

Warsaw's green wall solutions also confirmed the need to introduce new technologies adapted to more difficult climatic conditions, as exemplified by the green facade of the building of the Foundation

for Polish Science. The project, designed by FAAB Architektura Adam Białobrzeski, Adam Figurski, was made as an element of reconstruction with an adaptation of an apartment building from 1933. The elevation was composed of contrasting green and concrete elements in 2014. The green elevation with an area of 260 m^2 was originally supposed to be created by 20 species of plants, selected in such a way as to obtain a variable character of the elevation at any time of year (Chylińska-Żbikowska, 2019). The design uses a modular structure (filled with a special mat), fixed to a steel substructure. The automatic irrigation and fertilization system with sensors located in the modules controlled the use of rainwater from the retention tank, located under the ground surface, to water the green wall. As a result of problems with acclimatization of some species, individual biological parts of the facade were replaced. On the basis of the problems visible in this project, a technology enabling the realization of fully functioning vertical elevations was sought.

As a result, technology was invented and special plant species were selected, which in combination allow for the realization of green surface elevations, in a much more difficult climate in Warsaw than in Wrocław. The innovative technology was created as a result of cooperation between IQ Garden and Warsaw University of Life Sciences – SGGW as part of a grant financed by the National Centre for Research and Development, under which the research started in 2012 (Łaskarzewska, 2020). This technology was first applied to free-standing green walls on the square in front of the Warsaw Zodiac Pavilion of Architecture and was finished in 2018 (Fig. 4). The steel structure of the *gabions* has a specially prepared modular elevation (Łaskarzeska, 2020). The proper selection of soil was taken care of both for its insulating properties and moisture absorption. The thickness of the system was determined as a result of the conducted research, due to the freezing of the root ball. The systems proposed additional heating of the structure in the case of colder winters and an irrigation system allowing also to use rainwater from the square. In the first years since its establishment, the plant survived difficult winter conditions.

Another realization in this technology is the green wall on the facade of the Rotunda building (Fig. 5). The historic building was demolished and rebuilt using new technical and technological solutions. From the side of the Wiecha Passage, a vertical garden was designed to form the walls of a lowered square to commemorate the victims of a gas explosion in

Fig. 4. Surface greenery systems in the square in front of the Warsaw Zodiac Pavilion of Architecture (photo by A. Nowak)

Fig. 5. Surface systems of green elevation of the Rotunda building in Warsaw (photo by A. Nowak)

this object. The technology was enriched with an automatic irrigation system associated with sensors placed in the modular green wall system. Thanks to this, all plants remain in impeccable condition. By using vegetation as a *material* for the facade, a very interesting architectural effect was achieved. The space of the square is lowered in relation to the main pedestrian passage and creates a quiet and peaceful enclave, allowing for reverie and rest in the midst of the city noise. In this place, the advantages of the green elevations are particularly noticeable, such as control of temperature and humidity, due to the lower air circulation in the lower area. This vertical garden was constructed in 2019 by IQ Garden.

The latest realization in this technology is a vertical garden on the blind wall of the aforementioned Nobu Hotel at the corner of Koszykowa and Wilcza Streets constructed in 2020. The green facade was

Fig. 6. Surface systems of green elevation of the Nobu Hotel in Warsaw (photo by A. Nowak)

made in the same technology and fixed to the wall with a supporting grid. The main design idea was to provide a favorable idoku to the residents of the neighboring tenement house and increase the aesthetic value of this place.

SUMMARY

The development of technology has contributed to finding new opportunities for the use of greenery in the urban agglomeration. Modern technological solutions allow for a significant extension of traditional methods propagated by the precursors of green architecture, leading to making vegetation a material that shapes the aesthetic expression of facades of architectural objects and public spaces. Regardless of the type of technology used in the process of shaping contemporary elevations, green facades may constitute a specific character of the object and place, thus becoming its icon. The condition, however, is the conscious and appropriate goods of technological solutions, in order to minimize the risk of facade design failure, associated with the use of living material such as green, strongly susceptible to changes in the environment. The adaptation of technology and technical solutions to climatic conditions is one of the main barriers to the development of surface green systems. Nowadays, the number of examples of vertical gardens is increasing after some first realizations in which designers found some problems according to climate conditions, such as a cold, dry winter and a hot, dry summer. The conducted research on the possibilities of adaptation and creation of new technical solutions for the climate conditions of Warsaw is an important stimulus for development in this area. Based on new technologies adapted to climate conditions in Warsaw, there is a possibility to develop new strategies, which will include different types of green walls in the development strategy like, for example, Biodiversity strategy 2030. Modern technologies and concepts of green elevations set new trends in shaping pro-ecological architecture, consequently leading to the synergy of greenery, technology and art (Rokicki & Nowak, 2013), which is also exemplified by Warsaw's realizations.

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TECHNOLOGIE WYKONYWANIA WARSZAWSKICH ZIELONYCH ELEWACJI W KONTEKŚCIE REALIZACJI POLSKICH I ŚWIATOWYCH

STRESZCZENIE

Zielone elewacje są jednym z elementów nowoczesnej i zaawansowanej technologicznie architektury proekologicznej. W wyniku tego zjawiska zieleń stała się materiałem modyfikującym charakter obiektu architektonicznego, stanowiąc nowy jakościowo element w krajobrazie miejskim polskich miast. Rozwój technicznych możliwości kształtowania systemów roślinności pozwolił na różne zastosowania zieleni w architekturze również w trudniejszych warunkach klimatycznych, takich jak mroźna, sucha zima i gorące, suche lato, które możemy obserwować w Polsce. Wykorzystanie zieleni na elewacji ma wiele pozytywnych aspektów, które uzyskuje się w wyniku synergii natury, technologii i sztuki.

Słowa kluczowe: zielone elewacje, wertykalne ogrody, Warszawa, technologie budowlane, architektura