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6. PHOTOVOLTAICS AND CONTEMPORARY ARCHITECTURE IN CITYSCAPE

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Introduction

Since ancient times, technologies for building installations have influenced the architectural form. Roman aqueducts in the form of kilometre-long engineering structures shaped the natural, rural and urban landscape. The architectural form of the aqueducts and their exposure in the landscape was motivated by the function of bringing water from springs, usually located in the mountains, to distant cities. The Vitruvian triad: the form, the function and the structure united in an aqueduct testified to their beauty in ancient times. Nowadays, this beauty is also confirmed by the fact that their former functionality of a water supply system has already disappeared (Böhm, 2016).

New installation technologies affect the architectural form in different ways. A distinction should be made between their application to newly designed and existing civil structures. The impact is also different with regard to the scale and location of civil structures. It is of paramount importance that modern technologies and installations should also have, by increasing the functionality of civil structures, a positive impact on their beauty and display in the landscape. It may also be the case that it is selected technologies that determine the shape of the architectural form. When it comes to the logical unification of functions understood by modern installations, appropriate for their optimal operation of the structure ensuring durability and safety of the civil structure and the form determining the aesthetics, the contemporary Vitruvian triad also works.

Today, photovoltaic installations deserve special attention due to their ecological, economic and social importance, including their impact on the city landscape. It is important to be able to install them on a variety of civil structure scales. Numerous investments are being carried out in newly designed or adapted buildings, landscaping elements and public spaces in cities. The work is carried out by designers and engineers of various disciplines. They act alone or in multidisciplinary teams. This has a significant impact on the final result of the project.

It is not difficult to find examples of projects using photovoltaic panels. The energy standard of buildings has been improved, but at the same time their architectural form has been destroyed. In other cases, it happens that the aesthetics of a building overshadows the functionality of the new installation and ultimately reduces its efficiency. The conflicts that have arisen need to be resolved. To this end, it is to be found in the cooperation of designers from various industries, consisting in maintaining compromises of the best conditions for the civil structure (its functionality, structure and beauty).

New and renovated buildings exist in the constructed landscape. Using the "technological" exposure they simultaneously influence their exposure in the city landscape. Hence the need for a design that meets the conditions of both categories of centripetal and centrifugal exposure. This chapter proposes an algorithm of cooperation between an architect and an environmental engineer based on the analysis of the theory of perception, technological conditions for photovoltaic panel installations and selected examples of contemporary projects.

6.1. Contemporary architecture

The Centre Pompidou in Paris is a flagship example of late modernism architecture "talking about structure, technology and movement". The building erected in the 1970s, designed by Richard Rogers and Renzo Piano, became a manifesto of the use of technology and building installations as its essence and therefore the main element of the structure. The form of the building is an orderly emanation of the applied technological solutions. The installations formerly understood as the viscera of the building, have been brought outside and have defined the architectural aesthetics. The architects presented a new approach to design in which the technological sphere of the building was presented in the city landscape as its aesthetic value.

Today, we also find positive examples of modernised and newly designed projects in which the photovoltaic installation plays a significant role in their form, aesthetics and influence on the landscape of public space in the city.

The solutions are implemented on different scales: from the size of the city (e.g. Masdar) or its part (e.g. World Exhibition Pavilions EXPO 2020 in Dubai or Parc del Forum in Barcelona), through individual public or residential buildings, to the scale of landscaping elements

EXPO 2020 in Dubai will open late in 2021 due to the Covid-19 epidemic. Among its numerous pavilions, the Sustainability Pavilion (Fig. 6.1), designed by Grimshaw Architects, will be one of its main, themed ones. The building surrounded by a forest of solar trees will be used as a science museum after the exhibition. Elliptical roofs: the pavilion (120x90m) in the form of a giant funnel and the tree roofs (15x22m) spinning to follow the sun are covered with trapezoidal photovoltaic panels. The spectacular

architectural forms designed are a consequence of optimal adaptation to climatic conditions and exposure to the sun. At the same time, they represent an important value for the landscape of the EXPO 2020 exhibition in Dubai (Harrouk, 2020, WEB-1).

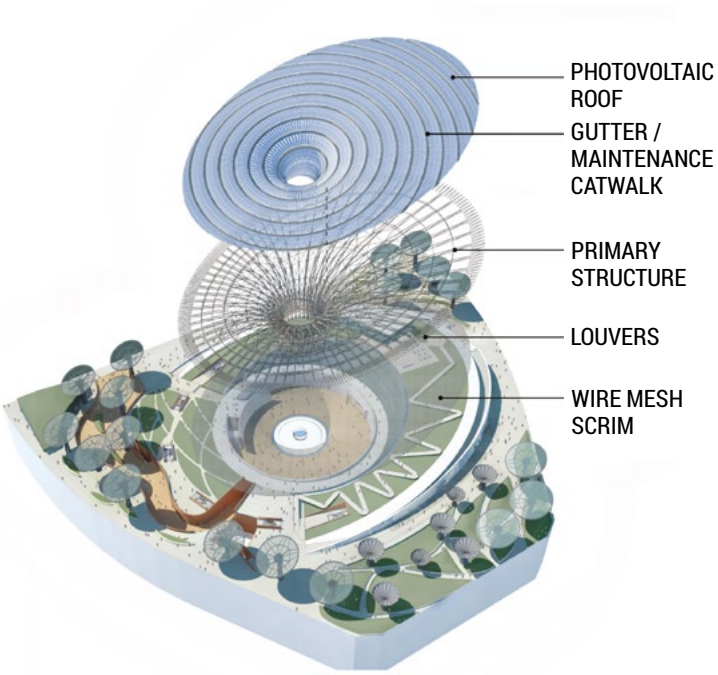

FIG. 6.1. The Sustanability Pavilion, EXPO 2021 (Source: WEB-1, Harrouk, 2020)

Placa Fotovoltaica is a giant pavilion whose roof (approx. 1700 sqm) is fully covered with photovoltaic panels (Fig. 6.2a). The pavilion has become the landmark of Barcelona, due to its unique exposition closing the viewing axis of the square against the sea. The pavilion is a distinctive feature of Parc dela Forum, which was founded in 2004 according to a design by Elias Torres and José Antonio Martínez Lapeña (WEB-1). It is a place for organising various cultural events (e.g. performances, concerts) and spending free time. The complex also includes Bosc de columns ("Forest of Columns") – a civil structure with an area of approx. 15000 sqm consisting of two roofed parts (Fig. 6.2b). It is used to hold various events. Its roof is almost half covered with photovoltaic panels. Significant photovoltaic surfaces of both civil structures have become a characteristic feature of their architectural form.

a b

FIG. 6.2. Parc dela mForum in Barcelona: a – Placa Fotovoltaica, b – Boscde columns "Forest of Columns" (Source: WEB-2)

The Powerhouse Telemark office building (by Snøhetta) built in Porsgrunn is the most energy-efficient building in Norway. It has the form of a diamond, designed to capture and retain solar energy. On the walls of the building 1400 sqm of photovoltaic panels are installed. They are also placed on car and bike shelters. The unique, modern shape of the 11-storey building is the landmark of the city (Bryła, 2020). Selected projects deserve attention mainly because photovoltaic panels have been used in them as an innovative building material with special properties, and not as an element added to finished structures. These are, for example, the bathing pavilion on an island on Lake Steinhuder Meer (Germany) covered with photovoltaic cells on arched roofs (architect Randal Stout, 2006), or the Archaeological Museum in Herne (Germany) by architect Von Buse Klapp Bruning, where skylights have whole roof slopes covered with solar cells (Kuczia, 2020).

An interesting example of the use of photovoltaic panels is the Kawelin Hotel in Białystok (designed by architect Piotr Łodziński and architect Zbigniew Baum). The building is located in a prominent place on Legionowa Street (Fig. 6.3a). Its corner location makes it visible from a considerable distance (Fig. 6.3b). The photovoltaic

panels were evenly and radially distributed on the semi-circular roof. The photovoltaic installation placed in the optimal direction for its operation was at the same time linked in terms of composition with the architectural form of the building already at the design stage.

a b

FIG. 6.3. Białystok, the Kawelin Hotel (Source: photos by D. Gawryluk, 2019)

The Decathlon chain shop in Olsztyn or KPK (Municipal Transport Company) buildings in Białystok are examples where photovoltaic panels were placed on façades. The modernisation of the buildings in order to reduce electricity costs was carried out with care to preserve the aesthetics of the façade and its legibility in the city landscape. The Decathlon shop in Olsztyn has also created a green wall as an accent of the main entrance. Modern, sustainable technological solutions influence economic benefits and at the same time build a positive corporate image.

a b

FIG. 6.4. Urban benches: a – Białystok, b – Siemiatycze (Source: photos by D. Gawryluk, 2018)

Photovoltaics is also a domain of landscaping elements or urban furniture. Benches with photovoltaic panels (e.g. Kosciuszko Square, Bialystok, Siemiatycze) (Fig. 6.4a,b) or roofed stands and lanterns equipped with panels (e.g. Prague Park, the Czech Republic, Sokółka) are pieces of equipment which enable the residents to draw energy obtained by this way free of charge. They are an incentive to spend time in public spaces. At the same time, they are aesthetic pieces of equipment, positively shaping the landscape of a given place.

Solar structures are designed and implemented also for educational purposes. A structure of this kind, presented at the China International Import Expo 2019 in Shanghai, is to be set up in a city park and make the public aware of the possibilities of using solar energy. Similar importance is also attached to the designs of solar walkways for Beijing (WEB-4). The concept of architect Piotr Kuczia was recognised at many competitions (first place at ICONIC Awards, Architecture Masterprize, A'Design, European Product Design Award, MUSE Design Awards). The plan provides for covering the railings of several hundred existing pedestrian walkways with photovoltaic panels. The author proposed solutions ranging from simple to complex parametric forms which could identify city districts. They would become their landmarks. At the same time, they would have an educational function in the use of clean energy in a metropolis struggling with smog (Kuczia, 2020).

6.2. Analysis of spatial conditions in various industries of design

The harmonious equipping of a civil structure with photovoltaic panels requires the cooperation of designers from the architectural and environmental engineering industries. Their work, based on the analysis of various spatial conditions for the industries, should lead to the placement of panels in a way that is optimal in terms of the function of the device (efficiency of its operation) and the aesthetics of the entire civil structure. Hence the need for a compromise between the centrifugal analysis (concerning the efficiency of the solar installation – environmental engineering) and the centripetal analysis (concerning the architecture of the building and its exposure in the landscape – architecture, landscaping).

6.2.1. Conditions for the aesthetic exposure of photovoltaic panels (landscape architecture)

Landscape (aesthetic) exposure of civil structures is examined using tools and methods used in landscaping. In Poland, analyses originating from the Krakow School of Landscaping (Bogdanowski, 1990) are used, such as: sightseeing analysis (Forczek-Brataniec, 2018), landscape absorbency studies and digital land analyses (Ozimek, 2019),

passive and active perception of a site in determining for example. the conditions of cultural parks in cities or historical military structures (Böhm, 2016). The research is also conducted on the scale of internal sights, city skyline and panoramas (Czyńska, 2017).

Such analyses and research are intended to prevent the devastation of the landscape and, at the same time, to allow for optimal locations for enclosed building projects. The basic principles they apply to vast panoramas also work well for internal sights of urban public spaces. They are based on ergonomic conditions of the human being and their possibilities of observing the landscape related to the construction of the human eye. The range of view defined by the vertical (30°) and horizontal (10° – sharp viewing angle, 60° – normal viewing angle, 120° – blurred viewing angle) of human vision affects the boundaries of the area of the landscape under analysis (Wejchert, 2009).

6.2.2. Conditions for the functional exposure of photovoltaic panels (environmental engineering)

Proper location of photovoltaic panels has a major impact on the effective acquisition of solar energy. While in the case of large photovoltaic farms, the usage of two-axis trackers, which enable the change of the direction and angle of the inclination of the panels in relation to the sun, depending on the time of day and year, ensures optimal system efficiency, in the case of permanently installed, immovable modules – the choice of their exposure must be carefully considered in advance. The research conducted in this technical point (Wacławek, Rodziewicz, 2011) has shown that optimal radiation absorption can be obtained at the angle of incidence of sunlight to normal to the module within the range of 60–70°. Moreover, in order to maintain a homogeneous current-voltage characteristic of the modules, it is necessary to ensure the operation of the interconnected cells in similar conditions, avoiding shading of some of them by, for example, surrounding buildings or trees. This is often difficult to achieve in urban developments, so at the planning stage it is necessary to analyse the length of the shade at different times of the year. It should also be noted that it is necessary to keep the surface of the panels clean, which may be difficult due to leaves falling on them, dust settling on them, or snow remaining on the surface.

6.2.3. Comparison of conditions

Optimal location of photovoltaic panels on a civil structure should be a compromise of technological and landscape conditions. The functional (centripetal) exposure of photovoltaic cells is related to the cardinal directions of the world (from the east, to south and west) including shading civil structures. The aesthetic (centrifugal) exposure of a civil structure with photovoltaic panels is conditioned by the possibility

of observing it in the city landscape. It applies to all the cardinal directions. The limitation is the obscuring structures. The overlap between the different industries is shown in the diagram in Fig. 6.5.

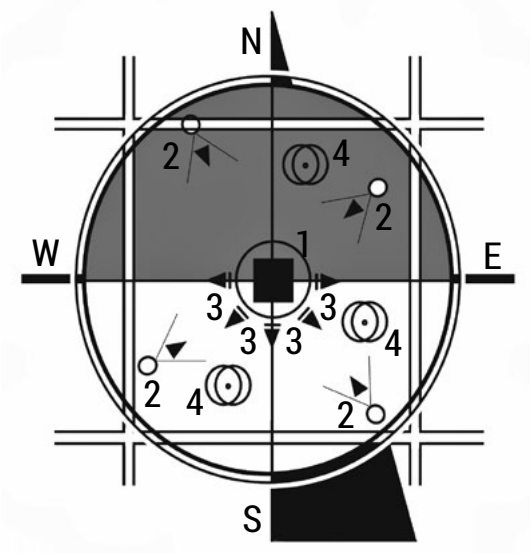

FIG. 6.5. Schema of object's exposition in cityscape: 1– analised object, 2 – location of observer (observation of es-thetical exposition / centripetal exposure, 60°-horizontal viewing angle), 3 – functional exposition of object (centrifugal exposure), 4 – obscuring objects (Source: own elaboration by D. Gawryluk, 2020)

6.2. Method of cooperation

Cooperation between designers from different industries should be correlated with the scope of the project.

The location of a sufficient number of photovoltaic panels on an existing building should be pre-determined by the installation engineer. In the next step, it should be analysed by means of exposure in the city landscape (landscape architect). Its results will lead to a correction in the distribution of panels so that they do not adversely affect the form of the building and its clarity in the landscape (joint design decisions). There may also be a case where the compromise conditions for the location of panels are not achievable. Then, the solution is to abandon the placement of photovoltaic panels in favour of looking for another technology using renewable energy sources and improving the standard of operation of the civil structure.

A newly designed civil structure gives a chance to use photovoltaic panels as an innovative building material with special utility, construction and aesthetic properties. The right approach will be to treat it as an integral element shaping

the architectural form and not to add it to the existing structure. Then the impact on the landscape of the entire building shape should be studied at the design stage (on the scale of the architectural and landscape interior, urban composition, and even the city skyline). The solution is to consciously integrate the panels with façades or canopies or to deliberately expose them in an architectural form.

Summary

Photovoltaic panels, apart from their utilitarian purpose, are increasingly used as an integral part of the architectural form. They meet all the criteria of the Vitruvian triad. They influence the functionality, form and structure of the building. They influence its beauty, and on a higher scale they also influence the landscape of the modern city.

Optimal use of photovoltaic panels requires the cooperation of designers from various industries. The presented algorithm of interdisciplinary cooperation will help to avoid the destruction of the form of civil structures and the city landscape. The presented method indicates the need for continuous further education of designers in their discipline, related industries and the ability to cooperate in an interdisciplinary way. Academic centres are an appropriate place for theoretical and practical research and training of students and practising engineers.

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