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ARCHITECTURE OF EXPO PAVILIONS – BEAUTY OR RATIONALITY?

ARCHITEKTURA PAWILONÓW WYSTAW EXPO – PIĘKNO CZY RACJONALNOŚĆ?

A b s t r a c t

The architecture of Expo pavilions since the first Exhibition in 1851 has been of great interest. It resulted from the fact that the objects were experimental in the sense of aesthetics, materials and structural solutions. It is probably difficult to say how many projects were in the search for emotions and how many derived from pragmatism and rationality. Today, ephemeral pavilions are a reflection of design trends, for example, seeking for unique aesthetics. The leading solutions, apart from innovative materiality, focus on amazing the viewer. Expo pavilions also designate directions in architecture design by implementing energy-saving solutions or lightweight materials. Exhibition objects are a living testimony of a diversity and a creative searches in architecture which do not limit to intuitive and aesthetic solutions, but also follow pragmatism and rationality.

Keywords: world expositions, Expo, exposition pavilions, curtain wall, energy efficiency, resource-efficiency

Streszczenie

Architektura pawilonów EXPO od czasu pierwszej wystawy w 1951 roku wzbudzała ogromne zainteresowanie. Wynikało to z faktu, że obiekty były z założenia eksperymentalne zarówno w sensie estetyki, konstrukcji, jak i rozwiązań materiałowych. Prawdopodobnie trudno dzisiaj stwierdzić, ile w projektach było poszukiwań emocjonalnych, a ile pragmatyzmu i racjonalności. Dziś efemeryczne pawilony są odzwierciedleniem tendencji projektowych, na przykład dążenia do niekonwencjonalności estetycznej. Dominują rozwiązania, których celem – poza innowacyjnością materii – jest zadziwienie widza. Pawilony EXPO wyznaczają także kierunki w projektowaniu przez poszukiwanie rozwiązań energooszczędnych lub lekkości materiałowej. Obiekty wystawowe są żywym świadectwem różnorodności poszukiwań twórczych w architekturze, nie ograniczają się do rozwiązań intuicyjnych i estetycznych, są również pragmatyczne i racjonalne.

Słowa kluczowe: wystawy światowe, Expo, pawilony wystawowe, ściana osłonowa, efektywność energetyczna, racjonalność materiałowa

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1. Introduction

Since the Industrial Revolution architecture has been dependent on novel building techniques and technological innovations. Pioneering solutions require experimentations. World Expositions, nominally used for the self-presentation of nations' achievements, thanks to the innovative approach have become a laboratory for experimentation in the field of architecture. Since The Crystal Palace, Expo pavilions have focused on innovative forms, structures and materials. Currently, this process sharpens implementation of sustainable materials, energy efficiency and user related comfort. The goal of the article is to raise the question of whether the positive achievements of world expositions were derived from an aesthetic or a rational background. The justification is managed by appropriate pavilions.

This issue mainly concerns an envelope or an external building skin, understood as a "packaging" of the interior usable space[1]. The concept of envelope is equated with the terminology: elevation, external wall, outer shell, facade, curtain wall, building skin, or cover. The envelope applies to vertical partitions (facade, France Pavilion, 2010 figure 1), horizontal (roof), and three-dimensional forms that surround the entire building (Poland Pavilion, 2010, Ill. 1). The metaphor of the building skin in the architectural context recalled by Wigginton and Harris applies its complex functions related to body protection, temperature and humidity control, and response to external stimuli[2].

The research relates to the PhD thesis entitled *Evolution of an envelope on World Exposition examples 1851–2012*, prepared in the Department of Civil Engineering, Architecture and Environmental Engineering, Lodz University of Technology under the supervision of Prof. Eng. Arch. Nina Juzwa.

2. The World Expositions between 1850 and 1980

In the era of industrialization, architectural development was motivated by industrial growth, the development of mechanics, electricity and finally by early computerization. Progress was driven by the technological race between industrialized countries. Pavilions in the history of World Expositions introduced a number of innovations related to form, structure, materials and aesthetics. The exhibitions introduced novel ideas and spatial, functional and technological innovations. Due to their prestigious character, Expos required unconventional actions and the potential of creative thinking was extremely demanded. World expositions were ahead of common architecture because they carried out structural and technological experiments that were too risky for permanent objects.

1 Building skin was mentioned by Schittich in *Building Skins Concepts Layers Materials* (2001), Wigginton and Harrisa in *Inteligent Skins* (2011), conferences *Solar Building Skins* (2011), *Advanced Building Skins* (2013) in Bressanone, *Advanced Building Skins* in Bern (2015) and Graz (2015).

2 Wigginton and Harris pay attention to the analogy of building envelope and a human skin, which react to external stimuli and provide the right conditions. The properties of the skin are not self-sufficient and require additional layers that will improve its performance, like clothing that provides additional thermal insulation. The building's skin functions in the same way. It requires additional layers and devices to provide the "interior" with optimal usage conditions, Wigginton and Harrisa in *Inteligent Skins* (2011)

The first official Expo object – the Crystal Palace (Paxton, 1851), completely changed the approach to the building design, due to its non-structural and prefabricated outer wall built up with glass and iron. The Galerie des Machines (Dutert, Contamin, 1889) opened a new era for large-scale objects, introducing the engineering construction system into architecture. The expositions presented the well-known L'Esprit Nouveau Pavilion (Le Corbusier, 1925) and the German Reich Pavilion (van der Rohe, 1929). Both used modern concrete skeletal structures filled with light non-structural walls. Moreover, the Finland Pavilion (Aalto, 1935), Czechoslovakia Pavilion (Krejcar, Bolivka, 1935) and Brazil Pavilion (Nemeyer, Costa, 1939) applied material innovations. The first one skillfully integrated traditional cover material with modernist proportions. Two others responded to the inadequate glass properties concerning energy and comfort by introducing thermal glass and *brise-soleil*[3].

Further innovations related to the form. The Philips Pavilion (Le Corbusier, 1958, figure 2) for the first time presented a unified, curvilinear, three-dimensionally bent envelope. The Geodesic Dome (Buckminster Fuller, 1967, Ill. 2) introduced a division between the core of the pavilion and the envelope. At the same time the pavilion tried to isolate the indoor climate conditions thanks to the steel-and-glass dome. Furthermore, known also as the Biosphere, its envelope applied a novel digital optimization to the structure and innovative self-regulating sun shades, finally being claimed to be the first responsive building skin. The novel impact of World Expositions were also innovative grid structures (Festival Roof, 1970, Tange), tension skins (German Pavilion, 1967, Frei) and air supported roofs (USA Pavilion 1967, Davis, Chermayeff)[4].

The period between 1850s and 1980s architecture introduced the separation of the building and its skin and a usage of innovative materials like glass, concrete or steel. New structures were implemented in architecture like skeletal, grid, tensile and pneumatic structures. All the innovative techniques and technologies were derived from rational foundations. Despite bringing novel aesthetics, architecture was mostly rational.

3. The World Expositions after 1980

After the accomplishment of many utopian projects at Expo '70 Osaka, the world has changed drastically. The publication *Limits to the Growth* by the Club of Rome and the oil crisis ended the optimistic race aimed at size and volume. There was no sense of competing any longer. Declining resources made the construction industry begin to search for ecological, energy-efficient and resource-efficient solutions. As a consequence, modern construction materials and enclosures were developed. It allowed for greater freedom of form types and a new envelope aesthetics[5]. Based on literature research and a multithreaded analysis of contemporary World Expo pavilions two main design trends in the development of modern envelope have been recognized.

First of all, it was observed that the architecture of the modern exhibition pavilions is strongly motivated by aesthetic features. This is an extremely important factor in the design

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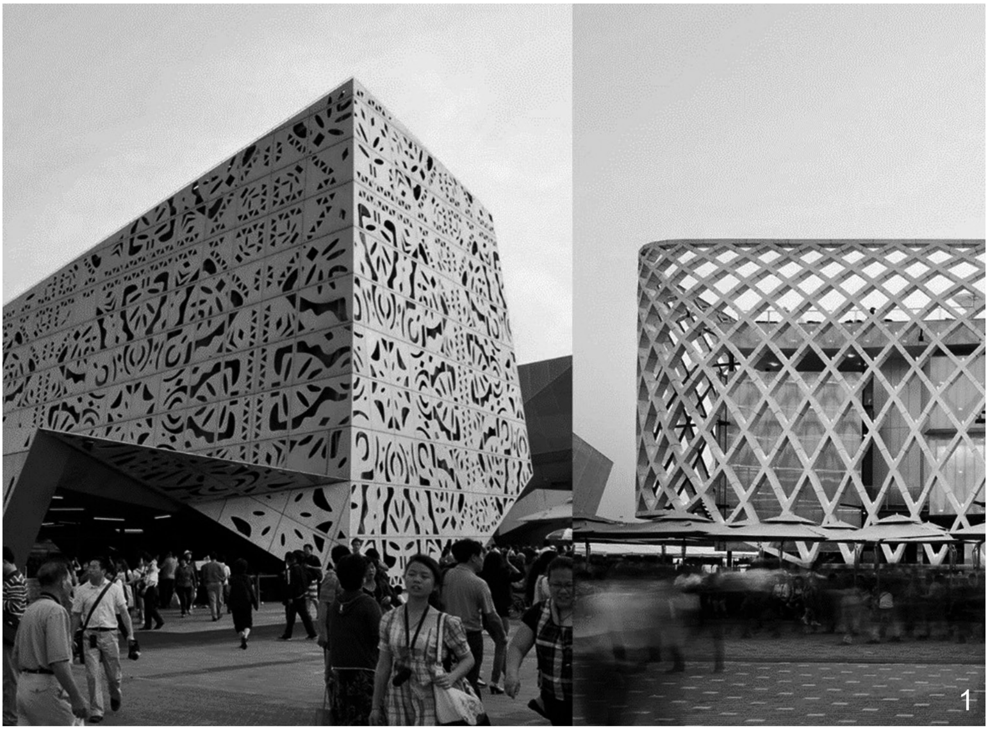
[3] W. Friebe, *Buildings of the World Expositions,* Berlin 1985.

[4] N. Juzwa, *Kształtowanie rozwiązań przemysłu na obszarach intensywnie zurbanizowanych,* Gliwice 1988.

[5] C. Schittich, *Building Skins Concepts Layers Materials,* Kempton 2001.



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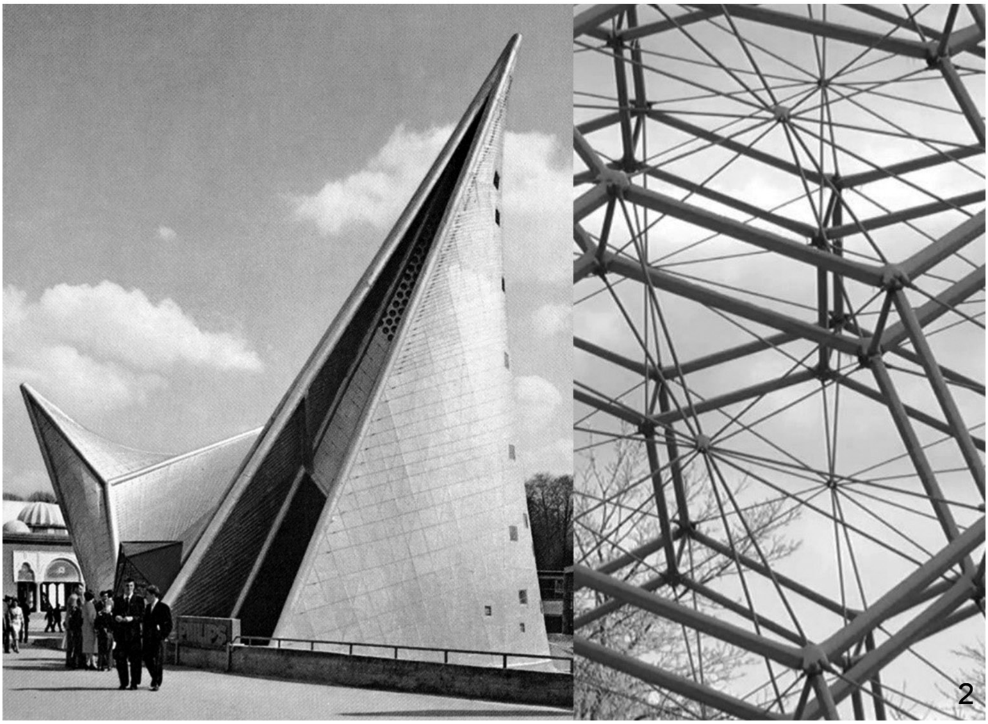

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process. It directs the need for an individual approach and unique emotional impact. The tendency is dominated by an innovative form and structural design, frequently resulted from application of CAD techniques[6]. Moreover, the external envelope demands traditional materials, although used in a creative way. In opposition, innovative, unknown materials tend to appear. The return to vernacular and ornament solutions was noticed after a hundred years of negligence. Also new technologies that shape the aesthetics of the envelope should not be underestimated.

Secondly, the growing importance of facades and envelope was recognized in the context of technical, technological, functional and ecological solutions[7]. The outer building skin might be responsible for a series of complex functions, such as savings and production of energy, ensuring user comfort and the usage of eco-friendly materials and those that are possible to recycle and reproduce[8]. These solutions prove that the architectural envelope apart from focusing on aesthetics is not entirely pointless[9]. The functional direction in building envelope design was chosen for further analyses both in this paper and the PhD research.

4. Visual attractiveness of the skin

Contemporary building envelopes attempt uniqueness. The attractiveness is achieved due to unique approach to the form, material or structure. The task of the skin is to highlight the object. Solutions are supposed to affect the emotions of the observer so that the object might be distinguished among many different solutions and might be remembered. The element of surprise becomes important. The pavilions that are not obvious and “impossible” to be built are especially interesting.

Visual attractiveness nowadays tends to non-linear geometry, unique material and modern technologies. The traditional concept of aesthetics has changed. The historical detail is replaced by modern materials or innovative technical and technological solutions. The search for the use of thin-walled cover materials and lightweight structure is clearly marked. The unconventionality of the envelope often results from the lack of difference between the façade and the roof, creating a homogeneous “skin” or a “package” for the object. In this way, a geometry is unique and incomprehensible.

The most common procedure for creating a unique envelope is the usage of multi-curved geometry or the usage of experimental material. Usually, both solutions are not used simultaneously. The expressive material harmonizes with the simple envelope geometry. The curved and complicated form, on the other hand, uses a uniform external wall and a simplified façade material.

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[6] T. Herzog, *Facade construction manual,* Munchen 2004.
[7] W. Celadyn, *Przegrody szklane w budownictwie energooszczędnym,* Kraków 2004.
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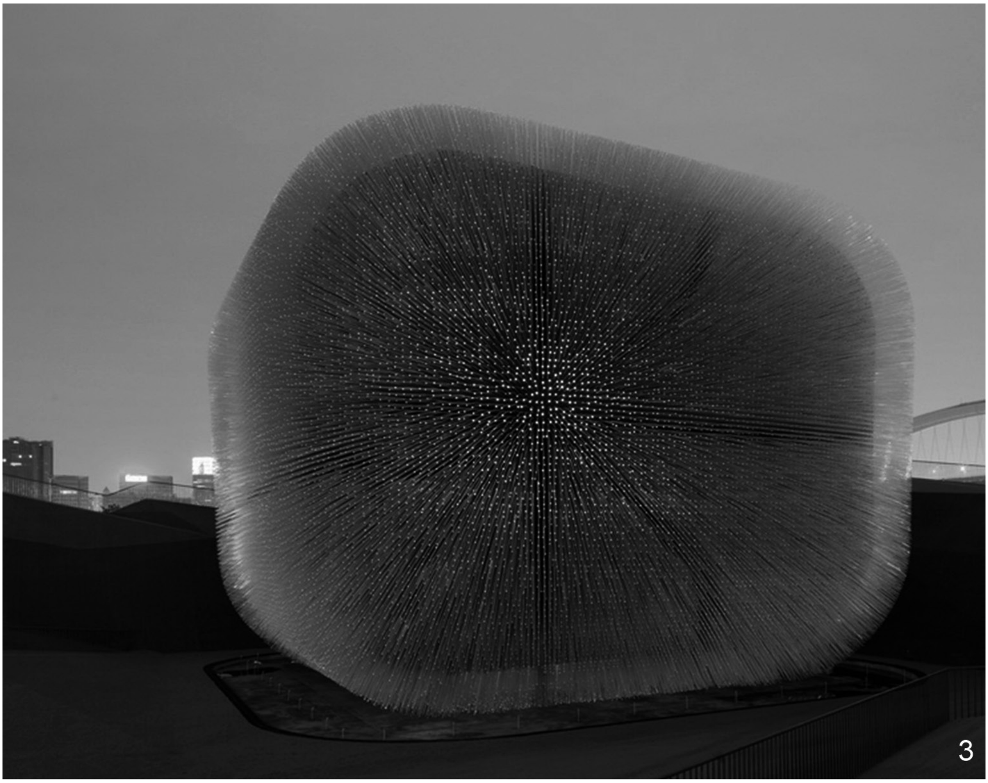
Ill. 1. Polish Pavilion,2010, French Pavilion, 2010
Ill. 2. Philips Pavilion,1958, Geodesic Dome, 1967



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Such a uniqueness and strong expression was the dominant feature of the British pavilion in Shanghai, 2010 (arch. Thomas Hatherwick, Ill. 3). It was due to simple form and experimental material. At first contact, the pavilion was an inconspicuous uniform object with rectangular geometry and rounded edges. What made it special was the surprising lightness[10] and the effect of disappearance of the edges. The effect was created by slim acrylic rods perpendicular to the envelope and fading at the edges. Additionally, the rods inside the pavilion created a multiple curved "plane".

An opposite approach was created in the Spanish pavilion in Shanghai, 2010 (arch. Enric Miralles, Benedetta Tagliabue, Ill. 4). The impressive skin was a combination of traditional material and unconventional form. The curved form was made using a complex steel structure covered with wicker panels. The multicurved wall was alleviated thanks to the homogeneous surface of the envelope and the natural material. Openwork panels formed an outer protective layer. They provided shading of the glass façade and an unconventional aesthetic effect. The panels were made of hand-woven wicker. Each of them had an individual shape, colour and execution.

The success of the pavilion was provided by a spectacular skin and a unique material. The pavilion was especially appreciated for the transfer of handicrafts to contemporary architecture. The architects had skillfully combined an individual material with modern curved geometry.

5. Non-aesthetic solutions

Architecture is also motivated by non-aesthetic solutions. Contemporary innovation is related to the ideas of ecology, environmental protection and sustainable development. The article attempts to indicate that the envelope in addition to the visual attractiveness "took over responsibility" for the energy-efficiency of the building and the comfort of its users. Nowadays, the skin saves energy, reacts to changing weather and climatic conditions, depending on the time of day, sun exposure and a wind power. Ecological materials are used in innovative constructions with the lightweight concept and rational management of the Earth's resources.

The study distinguished three main tendencies in the functional building envelope design related to resource efficiency, energy efficiency of the skin and user related comfort. In the further part of the paper a brief description of each directions is accompanied with basic goals and Expo pavilion examples. The case objects were chosen according to the innovative methods and experimental solutions to create the functional envelope. These pavilions are representatives of a large group of objects that used functional skin that were selected for the PhD thesis.

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[10] The object seemed to hover above the ground level, floating on delicate rods. Despite the fact that the structure engineers positively opined such an idea, the architects decided to strengthen the core with invisible steel poles.

Ill. 3. British Pavilion, Expo 2010 Shanghai

Ill. 4. Spanish Pavilion, Expo 2010 Shanghai

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5.1. Resource-efficiency

Typical building skin solutions regarding resource-efficiency concern an effective skeletal structure and a light-weight cover. Steel is recognized as the most efficient material for resource-efficient structures, because its elements reach a compromise between the weight and size of a single structural element. Most commonly, such structures are covered with a façade made of aluminium plates (Samsung Pavilion, 2012), wood (Canada Pavilion, 2010) or ceramic panels (Spain Pavilion, 2005) and glass facades (Lotte Pavilion, 2012).

The most innovative structures use tension systems and membrane covers like ETFE (Le Sed Pavilion, 2008). Geometrical freedom of single construction elements make it possible to create original architecture forms. On the other hand, unconventional solutions concern creative low-tech materials and construction systems. Such structures may achieve the same built strength and stability as comparable buildings in more advanced technologies (Japan Pavilion, 2000). Pavilions use ecological wood-like materials (Vietnam Pavilion, 2012) or others semi-related with building industry (compacted straw panels – Vanke 2049 Pavilion, 2012, plywood – Poland Pavilion, 2012) and unique in architecture: cork (Spain Pavilion, 2000) and wicker (Spain Pavilion, 2010).

Among other sustainable objects at Expo 2000 Hanover the Japan Pavilion (arch. Shiguru Ban, Ill. 5) attracted most of attention. It used maximum ecological solutions and low technologies. The three-dimensional barrel vault type envelope was made exclusively from natural materials like bamboo tubes, rope, cardboard, steel fasteners. All was covered by paper membrane to provide water resistance. The experimental skin was the lightest self-supported structure constructed with such a small amount of material[11]. In addition, only recycled materials and reusable components were used. In the case of demolition all the elements could have been reused, being intended to produce as low amount of waste as possible.

At the same time the pavilion distinguished itself with lightness, transparency of the outer layer and a structurally creative result. The pavilion achieved the same level of advancement and span as other high-tech solutions. The low technology structure become a well-known element by Shiguru Ban and his architectural signature.

On the opposite side of resource-efficiency concept the high-tech strategy appeared. It was the goal of UBPA-B3 2 Pavilion in Shanghai (Archea Studio, 2010, Ill. 6). The outer layer of the façade was created by rhomboid aluminum panels combined with stretched silicon foil ATEX3000, which limited the weight of the façade to the extreme minimum.

The lightness effect of the envelope was strengthened by curved corner panels. Rounded horizontal and vertical lines created the effect of continuous surface of the façade, covering all the building with homogenous image. The impression of curved skin was illusionary, because covering the roof with the same material was not necessary. The lightweight cover had a dynamic visual effect. The silicon layer vibrated in the wind underlining the delicacy of the building skin[12].

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[11] M. McQuaid, *Shigeru Ban Fabric architecture,* Londin/New York 2003.

[12] L. Andreini, *Archea Associati Favero & Milan Urban Best Practice B3-2 Pavilion Shanghai World Expo 2010,* Poggibonsi 2010.

Ill. 5. Japan Pavilion, Expo 2000 Hannover

Ill. 6. UBPA B-3 Pavilion, Expo 2010 Shanghai

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5.2. Energy-efficiency

The principles of energy efficiency direction are based on the geometry optimization, seasonal increasing and reducing of the heat load through the facade and energy production from renewable resources.

The most significant solutions of high technologies concern active use of solar energy. At the beginning solar skins tended to maximalize the use of roofs to produce maximum amount of energy (Urbanian Pavilion, 2010). Recent photovoltaic studies focus on integration of solar technologies with typical building components called BIPV, such as glass façade elements (Italy Pavilion, 2010) or tensile membranes (Japan Pavilion, 2010). Moreover, kinetic façade solutions contribute to energy efficiency by controlling indoor climate. The first facades were based on manually operated elements, such as shutters (Madrid Case Pavilion, 2010). Up-to-date technologies made it possible to create a self-reacting skin on changing climate conditions, like sun illumination (Venezuela Pavilion, 2000) or wind strength (Kinetic Pavilion, 2012).

In contrast to highly expensive and complex high-tech solutions, the traditional methods of construction are recalled. Designers tend to substitute a centralized HVAC system with natural methods of air exchange through façade or roof. Increasing importance is placed on façade buffers (double skin Madrid Case Pavilion, 2010), openwork layers (combination with glass façade – Spain Pavilion, 2005), water facades (evaporative cooling – Spain Pavilion, 2008), atriums (Italy Pavilion, 2010) and solar chimneys (Japan Pavilion, 2010).

Also other passive methods of using solar radiation are again becoming popular. The methods concern mainly energy gains and reductions on glass façades (Lotte Pavilion, 2012), the use of reflective surfaces in front of the building (Alsace Pavilion, 2010) and the use of thermal masses for delaying the effect of overheating and cooling (UK Pavilion, 1992).

The active group of energy-efficient buildings is represented by the highly advanced UK pavilion at the Expo 1992 Seville (arch. Nicolas Grimshaw, Ill. 7). Due to the high temperature and solar illumination it was necessary to use innovative reduction methods that prevented the pavilion from overheating. The shading solutions were chosen depending on the orientation of the facades and the degree of solar radiation. The southern facade applied stretched PVC material. The west side was indicated as a thermal buffer constructed by containers filled with sand and water, delaying the impact of sun radiation. Moreover, the roof was covered with photovoltaic panels placed over the roof. At the same time roof shades eliminated the possibility of overheating and enabled the electricity production. PV cells were placed on individually profiled, V-shaped holders over the envelope, enabling an additional ventilation under highly overheating photovoltaic panels. The electricity was used to cool the innovative east glass façade that was chilled with water circulating on its outer surface. The innovative solution allowed to limit sunlight penetration into the pavilion in the morning hours and provided a unique esthetical effect. As a result, the use of exclusive solutions enabled the internal temperature to be maintained below 26°C (up to 40°C outside), without any additional mechanical solutions.

The UK Pavilion was one of the greatest examples of high-tech style of British constructivism. With all the structure, details and technical devices expressed on the envelope the

Ill. 7. British Pavilion, Expo 1992 Seville
Ill. 8. Madrid Pavilion, 2010, Trade Fair Hall26, 2000

architecture was sharing all the information about the building installations and structure to the visitor. The architecture was frequently mentioned in the professional literature.

A much more subtle way of incorporating energy-efficient solutions was designed in the Madrid Case Pavilion in Shanghai (Alejandro Zaera-Polo, 2010, Ill. 8). The most important technique was the double skin façade. The inner layer was totally glazed. The outer skin was made with openwork bamboo coating made with movable shutters. It reduced the impact of warm climate on the interior and lowered the energy consumption necessary for building operation. The openwork shutters were individually operated to regulate indoor sun illumination. They were used on south, east and west facade mostly exposed on solar radiation. Bamboo panels reduced the sun amount reaching the interior and enabled ventilation between layers. North facade was designed as different double skin façade entirely from glass. The purpose was to enlighten the interior with reflected sunlight. Between glass layers ventilation operated in shaft system due to the chimney effect of warm air. The system extruded exhausted air from the interior and eliminated overheating on the façade[13].

Folding panels providedtotal freedom in shaping a unique building skin. The ability to change was wide, from hermetic closure to a completely open skin, especially in daily and seasonal schedules. The façade provided effectiveness, comfort and an unconventional visual effect.

5.3. User-related-efficiency

The third group mentioned in the article concerns optimal user comfort inside the building that can be imposed by adjusting the daylight, natural ventilation and acoustics through the envelope. Again the effect is reached by low-tech and high-tech solutions.

Low-tech solutions were based on natural ventilation. Concepts form: double glass façade (Expo Office Building, 2008), double façade with openwork layer (Canada Pavilion, 2010). Such examples allow an exterior skin, independent from the structure of the building, to be created. The complication of such structures is reworded with curved, uniformed skins (Japan Pavilion, 2005) and sophisticated details (Poland Pavilion, 2010). Moreover, natural ventilation is provided in atrium, patio or glass roof.

Among high-tech solutions, two strategies for an efficient skin are most common: façade louvers (Trade Fair Hall 26, 2000) and solar chimneys (Japan Pavilion, 2010). Moreover, it is worth mentioning that user-related comfort is provided by kinetic facades. They create variable conditions depending on climate needs due to the movement of skin elements (Kuwait Pavilion, 1992). Unfortunately, due to advanced technology and costs, these skins does not appear frequently.

The compilation of positive solutions was applied in the Trade Fair Hall 26 at the Expo 2000 Hanover (arch. Thomas Herzog, figure 8). A large usable floor area under a single wide envelope carried the risk of low illumination in the centre of the pavilion or significant electricity consumption due to artificial lightning. To neutralize the problem the saw-tooth

[13] N. Nuttall, *Final Review of the 2010 World Exposition, Shanghai, China, United Nations Environmental Programme (UNEP)*, Nairobi 2012.

roof was applied. The daylight redirecting and diffusing system was integrated. Horizontal louvers were placed just in front of the glass facade to redirect the daylight into the interior. Radiation was guided onto the bottom surface of the curved roof, which evenly distributed the reflected light inside the pavilion. In addition, roof skylights with steel mesh diffused the part of radiation without causing excessive overheating of the interior. The saw-tooth roof type also served as a natural air circulation system, which made it possible to eliminate mechanical ventilation. The air was blown into the interior at the bottom of the walls and distributed inside with glass tunnels. Gradually warmed air floated to the top where was sucked out by automatically controlled outlets, arranged at the highest point of the roof. The suction resulted from a wind force pressure. This experimental solution has proven its significance in practice. It was possible to limit the energy requirements in the building compared with buildings this size by up to 50%[14].

The architecture of the building completely resulted from the energy-efficiency concept. The form, structure and materials were subordinate to the general idea of improving ventilation and daylight effect.

6. Conclusions

World Exposition pavilions are characterized by an experimental nature and serve as laboratories for innovations. Especially because temporary architecture enables testing unproven techniques and technologies too risky for permanent objects. After checking whether the solutions are correct, they might be adapted to everyday architecture. The nature of every experiment is both a success and a failure. In many cases, Expo pavilions failed in aesthetics or function. Among them all, only a small number of objects deserve to be mentioned, while the rest is just the background to emphasize novel solutions. The long list of innovative exposition pavilions proved to be important in the evolution of the building envelope. Contemporary pavilions continue the positive route determined by former icons. The only difference is that the national competition for volume and techniques has been replaced by solutions for reducing energy consumption, comfortable and environmentally friendly operation.

The image of the building is in most cases dependent on form, materials and structure combined in a single building skin. Such a direction is focused on visual attractiveness. In recent years another direction was noticed. The skin is formed with a need for functional solution which with a help of modern techniques and technologies determine the exterior building image. At the beginning the energy-efficient concepts were visually neutral. The importance was placed in functional results rather than architectural attractiveness. Today, such solutions are developing dynamically and the visual effect seems to be taken under consideration. Modern techniques and technologies allow a broader approach towards both functional and aesthetic results. Recently, the right choice of skin solution seems to be more logical than it used to be. However, such a design method does not create attractive architecture. Not until a comprehensive approach focused on both functionality and aesthetics is introduced to create an interesting and useful envelope. Innovative energy-effective functions tend to create

[14] R. Hammann, *Creative Engineering, Architecture & Technology,* Berlin 2013.

new building skin features. These concepts affect geometry, structure and exterior materials and determine building techniques, specific technologies, layers and additional façade elements. All the solutions translate into distinctive skin results and aesthetics. Contemporary architecture requires a balance between functionality and aesthetics. Effective solutions give the envelope a sense, while the impressive visual attractiveness allows it to exist among the surrounding solutions.

The examples distinguished confirm that despite the technical nature and the use of modern technologies did not affect the loss of aesthetics. It was exactly the opposite. The end of the twentieth century convinced with the attractiveness of the exposed installation and engineering solutions. The facade automatically became a carrier of information used with building technologies were used. The canon of beauty has transformed and now is still evolving into a functional one. Today's technologies are becoming smaller, more efficient and a lot more attention is paid to their visual appeal. Functional and ecological solutions are not a new phenomenon but rather the result of a reorientation of objectives towards understanding that the buildings cannot be designed without paying any attention to location, climate, available materials, traditional techniques and innovative technologies.

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